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STERLING
TRUCKS

ACTERRA WORKSHOP MANUAL

Models: MX

STI-414, S19 (7/10P)

Published by
Daimler Trucks North America LLC
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Foreword

The purpose of this manual is to assist the service technician when the vehicle is serviced. Major drivetrain component service information is not included in this manual, but is located in each manufacturer's service manual.

Instructions and procedures are those recommended by Sterling Trucks or the component manufacturer.

Maintenance schedules and additional service information are included in the *Acterra® Maintenance Manual*.

IMPORTANT: Descriptions and specifications in this manual were in effect at the time of printing. Sterling Trucks reserves the right to discontinue models, and to change specifications or design at any time without notice and without incurring obligation. Descriptions and specifications contained in this publication provide no warranty, expressed or implied, and are subject to revision and editions without notice.

Refer to **www.Daimler-TrucksNorthAmerica.com** and **www.SterlingTrucks.com** for more information, or contact Daimler Trucks North America LLC at the address below.

Environmental Concerns and Recommendations

Whenever you see instructions in this manual to discard materials, you should attempt to reclaim and recycle them. To preserve our environment, follow appropriate environmental rules and regulations when disposing of materials.

NOTICE: Parts Replacement Considerations

Do not replace suspension, axle, or steering parts (such as springs, wheels, hubs, and steering gears) with used parts. Used parts may have been subjected to collisions or improper use and have undetected structural damage.

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Descriptions of Service Publications

Daimler Trucks North America LLC distributes the following major service publications in paper and electronic (via ServicePro®) formats.

Workshop/Service Manual

Workshop/service manuals contain service and repair information for all vehicle systems and components, except for major components such as engines, transmissions, and rear axles. Each workshop/service manual section is divided into subjects that can include general information, principles of operation, removal, disassembly, assembly, installation, specifications, and troubleshooting.

Maintenance Manual

Maintenance manuals contain routine maintenance procedures and intervals for vehicle components and systems. They have information such as lubrication procedures and tables, fluid replacement procedures, fluid capacities, specifications, and procedures for adjustments and for checking the tightness of fasteners. Maintenance manuals do not contain detailed repair or service information.

Driver's/Operator's Manual

Driver's/operator's manuals contain information needed to enhance the driver's understanding of how to operate and care for the vehicle and its components. Each manual contains a chapter that covers pretrip and post-trip inspections, and daily, weekly, and monthly maintenance of vehicle components. Driver's/operator's manuals do not contain detailed repair or service information.

Service Bulletins

Service bulletins provide the latest service tips, field repairs, product improvements, and related information. Some service bulletins are updates to information in the workshop/service manual. These bulletins take precedence over workshop/service manual information, until the latter is updated; at that time, the bulletin is usually canceled. The service bulletins manual is available only to dealers. When doing service work on a vehicle system or part, check for a valid service bulletin for the latest information on the subject.

IMPORTANT: Before using a particular service bulletin, check the current service bulletin validity list to be sure the bulletin is valid.

Parts Technical Bulletins

Parts technical bulletins provide information on parts. These bulletins contain lists of parts and BOMs needed to do replacement and upgrade procedures.

Web-based repair, service, and parts documentation can be accessed using the following applications on the AccessSterling.com website.

ServicePro

ServicePro® provides Web-based access to the most up-to-date versions of the publications listed above. In addition, the Service Solutions feature provides diagnostic assistance with Symptoms Search, by connecting to a large knowledge base gathered from technicians and service personnel. Search results for both documents and service solutions can be narrowed by initially entering vehicle identification data.

PartsPro

PartsPro® is an electronic parts catalog system, showing the specified vehicle's build record.

EZWiring

EZWiring™ makes Freightliner, Sterling, Western Star, Thomas Built Buses, and Freightliner Custom Chassis Corporation products' wiring drawings and floating pin lists available online for viewing and printing. EZWiring can also be accessed from within PartsPro.

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Descriptions of Service Publications

Warranty-related service information available on the AccessSterling.com website includes the following documentation.

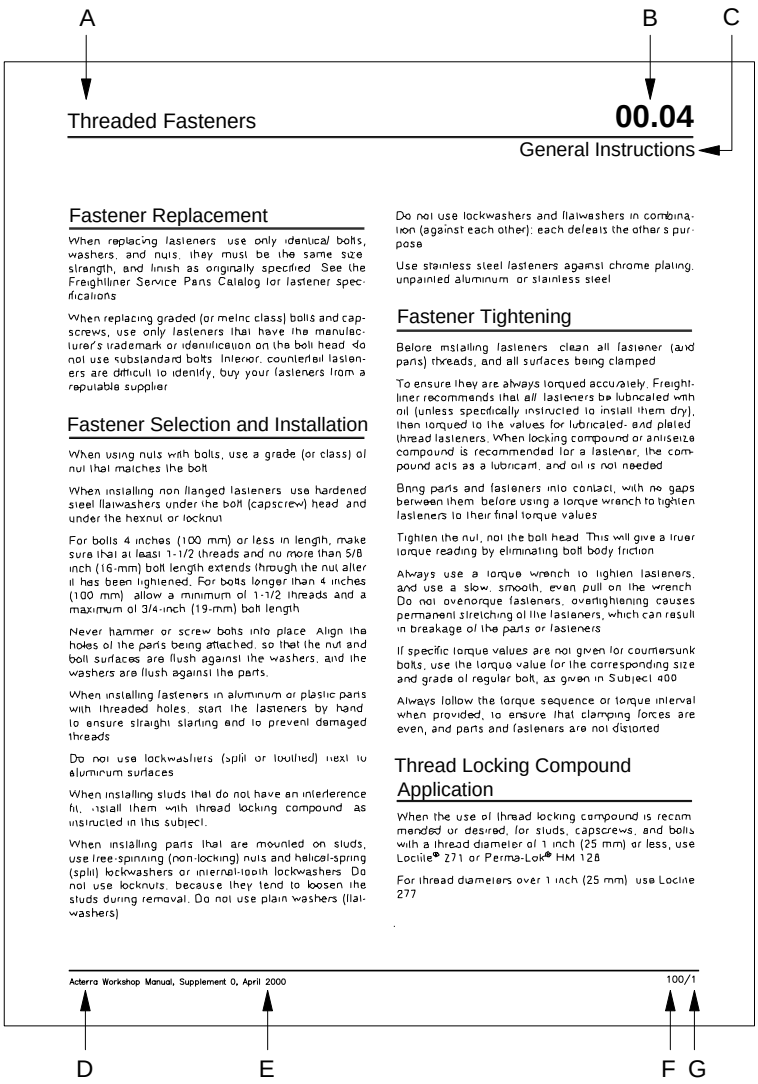
Recall Campaigns Recall campaigns cover situations that involve service work or replacement of parts in connection with a recall notice. These campaigns pertain to matters of vehicle safety. All recall campaigns are distributed to dealers; customers receive notices that apply to their vehicles.

Field Service Campaigns Field service campaigns are concerned with non-safety-related service work or replacement of parts. All field service campaigns are distributed to dealers; customers receive notices that apply to their vehicles.

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Page Description

For an example of an *Acterra Workshop Manual* page, see **Fig. 1**.



A. Section Title
B. Section Number (made up of the Group Number—first two digits, followed by a sequence number—last two digits)
C. Subject Title
D. Manual Title
E. Release (Supplement) Date
F. Subject Number
G. Subject Page Number

Fig. 1, Example of an Acterra Workshop Manual Page

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Workshop Manual Contents

Group No.	Group Title
00	General Information
01	Engine
09	Air Intake
13	Air Compressor
15	Alternators and Starters
20	Engine Cooling/Radiator
25	Clutch
26	Transmission
30	Throttle Control
31	Frame and Frame Components
32	Suspension
33	Front Axle
35	Rear Axle
40	Wheels and Tires
41	Driveline
42	Brakes
46	Steering
47	Fuel
49	Exhaust
54	Electrical, Instruments, and Controls
60	Cab
72	Doors
82	Windshield Wipers and Washer
83	Heater and Air Conditioner
88	Hood, Grille, and Cab Fenders
90	Fire Suppression Systems
91	Seats and Restraint Systems
98	Paint

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Vehicle Receipt

Prior to signing for vehicle delivery from a transporter company, the dealer is responsible for checking for transporter-related shortages or damages, and noting these discrepancies on the transporter's delivery receipt.

The dealer is also responsible for ensuring that the vehicle was built according to the Truck Sales Order/ Invoice.

Refer to Section 3 of the Daimler Trucks North America LLC *Warranty Manual* for details.

Vehicle Storage

There may be times when a vehicle is stored for long periods before customer delivery. To protect all vehicles from deterioration and weather, they must be properly maintained. Adequate protection and storage of new vehicles is the responsibility of the dealer.

Claims arising from loss and damage to improperly stored vehicles will not be reimbursed.

See Section 3 of the Daimler Trucks North America LLC *Warranty Manual* for instructions on storage of new vehicles.

Pre-Delivery Information

All pre-delivery inspections and services must be performed at an authorized Daimler Trucks North America LLC facility, assigned to fully qualified service personnel and recorded on the "New Vehicle Pre-Delivery Inspection" form.

Refer to Section 3 of the Daimler Trucks North America LLC *Warranty Manual* for details.

It is recommended the pre-delivery inspection be performed within 30 days of vehicle receipt.

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Hoses and Electrical Wiring Routing Standards

Cooling System

1. Cooling system hoses must clear all moving parts by a minimum of 1/4 inch (6 mm).
2. The 1-inch (25-mm) hose from the surge tank to the engine must be free of sumps and have allowance for engine torque.
3. All hoses from the engine hard pipes must be wrapped in convoluted tubing.
4. Hoses that are protected with convoluted tubing may be secured with tie straps to clear the inner fenders.
5. Cooling system hoses should not be twisted or kinked.
6. Cooling system hoses must be routed at least 6 inches (152 mm) from a heat source if the heat source does not have a heat shield. If a heat shield is provided, the hose must be routed at least 3 inches (76 mm) from the heat source.

HVAC System

1. Cushion clamps are required to support all A/C lines. Butterfly or figure-8 clamps (two cushion clamps) may be used to prevent rubbing or chafing.
2. Heater hoses that are protected with convoluted tubing may be fastened with tie straps. If not protected with convoluted tubing, only cushion clamps or butterfly clamps may be used for heater hoses.
3. A/C lines cannot be secured to air lines, fuel lines, or electrical wires.
4. HVAC hoses should be protected from damage by routing them away from hazards of heat, wheel splash (water, gravel, ice), human traffic, and moving parts of the vehicle.
5. HVAC hoses should be routed away from sharp points and edges (such as nuts, bolts, brackets, and frame rail edges), moveable parts, and sources of abrasion, cutting, pinching, or crushing.

NOTE: If hoses are covered with convoluted tubing, they may touch any of the above.

6. Hoses that are protected with convoluted tubing may come in contact with the bends on frame rails and filters.
7. HVAC hoses must be routed at least 6 inches (152 mm) from a heat source if the heat source does not have a heat shield. If a heat shield is provided, the hose must be routed at least 3 inches (76 mm) from the heat source.
8. All HVAC hoses must be routed so that regularly serviced components, such as fuel filters, fuel/water separators, oil filters, air filters, belts, and fill and drain plugs, are readily accessible for adjustment or replacement without the need to relocate or remove the hoses.
9. All A/C hoses in the engine compartment must have convoluted tubing.
10. If cushion clamps are used over convoluted tubing at existing clamp points, no additional tie straps or tape is needed.
11. When convoluted tubing is installed on the heater hose where it routes past the splash shield on the front right-hand side of the firewall, and if it uses existing clamps, no additional tie straps or tape is needed.

Auxiliary Heater

All auxiliary heater lines are deck-mounted hard piping with rubber hose at both ends. No additional tie straps are required.

Engine Plumbing

1. On vehicles equipped with the Cummins ISM engine and power steering, no additional tie straps or tape are needed if convoluted tubing is installed on the power steering hose where it routes under the frame rail.
2. The engine oil pressure line should not rub or chafe against the Teflon® discharge line.

Electrical Wiring

1. Wires that are bundled together should be fastened at 8- to 12-inch (203- to 305-mm) intervals. If anchor clamps are more than 12 inches (305

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Hoses and Electrical Wiring Routing Standards

mm) apart, a tie strap must be used between the anchor clamps.

2. Bundles of wires that are located in an exposed area, such as under the cab or outside the frame rail, need to be fastened with heavy-duty cable ties
3. Any wiring that will be exposed to water or heat must be covered with either loom or convoluted tubing. Loom or convoluted tubing need not butt up against Weather Pack® connectors.
4. Any wiring routed across the vehicle, on the engine crossmember, or across the rear of the engine, must be secured with a clamp or tie strap, and covered with either convoluted tubing or a loom.
5. Any wiring that may come into contact with sharp points and edges (such as nuts, bolts, brackets, and frame rail edges), moveable parts, and sources of abrasion, cutting, pinching, or crushing, must be protected by either a loom or convoluted tubing.
6. Unprotected breakouts (individual wires) of up to 8 inches (203 mm) are acceptable as long as these wires are routed safely away from sharp points and edges, moveable parts, and sources of abrasion, cutting, pinching, or crushing.
7. Gray, flame-retardant convoluted tubing may be used to protect wiring in the cab or the chassis. Black nylon convoluted tubing may only be used in the chassis.
8. All wiring must be routed so that regularly serviced components, such as fuel filters, fuel/water separators, oil filters, air filters, belts, and fill and drain plugs, are readily accessible for adjustment or replacement without the need to relocate or remove any wiring.
9. In exposed locations, such as the road light harness near the headlights, loose loops of wire must be secured with tie straps.
10. All wiring should be routed a minimum of 4 inches (102 mm) from the exhaust. In situations where the wiring is less than 4 inches (102 mm) from the exhaust, a heat shield must be placed between the wiring and the exhaust.

Battery Cables

1. Battery cables must be routed along an unobstructed path from the starter to the battery box. The cables must **not** rub or chafe on brackets, tanks, air lines, or fuel lines.
2. Battery cables and electrical wiring cannot be tied or secured to fuel lines, discharge lines, or air lines.
3. Battery cables must have support brackets no more than 30 inches (762 mm) apart. Tie straps must be within 6 inches (152 mm) of both sides of the support brackets, and every 12 inches (305 mm) between the brackets.
4. Battery cables must have convoluted tubing from the frame bracket to the batteries, and from the frame bracket to the starter.

Fuel Lines

1. Fuel lines must not be clamped to A/C lines, battery cables, jumper cables, or any other electrical wiring.
2. Stand-off brackets or clamps may be used to prevent fuel lines from rubbing against the frame.
3. Fuel lines must be routed at least 6 inches (152 mm) from a heat source. If a heat shield is provided, the fuel line must be at least 3 inches (76 mm) from the heat source.
4. Fuel lines that are parallel may be fastened together. Fuel lines that cross or that rub on metal, plastic, or electrical parts, need to be separated with butterfly clamps.

Chassis Air Lines and Brake Hoses

1. Hoses may come in contact with each other if they are parallel, or if they are bundled together.
2. If the hoses lie on the curve or flat surface of a bracket or crossmember, they do not need convoluted tubing.
3. Brake hoses may be clamped at the top of the axle housing, and touch or lie against the axle housing in its path to the brake chamber as this assembly moves together.

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4. Brake hoses must have slack between the last clamping point on the frame rail and the brake chamber to allow for full range of suspension travel.
5. Brake hoses should have butterfly clamps at breakout points.
6. Air lines and brake hoses that are bundled together should be fastened at 8- to 12-inch (203- to 305-mm) intervals. If anchor clamps are more than 12 inches (305 mm) apart, a tie strap must be used between the anchor clamps. Tie straps may be closer than 12 inches (305 mm) apart.
7. Hoses or lines that may come into contact with the sharp edge of a bracket or frame rail are to be protected by convoluted tubing.
8. Air lines and brake hoses that are parallel may be fastened together. Air lines and brake hoses that cross or that rub on metal, plastic, or electrical parts need to be separated with butterfly clamps.
9. Nylon or STX (wire braid) chassis air lines may be fastened together to prevent rubbing, as long as the lines are stationary.

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U.S. Customary to Metric			Metric to U.S. Customary		
When You Know	**Multiply By**	**To Get**	**When You Know**	**Multiply By**	**To Get**
Length					
inches (in)	25.4	millimeters (mm)	0.03937		inches (in)
inches (in)	2.54	centimeters (cm)	0.3937		inches (in)
feet (ft)	0.3048	meters (m)	3.281		feet (ft)
yards (yd)	0.9144	meters (m)	1.094		yards (yd)
miles (mi)	1.609	kilometers (km)	0.6215		miles (mi)
Area					
square inches (in^2)	645.16	square millimeters (mm^2)	0.00155		square inches (in^2)
square inches (in^2)	6.452	square centimeters (cm^2)	0.15		square inches (in^2)
square feet (ft^2)	0.0929	square meters (m^2)	10.764		square feet (ft^2)
Volume					
cubic inches (in^3)	16387.0	cubic millimeters (mm^3)	0.000061		cubic inches (in^3)
cubic inches (in^3)	16.387	cubic centimeters (cm^3)	0.06102		cubic inches (in^3)
cubic inches (in^3)	0.01639	liters (L)	61.024		cubic inches (in^3)
fluid ounces (fl oz)	29.54	milliliters (mL)	0.03381		fluid ounces (fl oz)
pints (pt)	0.47318	liters (L)	2.1134		pints (pt)
quarts (qt)	0.94635	liters (L)	1.0567		quarts (qt)
gallons (gal)	3.7854	liters (L)	0.2642		gallons (gal)
cubic feet (ft^3)	28.317	liters (L)	0.03531		cubic feet (ft^3)
cubic feet (ft^3)	0.02832	cubic meters (m^3)	35.315		cubic feet (ft^3)
Weight/Force					
ounces (av) (oz)	28.35	grams (g)	0.03527		ounces (av) (oz)
pounds (av) (lb)	0.454	kilograms (kg)	2.205		pounds (av) (lb)
U.S. tons (t)	907.18	kilograms (kg)	0.001102		U.S. tons (t)
U.S. tons (t)	0.90718	metric tons (t)	1.1023		U.S. tons (t)
Torque/Work Force					
inch-pounds (lbf·in)	11.298	Newton-centimeters (N·cm)	0.08851		inch-pounds (lbf·in)
foot-pounds (lbf·ft)	1.3558	Newton-meters (N·m)	0.7376		foot-pounds (lbf·ft)
Pressure/Vacuum					
inches of mercury (inHg)	3.37685	kilo Pascals (kPa)	0.29613		inches of mercury (inHg)
pounds per square inch (psi)	6.895	kilo Pascals (kPa)	0.14503		pounds per square inch (psi)

When You Know	Subtract	Then Divide By	To Get	When You Know	Multiply By	Then Add	To Get
degrees Fahrenheit (°F)	32	1.8	degrees Celsius (°C)		1.8	32	degrees Fahrenheit (°F)

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VIN for Vehicles Built through April 30, 2000

IMPORTANT: See **Subject 060** for the vehicle identification numbering system for vehicles built May 1, 2000, or later.

Federal Motor Vehicle Safety Standard 115 specifies that all vehicles sold in the U.S. be assigned a 17-character Vehicle Identification Number (VIN). Using a combination of letters and numerals, the VIN defines the manufacturer, model, and major characteristics of the vehicle. See **Table 1** for the character positions of a typical Sterling VIN, 480ALEBDXWA345678.

The VIN can be found on the Vehicle Specification Decal (see the driver's manual for decal location) and stamped on the outside of the left-hand frame rail about 24 to 40 inches (60 to 100 cm) aft of the front axle centerline. On Sterling vehicles built before July 1998, the VIN is stamped on the frame rail near the front axle position.

IMPORTANT: A new VIN-code structure will be used for all vehicles built after April 30, 2000. Character positions 1 through 4 and 9 through 17 are nearly the same in both versions, but positions 5 through 8 have been assigned slightly different parameters. As a result, the build date of a vehicle must be determined before the VIN can be decoded.

For all vehicles, a check digit (9th character) is determined by assignment of weighted values to the other 16 characters. These weighted values are processed through a series of equations designed to check validity of the VIN and to detect VIN alteration.

NOTE: Always specify the VIN when ordering parts.

Seventeen-Character Vehicle Identification Number (VIN)									
Typical VIN	**4 8 0**	**A**	**L**	**E B**	**D**	**X**	**W**	**A**	**345678**
Character Position	**1, 2, 3**	**4**	**5**	**6, 7**	**8**	**9**	**10**	**11**	**12 thru 17**
Decoding Table *	**Table 2**	**Table 3**	**Table 4**	**Table 5**	**Table 6**	**—**	**Table 7**	**Table 8**	**—**
Code Description									
Manufacturer, Make, Vehicle Type									
Chassis, Front Axle Position, Brakes									
Vehicle Model Series, Cab									
Engine Model, Horsepower Range									
Gross Vehicle Weight Rating (GVWR)									
Check Digit									
Vehicle Model Year									
Plant of Manufacture									
Production Number									

* For corresponding decoding information, see the applicable tables in this subject.

Table 1, Seventeen-Character Vehicle Identification Number (VIN)

VIN Positions 1, 2, and 3 (Manufacturer, Make, Vehicle Type)			
Code	**Vehicle Manufacturer**	**Vehicle Make**	**Vehicle Type**
2FW	Sterling, Canada-built	Sterling	Truck-Tractor
2FZ	Sterling, Canada-built	Sterling	Incomplete Vehicle
480	Sterling, U.S.-built	Sterling	Truck-Tractor

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VIN for Vehicles Built through April 30, 2000

VIN Positions 1, 2, and 3 (Manufacturer, Make, Vehicle Type)			
Code	**Vehicle Manufacturer**	**Vehicle Make**	**Vehicle Type**
49H	Sterling, U.S.-built	Sterling	Incomplete Vehicle

Table 2, VIN Positions 1, 2, and 3 (Manufacturer, Make, Vehicle Type)

VIN Position 4 (Chassis, Front Axle Position, Brakes)			
Code	**Chassis**	**Front Axle Position**	**Brakes**
A	4 x 2 Truck	Forward	Hydraulic
B	8 x 4 Truck-Tractor	Setback	Air
C	6 x 6 Truck-Tractor	Setback	Air
D	4 x 4 Truck	Setback	Hydraulic
E	4 x 4 Truck	Setback	Air
F	8 x 4 Truck	Forward	Air
G	8 x 4 Truck-Tractor	Forward	Air
H	4 x 2 Truck	Forward	Air
J	10 x 4 Truck	All	Air
K	4 x 2 Truck-Tractor	Forward	Air
L	6 x 2 Truck	Forward	Air
M	6 x 2 Truck-Tractor	Forward	Air
N	6 x 4 Truck	Forward	Air
P	6 x 4 Truck-Tractor	Forward	Air
R	10 x 6 Truck	Forward	Air
S	10 x 6 Truck-Tractor	Forward	Air
T	6 x 6 Truck	Setback	Air
U	8 x 6 Truck	All	Air
V	8 x 6 Truck-Tractor	All	Air
W	4 x 2 Truck-Tractor	Setback	Air
X	6 x 4 Truck	Setback	Air
Y	6 x 4 Truck-Tractor	Setback	Air
Z	6 x 2 Truck	Setback	Air
1	4 x 2 Truck	Forward	Air/Hydraulic
2	4 x 4 Truck	Setback	Air
3	4 x 2 Truck	Setback	Hydraulic
4	8 x 4 Truck	Setback	Air
5	6 x 2 Truck-Tractor	Setback	Air
6	4 x 2 Truck	Setback	Air

VIN Position 4 (Chassis, Front Axle Position, Brakes)			
Code	**Chassis**	**Front Axle Position**	**Brakes**
7	Glider	Setback	Air
8	Glider	Forward	Air
9	4 x 2 Truck	Setback	Air/Hydraulic
0	Glider	Setback	Hydraulic

Table 3, VIN Position 4 (Chassis, Front Axle Position, Brakes)

VIN Position 5 (Vehicle Model Series, Cab)	
Code	**Sterling Models**
A	L7500 series
B	L8500 series
C	L9501
D	L8511
E	L9500 series
F	L9522
G	A9522
H	A9500 series
J	A9513
K	L9513
L	L8501
M	L8513
N	L9511
R	L7501
S	ST9500
W	SC8000
2	SC6000
7	SC7000

Table 4, VIN Position 5 (Vehicle Model Series, Cab)

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VIN for Vehicles Built through April 30, 2000

VIN Positions 6 and 7 (Engine Manufacturer, Model, Horsepower Range)			
Code	**Engine Manufacturer**	**Engine Model**	**HP Range**
AY	Cummins	NTC / N14	207–251
BY	Cummins	NTC / N14	254–310
CX	Detroit Diesel	S-60, 11.1 L	331–402
CY	Cummins	NTC / N14	315–385
DY	Cummins	NTC / N14	389–475
DZ	Cummins	N14	476–580
EB	Caterpillar	C10 / 3176J	225–275
EC	Caterpillar	C10 / 3176J	276–335
ED	Caterpillar	C10 / 3176J	336–407
FA	Cummins	6BT 5.9 (diesel) / ISB	185–224
FB	Cummins	6BT 5.9 (diesel) / ISB	225–275
FF	Cummins	6BT 5.9/ ISB	153–184
JA	Caterpillar	CFE / 3126 (diesel)	185–224
JB	Caterpillar	CFE / 3126 (diesel)	225–275
JC	Caterpillar	CFE / 3126 (diesel)	276–335
JF	Caterpillar	CFE / 3126 (diesel)	153–184
KY	Cummins	L10	225–275
LA	Cummins	6C 8.3 (diesel) / ISC	185–224
LB	Cummins	6C 8.3 (diesel) / ISC	225–275
LC	Cummins	6C 8.3 (diesel) / ISC	276–335
LE	Cummins	ISC	336–407
MC	Cummins	M11 / ISM	276–335
MD	Cummins	M11 / ISM	336–407
PY	Detroit Diesel	S-60, 11.1 L	275–330
RY	Caterpillar	3406	270–330
SE	Detroit Diesel	S-60, 12.7 L	408–495
SY	Caterpillar	3406	333–407
UY	Caterpillar	3306	225–275
VY	Caterpillar	3406	225–269
WD	Caterpillar	C12 / 3176L	336–407
WE	Caterpillar	C12 / 3176L	408–495
WY	Caterpillar	3306	276–335
XY	Caterpillar	3406	408–495
XZ	Caterpillar	3406	496–605
YY	Detroit Diesel	S-60, 11.1 L	225–274
ZY	Detroit Diesel	S-60, 12.7 L	333–407

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VIN for Vehicles Built through April 30, 2000

VIN Positions 6 and 7 (Engine Manufacturer, Model, Horsepower Range)			
Code	**Engine Manufacturer**	**Engine Model**	**HP Range**
0Y	No Engine	—	—

Table 5, VIN Positions 6 and 7 (Engine Manufacturer, Model, Horsepower Range)

VIN Position 8 (Gross Vehicle Weight Rating)		
Code	**lb**	**kg**
A	26,001–33,000	11 794–14 968
B	33,001 or over	14 969 or over
C	19,501–26,000	8846–11 793
D	16,001–19,500	7258–8845
2	6001–10,000	2722–4536
3	10,001–14,000	4537–6350
4	14,001–16,000	6351–7257
9	N/A: Incomplete Vehicle or Glider	

Table 6, VIN Position 8 (Gross Vehicle Weight Rating)

VIN Position 10 (Vehicle Model Year)	
Code	**Model Year**
N	1992
P	1993
R	1994
S	1995
T	1996
V	1997
W	1998
X	1999
Y	2000

Table 7, VIN Position 10 (Vehicle Model Year)

VIN Position 11 (Plant of Manufacture)	
Code	**Plant of Manufacture**
A	St. Thomas, Ontario
H	Mt. Holly, North Carolina

Table 8, VIN Position 11 (Plant of Manufacture)

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VIN for Vehicles Built from May 1, 2000

IMPORTANT: See **Subject 050** for the vehicle identification numbering system for vehicles built before May 1, 2000.

Federal Motor Vehicle Safety Standard 115 specifies that all vehicles sold in the U.S. be assigned a 17-character Vehicle Identification Number (VIN). Using a combination of letters and numerals, the VIN defines the manufacturer, model, and major characteristics of the vehicle. See **Table 1** for the character positions of a typical Sterling VIN, 2FZPABAV11AA12345.

The VIN can be found on the Vehicle Specification Decal (see the driver's manual for decal location) and stamped on the outside of the frame rails about 24 to 40 inches (60 to 100 cm) aft of the front axle centerline.

IMPORTANT: A revised VIN-code structure will be used for all vehicles built after April 30, 2000. As a result, the build date of a vehicle must be determined before the VIN can be decoded.

Character positions 1 through 4 and 9 through 17 are nearly the same in both versions, but positions 5 through 8 have been assigned slightly different parameters.

Another new feature is that each product line has its own model list; that is, positions 5 and 6 are product-specific. For example, the code AB in positions 5 and 6 for a Sterling vehicle indicates an SC7000 Cargo. Code AB in the same position for a Freightliner vehicle represents an FLD112.

For all vehicles, a check digit (9th character) is determined by assignment of weighted values to the other 16 characters. These weighted values are processed through a series of equations designed to check validity of the VIN and to detect VIN alteration.

NOTE: Always specify the VIN when ordering parts.

Seventeen-Character Vehicle Identification Number (VIN)								
Typical VIN	**2 F Z**	**P**	**A B**	**A V**	**1**	**1**	**A**	**A 1 2 3 4 5**
Character Position	**1, 2, 3**	**4**	**5, 6**	**7, 8**	**9**	**10**	**11**	**12–17**
Code Description	World Manufacturer Identification	Chassis Configuration	Model, Cab, GVWR	Engine, Brakes	Check Digit Calculation	Model Year	Build Location	Production Serial Number
Decoding Table *	**Table 2**	**Table 3**	**Table 4**	**Table 5**	—	**Table 6**	**Table 7**	—

* For corresponding decoding information, see the applicable tables in this subject.

Table 1, Seventeen-Character Vehicle Identification Number (VIN)

VIN Positions 1, 2, and 3 (World Manufacturer Identification)			
Code	**Vehicle Manufacturer**	**Vehicle Make**	**Vehicle Type**
2FW	Sterling, Canada-built	Sterling	Truck-Tractor
2FZ	Sterling, Canada-built	Sterling	Incomplete Vehicle
480	Sterling, U.S.-built	Sterling	Truck-Tractor
49H	Sterling, U.S.-built	Sterling	Incomplete Vehicle

Table 2, VIN Positions 1, 2, and 3 (World Manufacturer Identification)

VIN Position 4 (Chassis Configuration)	
Code	**Chassis**
A	4 x 2 Truck
B	4 x 2 Truck-Tractor

VIN Position 4 (Chassis Configuration)	
Code	**Chassis**
D	4 x 4 Truck
E	4 x 4 Truck-Tractor

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VIN Position 4 (Chassis Configuration)	
Code	**Chassis**
F	6 x 2 Truck
G	6 x 2 Truck-Tractor
H	6 x 4 Truck
J	6 x 4 Truck-Tractor
K	6 x 6 Truck
L	6 x 6 Truck-Tractor
M	8 x 4 Truck
N	8 x 4 Truck-Tractor
P	8 x 6 Truck
R	8 x 6 Truck-Tractor
S	10 x 4 Truck
T	10 x 4 Truck-Tractor
U	10 x 6 Truck-Tractor
V	10 x 6 Truck-Tractor
X	Glider

Table 3, VIN Position 4 (Chassis, Front Axle Position, Brakes)

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**Class (GVWR)**
AA	SC7000 Cargo	COE	Class 6 *
AB	SC7000 Cargo	COE	Class 7 †
AC	SC7000 Cargo	COE	Class 8 ‡
AD	SC8000 Cargo	COE	Class 7
AE	SC8000 Cargo	COE	Class 8
AF	M5500 Acterra	Conventional	Class 5 §
AG	M6500 Acterra	Conventional	Class 5
AH	M6500 Acterra	Conventional	Class 6
AJ	M7500 Acterra	Conventional	Class 6
AK	M7500 Acterra	Conventional	Class 7
AL	M8500 Acterra	Conventional	Class 6
AM	M8500 Acterra	Conventional	Class 7
AN	M8500 Acterra	Conventional	Class 8

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**Class (GVWR)**
AP	L7500 Series	Conventional	Class 5
AR	L7500 Series	Conventional	Class 6
AS	L7500 Series	Conventional	Class 7
AT	L7500 Series	Conventional	Class 8
AU	L7500 Series Glider	Conventional	Glider
AV	L8500 Series	COE	Class 7
AW	L8500 Series	COE	Class 8
AX	L8500 Series Glider	COE	Glider
AY	L9500 Series	Conventional	Class 7
AZ	L9500 Series	Conventional	Class 8
A1	L9500 Series Glider	Conventional	Glider
A2	A9500 Series	Conventional	Class 7
A3	A9500 Series	Conventional	Class 8
A4	A9500 Series Glider	Conventional	Glider
A5	ST9500 Series	Conventional	Class 7
A6	ST9500 Series	Conventional	Class 8
A7	ST9500 Series Glider	Conventional	Glider
A8	L7501	Conventional	Class 6
A9	L7501	Conventional	Class 7
A0	L7501	Conventional	Class 8
BA	L8501	Conventional	Class 6
BB	L8501	Conventional	Class 7
BC	L8501	Conventional	Class 8
BD	L8511	Conventional	Class 7
BE	L8511	Conventional	Class 8
BF	L8513	Conventional	Class 7
BG	L8513	Conventional	Class 8
BH	L9501	Conventional	Class 7
BJ	L9501	Conventional	
BK	L9511	Conventional	Class 7
BL	L9511	Conventional	Class 8
BM	L9513	Conventional	Class 7
BN	L9513	Conventional	Class 8

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VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**Class (GVWR)**
BP	A9522	Conventional	Class 7
BR	A9522	Conventional	Class 8
BS	L9522	Conventional	Class 7
BT	L9522	Conventional	Class 8
BU	T-2	COE	Class 7
BV	T-2	COE	Class 8

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**Class (GVWR)**
BW	L9513	Conventional	Class 7
BX	L9513	Conventional	Class 8

* Class 6 GVWR is 19,501–26,000 lb.
† Class 7 GVWR is 26,001–33,000 lb.
‡ Class 8 GVWR is 33,001 lb and over.
§ Class 5 GVWR is 16,001–19,500 lb.

Table 4, VIN Positions 5 and 6 (Model, Cab, Class/GVWR)

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displace-ment (L)**	**Config-uration**	**Brakes**
AA	Caterpillar 3176	Diesel	10.3	I–6	Air
AB	Caterpillar 3176	Diesel	10.3	I–6	Hydraulic
AC	Caterpillar 3176	Diesel	10.3	I–6	Air/Hydraulic
AD	Caterpillar 3406	Diesel	14.6	I–6	Air
AE	Caterpillar 3406	Diesel	14.6	I–6	Hydraulic
AF	Caterpillar 3406	Diesel	14.6	I–6	Air/Hydraulic
AG	Caterpillar 3406E	Diesel	15.8	I–6	Air
AH	Caterpillar 3406E	Diesel	15.8	I–6	Hydraulic
AJ	Caterpillar 3406E	Diesel	15.8	I–6	Air/Hydraulic
AK	Caterpillar 3126/CFE	Diesel	7.2	I–6	Air
AL	Caterpillar 3126/CFE	Diesel	7.2	I–6	Hydraulic
AM	Caterpillar 3126/CFE	Diesel	7.2	I–6	Air/Hydraulic
AN	Caterpillar C10	Diesel	10.3	I–6	Air
AP	Caterpillar C10	Diesel	10.3	I–6	Hydraulic
AR	Caterpillar C10	Diesel	10.3	I–6	Air/Hydraulic
AS	Caterpillar C12	Diesel	12.0	I–6	Air
AT	Caterpillar C12	Diesel	12.0	I–6	Hydraulic
AU	Caterpillar C12	Diesel	12.0	I–6	Air/Hydraulic
AV	Caterpillar C15	Diesel	14.6	I–6	Air
AW	Caterpillar C15	Diesel	14.6	I–6	Hydraulic
AX	Caterpillar C15	Diesel	14.6	I–6	Air/Hydraulic

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VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displace-ment (L)**	**Config-uration**	**Brakes**
AY	Caterpillar C16	Diesel	15.8	I–6	Air
AZ	Caterpillar C16	Diesel	15.8	I–6	Hydraulic
A1	Caterpillar C16	Diesel	15.8	I–6	Air/Hydraulic
A2	Cummins L10	Diesel	10.8	I–6	Air
A3	Cummins L10	Diesel	10.8	I–6	Hydraulic
A4	Cummins L10	Diesel	10.8	I–6	Air/Hydraulic
A5	Cummins M11	Diesel	10.8	I–6	Air
A6	Cummins M11	Diesel	10.8	I–6	Hydraulic
A7	Cummins M11	Diesel	10.8	I–6	Air/Hydraulic
A8	Cummins ISM	Diesel	10.8	I–6	Air
A9	Cummins ISM	Diesel	10.8	I–6	Hydraulic
A0	Cummins ISM	Diesel	10.8	I–6	Air/Hydraulic
BA	Cummins NTC	Diesel	14.0	I–6	Air
BB	Cummins NTC	Diesel	14.0	I–6	Hydraulic
BC	Cummins NTC	Diesel	14.0	I–6	Air/Hydraulic
BD	Cummins N14	Diesel	14.0	I–6	Air
BE	Cummins N14	Diesel	14.0	I–6	Hydraulic
BF	Cummins N14	Diesel	14.0	I–6	Air/Hydraulic
BG	Cummins ISX/Signature	Diesel	14.9	I–6	Air
BH	Cummins ISX/Signature	Diesel	14.9	I–6	Hydraulic
BJ	Cummins ISX/Signature	Diesel	14.9	I–6	Air/Hydraulic
BK	Cummins C8.3	Diesel	8.3	I–6	Air
BL	Cummins C8.3	Diesel	8.3	I–6	Hydraulic
BM	Cummins C8.3	Diesel	8.3	I–6	Air/Hydraulic
BN	Cummins B5.9	Diesel	5.9	I–6	Air
BP	Cummins B5.9	Diesel	5.9	I–6	Hydraulic
BR	Cummins B5.9	Diesel	5.9	I–6	Air/Hydraulic
BS	Cummins ISC	Diesel	8.3	I–6	Air
BT	Cummins ISC	Diesel	8.3	I–6	Hydraulic
BU	Cummins ISC	Diesel	8.3	I–6	Air/Hydraulic

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VIN for Vehicles Built from May 1, 2000

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displace-ment (L)**	**Config-uration**	**Brakes**
BV	Cummins ISB	Diesel	5.9	I–6	Air
BW	Cummins ISB	Diesel	5.9	I–6	Hydraulic
BX	Cummins ISB	Diesel	5.9	I–6	Air/Hydraulic
BY	Cummins B5.9	Propane	5.9	I–6	Air
BZ	Cummins B5.9	Propane	5.9	I–6	Hydraulic
B1	Cummins B5.9	Propane	5.9	I–6	Air/Hydraulic
B2	Cummins B5.9	Natural Gas	5.9	I–6	Air
B3	Cummins B5.9	Natural Gas	5.9	I–6	Hydraulic
B4	Cummins B5.9	Natural Gas	5.9	I–6	Air/Hydraulic
B5	Cummins C8.3	Natural Gas	8.3	I–6	Air
B6	Cummins C8.3	Natural Gas	8.3	I–6	Hydraulic
B7	Cummins C8.3	Natural Gas	8.3	I–6	Air/Hydraulic
B8	Detroit Series 50	Diesel	8.5	I–4	Air
B9	Detroit Series 50	Diesel	8.5	I–4	Hydraulic
B0	Detroit Series 50	Diesel	8.5	I–4	Air/Hydraulic
CA	Detroit Series 55	Diesel	12.0	I–6	Air
CB	Detroit Series 55	Diesel	12.0	I–6	Hydraulic
CC	Detroit Series 55	Diesel	12.0	I–6	Air/Hydraulic
CD	Detroit Series 60	Diesel	11.1	I–6	Air
CE	Detroit Series 60	Diesel	11.1	I–6	Hydraulic
CF	Detroit Series 60	Diesel	11.1	I–6	Air/Hydraulic
CG	Detroit Series 60	Diesel	12.7	I–6	Air
CH	Detroit Series 60	Diesel	12.7	I–6	Hydraulic
CJ	Detroit Series 60	Diesel	12.7	I–6	Air/Hydraulic
CK	Detroit Series 60	Diesel	14.0	I–6	Air
CL	Detroit Series 60	Diesel	14.0	I–6	Hydraulic
CM	Detroit Series 60	Diesel	14.0	I–6	Air/Hydraulic
CN	Mercedes-Benz MBE900	Diesel	4.3	I–4	Air
CP	Mercedes-Benz MBE900	Diesel	4.3	I–4	Hydraulic
CR	Mercedes-Benz MBE900	Diesel	4.3	I–4	Air/Hydraulic

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VIN for Vehicles Built from May 1, 2000

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement (L)**	**Configuration**	**Brakes**
CS	Mercedes-Benz MBE900	Diesel	6.4	I–6	Air
CT	Mercedes-Benz MBE900	Diesel	6.4	I–6	Hydraulic
CU	Mercedes-Benz MBE900	Diesel	6.4	I–6	Air/Hydraulic
CV	Mercedes-Benz MBE4000	Diesel	12.0	I–6	Air
CW	Mercedes-Benz MBE4000	Diesel	12.0	I–6	Hydraulic
CX	Mercedes-Benz MBE4000	Diesel	12.0	I–6	Air/Hydraulic
CY	Cummins ISL	Diesel	8.3	I–6	Air
CZ	Cummins ISL	Diesel	8.3	I–6	Hydraulic
C1	Cummins ISL	Diesel	8.3	I–6	Air/Hydraulic
C2	Cummins B3.9	Diesel	3.9	I–4	Air
C3	Cummins B3.9	Diesel	3.9	I–4	Hydraulic
C4	Cummins B3.9	Diesel	3.9	I–4	Air/Hydraulic
C5	Cummins ISB 3.9	Diesel	3.9	I–4	Air
C6	Cummins ISB 3.9	Diesel	3.9	I–4	Hydraulic
C7	Cummins ISB 3.9	Diesel	3.9	I–4	Air/Hydraulic
00	No Engine	—	—	—	—

Table 5, VIN Positions 7 and 8 (Engine, Brakes)

VIN Position 10 (Model Year)	
Code	**Model Year**
Y	2000
1	2001
2	2002
3	2003
4	2004
5	2005
6	2006
7	2007

Table 6, VIN Position 10 (Vehicle Model Year)

VIN Position 11 (Build Location)	
Code	**Build Location**
A	St. Thomas, Ontario

VIN Position 11 (Build Location)	
Code	**Build Location**
H	Mt. Holly, North Carolina

Table 7, VIN Position 11 (Build Location)

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Threaded Fastener Types

The majority of threaded fasteners used throughout the vehicle have U.S. customary threads (diameter and pitch are measured in inches). See **Fig. 1**. However, the engine and some items attached to the cab use metric fasteners (diameter and pitch are measured in millimeters).

Most threaded fasteners used on the vehicle that are 1/2-inch diameter or larger are plain hex-type fasteners (non-flanged); *all* metric fasteners are non-flanged. Special hardened flatwashers are used under the bolt head, and between the part being attached and the hexnut, to distribute the load, and to prevent localized overstressing of the parts. The washers are cadmium- or zinc-plated, and have a hardness rating of 38 to 45 HRC.

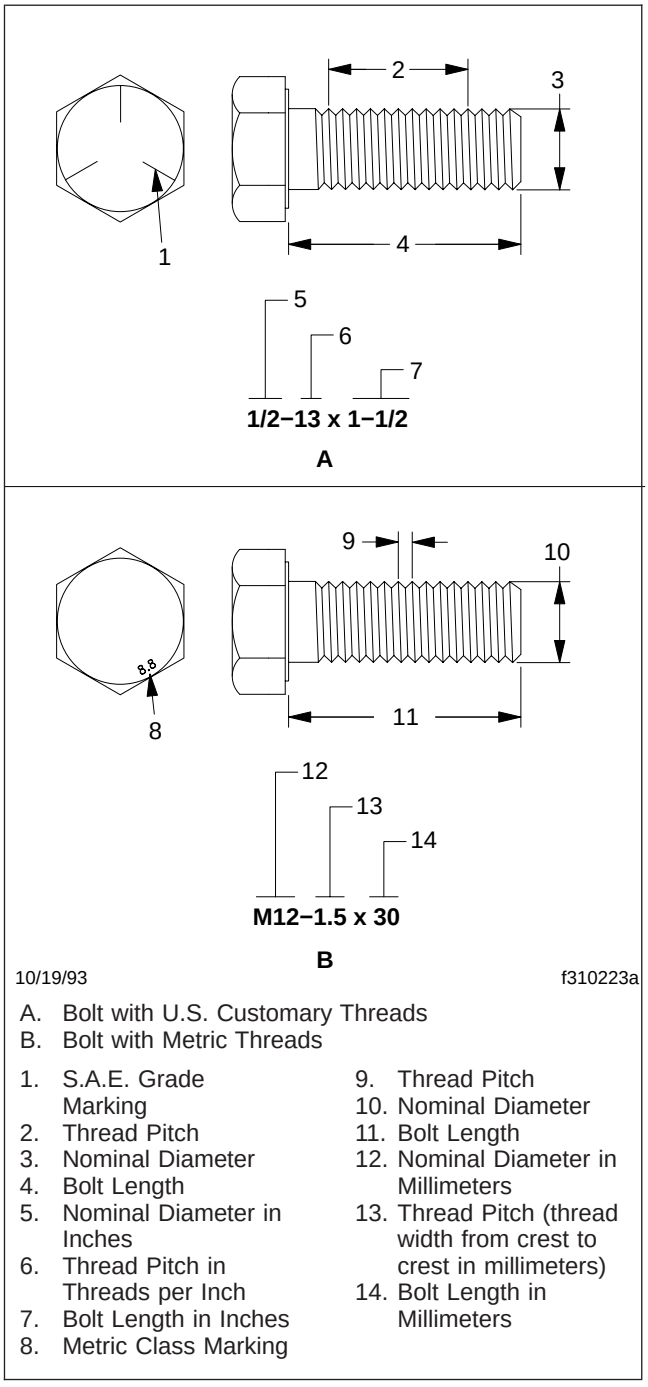
Some fasteners smaller than 1/2-inch diameter are flanged fasteners, which have integral flanges that fit against the parts being fastened. The flanges eliminate the need for washers.

NOTE: The standard fasteners used to assemble the vehicle frame and to attach components to the vehicle frame are threaded lockbolts (Spin Hucks). These fasteners are covered in **Section 31.00.**

Fastener Grades and Classes

Fasteners with U.S. customary threads are divided into grades established by the Society of Automotive Engineers (S.A.E.) or the International Fastener Institute (I.F.I.). The fastener grades indicate the relative strength of the fastener; the higher the number (or letter), the stronger the fastener. Bolt (capscrew) grades can be identified by the number and pattern of radial lines forged on the bolt head. See **Fig. 2**. Hexnut (and locknut) grades can be identified by the number and pattern of lines and dots on various surfaces of the nut. See **Fig. 3.** Nearly all of the bolts used on the vehicle are grades 5, 8, and 8.2. Matching grades of hexnuts are always used: grade 5 or grade B hexnuts are used with grade 5 bolts; grade 8, grade C, or grade G (flanged) hexnuts are used with grade 8 or 8.2 bolts.

Fasteners with metric threads are divided into classes adopted by the American National Standards Institute (ANSI). The higher the class number, the stronger the fastener. Bolt classes can be identified by the numbers forged on the head of the bolt. See **Fig. 4**. Hexnut (and locknut) classes can be identified by the marks or numbers on various surfaces of the



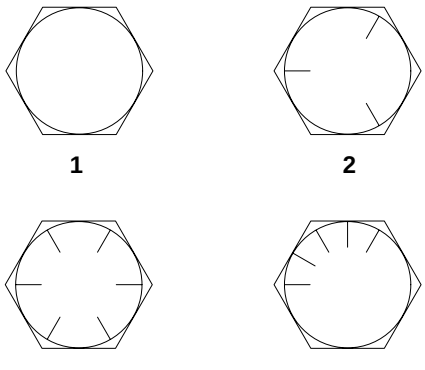
A. Bolt with U.S. Customary Threads
B. Bolt with Metric Threads

1. S.A.E. Grade Marking
2. Thread Pitch
3. Nominal Diameter
4. Bolt Length
5. Nominal Diameter in Inches
6. Thread Pitch in Threads per Inch
7. Bolt Length in Inches
8. Metric Class Marking
9. Thread Pitch
10. Nominal Diameter
11. Bolt Length
12. Nominal Diameter in Millimeters
13. Thread Pitch (thread width from crest to crest in millimeters)
14. Bolt Length in Millimeters

Fig. 1, Fastener Size and Thread Identification

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General Information



NOTE: Grade 2 bolts have no grade marking; grade 2 bolts are rarely used by Freightliner.These grade markings are used on plain hex-type and flanged bolts (capscrews). In addition to the grade markings, the bolt head must also carry the manufacturer's trademark or identification.

1. Grade 2
2. Grade 5
3. Grade 8
4. Grade 8.2

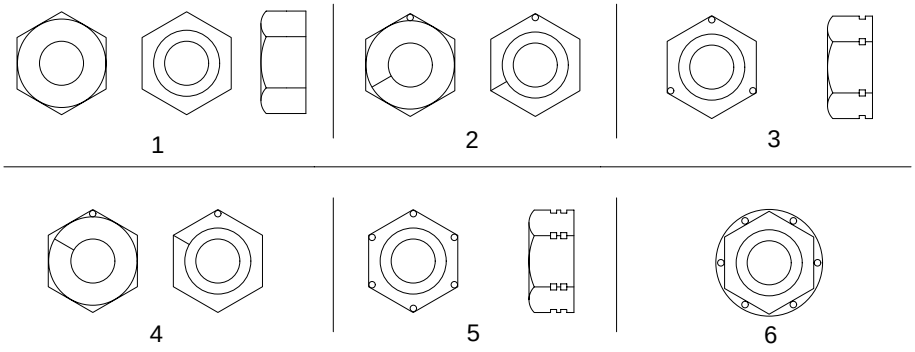
Fig. 2, Bolt Grades

nut. See **Fig. 5**. Class 8 hexnuts are always used with class 8.8 bolts; class 10 hexnuts with class 10.9 bolts.

Frame Fasteners

The standard fasteners used to assemble the vehicle frame and to attach most components to the vehicle frame are threaded lockbolts (Spin Hucks). These fasteners are covered in **Section 31.00.**

For some other components attached to the frame, grade 8 and 8.2 phosphate-and oil-coated hexhead bolts and grade C cadmium-plated and wax-coated prevailing torque locknuts are used. The prevailing torque locknuts have distorted sections of threads to provide torque retention. For attachments where clearance is minimal, low-profile hexhead bolts and grade C prevailing torque locknuts are used. See **Fig. 6**.

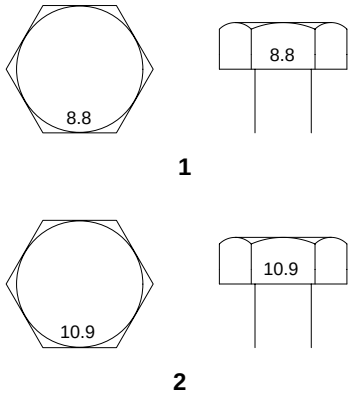


NOTE: Grade 2 (S.A.E.) and grade A (I.F.I.) nuts have no identification marks or notches; they are rarely used by Freightliner. Grade B (I.F.I.) nuts have three identification marks at 120 degrees, or 6 notches. Grade C (I.F.I.) nuts have three identification marks at 60 degrees, or 12 notches. Grade G (I.F.I.) flanged nuts have six identification marks as shown; each identification mark may be a dot, line, pair of dots or lines, or any other symbol at the manufacturer's option.

1. S.A.E. Grade 2 or I.F.I. Grade A Nut (strength compatible with grade 2 bolt.)
2. S.A.E. Grade 5 Nut (strength compatible with grade 5 bolt.)
3. I.F.I. Grade B Nut (strength compatible with grade 5 bolt.)
4. S.A.E. Grade 8 Nut (strength compatible with grade 8 or grade 8.2 bolt.)
5. I.F.I. Grade C Nut (strength compatible with grade 8 or grade 8.2 bolt.)
6. I.F.I. Grade G Nut (flanged locknut; strength compatible with grade 8 or grade 8.2 bolt.)

Fig. 3, Nut Grades

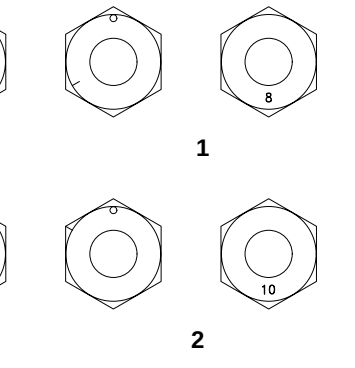
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NOTE: In addition to the class markings, the bolt head must also carry the manufacturer's trademark or identification.

1. Class 8.8
2. Class 10.9

Fig. 4, Bolt Classes

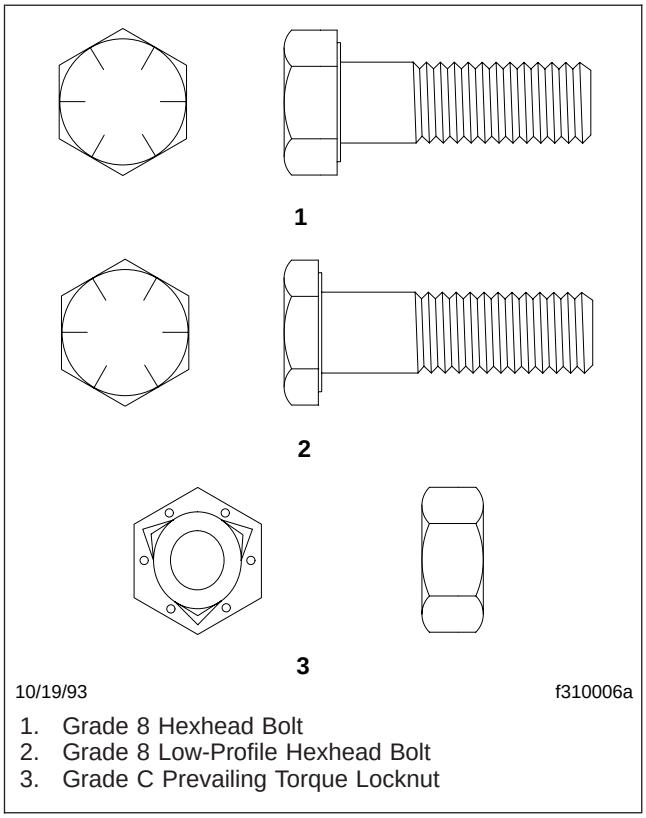


1. Class 8 Nut
2. Class 10 Nut

Fig. 5, Nut Classes

Tightening Fasteners

When a capscrew is tightened to its torque value in a threaded hole, or a nut is tightened to its torque value on a bolt, the shank of the capscrew or bolt is stretched slightly. This stretching (tensioning) results in a preload that reduces fatigue of the fasteners. The torque values given in the tables in **Specifications, 400** have been calculated to provide enough clamping force on the parts being fastened, and the correct tensioning of the bolt to maintain the clamping force.



1. Grade 8 Hexhead Bolt
2. Grade 8 Low-Profile Hexhead Bolt
3. Grade C Prevailing Torque Locknut

Fig. 6, Frame Fastener Identification

Use of a torque wrench to tighten fasteners will help prevent overtensioning them. Overtensioning causes permanent stretching of the fasteners, which can result in breakage of the parts or fasteners.

When torquing a fastener, typically 80 to 90 percent of the turning force is used to overcome friction; only 10 to 20 percent is used to stretch the capscrew or bolt. About 40 to 50 percent of the turning force is needed to overcome the friction between the underside of the capscrew head or nut and the washer. Another 30 to 40 percent is needed to overcome the friction between the threads of the capscrew and the threaded hole, or the friction between the threads of the nut and bolt.

The amount of torque required to tighten a fastener is reduced when the amount of friction is reduced. If a fastener is dry (unlubricated) and plain (unplated), the amount of friction is high. If a fastener is wax-coated or oiled, or has a zinc phosphate coating or cadmium plating, the amount of friction is reduced. Each of these coatings and combinations of coatings has a different effect. Using zinc-plated hardened

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flatwashers under the bolt (capscrew) head and nut reduces the amount of friction. Dirt or other foreign material on the threads or clamping surfaces of the fastener or clamped part also changes the amount of friction.

Even though each different condition affects the amount of friction, a different torque value cannot be given for each different condition. To ensure they are always torqued accurately, Freightliner recommends that all fasteners be lubricated with oil (unless specifically instructed to install them dry), then torqued to the values for lubricated- and plated-thread fasteners. When locking compound or anti-seize compound is recommended for a fastener, the compound acts as a lubricant, and oil is not needed.

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Fastener Replacement

When replacing fasteners, use only identical bolts, washers, and nuts; they must be the same size, strength, and finish as originally specified. Refer to the Freightliner *Service Parts Catalog* for fastener specifications.

When replacing graded (or metric class) bolts and capscrews, use only fasteners that have the manufacturer's trademark or identification on the bolt head; don't use substandard bolts. Inferior, counterfeit fasteners are difficult to identify; buy your fasteners from a reputable supplier.

Fastener Selection and Installation

When using nuts with bolts, use a grade (or class) of nut that matches the bolt.

When installing non-flanged fasteners, use hardened steel flatwashers under the bolt (capscrew) head, and under the hexnut or locknut.

For bolts 100 mm (4 inches) or less in length, make sure that at least 1-1/2 threads and no more than 16-mm (5/8-inch) bolt length extends through the nut after it has been tightened. For bolts longer than 100 mm (4 inches), allow a minimum of 1-1/2 threads and a maximum of 19-mm (3/4-inch) bolt length.

Never hammer or screw bolts into place. Align the holes of the parts being attached, so that the nut and bolt surfaces are flush against the washers, and the washers are flush against the parts.

When installing fasteners in aluminum or plastic parts with threaded holes, start the fasteners by hand, to ensure straight starting and to prevent damaged threads.

Don't use lockwashers (split or toothed) next to aluminum surfaces.

When installing studs that don't have an interference fit, install them with thread locking compound, as instructed in this subject.

When installing parts that are mounted on studs, use free-spinning (non-locking) nuts and helical-spring (split) lockwashers or internal-tooth lockwashers. Don't use locknuts, because they tend to loosen the studs during removal. Don't use plain washers (flatwashers).

Don't use lockwashers and flatwashers in combination (against each other); each defeats the other's purpose.

Use stainless steel fasteners against chrome plating, unpainted aluminum, or stainless steel.

Fastener Tightening

Before installing fasteners, clean all fastener (and parts) threads, and all surfaces being clamped.

To ensure they are always torqued accurately, Freightliner recommends that *all* fasteners be lubricated with oil (unless specifically instructed to install them dry), then torqued to the values for lubricated- and plated-thread fasteners. When locking compound or anti-seize compound is recommended for a fastener, the compound acts as a lubricant, and oil is not needed.

Bring parts and fasteners into contact, with no gaps between them, before using a torque wrench to tighten fasteners to their final torque values.

Tighten the nut, not the bolt head. This will give a truer torque reading by eliminating bolt body friction.

Always use a torque wrench to tighten fasteners, and use a slow, smooth, even pull on the wrench. Don't overtorque fasteners; overtightening causes permanent stretching of the fasteners, which can result in breakage of the parts or fasteners.

If specific torque values aren't given for countersunk bolts, use the torque value for the corresponding size and grade of regular bolt, as given in Subject 400.

Always follow the torque sequence or torque interval when provided, to ensure that clamping forces are even, and parts and fasteners aren't distorted.

Tighten frame fasteners periodically to offset the effects of "bedding in" (seating). Continued vehicle operation with loose frame fasteners could result in component, bracket, and frame damage. Refer to the Maintenance Schedule and Group 31 of the vehicle maintenance manual for intervals.

Thread Locking Compound Application

When the use of thread locking compound is recommended or desired, for studs, capscrews, and bolts

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General Instructions

with a thread diameter of 25 mm (1 inch) or less, use Loctite® 271 or Perma-Lok® HM-128.

For thread diameters over 25 mm (1 inch), use Loctite 277.

NOTE: Follow the safety precautions given on the locking compound container.

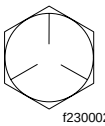
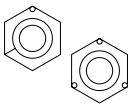
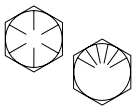
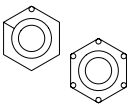
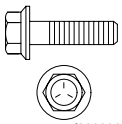
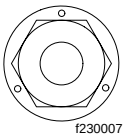
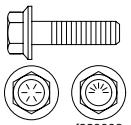
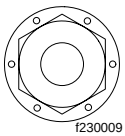
1. Clean the male and female threads of the fasteners, removing all dirt, oil, and other foreign material. If parts are contaminated, use Stoddard solvent for cleaning; then allow the fasteners to air dry for 10 minutes. Be sure solvent is completely gone before applying adhesive.
2. Transfer a small amount of the locking compound from the container to a paper cup or small non-metal dish.
3. Using a plastic brush (a metal brush will contaminate the compound), apply a small amount of compound to the entire circumference of 3 or 4 of the male threads that will be covered by the nut after it has been tightened. Be sure enough compound is applied to fill the inside of the nut threads, with a slight excess.
4. Install and torque the nut. Readjustment of the nut position is not possible after installation is complete, without destroying the locking effect.

NOTE: To disassemble the fasteners, heat the bond line to 200°C (400°F) before removing the nut. Every time the fasteners are disassembled, replace them. If any parts are damaged by overheating, replace the parts.

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This subject contains the following tables:

- Torque Values for U.S. Customary Thread Fasteners with Lubricated or Plated Threads
- Torque Values for U.S. Customary Thread Fasteners with Dry (Unlubricated) or Plain (Unplated) Threads
- Torque Values for Metric Thread Fasteners with Lubricated or Plated Threads

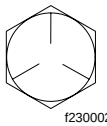
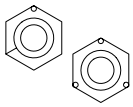
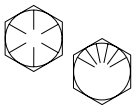
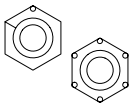
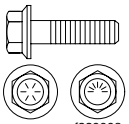
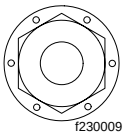
Torque Values for U.S. Customary Thread Fasteners with Lubricated * or Plated Threads †								
Thread Diameter–Pitch	Regular Hex				Flanged			
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut	Grade 5 Bolt	Grade B Nut	Grade 8 or 8.2 Bolt	Grade G Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)	
	 f230002	 f230003	 f230004	 f230005	 f230006	 f230007	 f230008	 f230009
1/4–20	7 (9)		8 (11)		6 (8)		10 (14)	
1/4–28	8 (11)		9 (12)		7 (9)		12 (16)	
5/16–18	15 (20)		16 (22)		13 (18)		21 (28)	
5/16–24	16 (22)		17 (23)		14 (19)		23 (31)	
3/8–16	26 (35)		28 (38)		23 (31)		37 (50)	
3/8–24	30 (41)		32 (43)		25 (34)		42 (57)	
7/16–14	42 (57)		45 (61)		35 (47)		60 (81)	
7/16–20	47 (64)		50 (68)		40 (54)		66 (89)	
1/2–13	64 (87)		68 (92)		55 (75)		91 (123)	
1/2–20	72 (98)		77 (104)		65 (88)		102 (138)	
9/16–12	92 (125)		98 (133)		80 (108)		130 (176)	
9/16–18	103 (140)		110 (149)		90 (122)		146 (198)	
5/8–11	128 (173)		136 (184)		110 (149)		180 (244)	
5/8–18	145 (197)		154 (209)		130 (176)		204 (277)	
3/4–10	226 (306)		241 (327)		200 (271)		320 (434)	
3/4–16	253 (343)		269 (365)		220 (298)		357 (484)	
7/8–9	365 (495)		388 (526)		320 (434)		515 (698)	
7/8–14	402 (545)		427 (579)		350 (475)		568 (770)	
1–8	—		582 (789)		—		—	
1–12	—		637 (863)		—		—	
1–14	—		652 (884)		—		—	

* Sterling recommends that all plated and unplated fasteners be coated with oil before installation.
† Use these torque values if either the bolt or nut is lubricated or plated (zinc-phosphate conversion-coated, cadmium-plated, or waxed).

Table 1, Torque Values for U.S. Customary Thread Fasteners with Lubricated or Plated Threads

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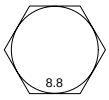
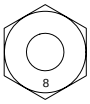
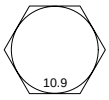
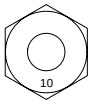
Specifications

Torque Values for U.S. Customary Thread Fasteners with Dry (Unlubricated) * Plain (Unplated) Threads †						
Thread Diameter–Pitch	Regular Hex				Flanged	
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut	Grade 8 or 8.2 Bolt	Grade G Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)	
	 f230002	 f230003	 f230004	 f230005	 f230008	 f230009
1/4–20	8 (11)		10 (14)		—	
1/4–28	9 (12)		12 (16)		—	
5/16–18	15 (20)		22 (30)		22 (30)	
5/16–24	17 (23)		25 (34)		—	
3/8–16	28 (38)		40 (54)		40 (54)	
3/8–24	31 (42)		45 (61)		—	
7/16–14	45 (61)		65 (88)		65 (88)	
7/16–20	50 (68)		70 (95)		—	
1/2–13	70 (95)		95 (129)		95 (129)	
1/2–20	75 (102)		110 (149)		—	
9/16–12	100 (136)		140 (190)		140 (190)	
9/16–18	110 (149)		155 (210)		—	
5/8–11	135 (183)		190 (258)		190 (258)	
5/8–18	155 (210)		215 (292)		—	
3/4–10	240 (325)		340 (461)		340 (461)	
3/4–16	270 (366)		380 (515)		—	
7/8–9	385 (522)		540 (732)		—	
7/8–14	425 (576)		600 (813)		—	
1–8	580 (786)		820 (1112)		—	
1–12	635 (861)		900 (1220)		—	
1–14	650 (881)		915 (1241)		—	

* Threads may have residual oil, but will be dry to the touch.
† Male and female threads (bolt and nut) must both be unlubricated and unplated; if either is plated or lubricated, use **Table 1**. Sterling recommends that all plated and unplated fasteners be coated with oil before installation.

Table 2, Torque Values for U.S. Customary Thread Fasteners with Dry (Unlubricated) Plain (Unplated) Threads

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Torque Values for Metric Thread Fasteners with Lubricated * or Plated Threads †				
Thread Diameter–Pitch	Class 8.8 Bolt	Class 8 Nut	Class 10.9 Bolt	Class 10 Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)	
	 f230010	 f230011	 f230012	 f230013
M6	5 (7)		7 (9)	
M8	12 (16)		17 (23)	
M8 x 1	13 (18)		18 (24)	
M10	24 (33)		34 (46)	
M10 x 1.25	27 (37)		38 (52)	
M12	42 (57)		60 (81)	
M12 x 1.5	43 (58)		62 (84)	
M14	66 (89)		95 (129)	
M14 x 1.5	72 (98)		103 (140)	
M16	103 (140)		148 (201)	
M16 x 1.5	110 (149)		157 (213)	
M18	147 (199)		203 (275)	
M18 x 1.5	165 (224)		229 (310)	
M20	208 (282)		288 (390)	
M20 x 1.5	213 (313)		320 (434)	
M22	283 (384)		392 (531)	
M22 x 1.5	315 (427)		431 (584)	
M24	360 (488)		498 (675)	
M24 x 2	392 (531)		542 (735)	
M27	527 (715)		729 (988)	
M27 x 2	569 (771)		788 (1068)	
M30	715 (969)		990 (1342)	
M30 x 2	792 (1074)		1096 (1486)	

* Sterling recommends that all plated and unplated fasteners be coated with oil before installation.
† Use these torque values if either the bolt or nut is lubricated or plated (zinc-phosphate conversion-coated, cadmium-plated, or waxed).

Table 3, Torque Values for Metric Thread Fasteners with Lubricated or Plated Threads

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List of Abbreviations

The following is a list of definitions for abbreviations and symbols used in Freightliner publications.

A ..... amperes
ABS ..... antilock braking system
ABS ..... acrylonitrile-butadiene-styrene
A/C ..... air conditioner
AC ..... alternating current
acc ..... accessories
ACPU ..... air conditioning protection unit
ADLO ..... auto-disengagement lockout
AGS ..... automated gear shift
a.m. ..... *ante meridiem* (midnight to noon)
AM ..... amplitude modulation
amp(s) ..... ampere(s)
AMT ..... automated mechanical transmission
AMU ..... air management unit
ANSI ..... American National Standards Institute
API ..... American Petroleum Institute
API ..... application programming interface
ARI ..... Air Conditioning and Refrigeration Institute
ASA ..... American Standards Association
ASF ..... American Steel Foundries
ASR ..... automatic spin regulator
assy. ..... assembly
ASTM ..... American Society for Testing and Materials
ATC ..... automatic temperature control
ATC ..... automatic traction control
ATC ..... automatic transmission control
ATD ..... aftertreatment device
ATF ..... automatic transmission fluid
ATS ..... aftertreatment system
attn ..... attention
aux. ..... auxiliary
av ..... *avoirdupois* (British weight system)
AWD ..... all-wheel drive
AWG ..... American wire gauge
AWS ..... American Welding Society
BAT ..... battery
BBC ..... bumper-to-back-of-cab
BHM ..... bulkhead module
BOM ..... bill of material
BTDC ..... before top dead center
Btu(s) ..... British thermal unit(s)
C ..... common (terminal)
CAC ..... charge air cooler
CAN ..... controller area network
CARB ..... California Air Resources Board
CAT ..... Caterpillar
CB ..... circuit breaker
CB ..... citizens' band
CBE ..... cab behind engine
CCA ..... cold cranking amperes
CD-ROM .. compact-disc/read-only memory
CDTC ..... constant discharge temperature control
CEL ..... check-engine light
CFC ..... chlorofluorocarbons (refrigerant-12)
cfm ..... cubic feet per minute
CFR ..... Code of Federal Regulations
CHM ..... chassis module
CLS ..... coolant level sensor
cm ..... centimeters
cm^3 ..... cubic centimeters
CMVSS .... Canadian Motor Vehicle Safety Standard
Co. ..... company
COE ..... cab over engine
Corp. ..... corporation
CPU ..... central processing unit
CRT ..... cathode ray tube
cSt ..... centistokes (unit of measurement for describing the viscosity of general liquids)
cu ft ..... cubic feet
cu in ..... cubic inches
CUM ..... Cummins
CWS ..... collision warning system
DC ..... direct current
DDA ..... Detroit Diesel Allison (obs)
DDC ..... Detroit Diesel Corporation
DDE ..... Detroit Diesel Engines
DDEC ..... Detroit Diesel Electronic (engine) Control
DDR ..... diagnostic data reader
DDU ..... driver display unit
def ..... defrost
DFI ..... direct fuel injection
DGPS ..... differential global positioning system
dia. ..... diameter
DIAG ..... diagnosis
DIP ..... dual inline package (switch)
DLM ..... datalink monitor
DLU ..... data logging unit
DMM ..... digital multimeter
DOC ..... diesel oxidation catalyst
DOT ..... Department of Transportation
DPF ..... diesel particulate filter
DRL ..... daytime running lights
DRM ..... dryer reservoir module
DSM ..... district service manager
DTC ..... diagnostic trouble code
DTC ..... discharge temperature control
DVOM ..... digital volt/ohm meter
ea. ..... each
EBS ..... electronic braking system
ECAP ..... electronic control analyzer programmer
ECAS ..... electronically controlled air suspension
ECI ..... electronically controlled injection
ECL ..... engine coolant level
ECM ..... electronic control module
ECT ..... engine coolant temperature
ECU ..... electronic control unit
EDM ..... electronic data monitor
EEPROM .. electrically erasable programmable read-only memory
EGR ..... exhaust gas recirculation
EMC ..... electromagnetic compatibility
EMI ..... electromagnetic interference
EOA ..... electric over air
EP ..... extreme pressure (describes an antiwear agent added to some lubricants)
EPA ..... Environmental Protection Agency
EPS ..... engine position sensor
ESD ..... electrostatic discharge
ESS ..... engine syncro shift (transmission)
etc. ..... *et cetera* (and so forth)
ETEC ..... electronic truck engine control
EUI ..... electronic unit (fuel) injectors

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List of Abbreviations

EXM ..... (chassis) expansion module
FAS ..... Freightliner air suspension
FET ..... field effect transistor
Fig. ..... figure
fl oz ..... fluid ounces
FLA ..... post-1984 advancements Freightliner COE
FLB ..... enhanced Freightliner FLA COE
FLC ..... steel-cab Freightliner 112 Conventional
FLD ..... post-1984 advancements Freightliner 112/120 aluminum-cab Conventional
FM ..... frequency modulation
FMCSA .... Federal Motor Carrier Safety Administration
FMEA ..... failure mode effects analysis
FMI ..... failure mode indicator
FMSI ..... Friction Materials Standards Institute
FMVSS .... Federal Motor Vehicle Safety Standard
FRP ..... fiberglass reinforced plastic
FSA ..... field service authorization
FSM ..... fleet service manager
ft ..... feet
ft^3 ..... cubic feet
ft^3/min ..... cubic feet per minute
FTL ..... Freightliner
F.U.E.L. .... fuel usage efficiency level
g ..... grams
gal ..... gallons
GAWR ..... gross axle weight rating
GL ..... gear lubricant
GND ..... ground
gpm ..... gallons per minute
GPS ..... global positioning system
GVWR ..... gross vehicle weight rating
HCOE ..... high cab over engine
HCU ..... hydraulic control unit
HD ..... heavy-duty
HEPA ..... high-efficiency particulate air (filter)
HEST ..... high exhaust system temperature
HFC ..... hydrogenated fluorocarbons (refrigerant-134a)
hp ..... horsepower
hp ..... high pressure
HRC ..... Rockwell "C" hardness
hr(s) ..... hour(s)
HSD ..... high-side driver
htr. ..... heater
HVAC ..... heating, ventilating, and air conditioning
H/W ..... hardware
Hz ..... hertz
ICU ..... instrumentation control unit
i.d. ..... inside diameter
ID ..... identification
IFI ..... Industrial Fasteners Institute
IGN ..... ignition
ILO ..... *in lieu of* (in the place of)
in ..... inches
in^3 ..... cubic inches
Inc. ..... incorporated
inH_2O ..... inches of water
inHg ..... inches of mercury
I/O ..... input/output
IP ..... instrument panel
ISO ..... International Organization for Standardization
IVS ..... idle validation switch
k ..... kilo (1000)
kg ..... kilograms
km ..... kilometers
km/h ..... kilometers per hour
kPa ..... kilopascals
kW ..... kilowatts
L ..... liters
lb ..... pounds
lbf·ft ..... pounds force feet
lbf·in ..... pounds force inches
LCD ..... liquid crystal display
LCOE ..... low cab over engine
LED ..... light-emitting diode
LH ..... left-hand
LH DR ..... left-hand drive
LHK ..... liters per hundred kilometers
LHS ..... low-hydrogen steel
LLC ..... limited liability company
L/min ..... liters per minute
LPG ..... liquefied petroleum gas
LSD ..... low-side driver
LVD ..... low-voltage disconnect
m ..... meters
max. ..... maximum
M-B ..... Mercedes-Benz
MESA ..... Mining Enforcement Safety Act
mfr. ..... manufacturer
mi ..... miles
MID ..... message identifier
MIL ..... military specification
min. ..... minutes
min. ..... minimum
misc. ..... miscellaneous
mL ..... milliliters
mm ..... millimeters
mod. ..... module
mpg ..... miles per gallon
mph ..... miles per hour
MSF ..... modular switch field
MSHA ..... Mining Safety and Health Administration
MVDA ..... Motor Vehicle Dealers Association
n ..... negative (front axle wheel alignment specification)
N ..... nitrogen
N/A ..... not applicable
N·cm ..... Newton-centimeters
NC ..... normally closed (terminal or switch)
NHTSA .... National Highway Traffic Safety Administration
NIOSH ..... National Institute for Occupational Safety and Health
NLGI ..... National Lubricating Grease Institute
N·m ..... Newton-meters
NO ..... normally open (terminal or switch)
no. ..... number
NPT ..... national pipe thread
NPTF ..... national pipe thread fitting
NT ..... nylon tube or nylon tubing
obs ..... obsolete
OCV ..... open circuit voltage
o.d. ..... outside diameter
O.D. ..... overdrive
OEM ..... original equipment manufacturer
OSHA ..... Occupational Safety and Health Administration
oz ..... ounces
ozf·in ..... ounces force inches

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List of Abbreviations

p ..... positive (front axle wheel alignment specification)
PACE ..... programmable electronically controlled engine
parm ..... parameter
PC ..... personal computer
PCB ..... printed circuit board
PDC(s) .... parts distribution center(s)
PDM ..... power distribution module
PEEC ..... programmable electronic engine control
PID ..... parameter identifier
PLC ..... power line carrier
PLD ..... *Pumpe-Linie-Düse* (pump-line-nozzle)
p.m. ..... *post meridiem* (noon to midnight)
p/n ..... part number
PRD ..... product requirements document
PSA ..... pressure-sensitive adhesive
psi ..... pounds per square inch
psia ..... pounds per square inch, atmosphere
psig ..... pounds per square inch, gauge
pt ..... pints
PTCM ..... pressure time control module
PTO ..... power takeoff
pvc ..... polyvinyl chloride
PWM ..... pulse width modulation
pwr ..... power
qt ..... quarts
qty. ..... quantity
R & O ..... rust inhibitors and oxidants
R–12 ..... refrigerant-12 (CFC)
R–134a .... refrigerant-134a (HFC)
RAM ..... random access memory
recirc. ..... recirculation
Ref(s). ..... reference(s)
regen ..... regeneration
RFI ..... radio frequency interference
RH ..... right-hand
RH DR ..... right-hand drive
R/I ..... removal and installation
RMA ..... return material authorization
ROM ..... read-only memory
rpm ..... revolutions per minute
R/R ..... removal and replacement
RSG ..... road speed governor
RSM ..... regional service manager
RTV ..... room temperature vulcanizing
RV ..... recreational vehicle
SA ..... source address
SAE ..... Society of Automotive Engineers
SB ..... service bulletin
SCU ..... system control unit (speedometer)
SD ..... severe-duty
SDU ..... step deployment unit
SEL ..... shutdown engine light
SEM ..... switch expansion module
SHM ..... switch hub module
SI ..... service information
SI ..... *Système International*
SID ..... subsystem identifier
SM ..... system malfunction
SMC ..... sheet molded compound
S/N ..... serial number
SPACE .... seat pretensioner activation for crash survival enhancement
SPN ..... suspect parameter number
sq in ..... square inches
SRT ..... standard repair time
SSD ..... side sensor display
SST ..... stainless steel
std. ..... standard
S/W ..... software
SW ..... switch
TAM ..... thermocouple amplifier module
TBS ..... turbo boost sensor
TCU ..... transmission control unit
TDC ..... top dead center
TDR ..... technician diagnostic routine
temp ..... temperature
TIG ..... tungsten inert gas
TPS ..... thermal protection switch
TPS ..... throttle position sensor
TRS ..... timing reference sensor
TSO ..... truck specification order
TSU ..... transmission shift unit
U.D. ..... underdrive
UNC ..... unified national coarse
UNF ..... unified national fine
U.S. ..... United States
U.S.A. ..... United States of America
USC ..... United States customary (measures)
V ..... volts
VCU ..... vehicle control unit
VDC ..... vehicle data computer
Vdc ..... volts, direct current
VIMS ..... vehicle information management system
VIN ..... vehicle identification number
VIP ..... vehicle instrumentation and protection (Kysor)
VIW ..... vehicle interface wiring (connector)
VOC ..... volatile organic compounds
VOM ..... volt-ohmmeter
VRS ..... variable resistance sensor
VSG ..... variable speed governor
VSS ..... vehicle speed sensor
VSU ..... vehicle security unit
WB ..... wire braid
WI ..... work instructions
WIF ..... water-in-fuel
WOT ..... wide open throttle
– ..... minus or negative
+ ..... plus or positive
± ..... plus-or-minus
> ..... greater than
< ..... less than
x ..... by (used in fastener size descriptions)
" ..... inches
° ..... degrees (of an angle)
°C ..... degrees Celsius (centigrade)
°F ..... degrees Fahrenheit
..... number
% ..... percent
& ..... and
© ..... copyright
™ ..... trademark
® ..... registered trademark

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Removal

NOTE: The following procedure involves removing the engine and the transmission as a unit. The engine can also be removed separately from the transmission.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front tires.
2. Drain the air system.
3. Disconnect the batteries.
4. Remove the hood. For detailed instructions, see **Section 88.00**, Subject 140.
5. Remove the engine splash shield under the hood on the passenger side.
6. Remove the engine cover inside the cab.
7. If needed, drain the oil. See **Fig. 1** for the location of the oil drain plug.

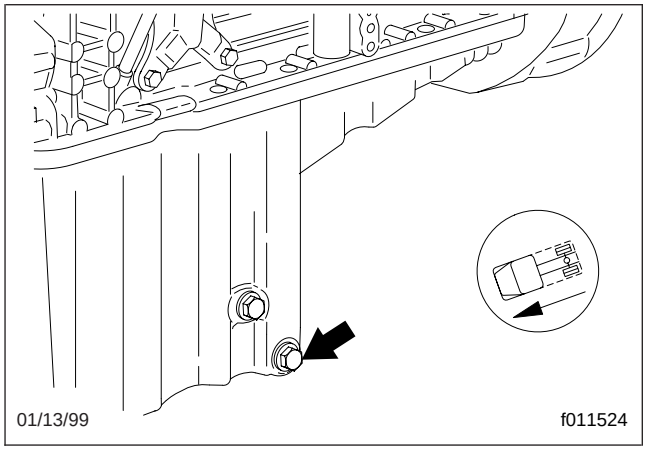


Fig. 1, Oil Drain Plug

⚠ WARNING

Drain the coolant only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

8. Drain the coolant from the radiator. See **Fig. 2**.
9. If equipped, remove the coolant hose standoff brackets.

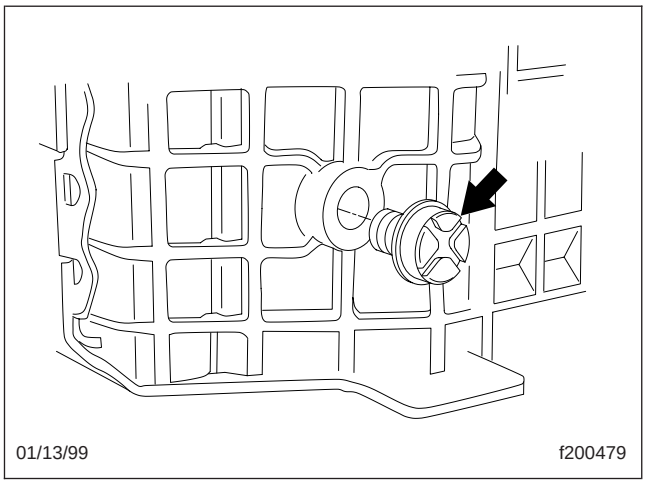
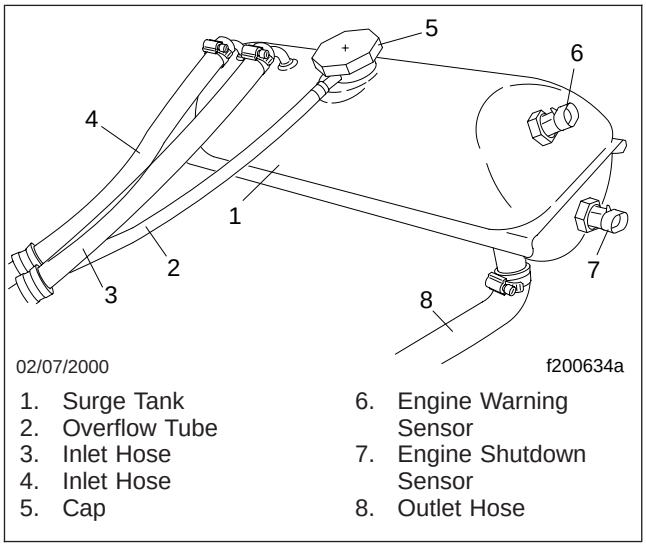


Fig. 2, Coolant Drain Plug

10. When the coolant has fully drained, remove all the coolant hoses from the engine. See **Fig. 3** for the coolant delivery hoses from the surge tank and **Fig. 4** for the upper coolant hose.



1. Surge Tank
2. Overflow Tube
3. Inlet Hose
4. Inlet Hose
5. Cap
6. Engine Warning Sensor
7. Engine Shutdown Sensor
8. Outlet Hose

Fig. 3, Coolant Hoses at the Surge Tank

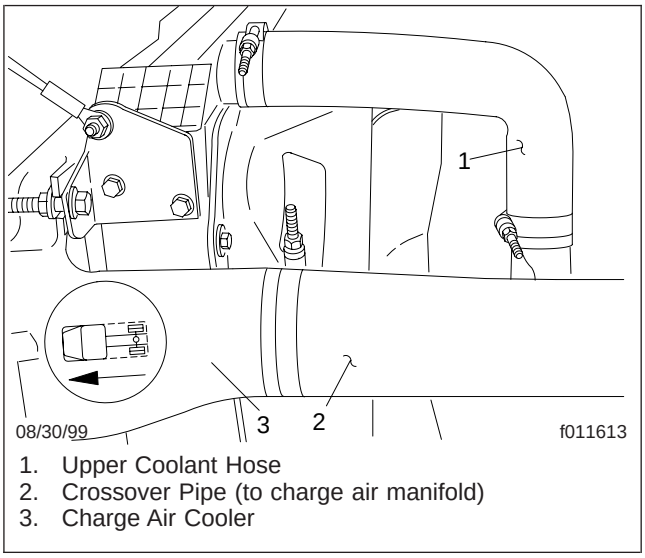
10.1 Remove the two small-diameter hoses attached to the surge tank, one going to the engine, the other to the radiator.

10.2 Remove the medium-diameter upper coolant hose attached to the front end of the crankcase near the cylinder head.

10.3 Remove the lower coolant hose assembly.

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Engine Removal and Installation



1. Upper Coolant Hose
2. Crossover Pipe (to charge air manifold)
3. Charge Air Cooler

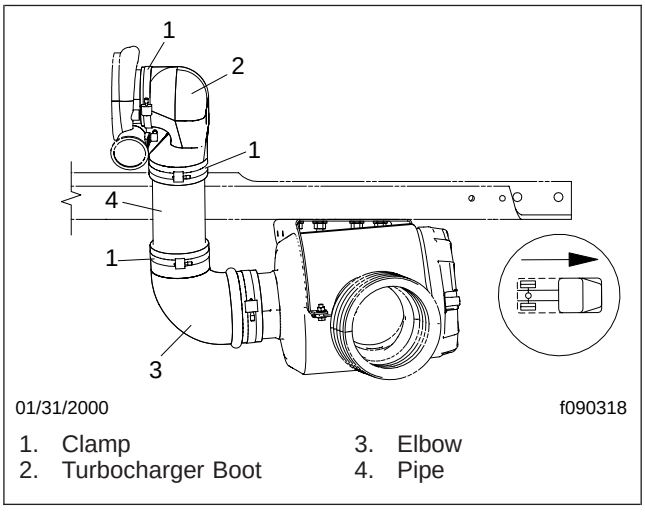
Fig. 4, Hoses (left side)

10.4 Remove the heater hose at the back of the engine.

10.5 Plug the openings with a clean shop towel.

11. If equipped with an automatic transmission, mark and disconnect the hydraulic hoses. Cover the hoses to prevent dirt from entering.

12. Remove the air intake pipes. See **Fig. 4** and **Fig. 5**.



1. Clamp
2. Turbocharger Boot
3. Elbow
4. Pipe

Fig. 5, Air Intake Ducting (vehicles built before September 15, 2002)

12.1 Remove the pipe from the intake manifold to the charge air cooler (crossover pipe).

12.2 Remove the pipe from the turbo outlet to the charge air cooler (turbo outlet pipe).

12.3 Remove the pipe from the air cleaner to the turbo inlet (air cleaner pipe).

12.4 Remove the air compressor inlet hose between the air cleaner pipe and the air compressor inlet tubing.

12.5 For ease of installation, mark the outlets on each pipe with a paint pen.

12.6 Plug the openings with a clean shop towel.

IMPORTANT: Leave all air conditioning hoses attached to avoid depressurizing the A/C system.

13. Remove the air conditioning (A/C) condenser. See **Fig. 6**. Wrap the condenser, with hoses attached, in a protective blanket, and secure it out of the way.

14. Remove the charge air cooler and radiator assembly. See **Fig. 7**. For charge air cooler detailed procedures, see the instructions in **Section 09.01**. For radiator detailed procedures, see the instructions for frame-rail mounted radiators in **Section 20.01**.

15. Remove the surge tank and lines. See **Fig. 3**.

15.1 Remove the drain hose and hard line attached to the right side of the frame rail.

15.2 Remove the surge tank.

16. Release the tension on the poly-V belt. See **Fig. 8**.

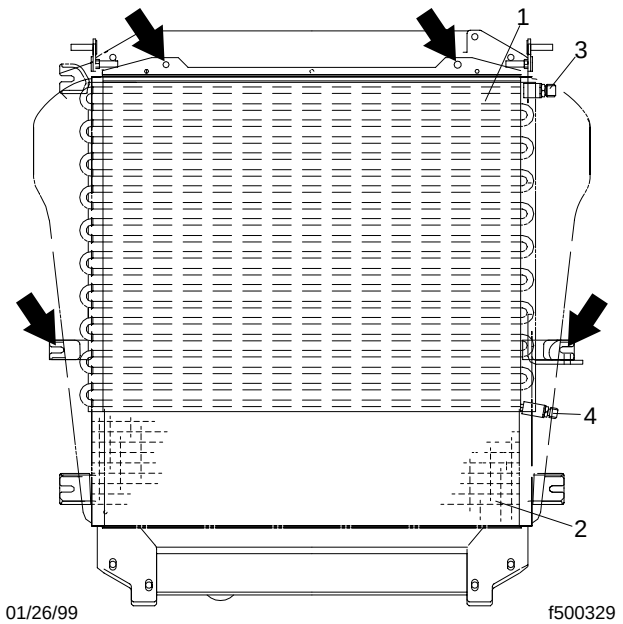
17. Disconnect the fuel lines from the fuel filter housing. See **Fig. 9**.

18. Disconnect the refrigerant compressor from the engine, but do not disconnect the refrigerant lines. See **Fig. 10**. Move the compressor out of the way. For instructions, see **Section 83.01**.

19. Disconnect the electrical connectors from the engine.

19.1 Remove all zip ties.

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Remove the four mounting bolts.

1. Air Conditioning (A/C) Condenser
2. Charge Air Cooler
3. Condenser Inlet
4. Condenser Outlet

Fig. 6, A/C Condenser

19.2 Disconnect the engine harness connector from the PLD (engine control unit). See **Fig. 11**.

19.3 Disconnect the exhaust brake solenoid connector, if installed. This connector is on the back of the engine.

19.4 Disconnect the ground wire at the back of the engine.

19.5 Disconnect the grid heater electrical connector attached to the boost manifold, if equipped.

20. Disconnect the power steering pump from the air compressor. Secure it, with the lines attached, up and out of the way. See **Fig. 12** or **Fig. 13**.
21. Disconnect the discharge line on the air compressor, if equipped.
22. Disconnect the signal line from the air reservoir to the governor, if equipped.
23. Remove the air line from the exhaust brake, if installed. See **Fig. 14**.
24. Disconnect the exhaust pipe. See **Fig. 15**.
25. Disconnect the starter electrical connector and the two engine ground straps.
26. Remove the electrical leads from the back of the alternator.
27. If equipped with a manual transmission, remove the shift tower and lever, and disconnect the clutch linkage.

    If equipped with an automatic transmission, mark and disconnect the wiring from the transmission ECM.
28. Remove the hydraulic clutch slave cylinder, if so equipped.

CAUTION

To avoid damage to the crankcase breather valve cover, make sure the chains on the front lifting eye provide adequate clearance.

29. Attach a lifting hoist to the engine. Run the chains through the front lifting eye and rear lifting fixture. See **Fig. 16** for attachment to the front lifting eye and **Fig. 17** for attachment to the rear lifting fixture.
30. Loosen the engine mounts. See **Fig. 18** for the front engine mount and **Fig. 19** for the rear engine mounts.

    30.1 Remove the front engine mounting bolt where it attaches to the front crossmember. Remove the isolators.

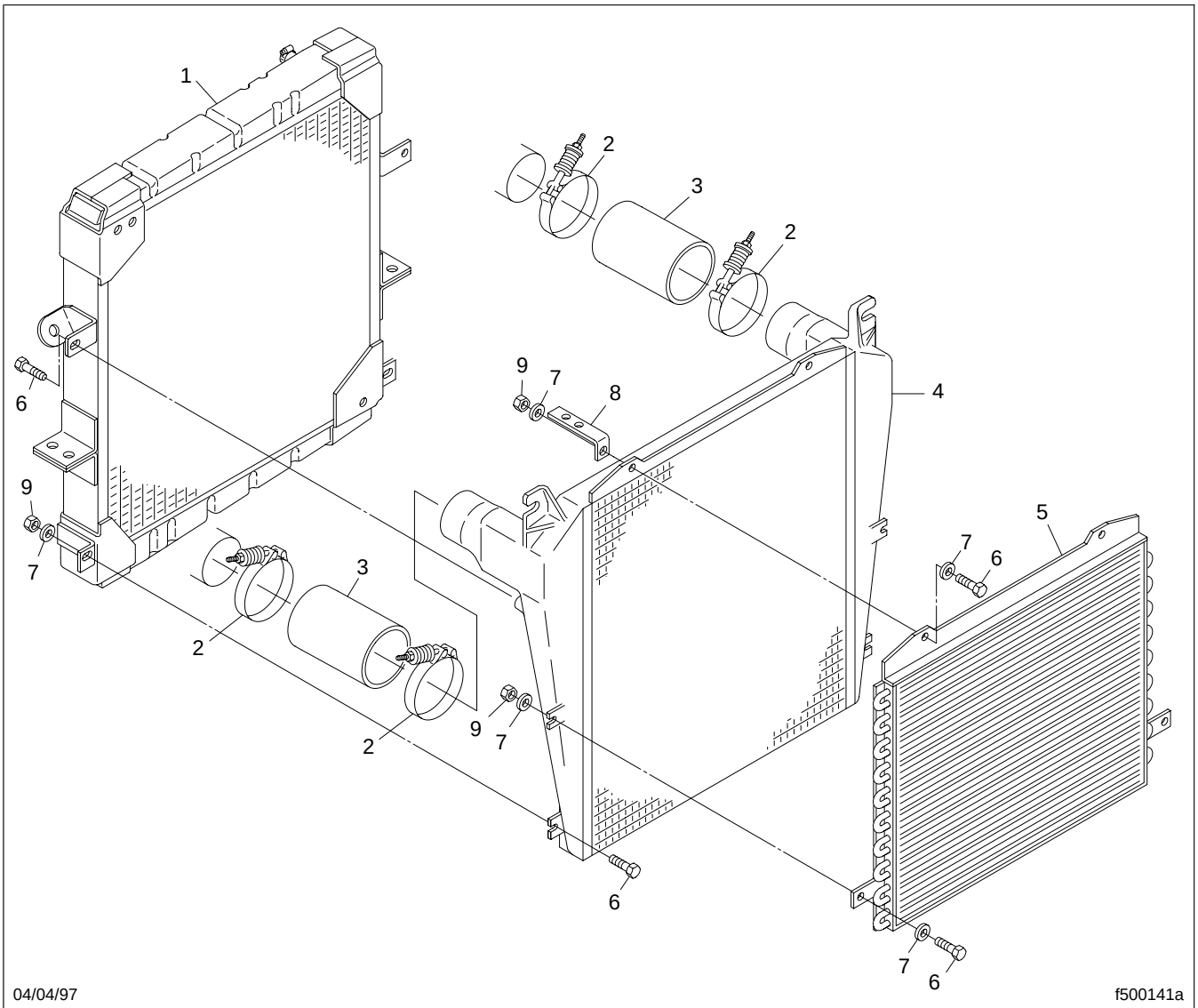
    30.2 Remove the bolt on each rear engine mount that attaches the engine leg to the frame-rail-mounted bracket. Remove the isolators.
31. Support the rear of the transmission with a jack.

WARNING

The crane and lifting chains used to remove the engine must be capable of safely lifting and supporting two metric tons. Once the engine mounts are disconnected, do not get under the engine until it is securely supported on engine stands.

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Engine Removal and Installation



1. Radiator
2. Constant-Torque Hose Clamp
3. Charge Air Hose
4. Charge Air Cooler (CAC)
5. A/C Condenser
6. Mounting Bolt
7. Washer
8. Stand-Off Bracket
9. Nut

Fig. 7, Charge Air Cooler and Radiator

An unsecured engine may fall, causing personal injury or death, and component damage.

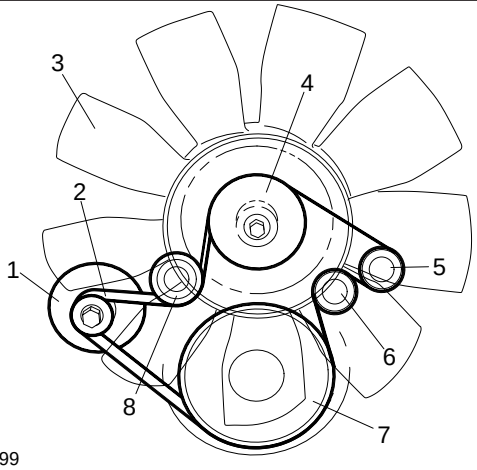
32. Remove the engine and the transmission from the vehicle. See **Fig. 20**.

    32.1 Raise the hoist slightly until it is holding the full weight of the engine.

    32.2 Raise the engine and transmission just enough to allow them to move forward until they can be lifted without hitting the frontwall.

NOTE: An assistant is helpful when removing the engine and transmission from the vehicle.

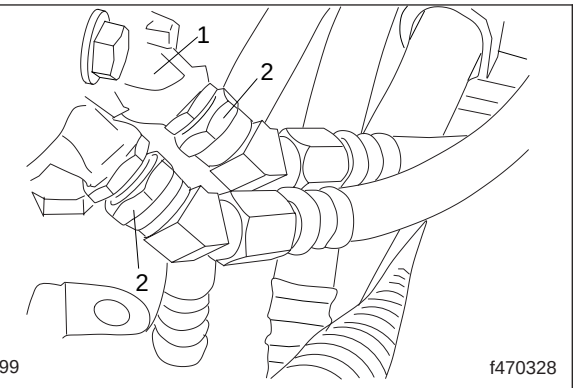
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1. Alternator
2. Poly-V Belt
3. Fan
4. Fan Pulley
5. Refrigerant Compressor
6. Idler Pulley
7. Vibration Damper
8. Belt Tensioner

Fig. 8, Belt Routing



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1. Fuel Filter
2. Fuel Line Fittings

Fig. 9, Fuel Lines

32.3 Pull the engine and transmission forward and up to clear the vehicle. If a new engine is to be installed, remove the transmission and transfer all needed components from the old engine to the new engine.

Installation

1. If the transmission was removed, install it on the engine timing case. Tighten the timing case to transmission mounting bolts 33 lbf·ft (45 N·m). For detailed procedures, see **Group 26**.

⚠ WARNING

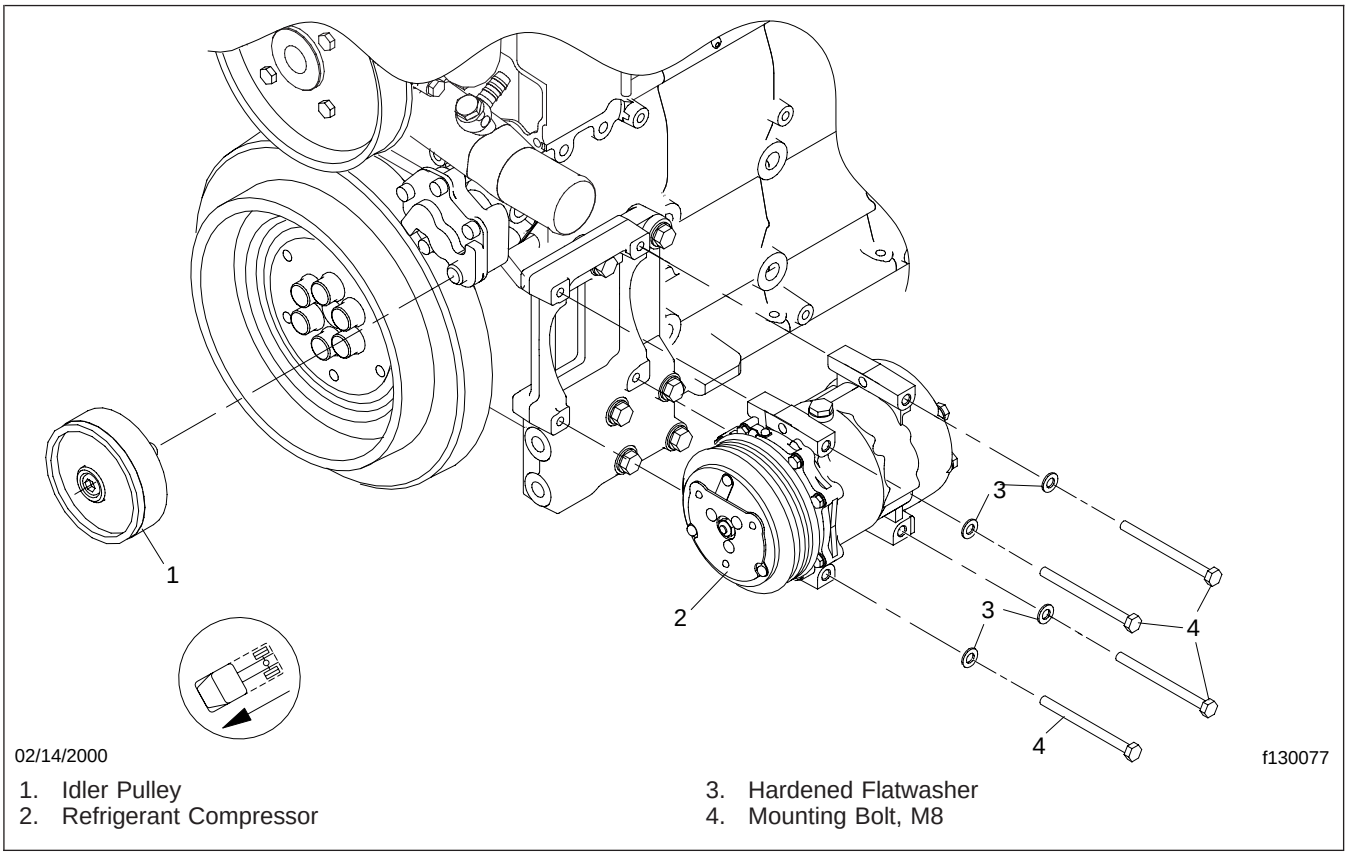
The crane and lifting chains used to remove the engine must be capable of safely lifting and supporting two metric tons. Once the engine mounts are disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death, and component damage.

NOTE: An assistant is helpful when positioning the engine and transmission in the vehicle.

2. Using the hoist as removed, lower the engine and transmission into the engine compartment until the transmission is resting on the jack used during removal. Check clearances on all sides, as removed.
3. Install the front engine mounting bolt, isolator, and nut.
   - 3.1 Position the isolator on the crossmember.
   - 3.2 Move the engine on the hoist until it rests directly on the isolator.
   - 3.3 Insert the bolt through the crossmember, isolator, and engine. Install and tighten the nut.
   - 3.4 Tighten the nut 136 lbf·ft (184 N·m).
4. Install both rear engine isolators. See **Fig. 19**.
   - 4.1 Lower the jack under the rear of the engine slightly, until the hole in the engine leg lines up with the hole in the frame-rail-mounted bracket.
   - 4.2 Install the engine isolators, bolts and nuts. Tighten them 136 lbf·ft (184 N·m).
   - 4.3 Lower and remove the jack.
5. Remove the hoist from the front lifting eye and the rear lifting fixture.
6. If removed, install the air line on the exhaust brake. See **Fig. 14**.

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Engine Removal and Installation



1. Idler Pulley
2. Refrigerant Compressor
3. Hardened Flatwasher
4. Mounting Bolt, M8

Fig. 10, Refrigerant Compressor

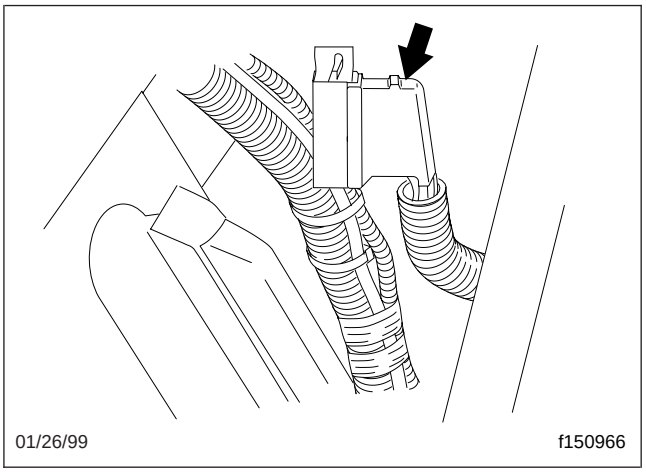
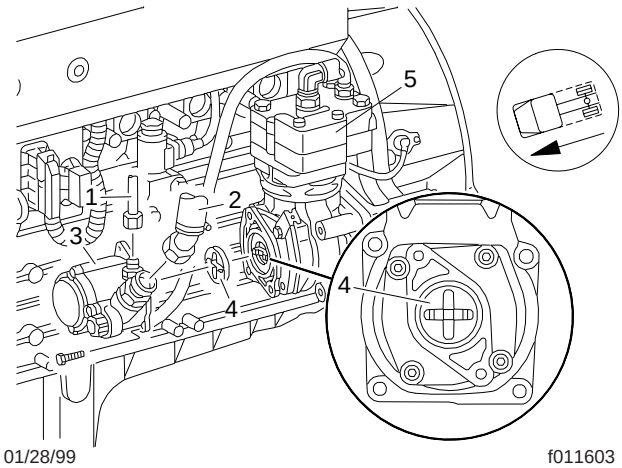


Fig. 11, Engine Harness Connector

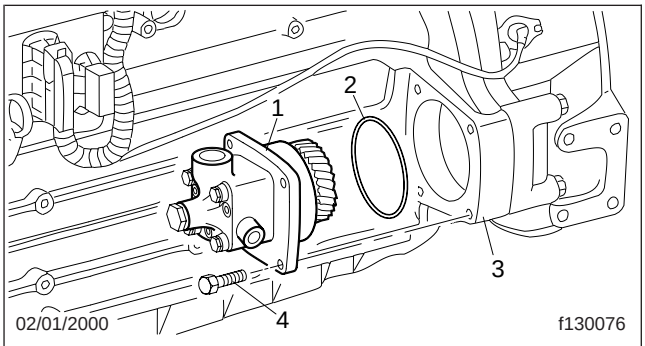
7. Connect the exhaust pipe. See **Fig. 15**.
8. Connect the starter electrical connector and the two engine ground straps.
9. Install the alternator wiring on the alternator terminals.
10. Install the refrigerant compressor. See **Fig. 10**. Tighten the mounting bolts 13 lbf·ft (18 N·m).
11. Install and put tension on the poly-V belt. See **Fig. 8**.
    - 11.1 Route the belt through and around the fan, alternator, idler, and refrigerant compressor pulleys.
    - 11.2 Relax the tension on the belt tensioner.
    - 11.3 Route the belt through the belt tensioner pulley and allow the belt tensioner to tighten the belt.
    - 11.4 Check all the pulleys to make sure the belt is correctly installed and aligned.
12. Connect the electrical connectors to the engine.

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1. Pressure Line
2. Return Line
3. Power Steering Pump
4. Cross Plate
5. Air Compressor

Fig. 12, Power Steering Pump, Air Compressor-Mounted



1. Power Steering Pump
2. O-Ring
3. Crankcase
4. Capscrew

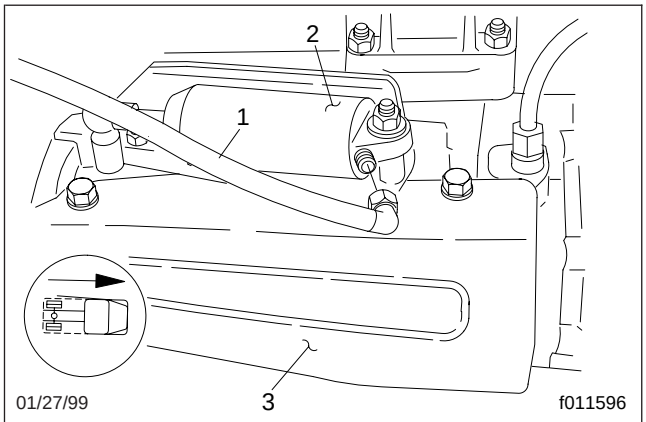
Fig. 13, Power Steering Pump, Crankcase-Mounted

12.1 Connect the ground wire at the back of the engine.

12.2 Connect the grid heater electrical connector, if equipped.

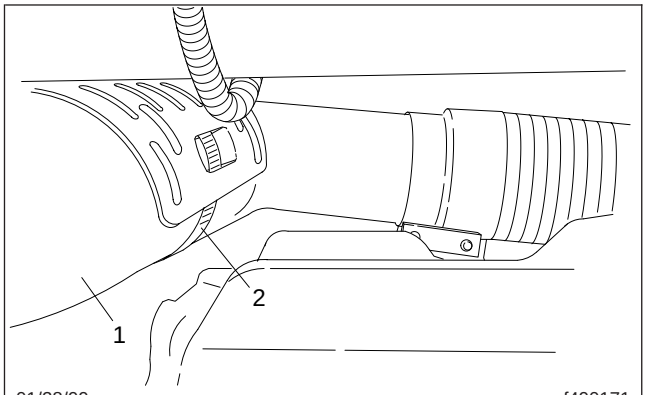
12.3 Connect the engine harness connector to the PLD (engine) control unit. See **Fig. 11**.

12.4 If removed, connect the exhaust brake solenoid connector.



1. Compressed Air Line
2. Exhaust Brake
3. Turbocharger

Fig. 14, Exhaust Brake Air Line



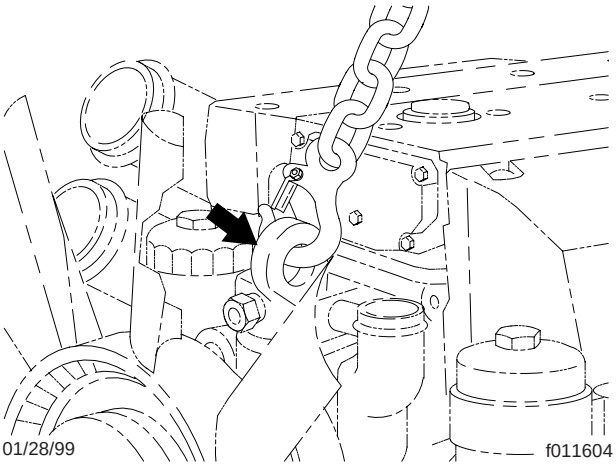
1. Exhaust Pipe
2. Clamp

Fig. 15, Exhaust Pipe

13. Connect the fuel lines to the fuel filter housing. See **Fig. 9**.
14. Connect the power steering pump. See **Fig. 12** or **Fig. 13**.
15. Connect the discharge line on the air compressor.
16. Connect the signal line from the air reservoir to the governor, if equipped.
17. Install the surge tank and lines. See **Fig. 3**.
18. Install the radiator and charge air cooler assembly. See **Fig. 7**. For detailed radiator instructions, see the procedures for frame-rail mounted radia-

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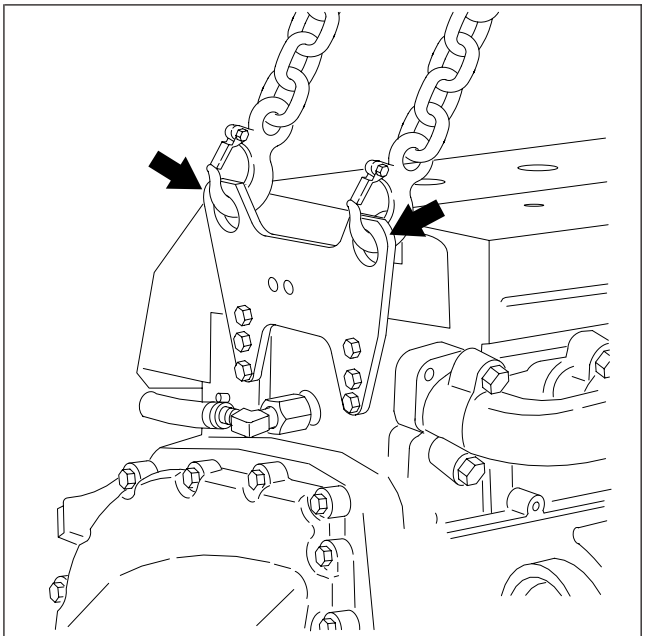
Engine Removal and Installation



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When lifting, be sure the front lifting eye is clear of the crankcase breather valve cover.

Fig. 16, Front Lifting Eye

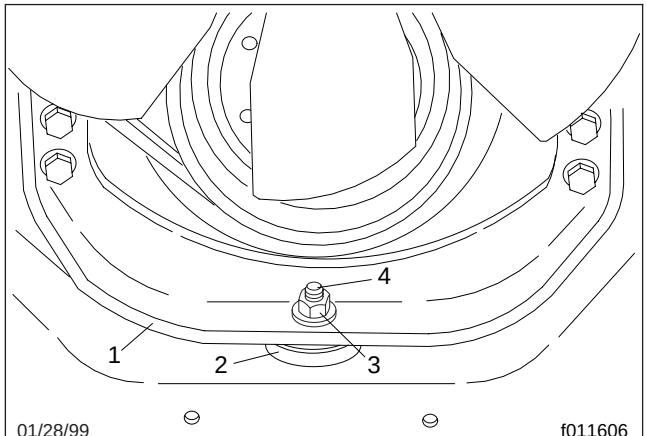


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When lifting, be sure the rear lifting fixture is clear of the frontwall.

Fig. 17, Rear Lifting Fixture

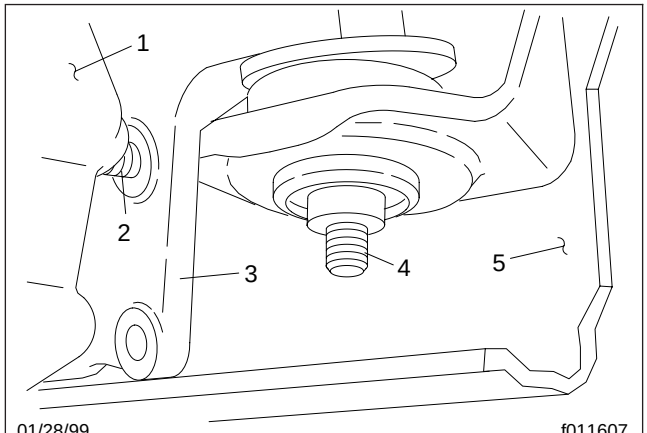
tors in **Section 20.01**. Tighten the nuts on the radiator brace isolators 25 lbf·ft (34 N·m). For charge air cooler detailed instructions, see the



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1. Engine Crossmember
2. Isolator
3. Hexnut, 5/8–11
4. Mounting Bolt, 5/8–11

Fig. 18, Front Engine Mount



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1. Timing Case
2. Engine Mounting Capscrew, 1/2–13
3. Engine Leg
4. Mounting Bolt, 3/4–10
5. Frame Rail

Fig. 19, Rear Engine Mount

procedures in **Section 09.01**. Tighten the mounting bolts 16 lbf·ft (22 N·m).

19. Install the A/C condenser and secure all hoses. See **Fig. 6**. Tighten the mounting bolts 16 lbf·ft (22 N·m).
20. Install the coolant hoses. See **Fig. 3** and **Fig. 4**.
    - 20.1 Install the two small-diameter coolant delivery hoses attached to the surge tank.

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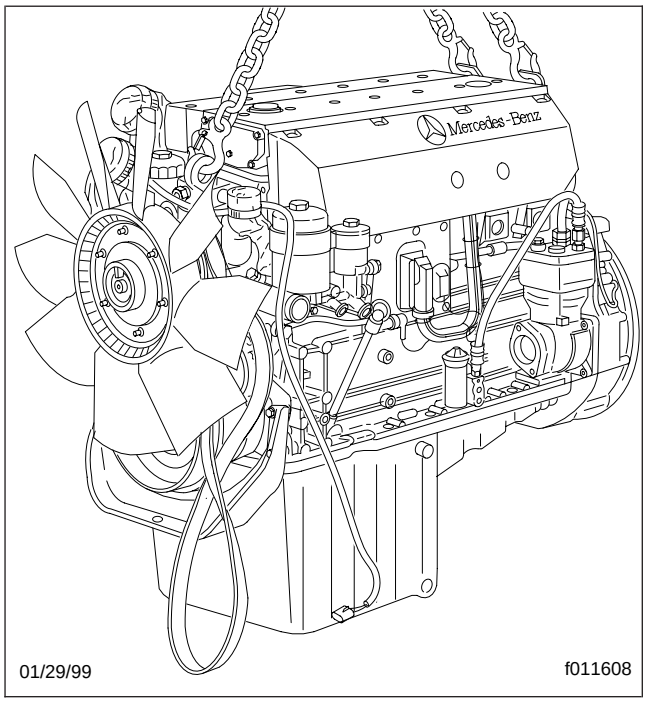


Fig. 20, Engine Removed from the Vehicle (transmission removed)

20.2 Install the medium-diameter upper coolant hose attached to the front end of the crankcase, near the cylinder head.

20.3 Install the lower coolant hose assembly.

20.4 Install the heater hose at the back of the engine.

21. Install the coolant hose standoff brackets, if equipped.

22. Install the charge air cooler pipes, as marked on removal. Make sure the pipes fit well and the clamps are tight. Make sure the crossover pipe is oriented correctly.

22.1 Install the crossover pipe leading between the charge air cooler and the intake manifold.

22.2 Install the turbo outlet pipe between the turbo outlet and the charge air cooler.

23. Install the air cleaner pipe, as marked on removal. Make sure the pipe fits well down on the inlet, is firmly connected, and the clamps are tight.

24. Install the air compressor inlet hose, as marked on removal. Make sure the hose fits well down on the air compressor inlet tubing, is firmly connected, and the clamp and elbow are tight.

25. If removed, install the hydraulic clutch slave cylinder.

26. Install the coolant drain plug. Fill the radiator with coolant. Make sure the coolant drain plug is tight and is not leaking.

27. If applicable, install the oil drain plug and tighten it 48 lbf·ft (65 N·m). Fill the engine with oil. Make sure the oil drain plug is tight and is not leaking.

28. If equipped with an automatic transmission, connect the transmission hydraulic hoses as previously marked. Connect the transmission ECM wiring.

    If equipped with a manual transmission, connect the shift tower and lever. Connect the clutch linkage.

29. Install the passenger-side splash panel.

30. Install the hood. For detailed instructions, see **Section 88.00**.

31. Install the engine cover in the cab.

32. Connect the batteries.

33. Start the engine test it for good operation. Pay attention to oil pressure, coolant temperature, warning lights, fluid leaks and any other signs of a problem. Correct any problems as needed.

34. Remove the chocks from the front tires.

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See **Fig. 1** for a full view of the single engine or exhaust brake wiring.

See **Fig. 2** for a full view of the engine and exhaust brake combination wiring.

See **Fig. 3** for a full view of the grid heater wiring.

See **Fig. 4** and **Fig. 5** for partial views of the grid heater wiring.

See **Fig. 6** for a full view of the fan clutch wiring.

See **Fig. 7** and **Fig. 8** for partial views of the fan clutch wiring.

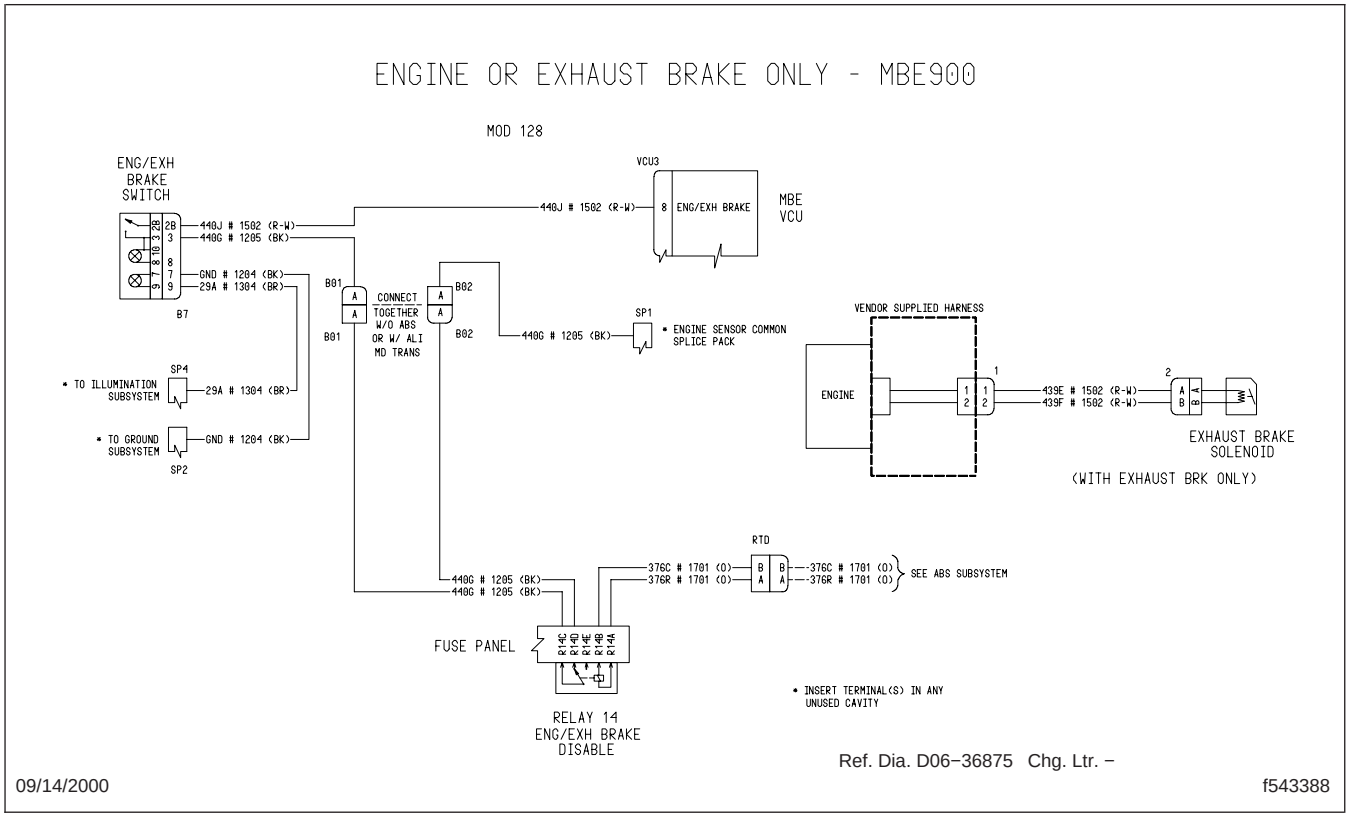


Fig. 1, Single Engine or Exhaust Brake Wiring (full view)

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Specifications

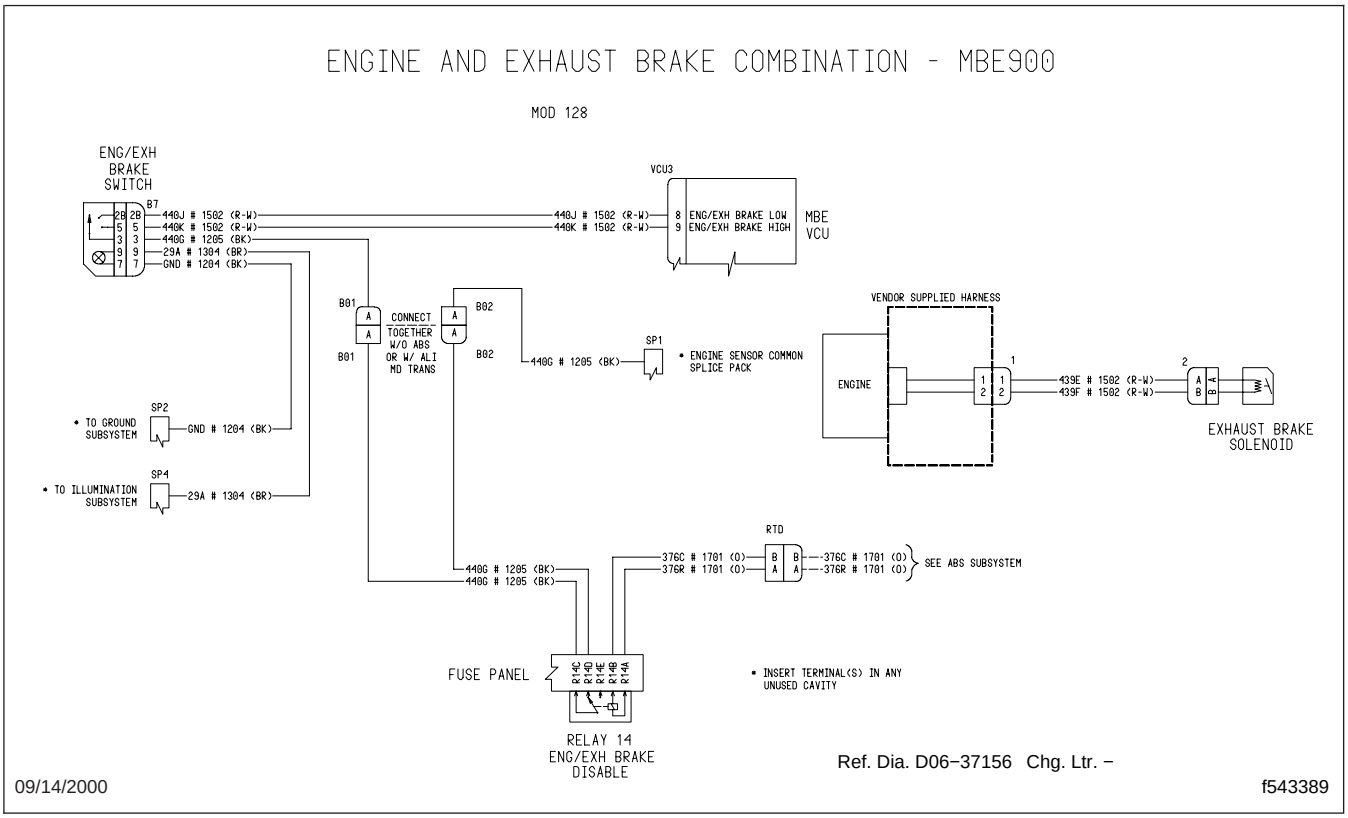


Fig. 2, Engine and Exhaust Brake Combination Wiring (full view)

Torque Values, Engine Removal and Installation			
Description	**Size**	**lbf·ft (N·m)**	**lbf·in (N·cm)**
A/C Condenser to Charge Air Cooler Locknuts	5/16–18	16 (22)	—
Charge Air Cooler to Radiator Locknuts	5/16–18	16 (22)	—
Front Engine Mounting Nut, Gr. 8	5/8–11	136 (184)	—
Oil Drain Plug	—	48 (65)	
Radiator Isolator Mounting Nuts	7/16–14	25 (34)	—
Rear Engine Mount Isolator Capscrews, Gr. 8	3/4–10	241 (347)	—
Refrigerant Compressor Mounting Bolts	M8x100	13 (18)	—
Starter Mounting Bolts	—	37 (50)	—
Timing Case to Transmission Mounting Capscrews	—	33 (45)	—

Table 1, Torque Values, Engine Removal and Installation

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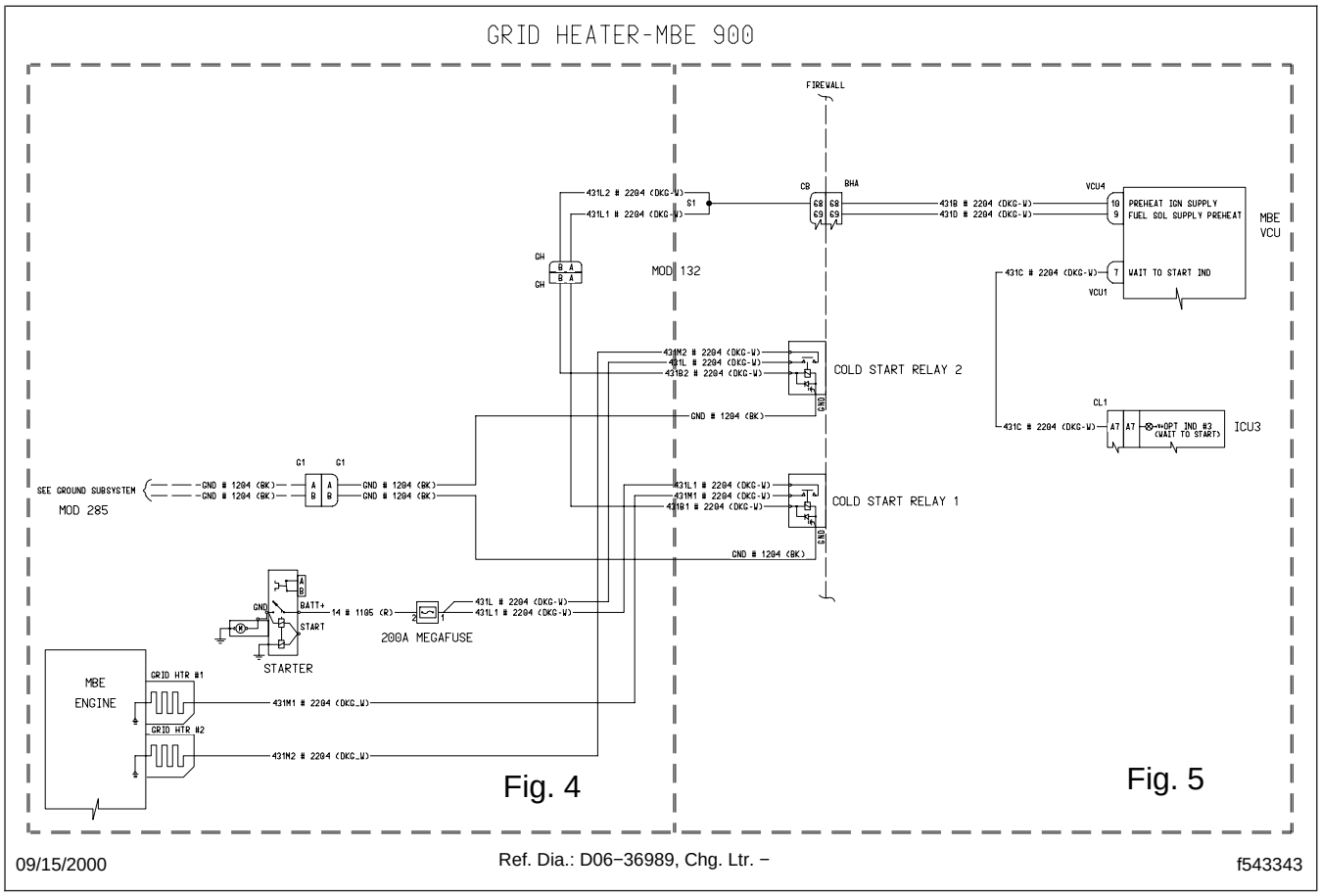


Fig. 3, Grid Heater Wiring (full view)

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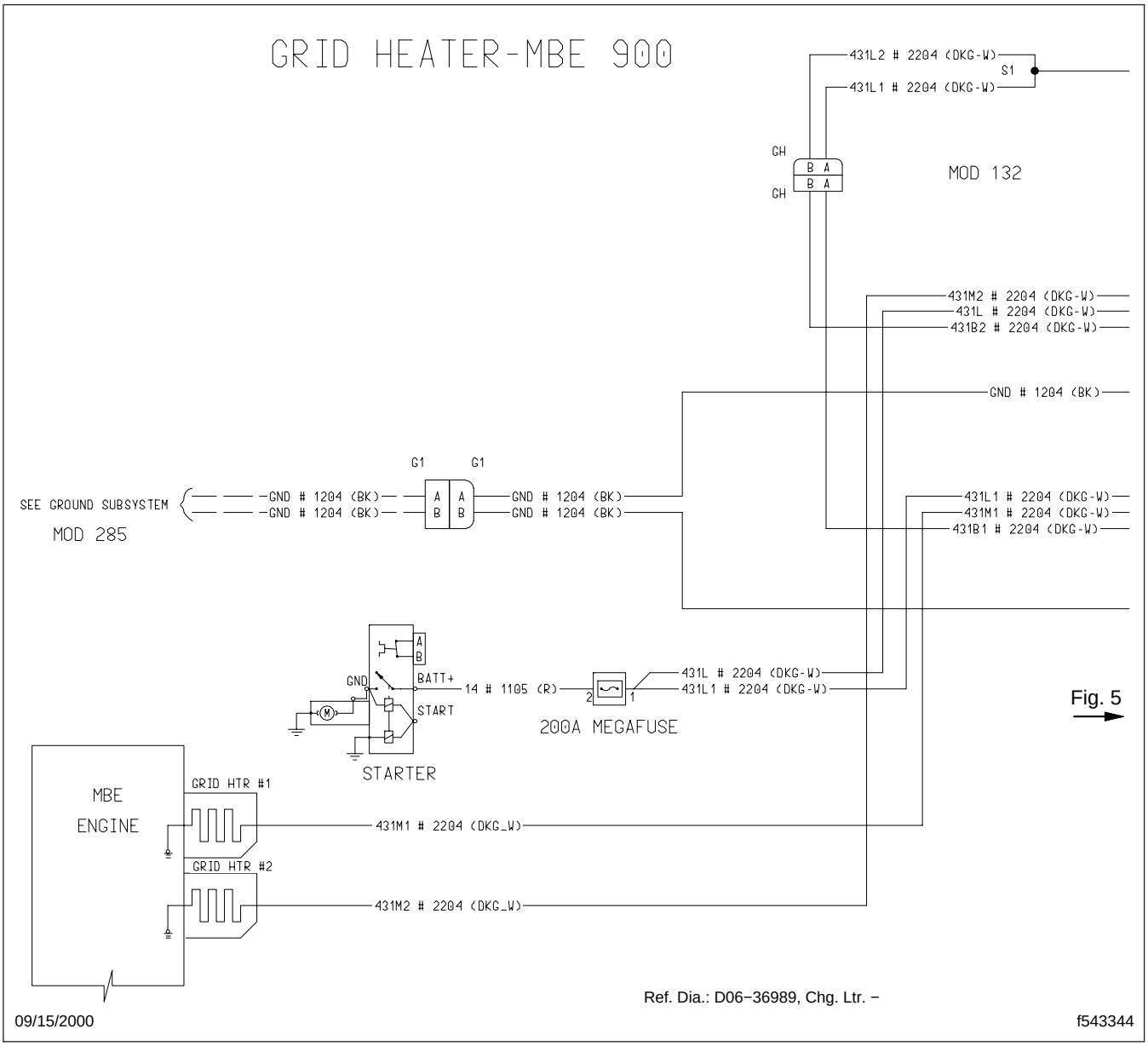


Fig. 4, Grid Heater Wiring (partial view)

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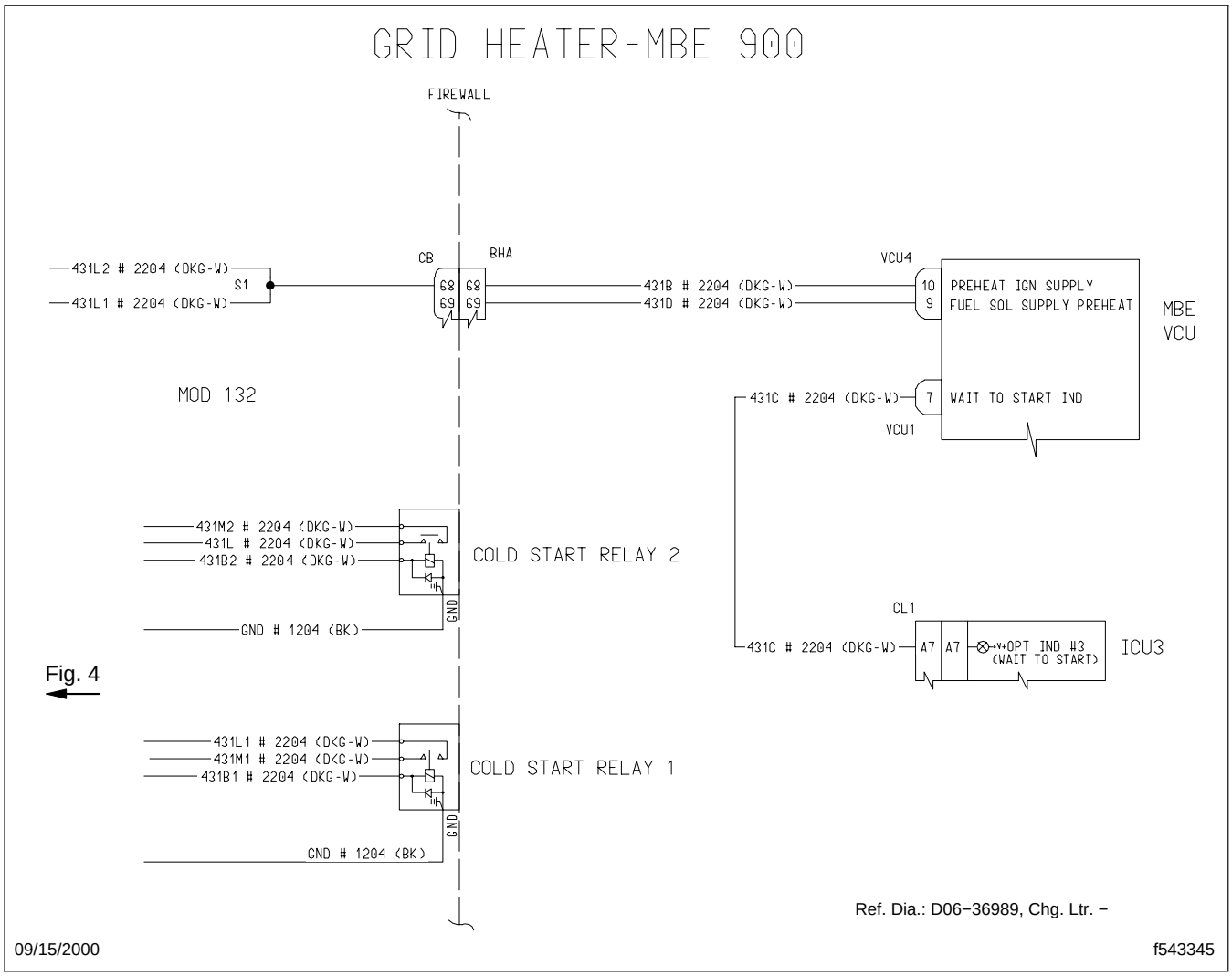


Fig. 5, Grid Heater Wiring (partial view)

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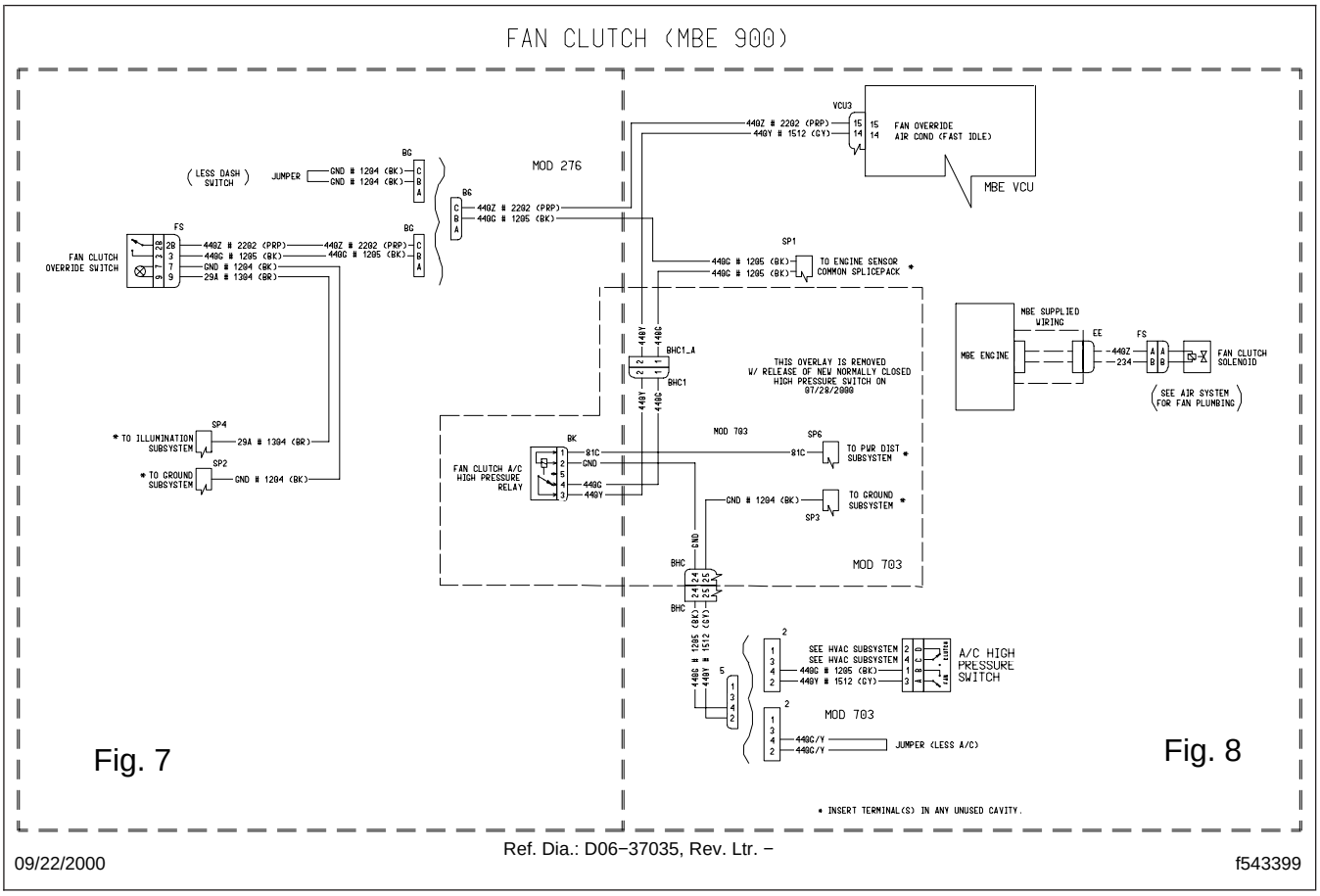


Fig. 6, Fan Clutch Wiring (full view)

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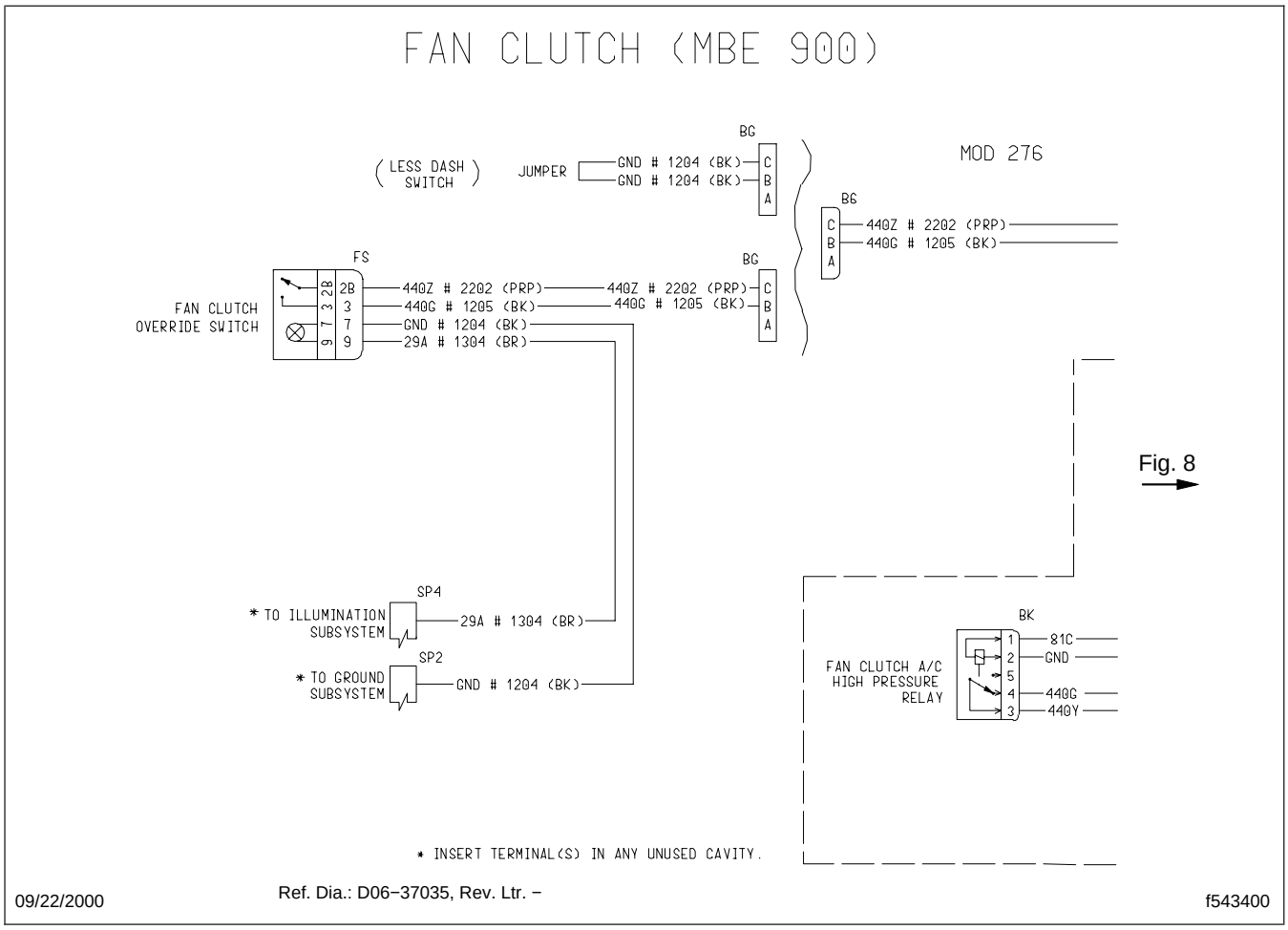


Fig. 7, Fan Clutch Wiring (partial view)

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Specifications

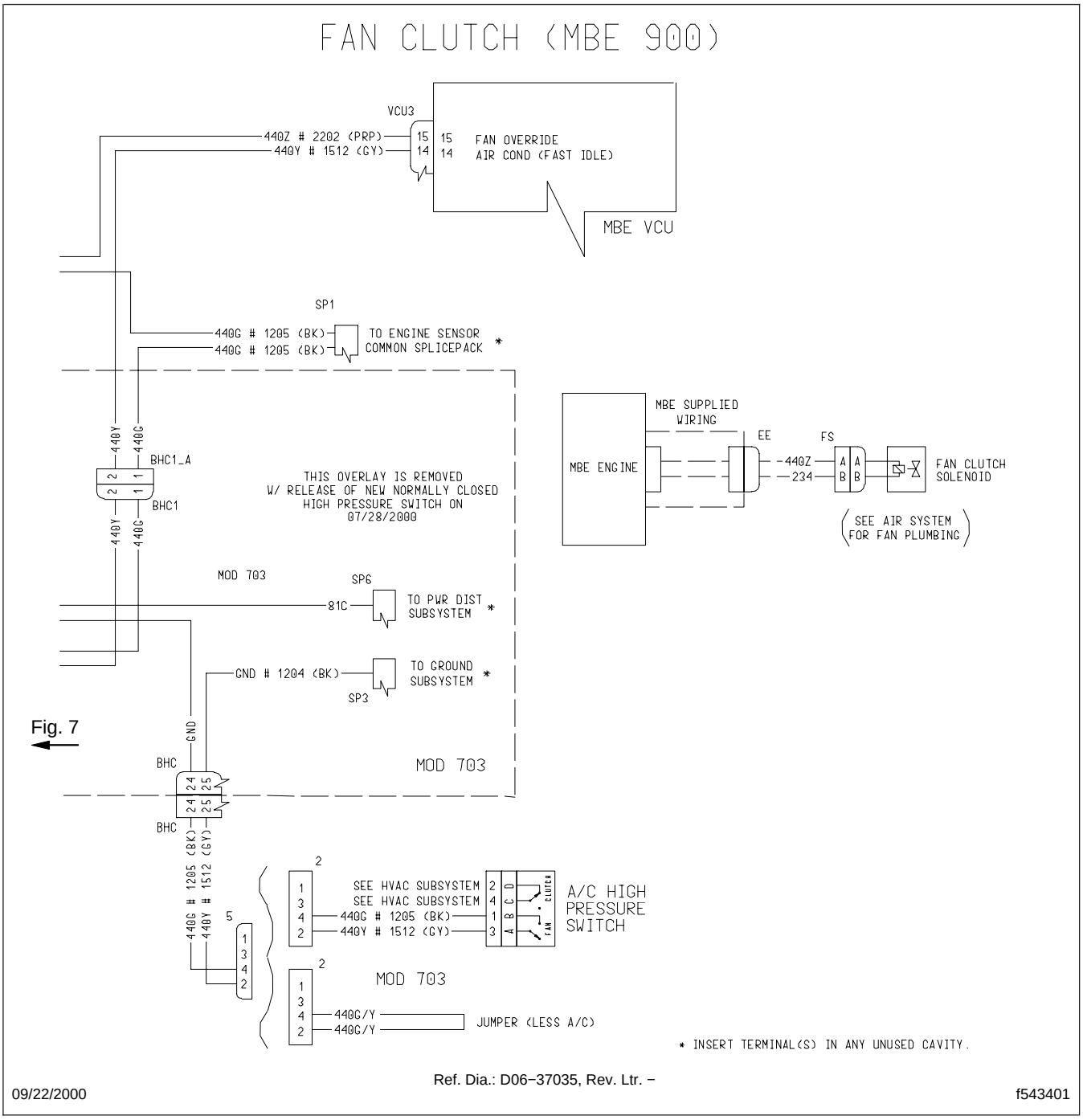


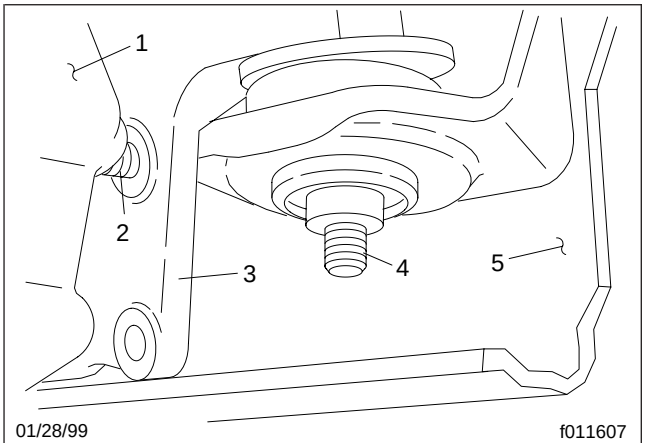
Fig. 8, Fan Clutch Wiring (partial view)

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General Information

Three mounts support the engine and transmission. Two of the engine mounts support the rear of the engine and transmission assembly. The third supports the front of the assembly.

Each of the rear engine mounts is bolted to the inside of the frame rail near the flywheel housing. See **Fig. 1**. These mounts support legs which are bolted to the flywheel housing. Engines use a rear engine leg that rests flat on the mount.



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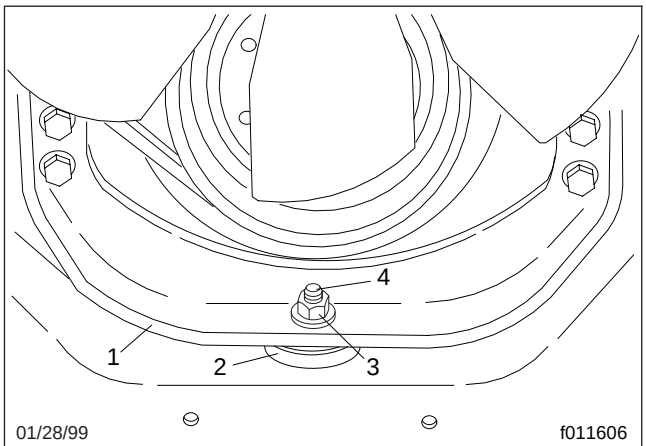
NOTE: Right mount shown.

1. Flywheel Housing
2. Engine Leg Capscrew, 16 mm
3. Engine Leg
4. Isolator Bolt, 3/4–10
5. Frame Rail

Fig. 1, Rear Engine Mount (MBE900 engine shown)

The front engine mount is under the front of the engine. See **Fig. 2**. It supports a bracket which is bolted to the engine at each side of the vibration damper pulley.

To isolate the engine and transmission from road shock and to isolate the vehicle frame from engine vibration, the engine mounts are sandwiched between rubber isolator cushions (sometimes called restriction pads). Washers protect the cushions from wearing on the engine support brackets, and a single bolt runs through the mount, cushions, and washers to hold the assembly together and hold the engine on the mount.



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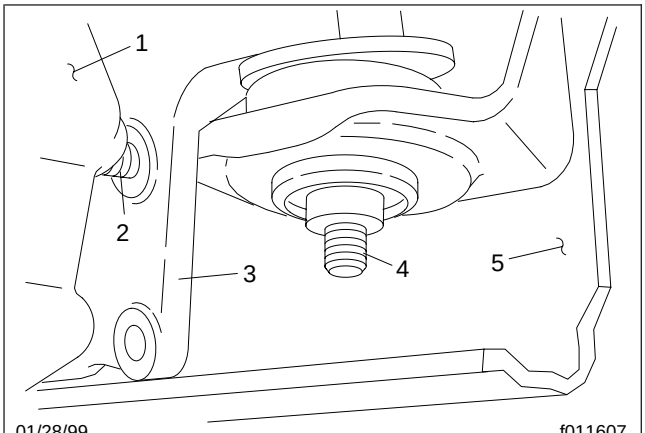
1. Engine Mount Bracket
2. Isolator
3. Hexnut, 5/8–11
4. Mounting Bolt, 5/8–11

Fig. 2, Front Engine Mount (MBE900 engine shown)

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Replacement

See **Fig. 1** for this procedure.



1. Flywheel Housing
2. Engine Leg Capscrew, M16 x 2 x 55
3. Engine Leg
4. Isolator Bolt, 3/4–10
5. Frame Rail

Fig. 1, Rear Engine Mount

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.

⚠ WARNING

The jack used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death and component damage.

2. Disconnect the engine from the right rear engine mount.
   - 2.1 Place a jack under the rear of the engine and raise the jack until it is braced against the engine.
   - 2.2 Remove the bolt and the lower isolator from the right rear engine mount. Save the fasteners, isolator and washer.
   - 2.3 Loosen the isolator bolt on the left rear engine mount.
   - 2.4 Lift the engine slightly to take its weight off the right rear engine mount. Place engine stands under the engine to keep it off the engine mount.
   - 2.5 Once the weight is removed from the mount, remove the upper isolator. Save the isolator and washer.
3. Remove the four bolts which secure the mount to the frame rail. Remove the mount from the frame rail.

   If necessary, remove the four bolts which secure the right engine leg to the flywheel housing and remove the leg from the engine.
4. Place a new engine mount against the inside of the frame rail and secure it with bolts, washers and nuts.

   For MBE900 and Cummins ISC engines, tighten the nuts 80 lbf·ft (108 N·m).

   For Caterpillar engines, tighten the nuts 45 lbf·ft (61 N·m).
5. If removed, install the engine leg on the right side of the flywheel housing. Apply thread-lock compound to the bracket mounting bolts.

   For MBE900 engines, tighten the bolts 92 lbf·ft (125 N·m).

   For Caterpillar engines, tighten the bolts 100 lbf·ft (136 N·m).

   For Cummins engines, tighten the bolts 60 lbf·ft (81 N·m).
6. Inspect the engine mount rubber isolators for wear or damage and replace them if necessary.

⚠ CAUTION

Do not lubricate the components with oil, grease or silicone lubricants; they will deteriorate the rubber isolators. Use soap and water to lubricate the components.

7. Install the upper isolator in the engine mount. If applicable, place the washer on the isolator.

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Rear Engine Mount Replacement

WARNING

The jack used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death, and component damage.

8. Secure the engine to the engine mounts.
   - 8.1 If not in place, set a jack under the rear of the engine and raise the jack until it is braced against the engine.
   - 8.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.
   - 8.3 Holding the lower isolator and washer in place, install the bolt in the right rear engine mount, and secure it with the nut and hardened washer. Hand-tighten the nut.

WARNING

The jack used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death and component damage.

9. Disconnect the engine from the left rear engine mount.
   - 9.1 Place a jack under the rear of the engine and raise the jack until it is braced against the engine.
   - 9.2 Remove the bolt and lower isolator from the left rear engine mount. Save the fasteners, isolator and washer.
   - 9.3 Lift the engine slightly to take its weight off the left rear engine mount. Place engine stands under the engine to keep it off the engine mount.
   - 9.4 Once the weight is removed from the mount, remove the upper isolator. Save the isolator and washer.
10. Remove the capscrews which secure the mount to the frame rail. Remove the mount from the frame rail.

    If necessary, remove the four capscrews which secure the left engine leg to the flywheel housing and remove the leg from the engine.
11. Place a new engine mount against the inside of the frame rail and secure it with bolts, washers and nuts.

    For MBE900 and Cummins ISC engines, tighten the nuts 80 lbf·ft (108 N·m).

    For Caterpillar engines, tighten the nuts 45 lbf·ft (61 N·m).
12. If removed, install the engine leg on the left side of the flywheel housing. Apply thread-lock compound to the bracket mounting bolts.

    For MBE900 engines, tighten the bolts 92 lbf·ft (125 N·m).

    For Caterpillar engines, tighten the bolts 100 lbf·ft (136 N·m).

    For Cummins engines, tighten the bolts 60 lbf·ft (81 N·m).
13. Inspect the engine mount rubber isolators for wear or damage and replace them if necessary.

CAUTION

Do not lubricate the components with oil, grease or silicone lubricants; they will deteriorate the rubber isolators. Use soap and water to lubricate the components.

14. Install the upper isolator in the engine mount. If applicable, place the washer on the isolator.

WARNING

The jack used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death and component damage.

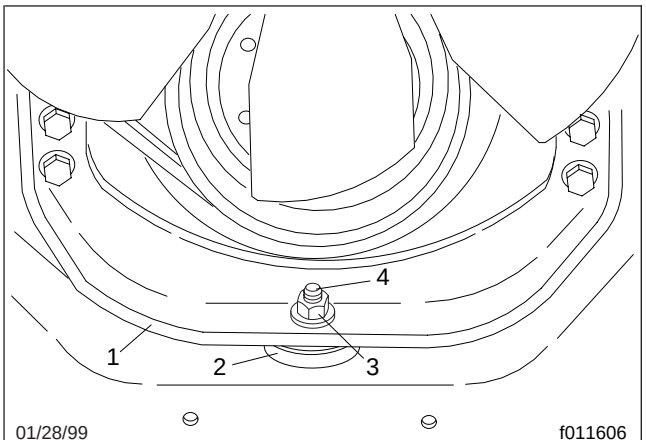
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15. Secure the engine to the engine mounts.
    - 15.1 If not in place, set a jack under the rear of the engine and raise the jack until it is braced against the engine.
    - 15.2 Lift the engine slightly to remove the engine stands. Remove the stands and carefully lower the engine onto the engine mount.
    - 15.3 Holding the lower isolator in place, install the bolt in the left rear engine mount and secure it with the nut and hardened washer.
16. Torque both rear isolator bolts 241 lbf·ft (327 N·m).
17. Remove the jack from under the engine.
18. Remove the chocks from the rear tires.

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Replacement

See **Fig. 1**, **Fig. 2**, and **Fig. 3** for this procedure.



1. Engine Mount Bracket
2. Isolator
3. Hexnut, 5/8–11
4. Mounting Bolt, 5/8–11

Fig. 1, Front Mount Assembly (MBE900 engines)

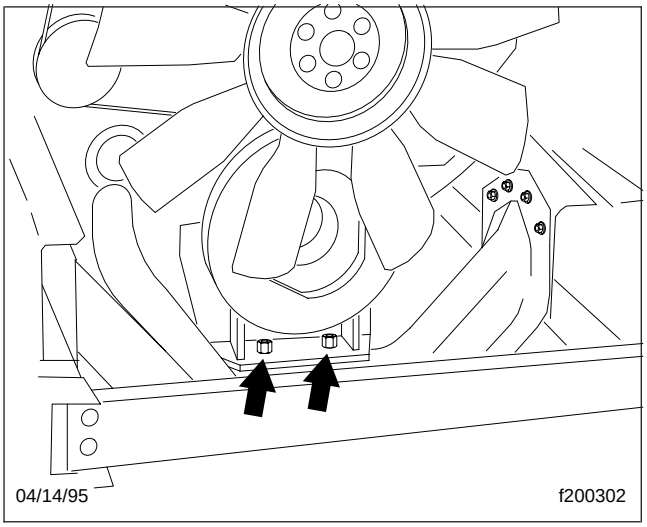
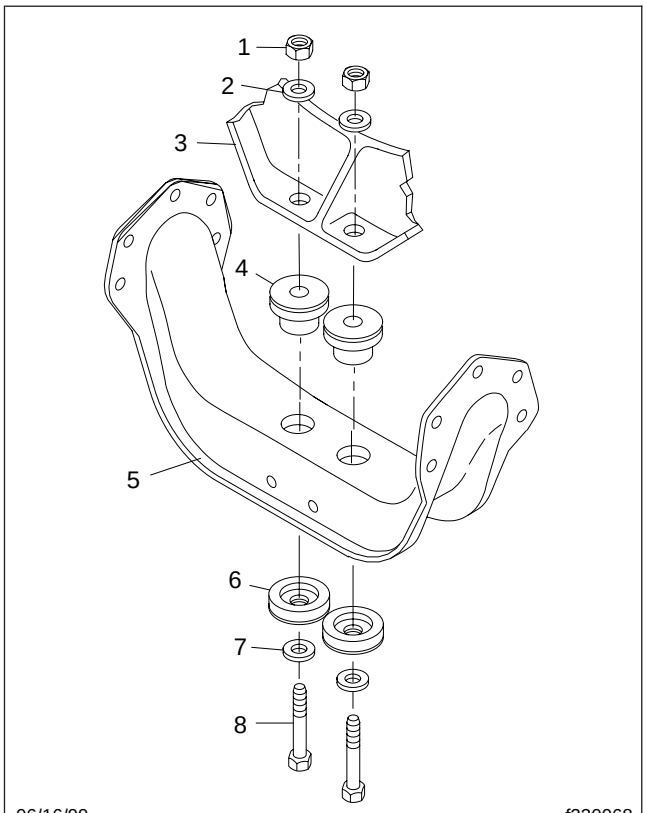


Fig. 2, Front Mount Assembly (Caterpillar engines)

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Open the hood.



1. Hexnut, 5/8–11 (2 qty.)
2. Hardened Washer (2 qty.)
3. Front Engine Support Bracket
4. Upper Isolator
5. Front Underslung Crossmember
6. Lower Isolator (2 qty.)
7. Flatwasher (2 qty.)
8. Hexbolt, 5/8–11 (2 qty.)

Fig. 3, Front Mount Assembly (Cummins ISC engines)

3. Remove the bolt and lower isolator from the front engine mount. Save the fasteners, isolator and washer.

⚠ WARNING

The lifting device and chain used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death and component damage.

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Front Engine Mount Replacement

4. Attach a chain to the front engine lifting hook(s) and position a lifting device to lift the engine. Attach the chain to the lifting device and raise the chain to remove any slack.

⚠ CAUTION

Do not lift the front of the engine too much as damage may be caused to the fan or fan shroud.

NOTE: In order to raise the front of the engine, you may have to loosen the bolts that run through the rear engine mounts.

5. Lift the engine slightly to take its weight off the front engine mount. Place engine stands under the engine to keep it off the engine mount.
6. Remove the upper isolator.
7. If necessary, remove the bolts which secure the engine support bracket to the front of the engine. See the engine manufacturer's manual for instructions.
8. If necessary, install a new engine support bracket on the front of the engine. See the engine manufacturer's manual for instructions.
9. Inspect the engine mount rubber isolators for wear or damage and replace them if necessary.

⚠ CAUTION

Do not lubricate the components with oil, grease, or silicone lubricants; they will deteriorate the rubber isolators. Use soap and water to lubricate the components.

10. Install the upper isolator in the engine mount.

⚠ WARNING

The lifting device and chain used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death and component damage.

11. Attach a chain to the front engine lifting hook(s). Attach the chain to a lifting device and raise the chain to remove any slack.
12. Lift the engine slightly to remove the engine stands. Remove the stands and carefully lower the engine onto the engine mount.
13. Holding the lower isolator in place, install the bolt in the front engine mount and secure it with the nut and washers. Tighten the nut 150 lbf·ft (203 N·m).

NOTE: If you loosened the bolts that run through the rear engine mounts, tighten those bolts 241 lbf·ft (327 N·m).

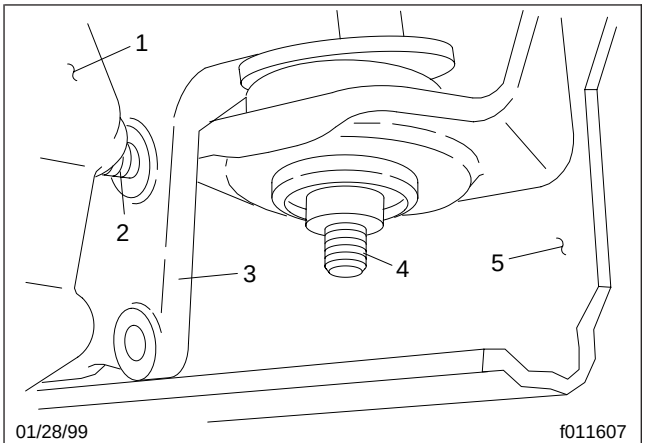
14. Remove the lifting chain from the engine lifting hooks.
15. Close and latch the hood.
16. Remove the chocks from the rear tires.

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Rear Engine Mount Isolator Replacement

Replacement

See **Fig. 1** for this procedure.



1. Flywheel Housing
2. Engine Leg Capscrew, M16 x 2 x 55
3. Engine Leg
4. Isolator Mounting Bolt, 3/4–10
5. Frame Rail

Fig. 1, Rear Engine Mount (MBE900 engine shown)

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.

⚠ WARNING

The jack used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death and component damage.

2. Disconnect the engine from the right rear engine mount.
   - 2.1 Place a jack under the rear of the engine, and raise the jack until it is braced against the engine.
   - 2.2 Remove the bolt and lower isolator from the right rear engine mount. Save the fasteners and washers. Discard the rubber isolator.
   - 2.3 Loosen the isolator bolt on the left rear engine mount.
   - 2.4 Lift the engine slightly to take its weight off the right rear engine mount. Place engine stands under the engine to keep it off the engine mount.
   - 2.5 Once the weight is removed from the mount, remove the upper isolator. Save the washer. Discard the isolator.
3. Inspect the new engine mount rubber isolators for wear or damage and replace them if necessary.

⚠ CAUTION

Do not lubricate the new components with oil, grease or silicone lubricants; they will deteriorate the rubber isolators. Use soap and water to lubricate the components.

4. Install the new upper isolator in the engine mount. If applicable, place the washer on the isolator.

⚠ WARNING

The jack used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death and component damage.

5. Secure the engine to the engine mount.
   - 5.1 If not in place, set a jack under the rear of the engine and raise the jack until it is braced against the engine.
   - 5.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.
   - 5.3 Holding the lower isolator in place, install the bolt in the right rear engine mount, and secure it with the nut and hardened washer. Hand-tighten the nut.

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Rear Engine Mount Isolator Replacement

⚠ WARNING

The jack used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death, and component damage.

6. Disconnect the engine from the left rear engine mount.
   - 6.1 Place a jack under the rear of the engine, and raise the jack until it is braced against the engine.
   - 6.2 Remove the bolt and upper isolator from the left rear engine mount. Save the fasteners and washers. Discard the rubber isolators.
   - 6.3 Lift the engine slightly to take its weight off the left rear engine mount. Place engine stands under the engine to keep it off the engine mount.
   - 6.4 Once the weight is removed from the mount, remove the upper isolator. Save the washer. Discard the isolator.
7. Inspect the new engine mount rubber isolators for wear or damage and replace them if necessary.

⚠ CAUTION

Do not lubricate the new components with oil, grease or silicone lubricants; they will deteriorate the rubber isolators. Use soap and water to lubricate the components.

8. Install the new upper isolator in the engine mount. If applicable, place the washer on the isolator.

⚠ WARNING

The jack used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death and component damage.

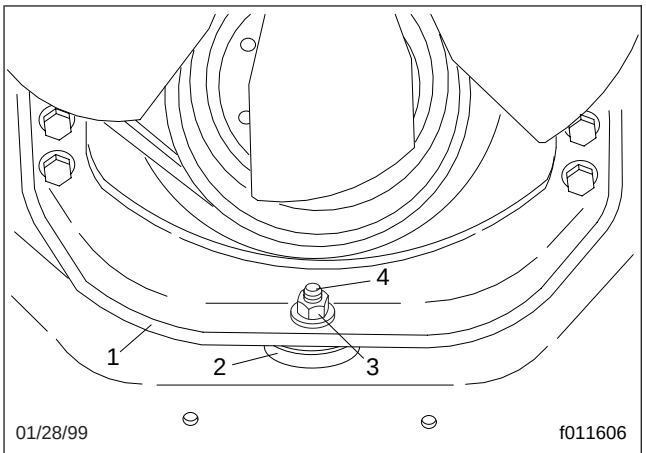
9. Secure the engine to the engine mount.
   - 9.1 If not in place, set a jack under the rear of the engine and raise the jack until it is braced against the engine.
   - 9.2 Lift the engine slightly to remove the engine stands. Remove the stands and carefully lower the engine onto the engine mount.
   - 9.3 Holding the lower isolator in place, install the bolt in the left rear engine mount and secure it with the nut and hardened washer.
10. Torque both rear isolator bolts 241 lbf·ft (327 N·m).
11. Remove the jack from under the engine.
12. Remove the chocks from the rear tires.

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Front Engine Mount Isolator Replacement

Replacement

See **Fig. 1** for this procedure.



1. Engine Mount Bracket
2. Hardened Washer
3. Front Engine Support Bracket
4. Bolt

Fig. 1, Front Mount Assembly (Mercedes-Benz engine shown)

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Open the hood.

WARNING

The lifting device and chain used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death and component damage.

3. Disconnect the engine from the front engine mount.
   - 3.1 Attach a chain to the front engine lifting hook(s), and position a lifting device to lift the engine. Attach the chain to the lifting device and raise the chain to remove any slack.
   - 3.2 Remove the bolt and lower isolator from the front engine mount. Save the fasteners and washer. Discard the rubber isolator cushion.

CAUTION

Do not lift the front of the engine too much as damage may be caused to the fan or fan shroud.

NOTE: In order to raise the front of the engine, you may have to loosen the bolts that run through the rear engine mounts.

   - 3.3 Lift the engine slightly to take its weight off the front engine mount. Place engine stands under the engine to keep it off the engine mount.
   - 3.4 Once the weight is removed from the mount, remove the upper isolator. Save the washer. Discard the isolator.
4. Inspect the new front engine mount rubber isolators for wear or damage and replace them if necessary.

CAUTION

Do not lubricate the new components with oil, grease or silicone lubricants; they will deteriorate the rubber isolators. Use soap and water to lubricate the components.

5. Install the upper isolator in the engine mount.

WARNING

The lifting device and chain used to lower the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely installed on the engine mount. An unsecured engine may fall, causing personal injury or death and component damage.

6. Secure the engine to the front engine mount.
   - 6.1 Attach a chain to the front engine lifting hook(s). Attach the chain to a lifting device, and raise the chain to remove any slack.

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Front Engine Mount Isolator Replacement

6.2 Lift the engine slightly to remove the engine stands. Remove the stands and carefully lower the engine onto the engine mount.

6.3 Holding the lower isolator in place, install the bolt in the front engine mount and secure it with the nut and washer. Tighten the nut 150 lbf·ft (203 N·m).

NOTE: If you loosened the bolts that run through the rear engine mounts, tighten those bolts 241 lbf·ft (327 N·m).

6.4 Remove the lifting chain from the engine lifting hook(s).

7. Close and latch the hood.
8. Remove the chocks from the tires.

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Rear Engine Mount Replacement, EPA07 Engines

Removal

NOTE: The rear engine mounts for EPA07 engines are designed to last for the life of the vehicle, and should not normally need replacing. The isolators are bonded to the brackets and cannot be replaced separately.

If the rear engine mounts need replacing due to damage, or if you are removing and installing the engine, use this procedure.

In the past, substituting softer isolators from the MBE4000 engine was a way to sometimes remedy engine vibration problems with other engines. This will not work with the EPA07 engines, because all the engine isolators now have the same durometer hardness.

1. Shut down the engine, set the parking brake, and chock the tires.
2. Drain the air tanks.
3. Disconnect all the cables from the batteries. Cover them, using dry rags and tie straps.
4. Remove the battery MEGA-fuse block from the left-side frame rail, underneath the cab. The mounting nuts are inboard of the frame rail.
5. Open the hood.
6. If present, remove the two tow hooks from the right frame rail.
7. Remove the rain tray.
   - 7.1 Mark, then remove the wiper arms.
   - 7.2 Disconnect any hoses or drains from the bottom of the rain tray.
   - 7.3 Remove the fasteners that hold the rain tray to the frontwall.
   - 7.4 Remove the rain tray from the vehicle.
8. Remove the right and left quarter fenders and the inner splash shields.
9. Remove the air intake canister assembly.
10. Remove the mounting bracket for the air intake canister.
11. Remove the turbocharger heat shield.
12. Disconnect the air lines from the primary air tank, then remove the tank from the vehicle.
13. Make sure the aftertreatment device (ATD) is cool, then remove it from the vehicle.

⚠ CAUTION

The ATD assembly weighs from 125 to 150 pounds (57 to 68 kg) and must be protected from impact or sharp jolts. Dropping the ATD, or subjecting it to jarring impact can crack the diesel particulate filter (DPF) inside, which is built on a ceramic substrate. If that happens, the DPF is ruined and must be replaced.

A secure support is necessary to remove and install the ATD safely. The ATD must be held securely to protect it from falling, or hitting hard against something else.

The horizontal ATD lifting device (TLZ00785) is designed to handle a horizontal ATD. Vertical ATDs require a shop hoist secured to the lifting ears on top.

- 13.1 Put a transmission jack (or equivalent) under the ATD, and strap the ATD to the jack.
- 13.2 Disconnect the five sensors from the ATD.

⚠ WARNING

Wear adequate eye protection, such as safety goggles or a face shield, when working with the ATD mounting bands. The mounting bands are under spring tension, and can cause eye injury or other personal harm if they spring out of control.

- 13.3 Remove the Marmon clamps from each end of the ATD.
- 13.4 Disconnect the ATD from the exhaust tubing, and remove it from the vehicle. Keep the ATD strapped to the jack, and make sure it is placed away from any combustible materials.

14. Remove the cab skirts from both sides of the vehicle.
15. Disconnect and remove the exhaust tubing from the turbocharger.
16. As applicable, remove the steps, air fairings, fuel tank(s), and/or the battery box.

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Rear Engine Mount Replacement, EPA07 Engines

For instructions on removing the fuel tank(s), refer to **Group 47** in this manual.

17. Remove the fasteners that hold the driveline midship-bearing bracket to the frame crossmember.
18. Using suitable straps, secure the driveline and the midship bearing to the frame crossmember. Make sure the driveshaft is supported loosely enough so that the slip joint aft of the midship bearing will be able to extend when the engine is raised.
19. Remove the overslung crossmember from the transmission housing.
    - 19.1 If present, remove the standoff bracket for the A/C refrigerant line from the top of the overslung crossmember. Leave the line attached to the bracket.
    - 19.2 Remove the fasteners that hold the overslung crossmember to the transmission housing, then remove it.
20. Disconnect both ends of the clutch linkage and remove it from the vehicle.
21. Remove the shifter and shifter boot from the transmission.
22. Raise the front of the vehicle so the tires are off the ground, and support it with safety stands. Put the safety stands behind the rear spring hangers for the front suspension.

⚠ WARNING

Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, allowing the vehicle to fall, which could result in serious injury or death.

23. From underneath the vehicle, install a suitable lifting bracket or stand, such as an engine shipping stand (for Detroit Diesel Series 60 engines) on the rear of the engine. See **Fig. 1**.

    If using the Detroit Diesel engine shipping stand, there should be two holes on each side of the engine block, just forward of the bell housing. These should match up with the holes in the engine shipping stand. When any stand or bracket is installed correctly, it should not be touching the floor, and should be wide enough and strong enough to support a jack to raise the engine.

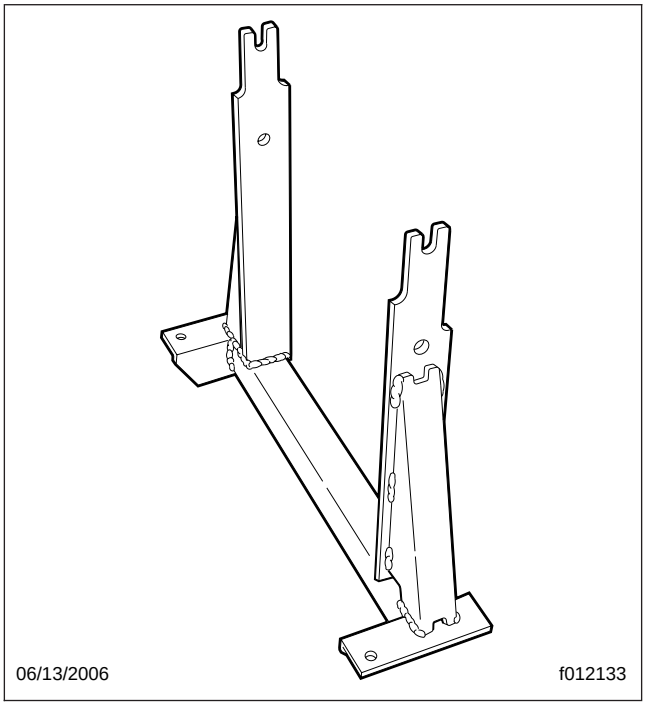
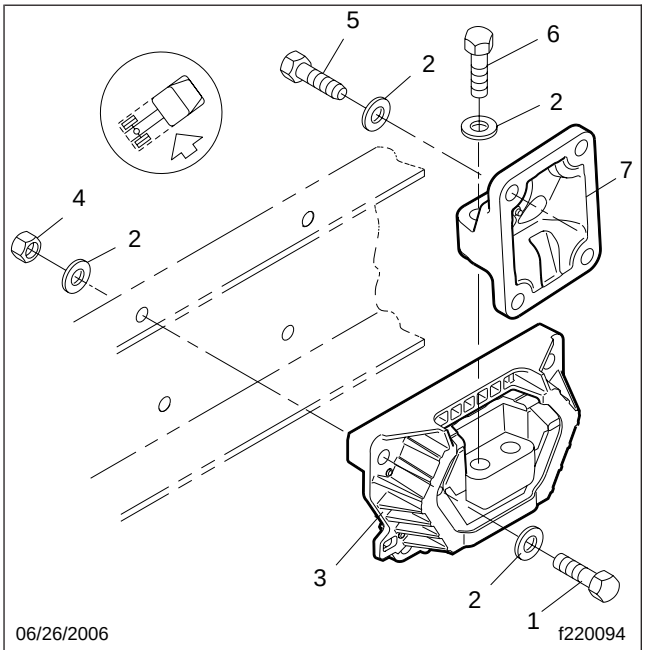


Fig. 1, Engine Shipping Stand, Detroit Diesel Series 60 Engine

24. If present, remove the starting aid bottle from the left-side frame rail.
25. On one side of the vehicle, remove the two mounting hexbolts that hold the engine leg to the frame-rail engine mount. See **Fig. 2**. If needed, repeat the procedure on the other side of the vehicle.
26. Place a jack under the engine shipping stand (or other suitable stand/bracket) attached to the rear of the engine, and gradually raise that side of the engine until the bottom of the engine leg is above the top of the frame rail.
27. Remove the four fasteners that hold the rear engine mount to the frame rail. See **Fig. 3**.
28. Remove the rear engine mount from the vehicle.
29. If needed, remove the four bolts that hold the engine leg to the transmission housing. Remove the engine leg.

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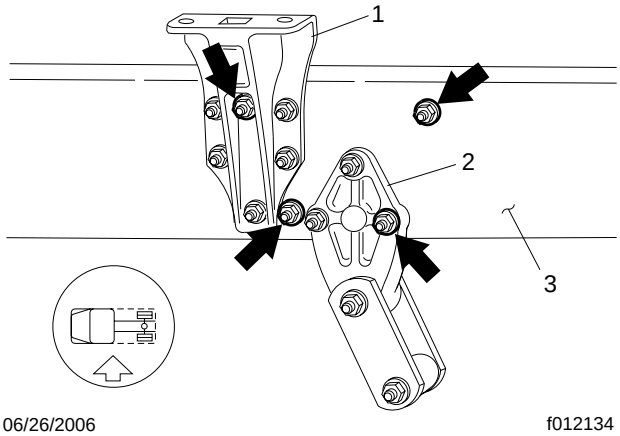
Rear Engine Mount Replacement, EPA07 Engines



06/26/2006 f220094

1. Hexbolt, 5/8–11
2. Hardened Washer
3. Rear Engine Mount Assembly
4. Hexnut, 5/8–11
5. Capscrew, 5/8–11
6. Capscrew, 3/4–10
7. Engine Leg

Fig. 2, Rear Engine Mount and Engine Leg



06/26/2006 f012134

NOTE: The engine mount is not visible in this view.

1. Cab Mounting Bracket
2. Front Spring-Shackle Hanger
3. Frame Rail

Fig. 3, Engine Mount-to-Frame Rail Fasteners

Installation

1. If applicable, install the engine leg on the bell housing. Apply Loctite® 271 (or equivalent) to the threads of the capscrews, and tighten to 320 lbf·ft (434 N·m).
2. With the engine supported, install the rear engine mount on the frame rail. Install the four 5/8–11 hexbolts with the bolt heads inboard. Tighten the hexnuts 136 lbf·ft (184 N·m).
3. If applicable, repeat the above procedure on the other side of the vehicle.
4. Lower the engine onto the rear engine mount.
5. Apply Loctite 271 to the threads of the two 3/4–10 hexbolts. Install them and the hardened washers in the holes of the engine leg and the rear engine mount and tighten to 320 lbf·ft (434 N·m).
6. Remove the fasteners that hold the engine shipping stand to the side of the transmission, and remove the stand.
7. Install the clutch linkage.
8. Install the overslung crossmember.
9. Install the shifter and shifter boot on the transmission.
10. Install the standoff bracket for the A/C refrigerant line, then attach the line to the bracket.
11. If it was removed, install the starting aid bottle to the left-side frame rail.
12. Attach the driveline midship bearing and its bracket to the frame crossmember.
13. Connect the exhaust tubing to the turbocharger.
14. Install the cab skirts to the bottom of the cab.
15. Install the ATD to the exhaust tubing. As previously marked, connect the wiring to the sensors on the ATD.
16. Install the primary air tank and connect the air lines to it.
17. In the engine compartment, install the turbocharger heat shield.
18. Install the mounting bracket for the air-intake canister.
19. Install the air-intake canister to the mounting bracket.

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Rear Engine Mount Replacement, EPA07 Engines

20. Install the right and left inner splash shields.
21. Install the right and left quarter fenders.
22. As applicable, install the steps, air fairings, fuel tank(s), and/or the battery box.

    For instructions on installing the fuel tank(s), refer to **Group 47** in this manual.
23. Using the previously removed fasteners, install the rain tray on the frontwall.
24. Connect the hoses and drains to the bottom of the rain tray.
25. As previously marked, install the wiper arms.
26. If they were removed, install the two tow hooks on the side of the right frame rail.
27. Close the hood.
28. Install the battery MEGA-fuse block on the left-side frame rail, underneath the cab.
29. Connect the battery cables.
30. Remove the chocks.

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Specifications

Engine Mount Torques, Pre-EPA07 Engines			
Description	**Grade**	**Size**	**Torque lbf·ft (N·m)**
All Engines			
Front Engine Mount Isolator Bolt	8	5/8–11	150 (203)
Rear Engine Mount Isolator Bolt	8	3/4–16	241 (327)
Mercedes-Benz Engines			
Rear Engine Mount to Frame Rail Bolts	8	1/2–13	80 (108)
Engine Leg-to-Flywheel Bolts	10.9	M16 x 2 x 55 mm	92 (125)
Front Support Bracket to Engine Bolts	10.9	M12	90 to 110 (122 to 150)
Engine Leg-to-Flywheel Bolts:			
Cummins ISC Engines	10.9	M12 x 40 mm	60 (81)
Caterpillar 3126 & C-7 Engines	10.9	M14 x 2 x 45 mm	100 (136)

Table 1, Engine Mount Torques, Pre-EPA07 Engines

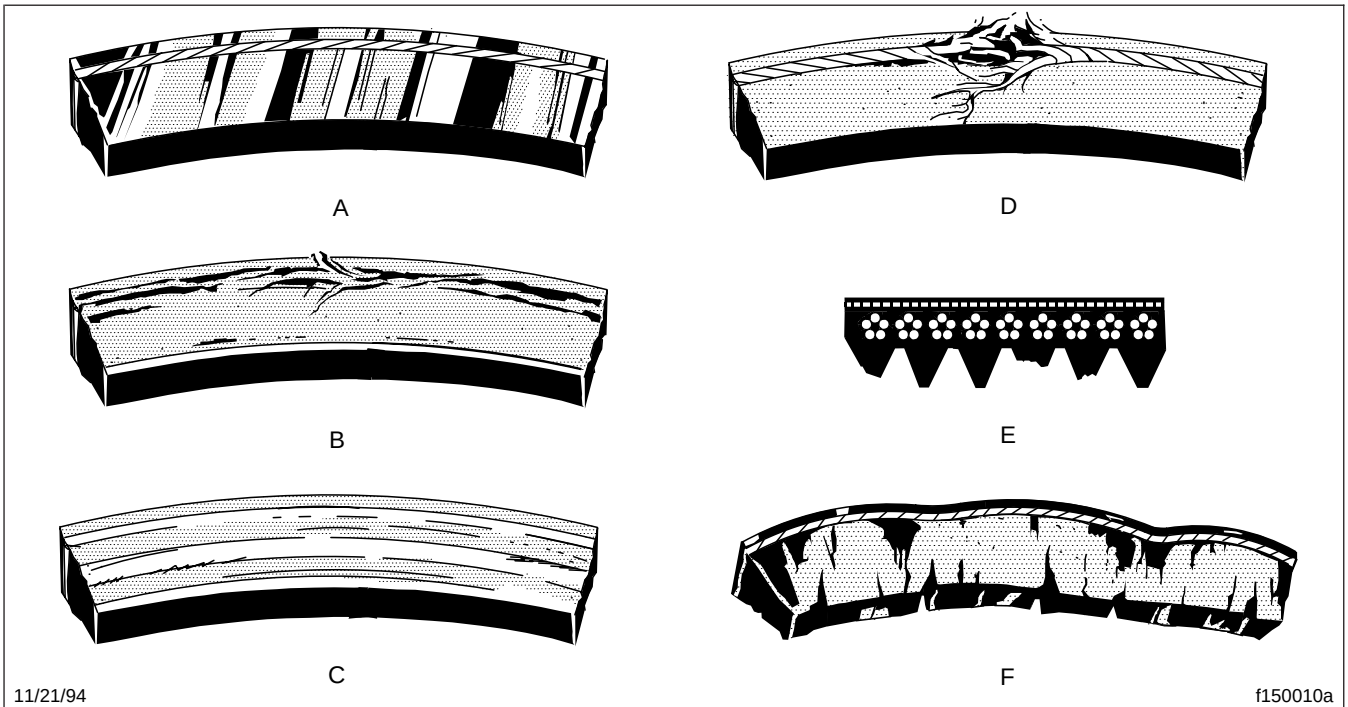
Engine Mount Torques, EPA07 Engines			
Description	**Fastener Size**	**Grade/ Class**	**Torque: lbf·ft (N·m)**
Engine Mount-to-Frame Rail Capscrew	5/8–11	8	120–152 (163–206)
Engine Leg-to-Flywheel Housing Bolts:			
Detroit Diesel Series 60 Engines	5/8–11 x 2-1/4 Inch	8	136 (184)
MBE4000 Engines	M16 x 1.5 x 60 mm (upper) M16 x 1.5 x 50 mm (lower)	10.9	175 (237)
Caterpillar Engines (C13 & C15)	3/4–10 x 2-3/4 Inch	8	170–210 (230–285)
Engine Leg-to-Engine Mount Capscrew	3/4–10	8	300 (407)
Front Engine Bracket-to-Front Engine Mount Capscrew	3/4–10	8	213–269 (289–365)

Table 2, Engine Mount Torques, EPA07 Engines

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Inspection

Inspect all used drive belts (including those that are being replaced). See **Fig. 1**.



A. Glazing
B. Separating Layers
C. Streaked Sidewalls
D. Tensile Break
E. Uneven Ribs
F. Cracks

Fig. 1, Drive Belt Problems

NOTE: For an installed belt, gently twist it about 90 degrees so you can see the sidewalls and bottom.

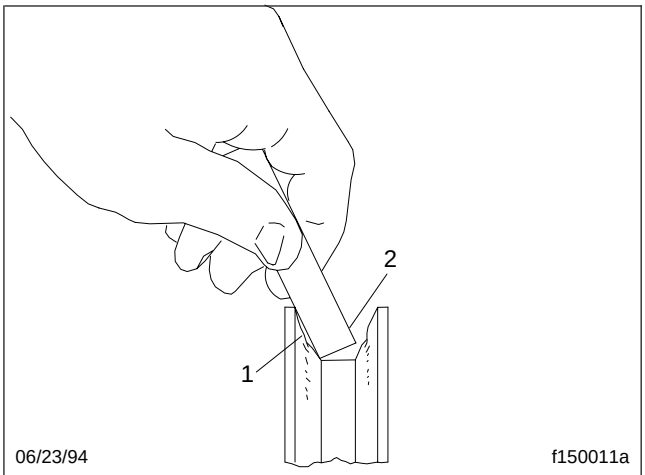
Replace a belt if any problem is found. Replace both belts of a set at the same time. Matched belts must be from the same manufacturer.

1. Inspect for glazing (shiny sidewalls). Glazing is caused by friction created when a loose belt slips in the pulleys. It can also be caused by oil or grease on the pulleys.
2. Inspect for separating layers. Oil, grease or belt dressings can cause the belt to fall apart in layers. If engine parts are leaking, repair the leaks. Do *not* use belt dressings on any belt.
3. Check for jagged or streaked sidewalls. These are the result of a foreign object (such as sand or small gravel) in the pulley or a rough pulley wall surface.
4. Check for tensile breaks (breaks in the cord body). Cuts in a belt are usually caused by large foreign objects in the pulley, or by prying or forcing the belt during installation or removal.
5. On poly-V belts, check for uneven ribs. Foreign objects in the pulley will erode the undercord ribs, causing the belt to lose its gripping power.
6. Inspect for cracks. Small, irregular cracks are usually signs of an old belt.
7. Check all pulley bearings for roughness. Replace the bearings if they are rough.
8. Inspect all pulleys for foreign objects, oil or grease in the grooves. Use a non-flammable cleaning solvent to remove oils. Use a wire brush to remove rust and a file to remove burrs.
9. Inspect the pulleys for wear on the inner walls. Hold a small straightedge against the inside of

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Pulley and Drive Belt Inspection

the pulley walls or use your little finger or fingernail to find grooves in the inner walls. See **Fig. 2**. If there are any grooves, replace the pulley.



1. Groove in Pulley Wall
2. Small Straightedge

Fig. 2, Pulley Inspection

10. Check the alignment of pulleys. See **Fig. 3**. Use a thin straightedge that is longer than the longest span between the pulleys. Place the straightedge into the V-grooves of two pulleys at a time. The straightedge should be parallel to the outer edges of the pulleys; if not, the pulleys are misaligned.

    Pulley misalignment must not be more than 1/16-inch for each foot (1.6 mm for each 305 mm) of distance between the centers of the pulleys.

    If the pulleys are misaligned, adjust them or their brackets if possible. Replace bent or broken pulleys, pulley brackets or shafts.

11. Check all drive component mounting parts for loose fasteners, cracks or other damage. Tighten loose fasteners. Repair or replace cracked or damaged brackets.

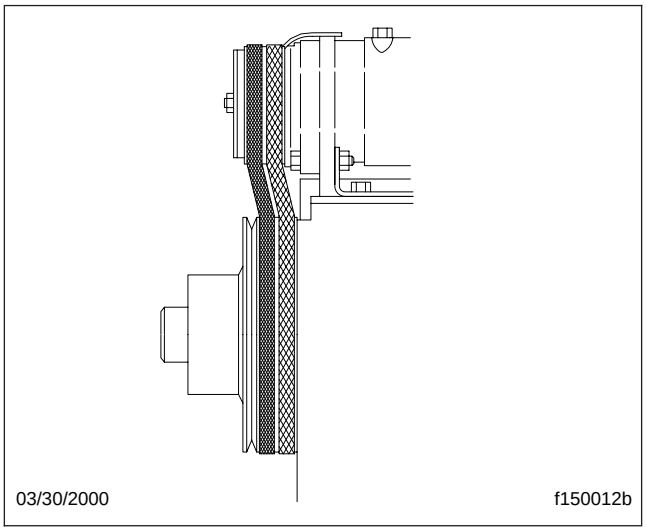


Fig. 3, Side View of Misaligned Pulleys

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Poly-V Belt Removal and Installation, Mercedes-Benz MBE900 Engine

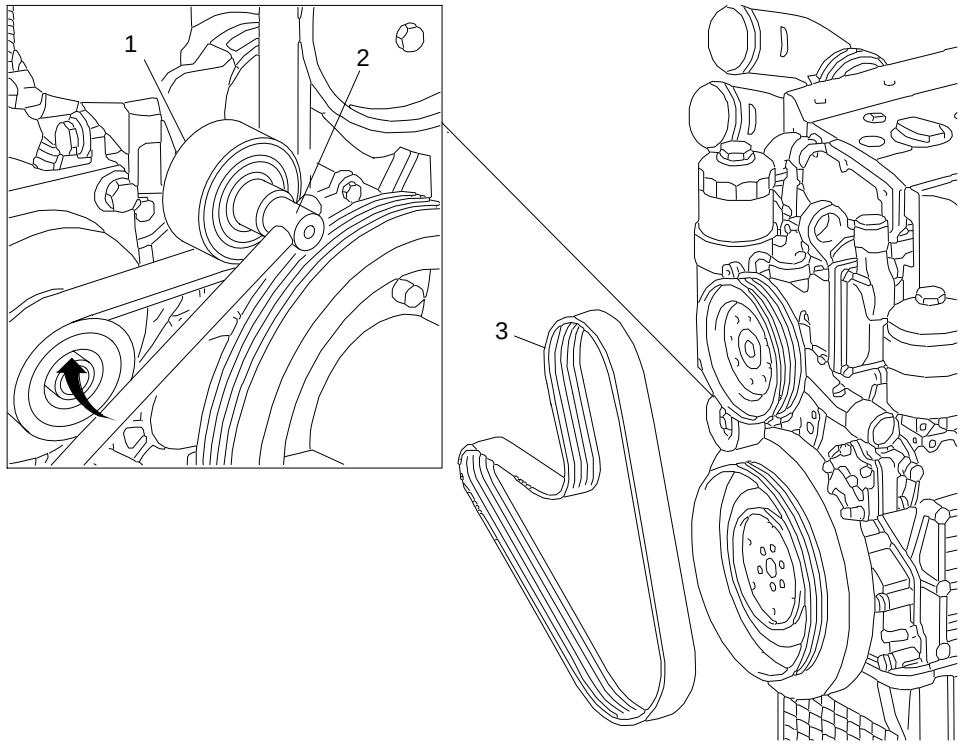
Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Place a T-handle and socket-wrench bit on the tensioning pulley bolt. See **Fig. 1**.

   Lift the T-handle (swivel the tensioning pulley clockwise) to remove the tension from the poly-V belt. Hold the tensioning pulley in this position for the next step.
3. Remove the poly-V belt from the alternator and coolant-pump pulleys. Be careful not to kink, stretch, or otherwise damage the belt.
4. Lower the T-handle to return the tensioning pulley to its original position. Remove the socket-wrench bit from the pulley bolt.
5. Inspect the poly-V belt for nicks, wear, or other damage. Replace the belt if necessary.
6. Inspect the following parts and replace any that are damaged or worn:
   - vibration damper
   - alternator pulley
   - coolant-pump pulley
   - belt tensioner
   - tensioning pulley

Installation

1. Fit the poly-V belt on the belt pulleys. Be careful not to kink, stretch, or otherwise damage the belt. Do not fit the belt onto the tensioning pulley yet.



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1. Belt Tensioner with Tensioning Pulley
2. T-Handle with Socket-Wrench Bit
3. Poly-V Belt

Fig. 1, Poly-V Belt Removal

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Poly-V Belt Removal and Installation, Mercedes-Benz MBE900 Engine

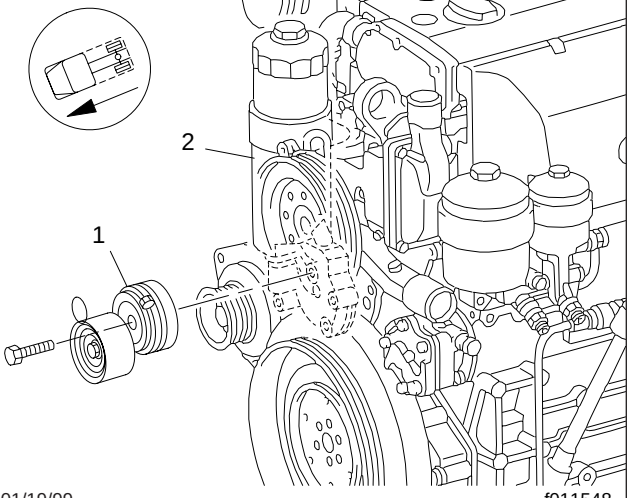
2. Place the T-handle and socket-wrench bit on the tensioning pulley bolt. Swivel the tensioning pulley clockwise to overcome the spring tension.
3. With the belt in place, lower the T-handle to return the tensioning pulley to its original position, allowing the belt tensioner to automatically put the correct tension on the belt.
4. Remove the socket-wrench bit from the pulley bolt.
5. Check the poly-V belt to make sure it is in the correct position and properly aligned on the pulleys.
6. Remove the chocks from the tires.

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Belt Tensioner Removal and Installation, Mercedes-Benz MBE900 Engine

Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the poly-V belt from the alternator and coolant-pump pulleys. See **Subject 110** for instructions.
3. Remove the hexhead capscrew and belt tensioner from the oil-filter housing. See **Fig. 1**.



1. Belt Tensioner with Tensioning Pulley
2. Oil-Filter Housing

Fig. 1, Belt Tensioner Removal

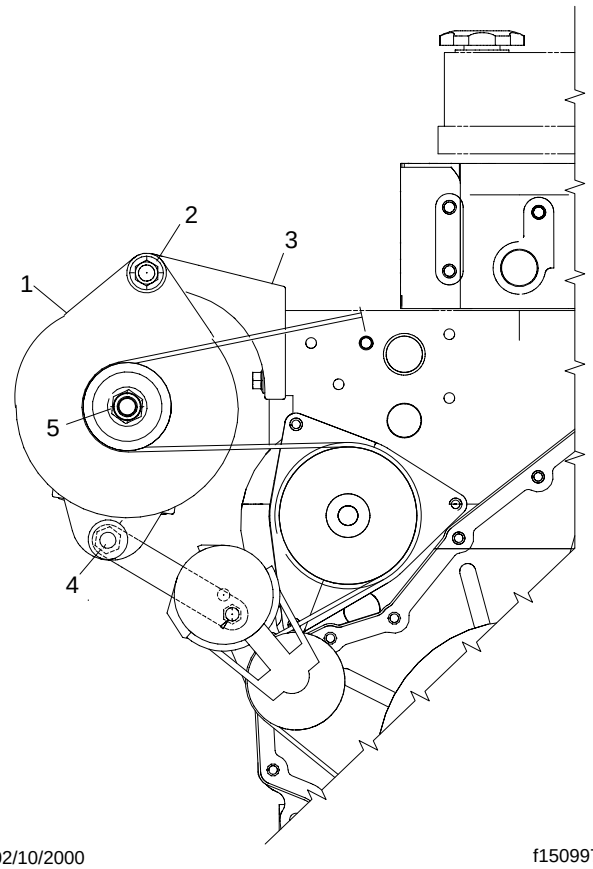
Installation

1. Align the pins on the belt tensioner with the holes in the oil-filter housing.
2. Install the belt tensioner on the oil-filter housing and secure in place with the hexhead capscrew. Tighten the capscrew 37 lbf·ft (50 N·m).
3. Install the poly-V belt on the alternator and coolant-pump pulleys. See **Subject 110** for instructions.
4. Remove the chocks from the tires.

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Fan and Alternator Belt Replacement, Cummins ISB and ISC Engines

Replacement (See Fig. 1 and Fig. 2)



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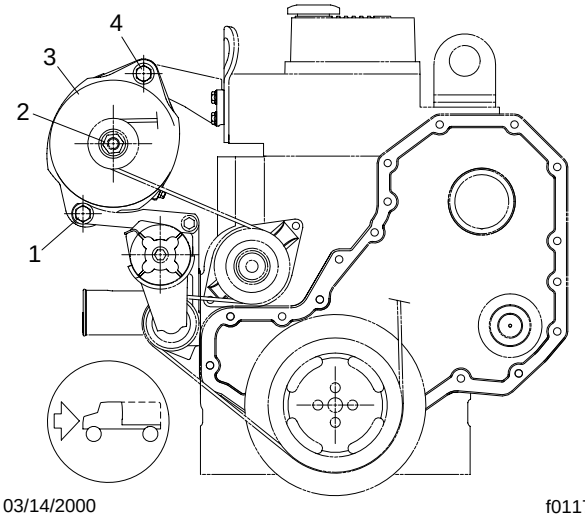
1. Alternator
2. Hexhead Capscrew, 1/2–13 x 6.5
3. Mounting Bracket
4. Hexhead Capscrew, 1/2–13 x 1.25
5. Pulley Nut

Fig. 1, Alternator Installation, Cummins ISC Engine

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.

NOTE: Vehicles with air conditioning have two possible configurations: refrigerant compressor driven by the fan and alternator belt or refrigerant compressor driven by a refrigerant compressor belt.

2. If the vehicle is equipped with air conditioning and has a refrigerant compressor belt, remove the refrigerant compressor belt. For instructions, see **Subject 140**.



03/14/2000 f011745

1. Hexhead Capscrew, 1/2–13 x 1.25
2. Pulley Nut
3. Alternator
4. Hexhead Capscrew, 1/2–13 x 6.5

Fig. 2, Alternator Mounting, Cummins ISB Engine

3. Insert a breaker bar (3/8- or 1/2-inch) in the belt tensioner.
4. Rotate the tensioner up and off the belt.
5. Holding the belt tensioner up, remove the belt from the alternator pulley.
6. Slowly release the belt tensioner and remove the breaker bar.
7. Lower the belt and take it off of the vibration damper.
8. Raise the belt and take it off over the fan.
9. Inspect the pulleys and the belt (even if installing a new belt) as instructed in **Subject 100**.
10. Loop the belt around the fan and align it in the rear channel of the fan pulley.
11. Loop the belt down and around the vibration damper pulley.
12. Insert a breaker bar (3/8- or 1/2-inch) in the belt tensioner.

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Fan and Alternator Belt Replacement, Cummins ISB and ISC Engines

13. Rotate the tensioner up while installing the belt on the alternator pulley.
14. Slowly release the tensioner assembly onto the belt. The tensioner automatically tightens the belt to the correct tension.
15. Remove the breaker bar from the tensioner.
16. The Cummins belt tensioner automatically adjusts the fan and alternator belt to the correct tension. If the belt slips, repair or replace the tensioner. For instructions, see the *Cummins Shop Manual*.
17. Remove the chocks from the rear tires.

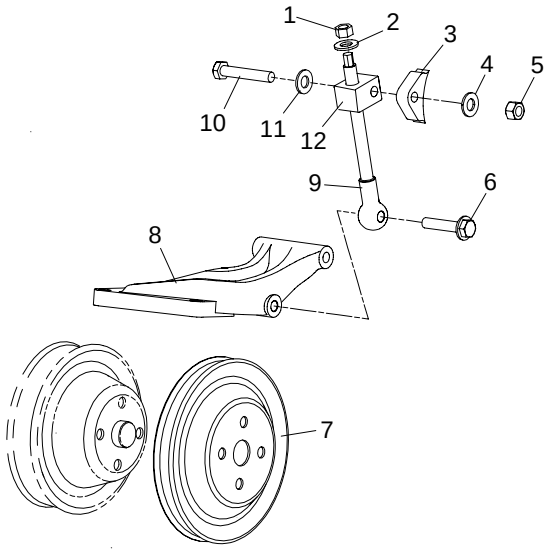
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Refrigerant Compressor Belt Replacement, Cummins ISB and ISC Engines

Replacement

NOTE: If the refrigerant compressor is driven by a serpentine belt, see **Subject 130**.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Loosen the 12 mm hexnut on the adjusting rod. See **Fig. 1**.

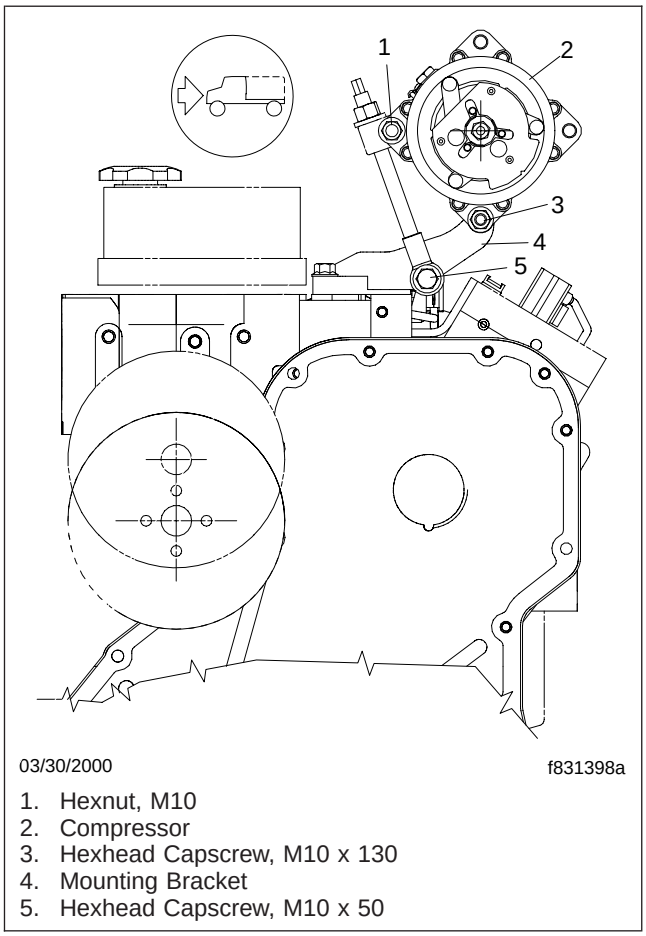


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1. Hexnut, M12
2. Washer
3. Compressor Ear
4. Hardened Washer
5. Hexnut, M10
6. Hexhead Capscrew, M10
7. Drive Pulley
8. Mounting Bracket
9. Adjusting Link
10. Hexhead Capscrew, M10
11. Hardened Washer
12. Adjusting Link End

Fig. 1, Adjusting Rod

3. Loosen the 10 mm hexnut on the adjusting link.
4. Loosen the 10 mm hexhead capscrew holding the compressor to the mounting bracket. See **Fig. 2** or **Fig. 3**.
5. Pivot the compressor to loosen the drive belt.



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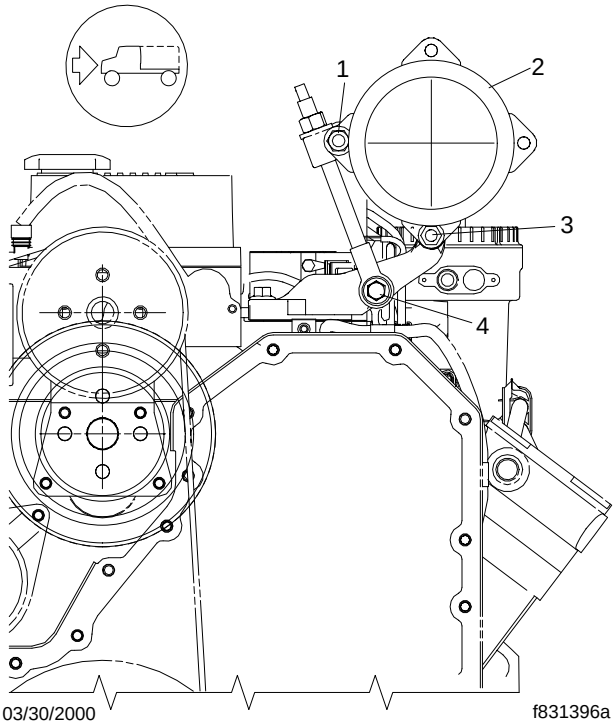
1. Hexnut, M10
2. Compressor
3. Hexhead Capscrew, M10 x 130
4. Mounting Bracket
5. Hexhead Capscrew, M10 x 50

Fig. 2, Compressor Mounting, Cummins ISC Engine

6. Remove the drive belt. Do not pry or roll it off the pulleys.
7. Inspect the pulleys and the belt (even if installing a new belt) as instructed in **Subject 100**.
8. Loop the belt around the fan and the compressor and align it in the front channels of the pulleys.
9. Pivot the compressor to hold the drive belt in position.
10. Install a belt tension gauge at the center of the belt's longest free-span.
11. Tighten the compressor belt by turning the adjusting rod hexnut to rotate the compressor up and away from the fan pulley. Tighten the belt to 100 lb (45 kg).

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Refrigerant Compressor Belt Replacement, Cummins ISB and ISC Engines



1. Hexnut, M10
2. Compressor
3. Hexhead Capscrew, M10 x 130
4. Hexhead Capscrew, M10 x 50

Fig. 3, Compressor Mounting, Cummins ISB Engine

IMPORTANT: Do not overtighten the belts. Too much tension shortens belt and bearing life.

12. Tighten the 10 mm hexnut on the adjusting link 30 to 40 lbf·ft (41 to 54 N·m).
13. Tighten the 12 mm hexnut on the adjusting rod 37 to 47 lbf·ft (50 to 64 N·m).
14. Tighten both 10 mm hexhead capscrews holding the compressor to the mounting bracket 30 to 40 lbf·ft (41 to 54 N·m).
15. Check the belt tension again and adjust if needed.
16. If installing a new compressor belt, operate the engine for about 20 minutes. Check the belt tension. All new belts will lose tension after 20 minutes of operation.

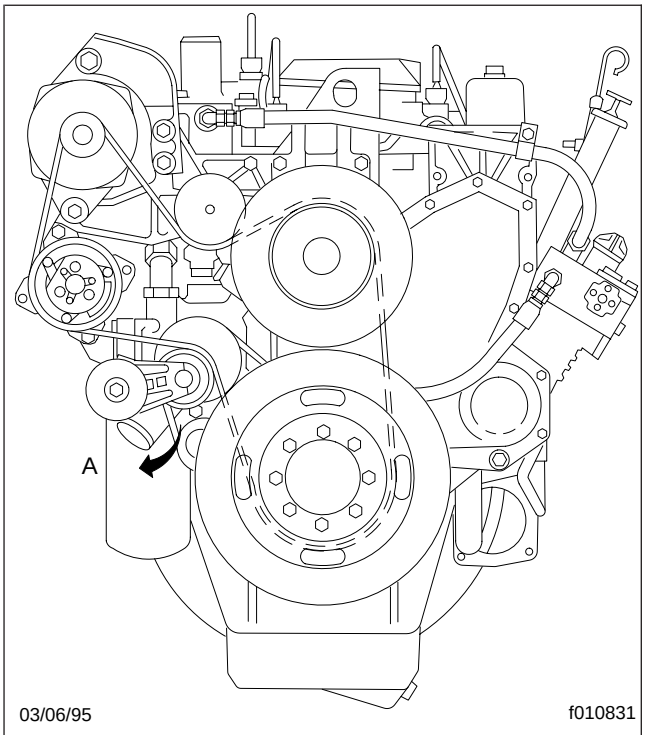
    If necessary, adjust the belt to 100 lb (45 kg).
17. Remove the chocks from the tires.

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Accessory Drive Belt Replacement, Caterpillar™ 3126B Engine

Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Insert a 1/2-inch rachet drive into the square hole in the belt tensioner and turn the tensioner clockwise. See **Fig. 1**.



A. Turn the belt tensioner clockwise, off the belt.

Fig. 1, Accessory Drive Belt

3. Remove the engine accessory drive belt.
4. Inspect the pulleys and the drive belt (even if installing a new belt) as instructed in **Subject 100**.
5. Position the drive belt over all the pulleys *except the drive belt tensioner.* For the correct belt routing, see **Fig. 1**.
6. Insert a 1/2-inch rachet drive into the square hole in the belt tensioner and turn the tensioner clockwise. See **Fig. 1**.
7. Position the tensioner against the belt and remove the rachet drive from the tensioner.
8. The Caterpillar belt tensioner automatically adjusts the belt to the correct tension. If the belt slips, repair or replace the tensioner. For instructions, see the *Caterpillar Shop Manual*.
9. Remove the chocks from the rear tires.

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Specifications

Torque Values	
Description	**lbf·ft (N·m)**
Mercedes-Benz MBE900 Engines	
Belt Tensioner Hexhead Capscrew	37 (50)
Cummins Engines	
Adjusting Link Hexnut	30 to 40 (41 to 54)
Adjusting Rod Hexnut	37 to 47 (50 to 64)
Refrigerant Compressor Mounting Hexhead Capscrew	30 to 40 (41 to 54)

Table 1, Torque Values

Drive Belt Tensions, Cummins	
Description	**Tension lb (kg)**
Refrigerant Compressor Belt	100 (45)

Table 2, Drive Belt Tensions, Cummins

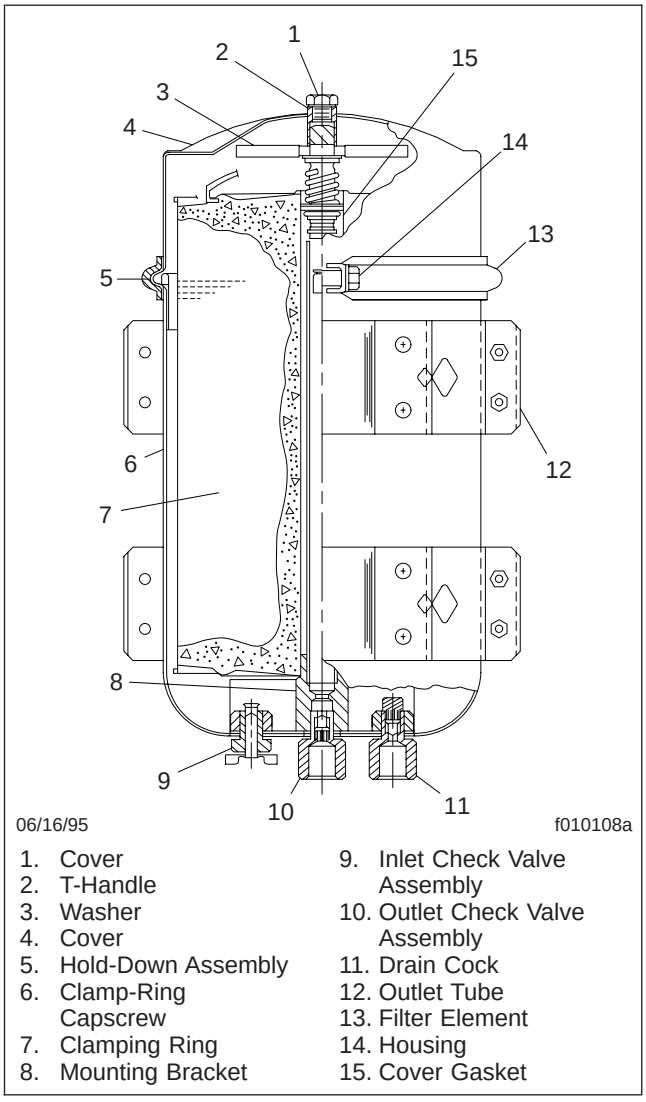
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General Information

Normal engine operation produces a variety of contaminants such as resins, and gums. The bypass oil filter, used with a full-flow filter, traps these contaminants and prevents excessive wear of engine parts.

The Luber-finer® model 750–CT bypass filter bleeds a small portion of oil flow from the oil lubrication system and returns filtered oil directly to the engine. The bypass filter removes small contaminants that the full-flow filter does not capture.

Engine oil enters through the inlet check valve assembly, filling the filter housing. See **Fig. 1**. In the housing, pressure forces the oil through the sides of the filter element. Filtered oil is channeled through openings in the hold-down assembly, then collected in the outlet tube. From the outlet tube, filtered oil goes back to the engine through the outlet check valve assembly.

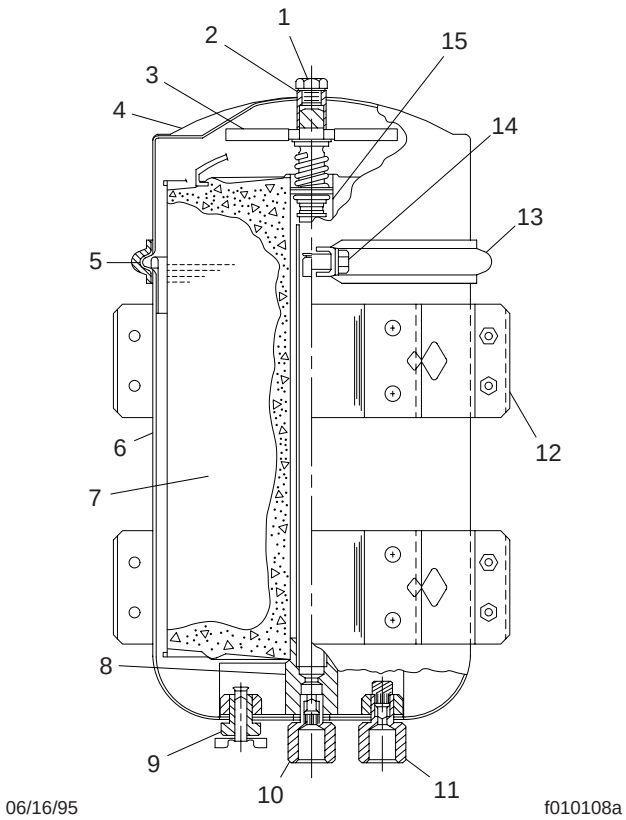


1. Cover
2. T-Handle
3. Washer
4. Cover
5. Hold-Down Assembly
6. Clamp-Ring Capscrew
7. Clamping Ring
8. Mounting Bracket
9. Inlet Check Valve Assembly
10. Outlet Check Valve Assembly
11. Drain Cock
12. Outlet Tube
13. Filter Element
14. Housing
15. Cover Gasket

Fig. 1, Luber-finer Model 750–CT Bypass Oil Filter

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Replacement (See Fig. 1)



1. Cover
2. T-Handle
3. Washer
4. Cover
5. Hold-Down Assembly
6. Clamp-Ring Capscrew
7. Clamping Ring
8. Mounting Bracket
9. Inlet Check Valve Assembly
10. Outlet Check Valve Assembly
11. Drain Cock
12. Outlet Tube
13. Filter Element
14. Housing
15. Cover Gasket

Fig. 1, Oil Filter, Exploded View

IMPORTANT: Do the following procedure at every scheduled engine oil change.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Loosen the vent plug capscrew. Open the drain cock and allow the oil to drain.
3. Remove the clamp-ring capscrews. Remove the clamp ring and lift the cover off the filter housing.
4. Unscrew the hold-down assembly T-handle and remove the assembly from the housing.
5. Remove and discard the oil filter element.
6. Clean the inside of the housing, and the hold-down assembly, with solvent.
7. Close the drain cock.
8. Install a new filter element.
9. Check the cover gasket for damage, and replace it if needed.
10. Install the hold-down assembly and securely tighten the T-handle.
11. Position the cover on the housing. Install the clamp ring and capscrews. Alternately tighten the clamp capscrews to ensure a uniform seal between the cover and gasket.
12. Add oil to the crankcase. Start the engine and let it idle until normal operating oil pressure is reached.
13. Loosen the vent plug capscrew and bleed any trapped air from the filter housing. Tighten the vent plug capscrew as soon as oil appears at the fitting.
14. Shut down the engine and add oil as needed to bring the oil level up to the high ("H") mark on the dipstick.

⚠ CAUTION

Operating the engine with the oil level below the low ("L") mark, or above the high mark, could result in engine damage.

15. Remove the chocks from the tires.

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Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries.
   - 2.1 Disconnect the battery ground cable at the vehicle frame.
   - 2.2 Disconnect the positive battery cable from the batteries.
3. Drain the vehicle coolant and air systems.
4. Remove the hood. For instructions, see **Group 88**.

⚠ WARNING

Drain the coolant only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

5. Drain the radiator.
   - 5.1 Place a suitable container under the driver's side corner of the radiator. See **Fig. 1**.
   - 5.2 Remove the surge tank cap.
   - 5.3 Unscrew the plug on the bottom of the radiator.
   - 5.4 After the coolant has drained, screw the plug into the radiator and tighten it firmly.
6. Remove the air cleaner housing.
   - 6.1 Remove the right fender splash shield.
   - 6.2 Remove the air compressor intake hose that runs from the engine air intake pipe to the compressor, if equipped.
   - 6.3 Remove the air intake ducting between the air cleaner housing and the turbocharger. See **Fig. 2**.
   - 6.4 Remove the hoses that run between the turbocharger and the charge air cooler and between the charge air cooler and the engine.

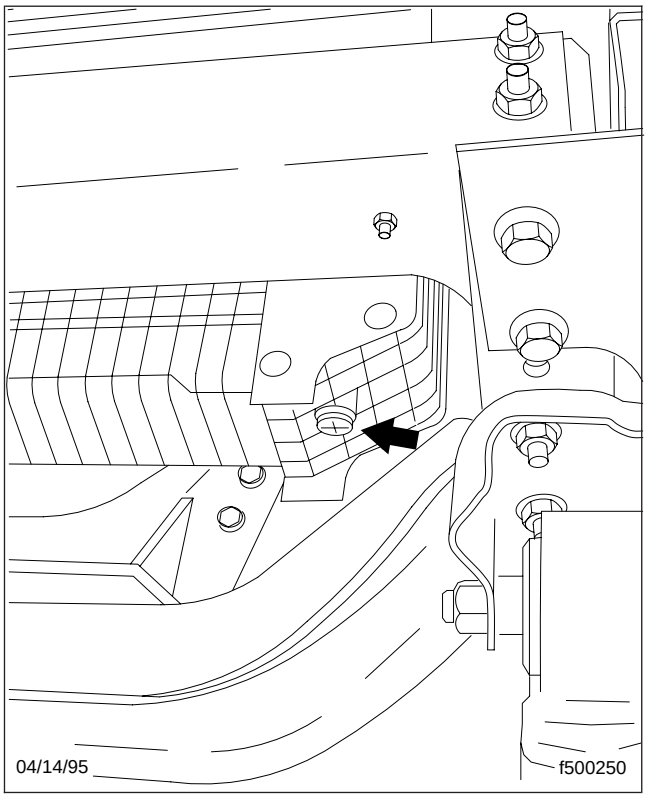
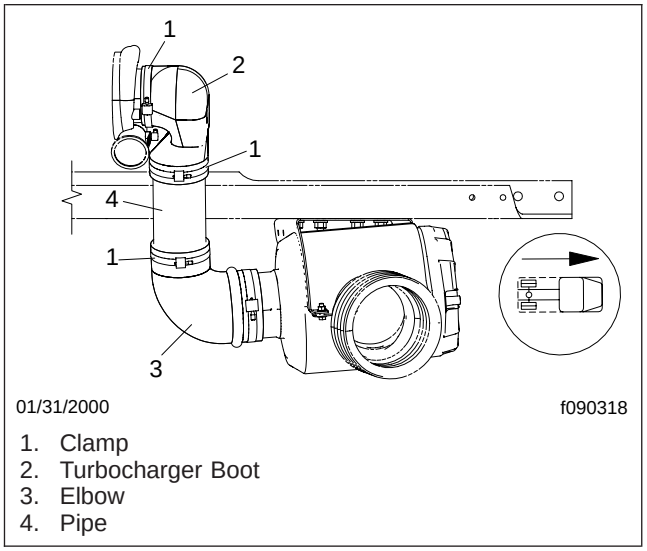


Fig. 1, Radiator Drain Plug



1. Clamp
2. Turbocharger Boot
3. Elbow
4. Pipe

Fig. 2, Air Intake Ducting

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Engine Removal and Installation

6.5 Disconnect the vent lines from the radiator and the engine and move the lines aside.

6.6 Remove the radiator inlet hose from the radiator and the engine.

6.7 Disconnect the radiator outlet hose from the bottom of the radiator.

6.8 Disconnect the wiring to the horn.

6.9 Disconnect the radiator right-hand strut from the air cleaner housing bracket.

6.10 Disconnect the right-side air recirculation shield from the radiator. This includes disconnecting the two push-type fasteners that hold the shield to a bracket attached to the top of the radiator. See **Fig. 3**.

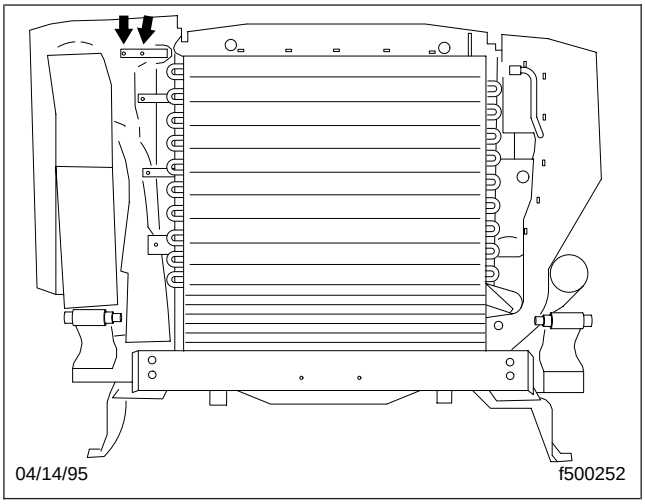


Fig. 3, Air Recirculation Shields and Fasteners

6.11 Remove the four 1/2–13 bolts that hold the air cleaner housing bracket to the frame rail.

6.12 As a unit, remove the air cleaner housing, the housing bracket, the right-side air recirculation shield and the horn from the vehicle.

7. Remove the radiator.

7.1 Free the refrigerant lines from all routing clamps and stand-off brackets between the compressor and the condenser. See **Fig. 4**.

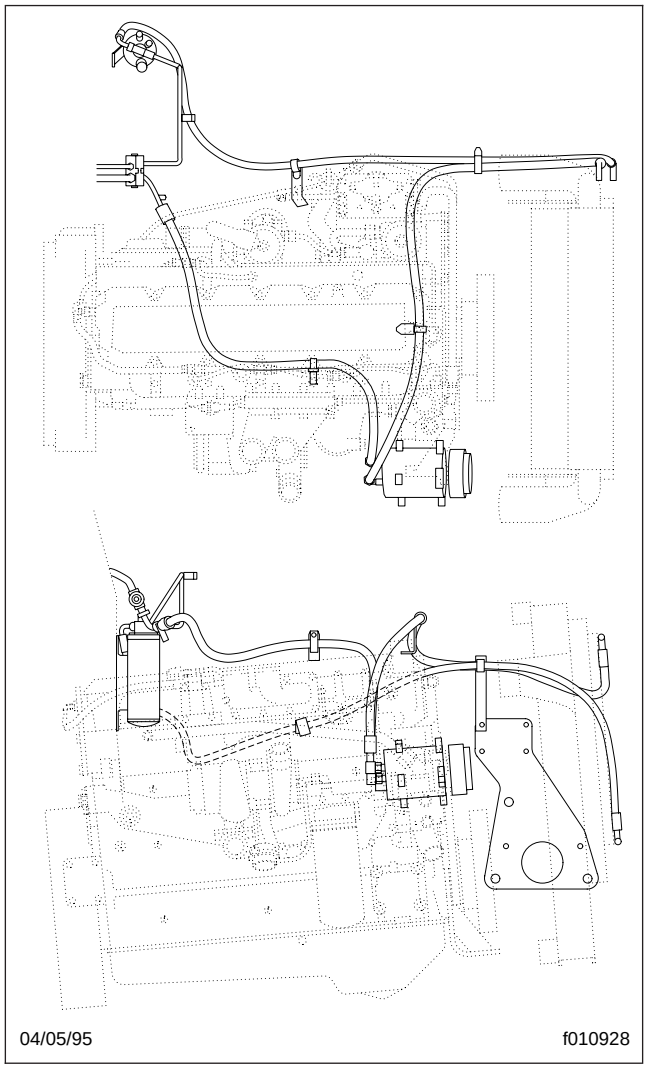


Fig. 4, Refrigerant Line Routings

7.2 Remove the condenser mounting fasteners and move the condenser aside.

7.3 Remove the left-side air recirculation shield from the radiator/charge air cooler assembly.

7.4 Disconnect the right-side radiator strut from the radiator.

7.5 Attach a lifting chain to the two rear hood attachment studs at the top of the radiator and attach the chain to a lifting crane. See **Fig. 5**.

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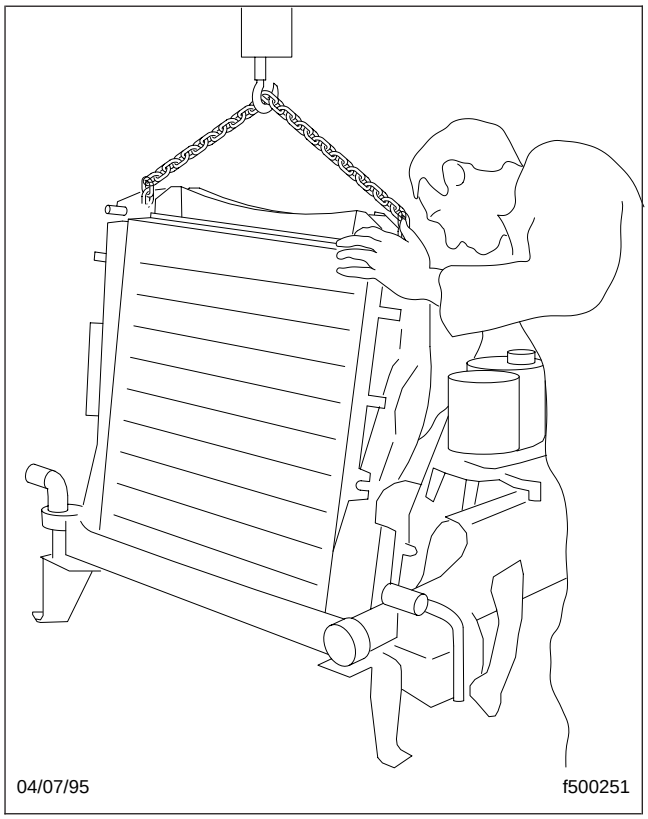


Fig. 5, Lifting the Radiator

7.6 Disconnect the radiator/charge air cooler from its frame rail mounts.

7.7 Remove the fasteners that hold the fan shroud to the radiator and move the shroud back against the engine.

7.8 Lift the radiator/charge air cooler assembly from the vehicle.

8. Move the refrigerant compressor aside.

8.1 Disconnect the compressor wiring.

8.2 Remove the accessory drive belt. For instructions, see **Section 01.02**.

8.3 Remove the compressor mounting fasteners and move the compressor aside.

8.4 Use tie straps to secure the refrigerant compressor and condenser out of the way.

9. Disconnect the heater hoses.

9.1 Disconnect the heater return hose from the water pump and move the hose aside. See **Fig. 6**.

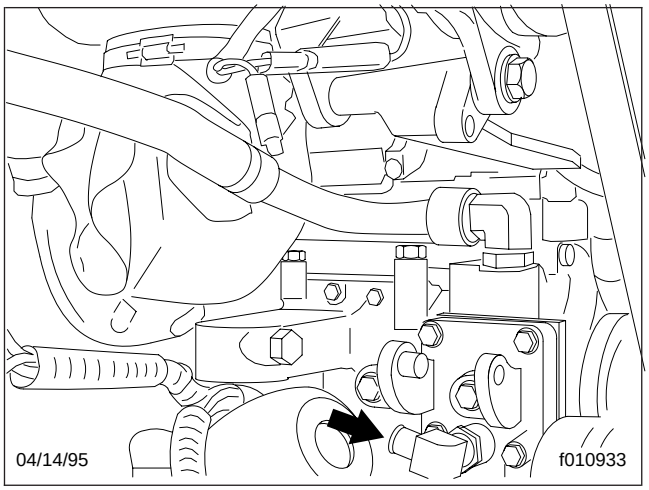
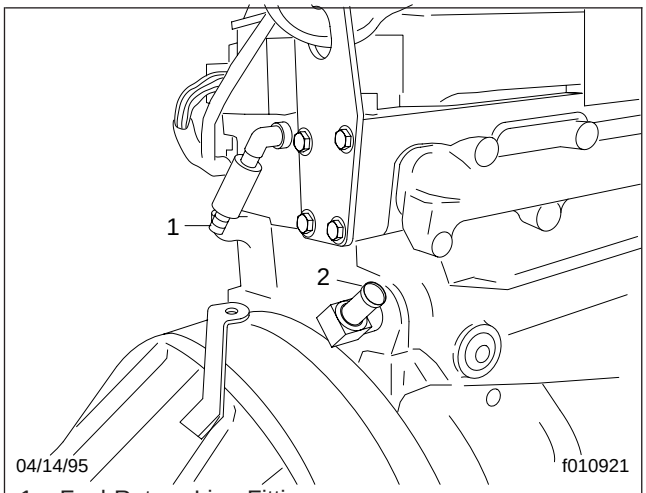


Fig. 6, Heater Return Hose Connection

9.2 Disconnect the heater supply hose from the rear of the engine block, and move the hose aside. See **Fig. 7**.



1. Fuel Return Line Fitting
2. Heater Supply Hose Fitting

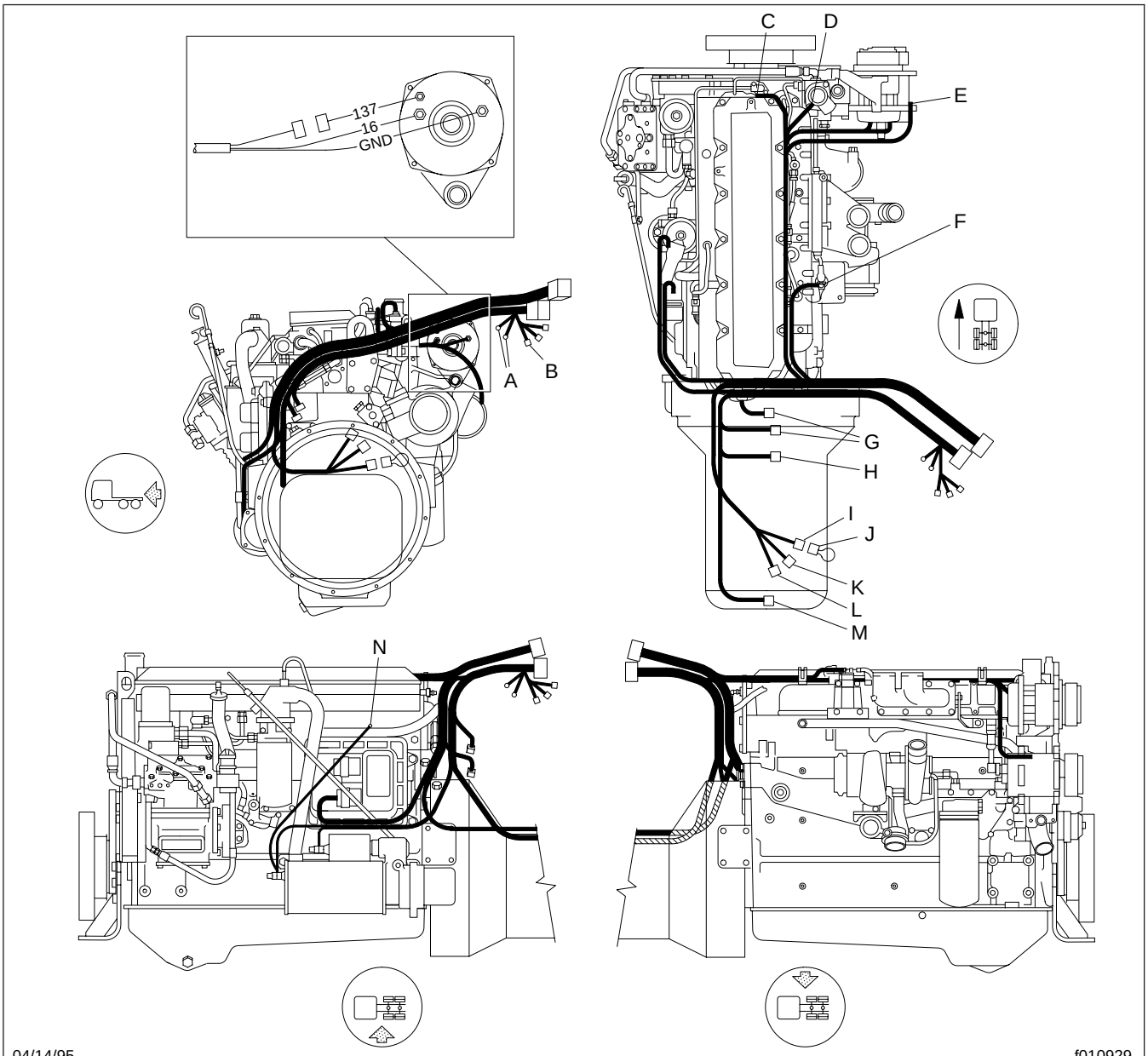
Fig. 7, Fuel Return and Heater Supply Connections

10. Label and disconnect the wiring. See **Fig. 8**.

10.1 Disconnect the wiring from the starter. See **Fig. 9**.

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Engine Removal and Installation



A. To Cab Studs
B. To Mag Switch
C. To Fan Clutch Solenoid
D. To Coolant Temperature Switch
E. To Refrigerant Compressor
F. To Grid Heater (Intake Air Heater)
G. To Tachometer Sensor
H. To Back Up Switch Wiring Harness
I. To Neutral Start Switch
J. Jumper Assembly
K. To Vehicle Speed Sensor
L. To Speedometer
M. To Vehicle Speed Sensor
N. To Ground Stud

Fig. 8, Wiring Harnesses

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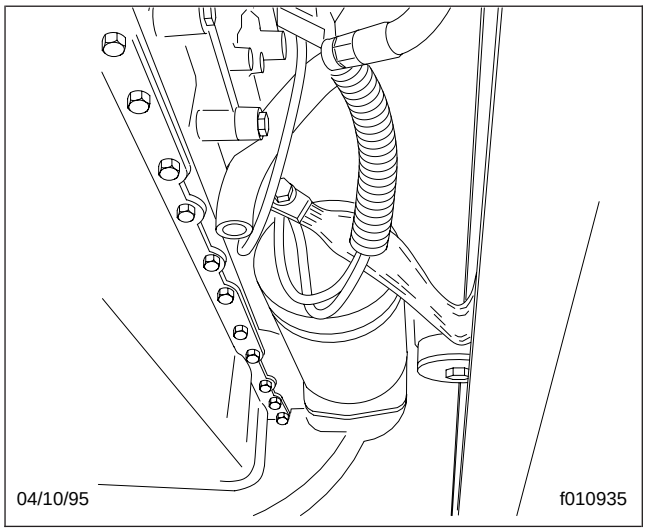


Fig. 9, Starter Wiring Connections

10.2 Disconnect the ground strap from the alternator.

10.3 Disconnect the wiring from the alternator.

10.4 Disconnect the wiring from the accumulator.

10.5 Disconnect the wiring from the fan clutch.

10.6 Disconnect the wiring from the coolant temperature sensors.

10.7 Unplug the lower wiring harness connector from the electronic control module. See **Fig. 10**.

11. Disconnect the power steering components.

11.1 Place a suitable container under the power steering fluid reservoir and remove the hoses from the bottom of the reservoir. Allow the fluid to drain completely.

11.2 At the power steering fluid pump, disconnect the hose that runs from the pump to the steering gear.

11.3 Secure any loose or disconnected hoses to the engine with tie straps.

12. Disconnect the air lines from the air governor on top of the air compressor.

13. At the fuel/water separator, disconnect the fuel delivery line that runs to the engine.

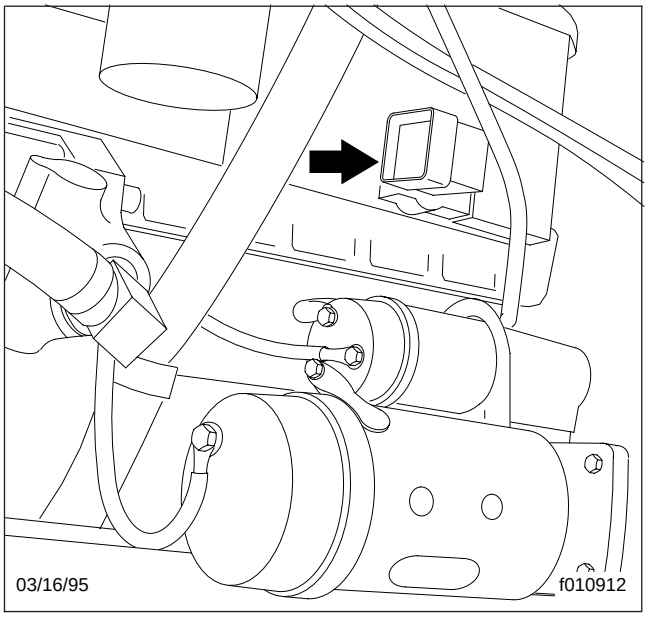


Fig. 10, ECM Connector

14. Disconnect the forward end of the clutch rod and tie-strap the rod to the engine.

15. Disconnect the parking brake cable, if equipped.

16. Disconnect the surge tank lines and remove the surge tank. For instructions, see **Group 20**.

17. Disconnect the air line from the fan clutch solenoid. See **Fig. 11**.

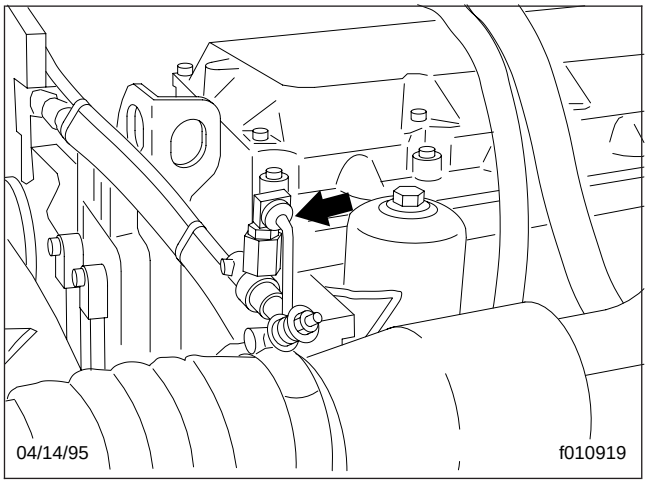


Fig. 11, Fan Clutch Solenoid

18. Remove the engine cover inside the cab.

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Engine Removal and Installation

19. Remove the shift tower. For instructions, see **Group 26**.
20. Remove the exhaust ducting.
    - 20.1 Loosen the V-band clamp that holds the forward end of the exhaust ducting to the rear of the turbocharger.
    - 20.2 Under the cab, disconnect the exhaust pipe from the saddle clamp mounted on the flywheel housing. See **Fig. 12**.

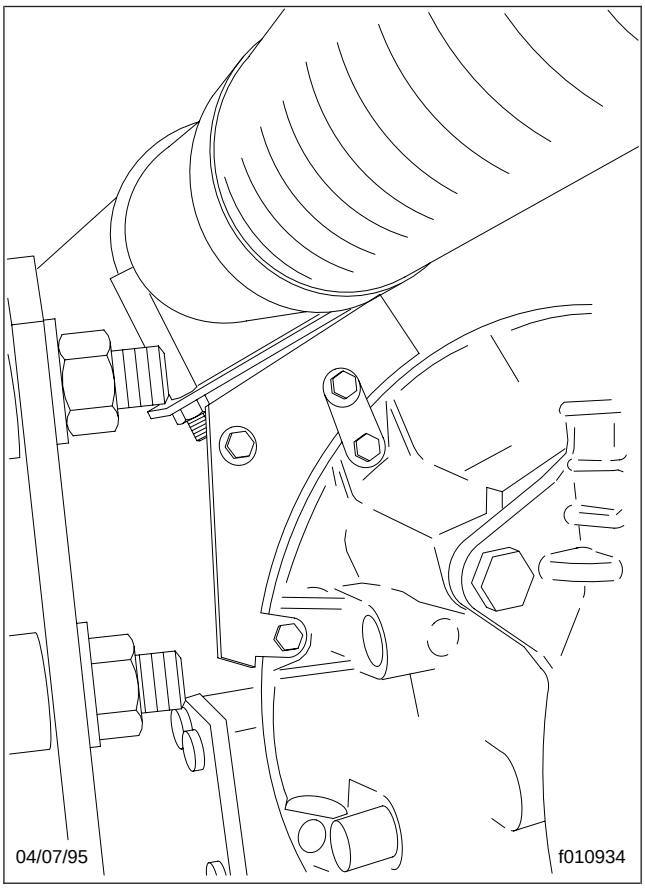


Fig. 12, Exhaust Bracket on Flywheel Housing

21. Disconnect the driveline from the transmission.
    - 21.1 Place a stand under the driveline and disconnect the driveline from the transmission. For instructions, see **Group 41**.
    - 21.2 Place a second stand under the driveline and disconnect the driveline midship bearing bracket. See **Fig. 13**. For instructions, see **Group 41**.

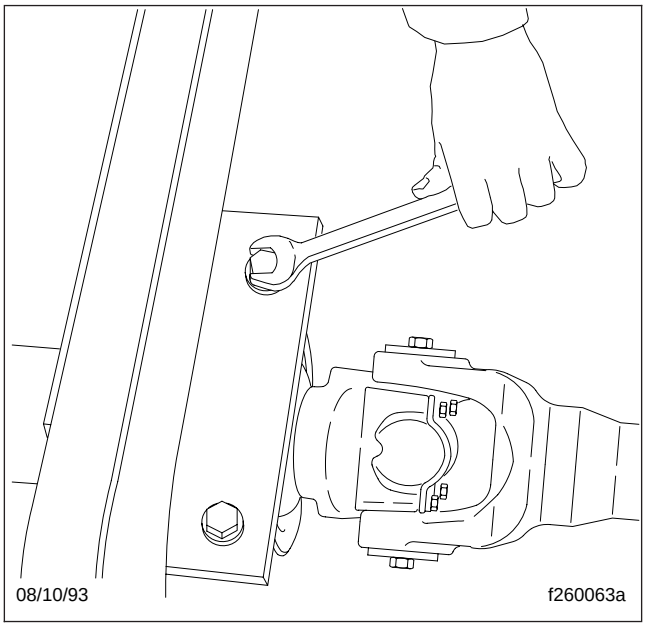


Fig. 13, Midship Bearing Bracket

    - 21.3 Move the driveline out of the way.
22. While under the vehicle, disconnect all other engine and transmission components.
    - 22.1 Disconnect the battery cable stand off bracket by the left rear engine mount.
    - 22.2 Disconnect the wiring from the speed sensor at the transmission output.
    - 22.3 Disconnect the wiring harness connectors from the back-up alarm switch and the neutral start switch on the transmission top cover. See **Fig. 14**.
    - 22.4 Remove the heat shield over the wiring harness, forward of the right rear engine mount. See **Fig. 15**.
    - 22.5 Disconnect the fuel supply line from the junction plate mounted on top of the transmission.
    - 22.6 Disconnect the fuel return line from the back of the engine block. See **Fig. 7**.
    - 22.7 Disconnect the wire-braid air compressor outlet line from the chassis air supply line.

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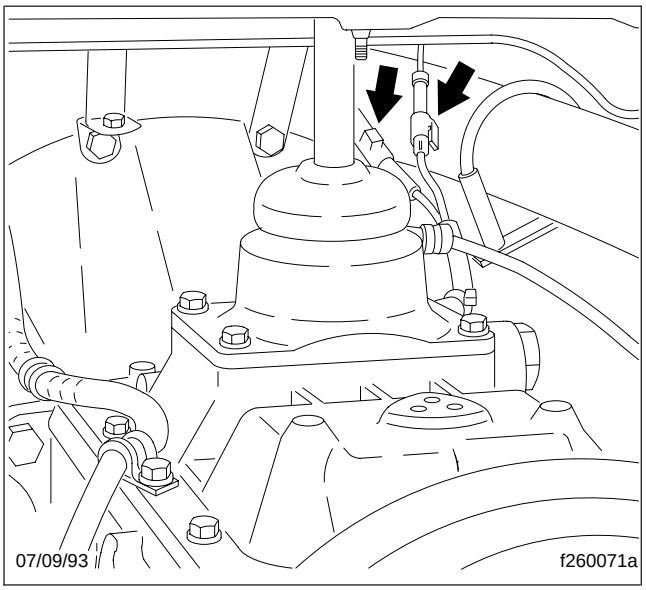


Fig. 14, Transmission Wiring Connectors

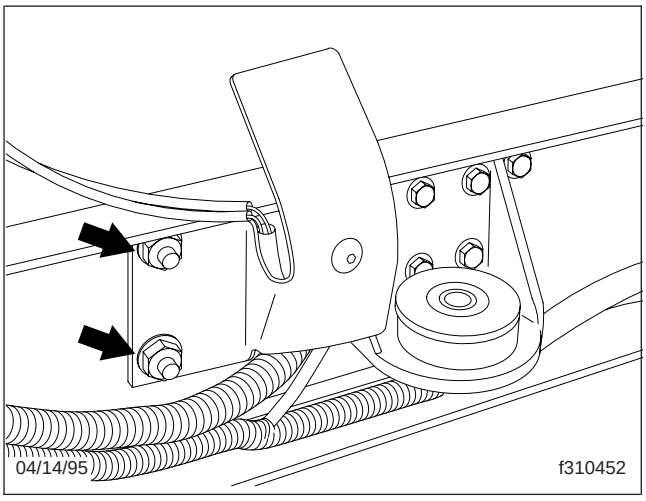


Fig. 15, Wiring Harness Heat Shield Fasteners

⚠ DANGER

The crane and lifting chains used to remove the engine must be capable of safely lifting and supporting two metric tons. Once the engine mounts are disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing severe personal injury or death, and component damage.

23. Remove the engine from the vehicle.

    23.1 Attach the chain to the existing lifting eyes at the front and the rear of the engine. See **Fig. 16**.

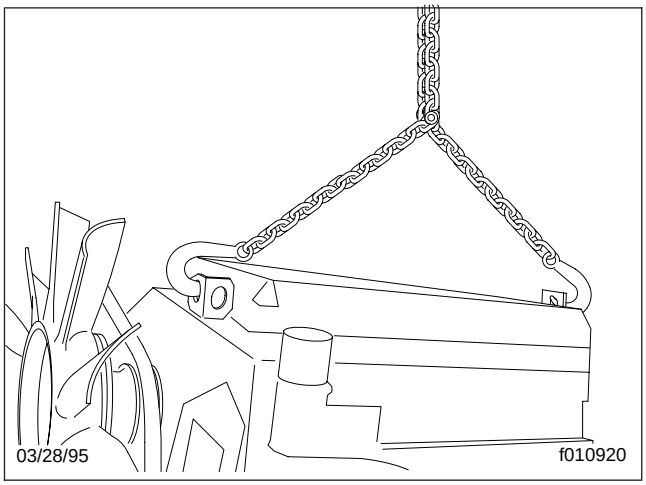


Fig. 16, Lifting Chain Installed

    23.2 With the engine lifting eyes connected by chain to the crane, raise the crane enough to tighten the chains, but not enough to lift the front of the vehicle.

    23.3 With the engine securely supported by the crane and lifting chains, disconnect the rear engine legs from the engine mounts on the frame rails.

    On each engine leg, remove the nut from the bolt that runs down through the engine leg, rubber isolators and engine mount. Save the fasteners and isolators.

    23.4 Remove the nuts from the bolts that fasten the front engine support bracket to the underslung crossmember. See **Fig. 17**.

    23.5 Using the crane, lift the engine and pull it forward.

    23.6 Once the engine and transmission are clear of the vehicle, place the engine on engine stands.

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Engine Removal and Installation

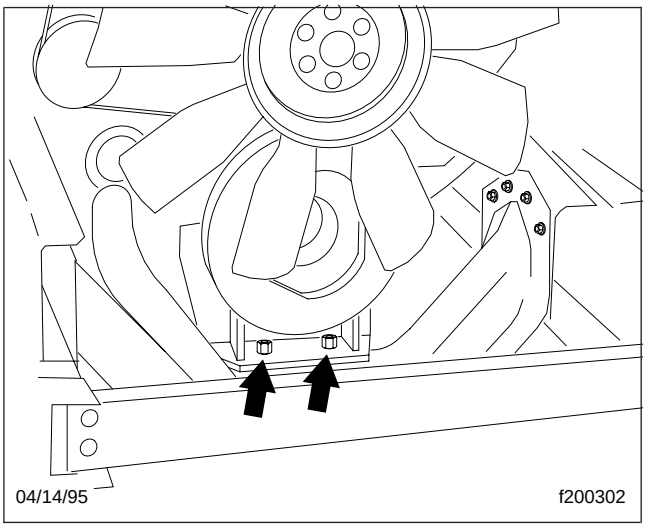


Fig. 17, Front Engine Mount Fasteners

Installation

DANGER

The crane and lifting chains used to install the engine must be capable of safely lifting and supporting two metric tons. Once the engine is removed from the engine stands, do not get under the engine until it is securely supported on the engine mounts. An unsecured engine may fall, causing severe personal injury or death, and component damage.

1. Install the engine and transmission in the vehicle.
   - 1.1 Attach the chain to the existing lifting eyes at the front and the rear of the engine.
   - 1.2 With the two engine lifting eyes connected by chain to the crane, lift the engine and position it in the engine compartment.
   - 1.3 Connect the engine to the rear engine mounts, and tighten each bolt that runs down through the engine leg, rubber isolators and engine mount 241 lbf·ft (327 N·m).
   - 1.4 Assemble the lower isolator under the underslung crossmember and the front engine support bracket and secure the front engine mount with nuts and washers. Tighten the nuts 136 lbf·ft (184 N·m).
   - 1.5 Once the engine is securely installed in the vehicle, remove the lifting chains.
2. Under the vehicle, connect all engine and transmission components.
   - 2.1 Connect the wiring to the speed sensor at the transmission output.
   - 2.2 Connect the wiring harness connectors to the back-up alarm switch and the neutral start switch on the transmission top cover.
   - 2.3 Connect the fuel supply line to the junction plate mounted on top of the transmission.
   - 2.4 Connect the fuel return line to the back of the engine block.
   - 2.5 Connect the wire-braid air compressor outlet line to the chassis air supply line.
   - 2.6 Install the heat shield over the wiring harness, forward of the right rear engine mount. See **Fig. 15**.
   - 2.7 Route and clamp the battery cable.
3. Connect the driveline.
   - 3.1 Connect the driveline to the transmission. For instructions, see **Group 41**.
   - 3.2 Connect the driveline midship bearing bracket. For instructions, see **Group 41**.
4. Connect the parking brake cable, if equipped.
5. Install the exhaust ducting.
   - 5.1 Under the cab, connect the exhaust pipe to the saddle clamp mounted on the flywheel.
   - 5.2 Tighten the V-band clamp that holds the forward end of the exhaust ducting to the rear of the turbocharger 85 lbf·in (940 N·cm).
6. Install the surge tank and connect the surge tank lines. For instructions, see **Group 20**.
7. Connect the air line to the fan clutch solenoid. See **Fig. 11**.

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8. At the left side of the engine, connect the air lines to the air governor on top of the air compressor.
9. At the fuel/water separator, connect the fuel delivery line that runs to the engine.
10. Connect the forward end of the clutch rod and remove any tie straps that hold the rod to the engine.
11. Connect the power steering components.
    - 11.1 Connect the hoses to the bottom of the power steering fluid reservoir.
    - 11.2 At the power steering fluid pump, connect the hose that runs from the pump to the steering gear.
    - 11.3 With all the hoses connected, fill the power steering fluid reservoir.
12. Connect the engine wiring.
    - 12.1 Connect the wiring to the starter.
    - 12.2 Connect the ground strap to the alternator.
    - 12.3 Connect the wiring to the alternator.
    - 12.4 Connect the wiring to the accumulator.
    - 12.5 Connect the wiring to the fan clutch.
    - 12.6 Connect the wiring to the coolant temperature sensors.
    - 12.7 Plug the lower wiring harness connector into the electronic control module.
13. Connect the heater hoses.
    - 13.1 Connect the heater return hose to the water pump.
    - 13.2 Connect the heater supply hose to the rear of the engine block.
14. Install the refrigerant compressor.
    - 14.1 Connect the compressor wiring.
    - 14.2 Install the compressor mounting fasteners. For instructions, see **Group 83**.
    - 14.3 Install the accessory drive belt. For instructions, see **Section 01.02**.
15. Install the radiator.
    - 15.1 Attach a lifting chain to the two hood attachment studs at the top of the radiator and attach the chain to a lifting crane.
    - 15.2 Lift the radiator/charge air cooler assembly and position it on the radiator mounts.
    - 15.3 Install the radiator/charge air cooler on its frame rail mounts. For instructions, see **Group 20**.
    - 15.4 Install the fan shroud on the radiator.
    - 15.5 Connect the vent lines to the radiator and the engine.
    - 15.6 Install the radiator inlet hose between the radiator and the engine.
    - 15.7 Connect the radiator outlet hose to the bottom of the radiator.
    - 15.8 Install the condenser on the radiator and charge air cooler.
    - 15.9 Route the refrigerant lines between the compressor and the condenser, and secure the lines with clamps and stand-off brackets.
    - 15.10 Install the left-side air recirculation shield.
16. Install the air cleaner housing.
    - 16.1 As a unit, position the air cleaner housing, the housing bracket, the right-side air recirculation shield and the horn on the vehicle.
    - 16.2 Install the four 1/2–13 bolts that hold the air cleaner housing mounting bracket to the frame rail. For instructions, see **Group 09**.
    - 16.3 Connect the radiator right-hand strut to the air cleaner housing bracket.
    - 16.4 Connect the right-side air recirculation shield to the radiator. This includes connecting the two push-type fasteners that hold the shield to a bracket attached to the top of the radiator.
    - 16.5 Connect the air intake ducting between the air cleaner housing and the turbocharger and connect the hoses that run between the turbocharger and the charge air cooler and between the charge air

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Engine Removal and Installation

cooler and the engine. Clamp the hoses to the A-shaped bracket on top of the engine.

16.6 Install the air compressor intake hose that runs from the engine air intake pipe to the compressor, if equipped.

16.7 Install the right fender splash shield.

16.8 Connect the wiring to the horn.

17. Install the shift tower.
18. Install the engine cover inside the cab.
19. Fill the radiator.
20. Install the hood. For instructions, see **Group 88**.
21. Connect the batteries.
22. Remove the chocks from the rear tires.
23. Start the engine and check for leaks. Repair any leaks found.
24. Test drive the vehicle.

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See **Fig. 1** for a full view of the grid heater wiring.

See **Fig. 2** for a full view of the fan clutch wiring.

See **Fig. 3** and **Fig. 4** for partial views of the fan clutch wiring.

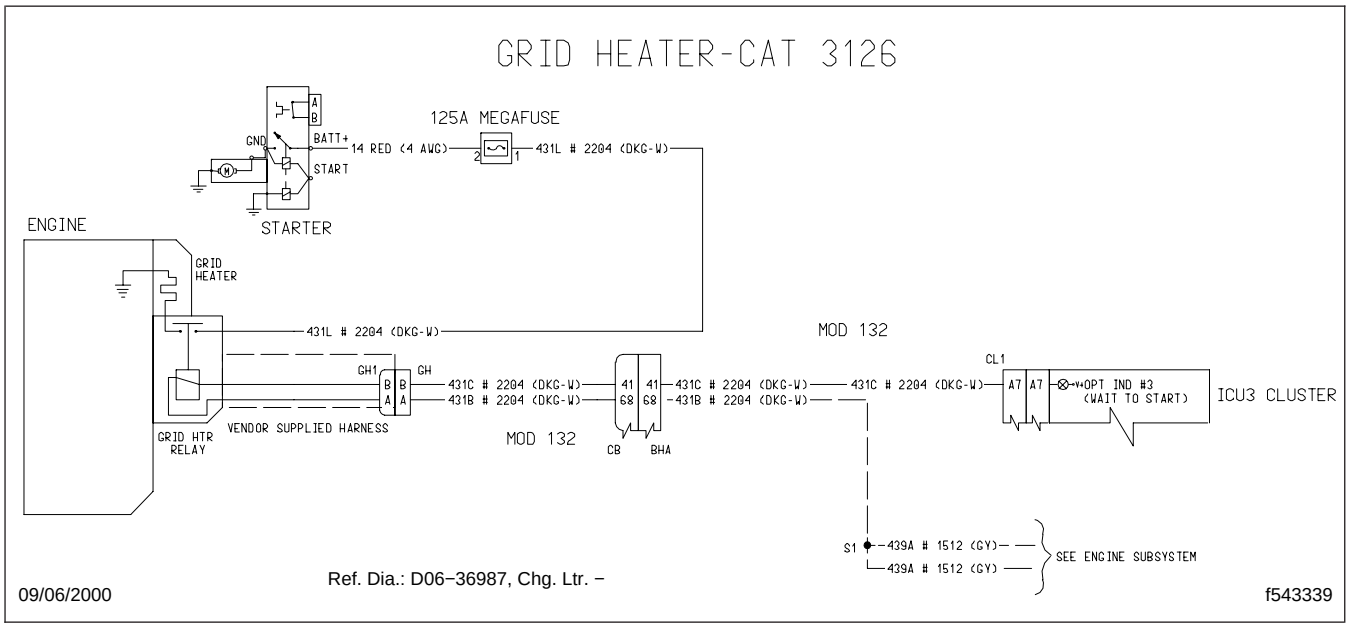
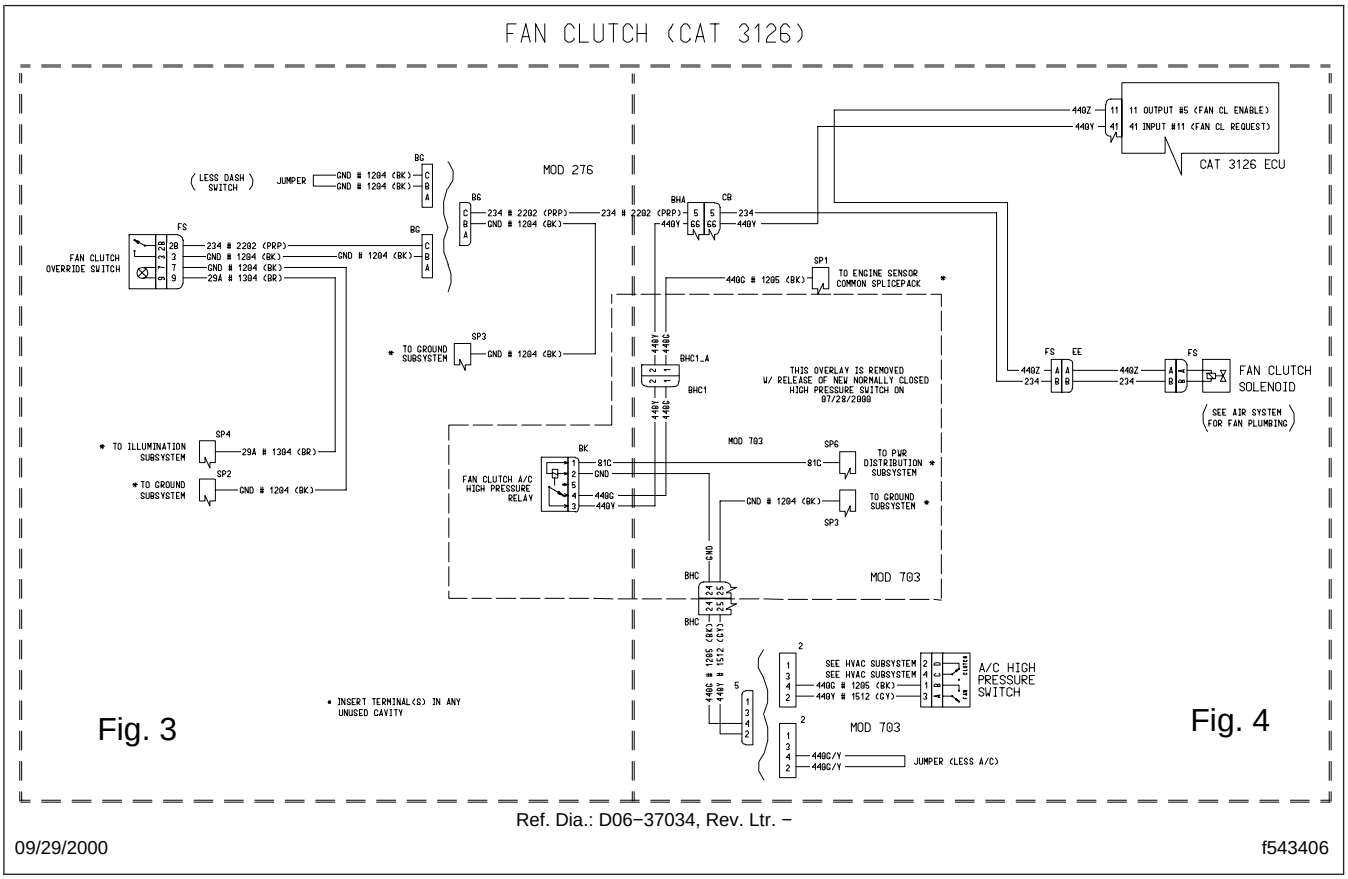


Fig. 1, Grid Heater Wiring (full view)

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Specifications



Ref. Dia.: D06−37034, Rev. Ltr. −

09/29/2000 f543406

Fig. 2, Fan Clutch Wiring (full view)

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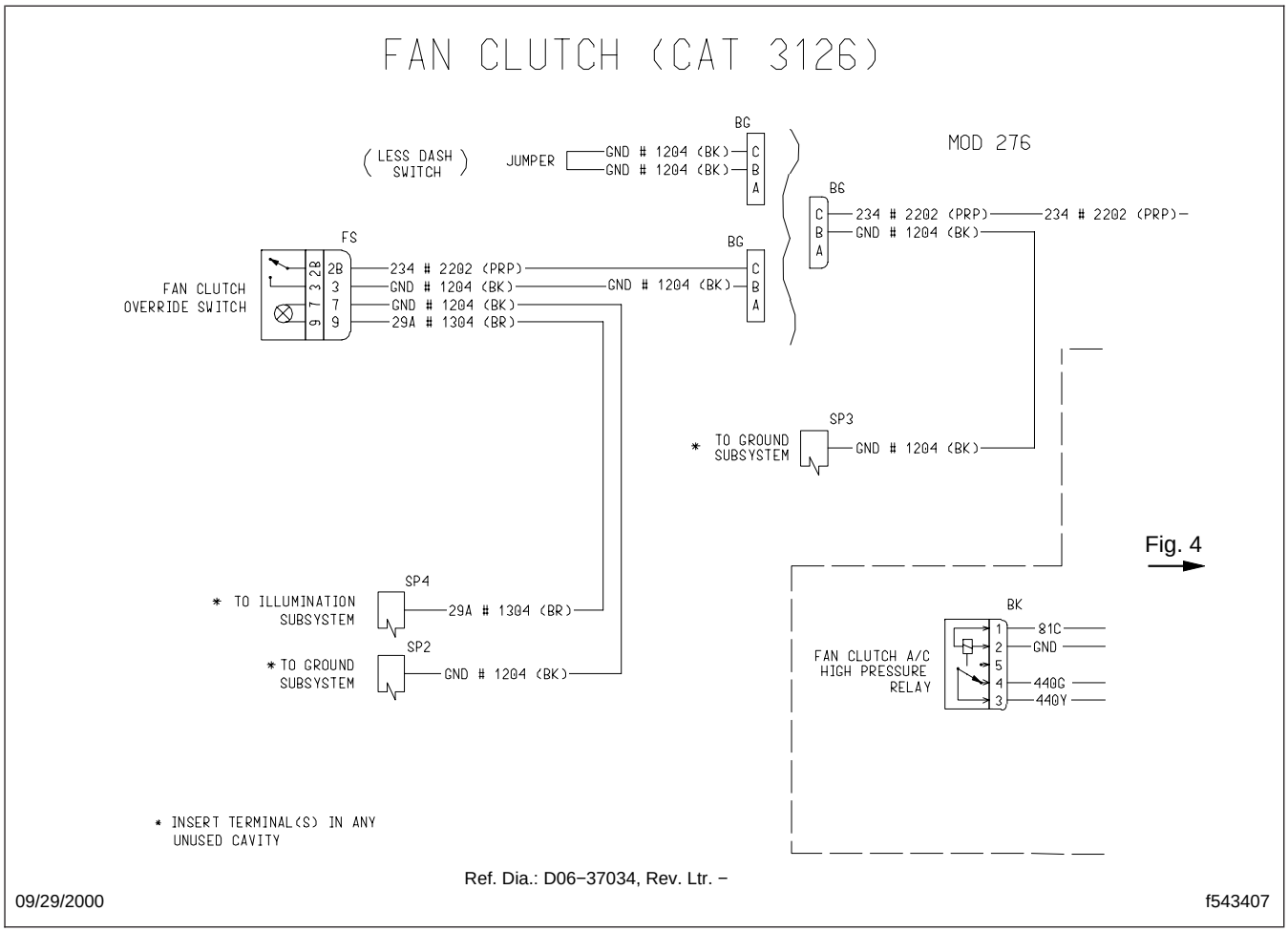


Fig. 3, Fan Clutch Wiring (partial view)

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Specifications

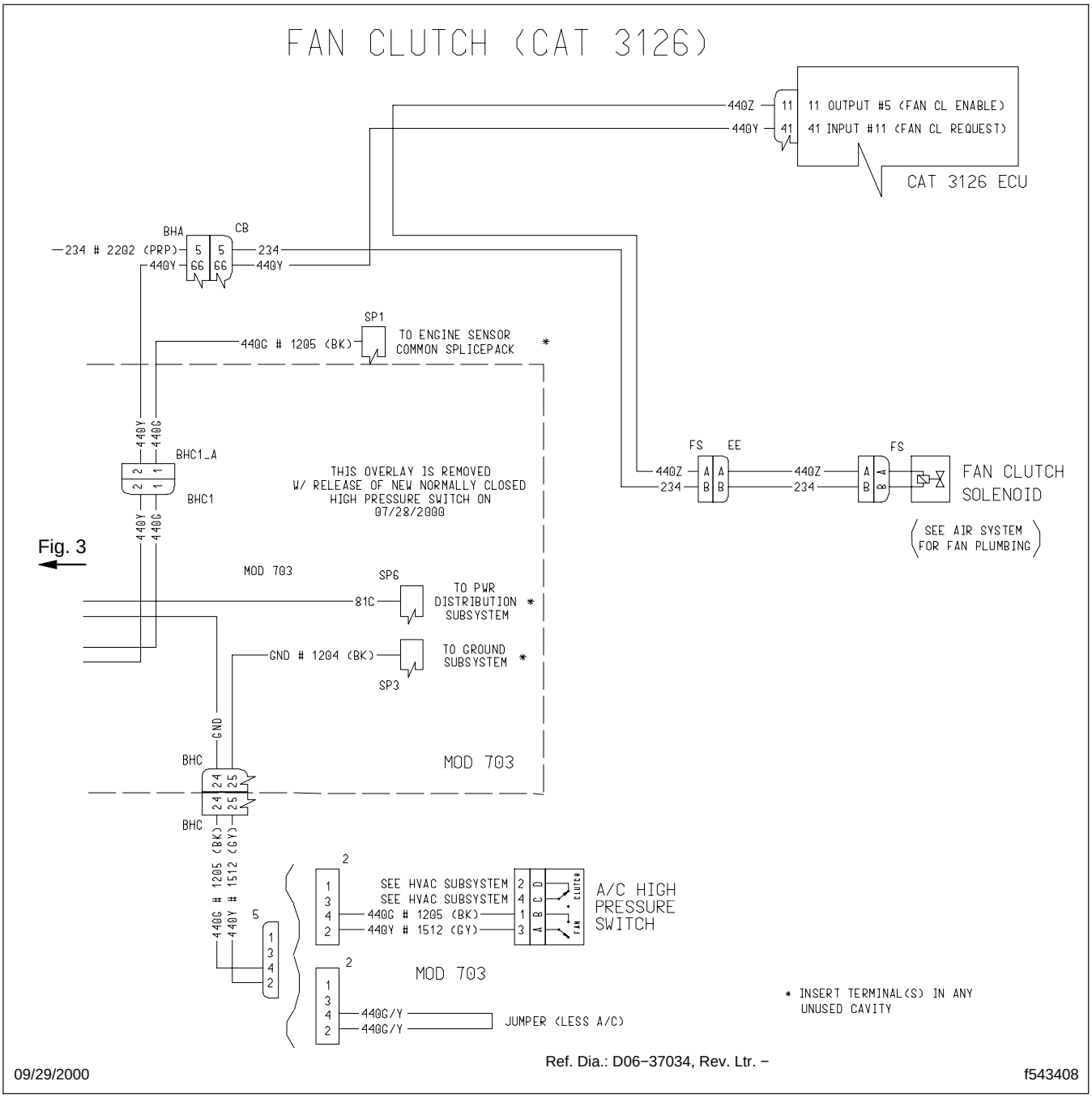


Fig. 4, Fan Clutch Wiring (partial view)

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See **Fig. 1** for a full view of the grid heater wiring.

See **Fig. 2** and **Fig. 3** for partial views of the grid heater wiring.

See **Fig. 4** for a full view of the fan clutch wiring.

See **Fig. 5** and **Fig. 6** for partial views of the fan clutch wiring.

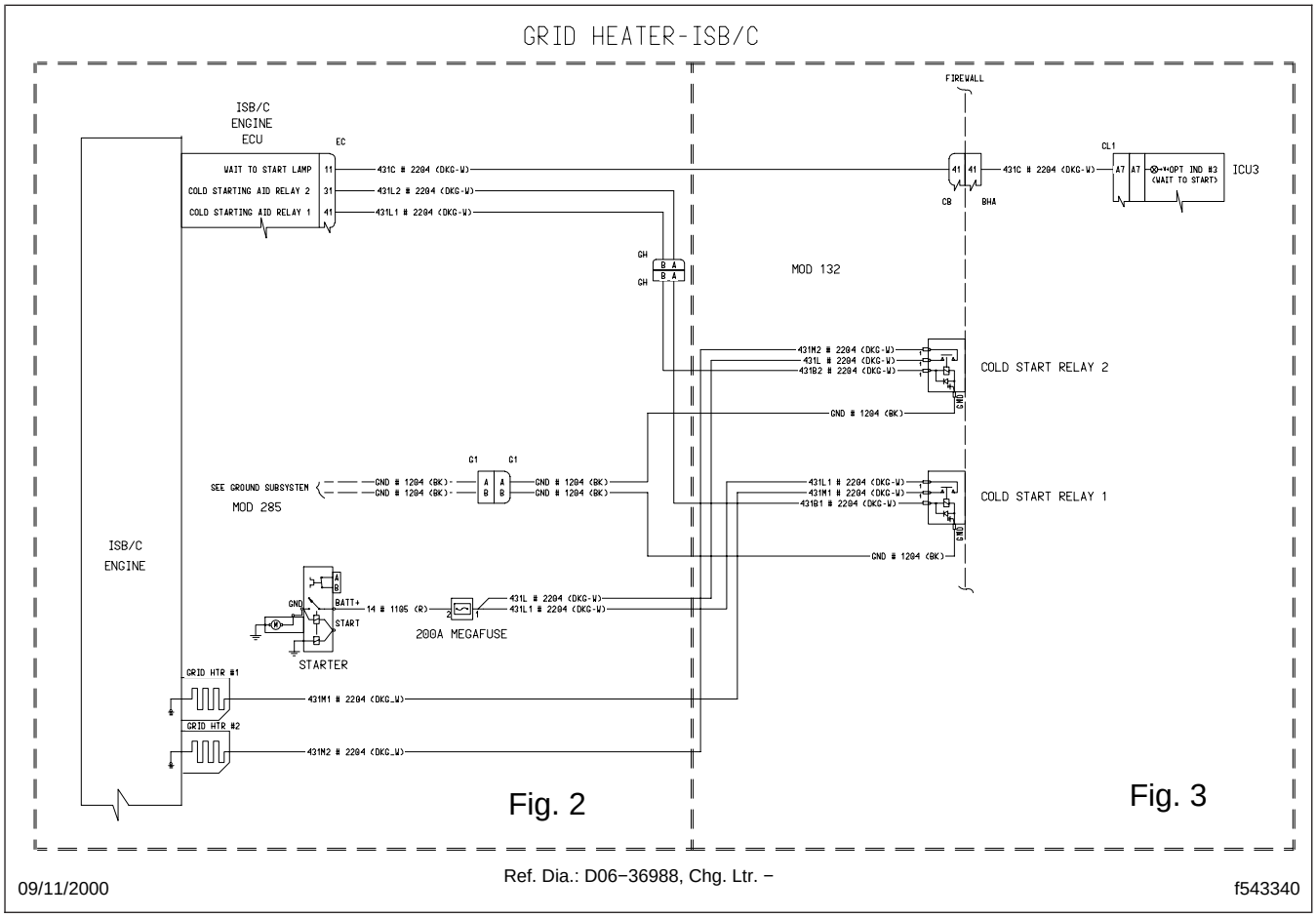


Fig. 1, Grid Heater Wiring (full view)

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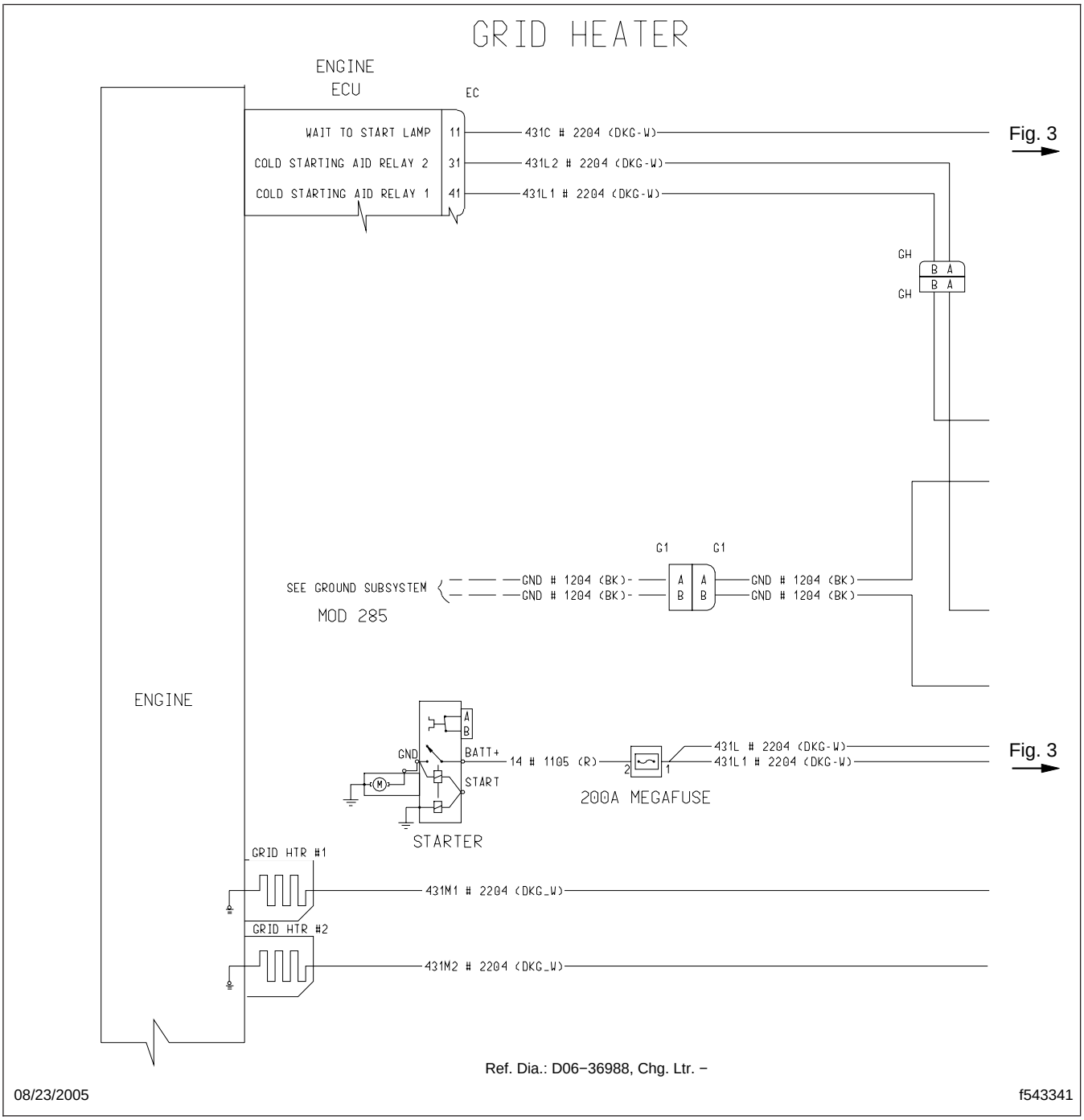


Fig. 2, Grid Heater Wiring (partial view)

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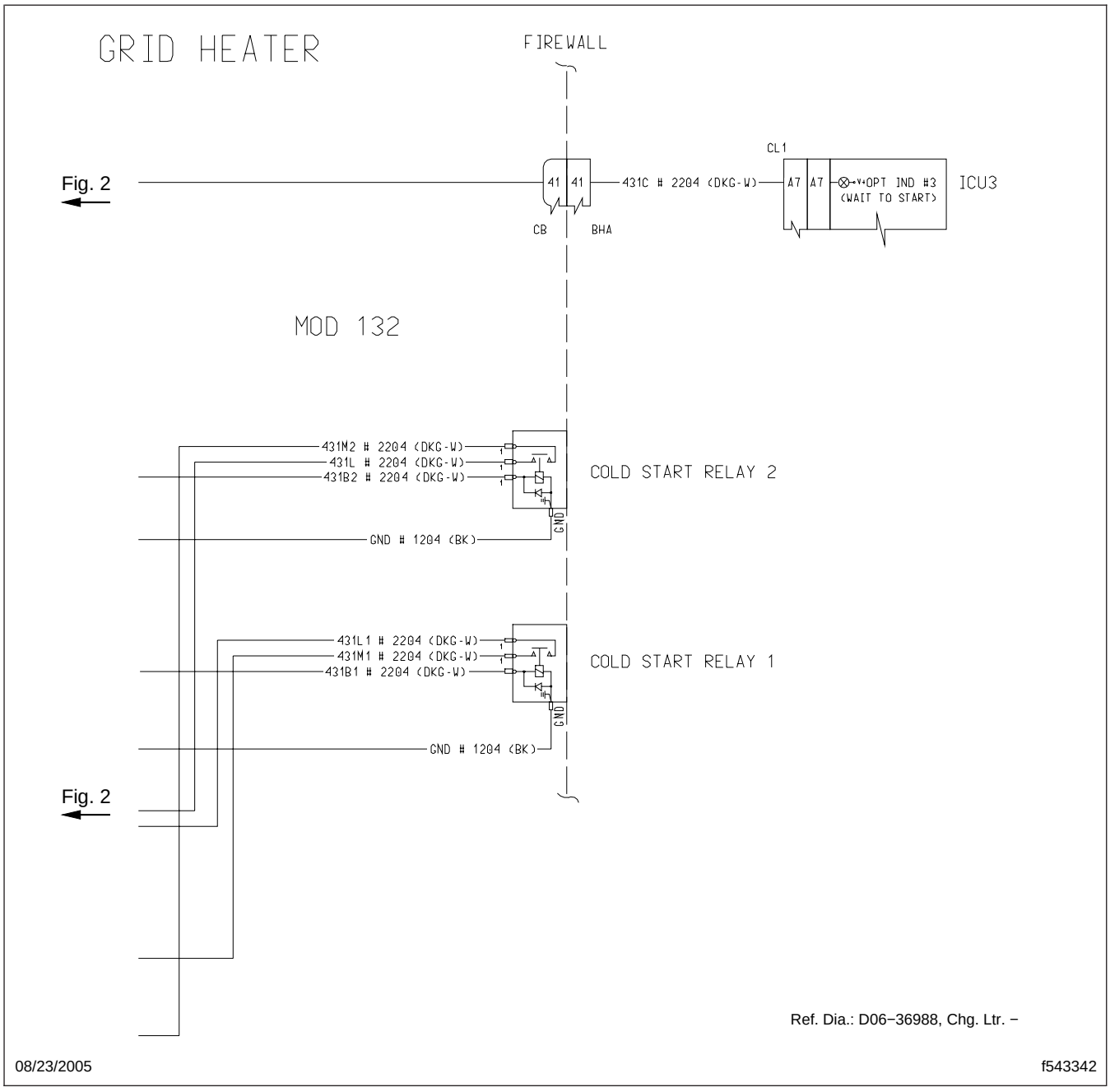
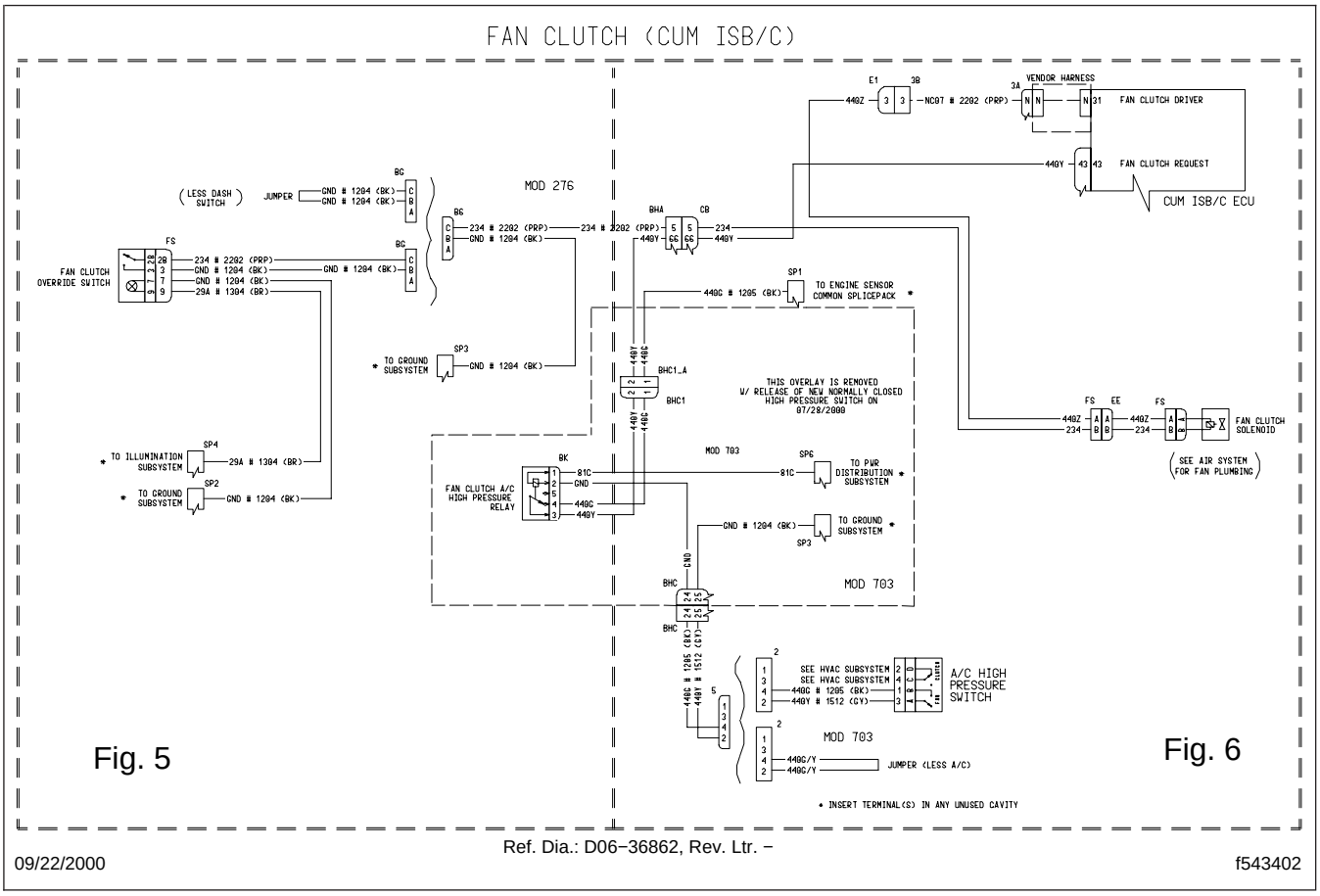


Fig. 3, Grid Heater Wiring (partial view)

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Fig. 4, Fan Clutch Wiring (full view)

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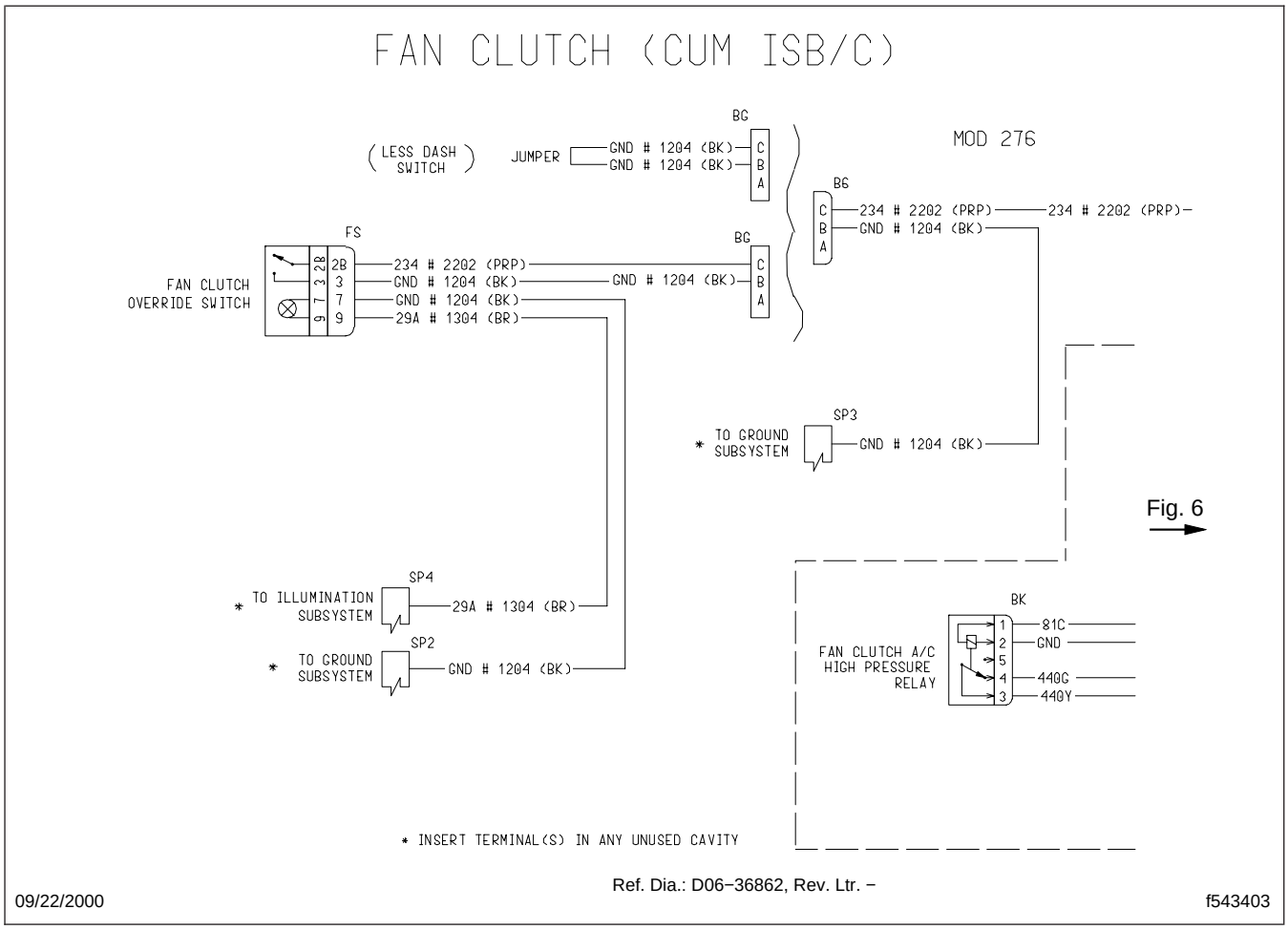


Fig. 5, Fan Clutch Wiring (partial view)

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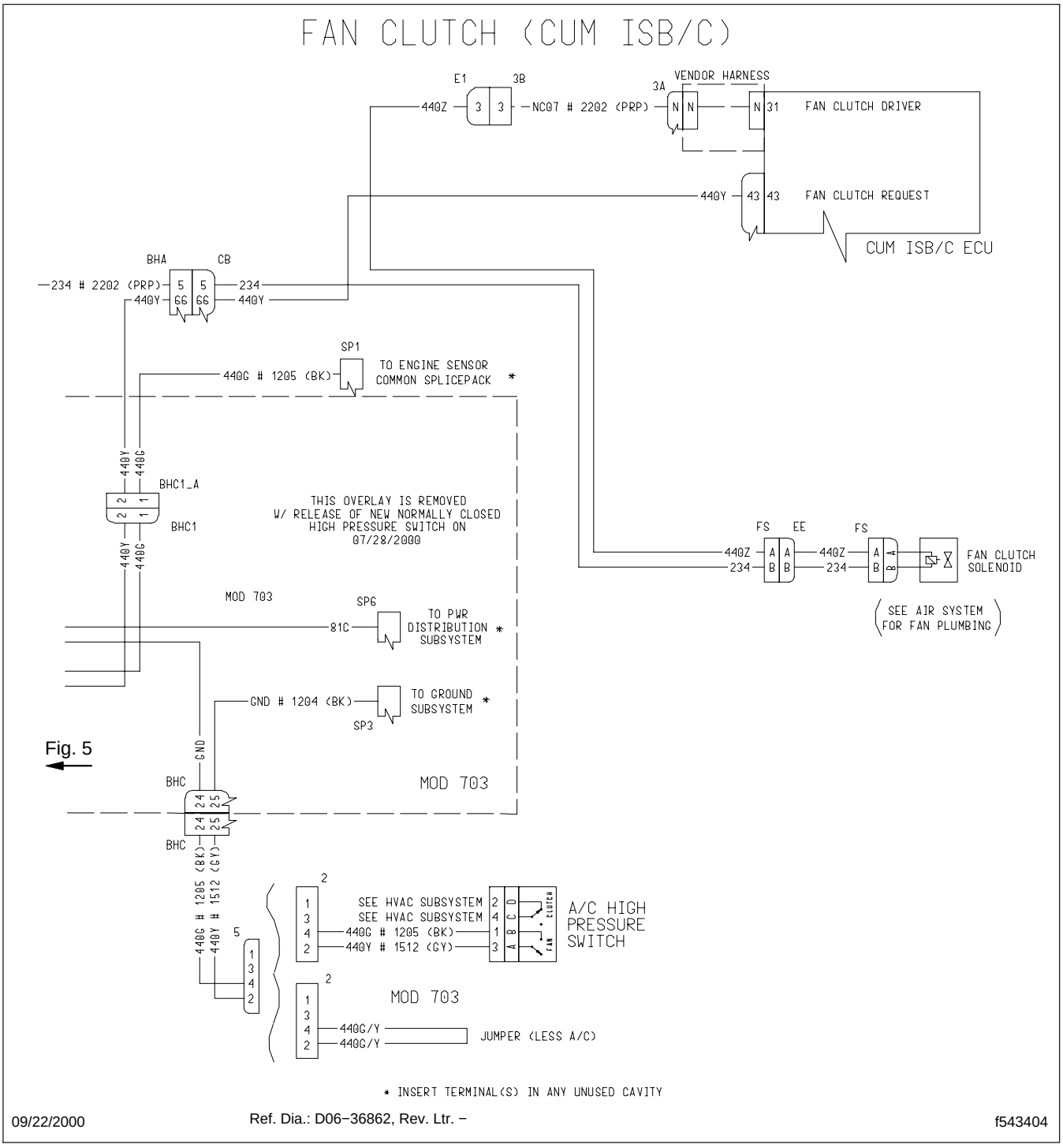


Fig. 6, Fan Clutch Wiring (partial view)

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See **Fig. 1** for a full view of the exhaust brake wiring for the Caterpillar™ 3126B engine with an Allison MD transmission.

See **Fig. 2** for a full view of the exhaust brake wiring for the Caterpillar 3126B engine with an Allison 1000, 2000 or 2400 transmission.

See **Fig. 3** for a full view of the exhaust brake wiring for the Caterpillar 3126B engine with a manual, Allison AT or MT, or Eaton® AutoShift transmission.

See **Fig. 4** for a full view of the exhaust brake wiring for the Cummins ISB or ISC engine with an Allison MD transmission.

See **Fig. 5** and **Fig. 6** for partial views of the exhaust brake wiring for the Cummins ISB or ISC engine with an Allison MD transmission.

See **Fig. 7** for a full view of the exhaust brake wiring for the Cummins ISB or ISC engine with an Allison 1000, 2000 or 2400 transmission.

See **Fig. 8** and **Fig. 9** for partial views of the exhaust brake wiring for the Cummins ISB or ISC engine with an Allison 1000, 2000 or 2400 transmission.

See **Fig. 10** for a full view of the exhaust brake wiring for the Cummins ISB or ISC engine with a manual, Allison AT or MT, or Eaton AutoShift transmission.

See **Fig. 11** and **Fig. 12** for partial views of the exhaust brake wiring for the Cummins ISB or ISC engine with a manual, Allison AT or MT, or Eaton AutoShift transmission.

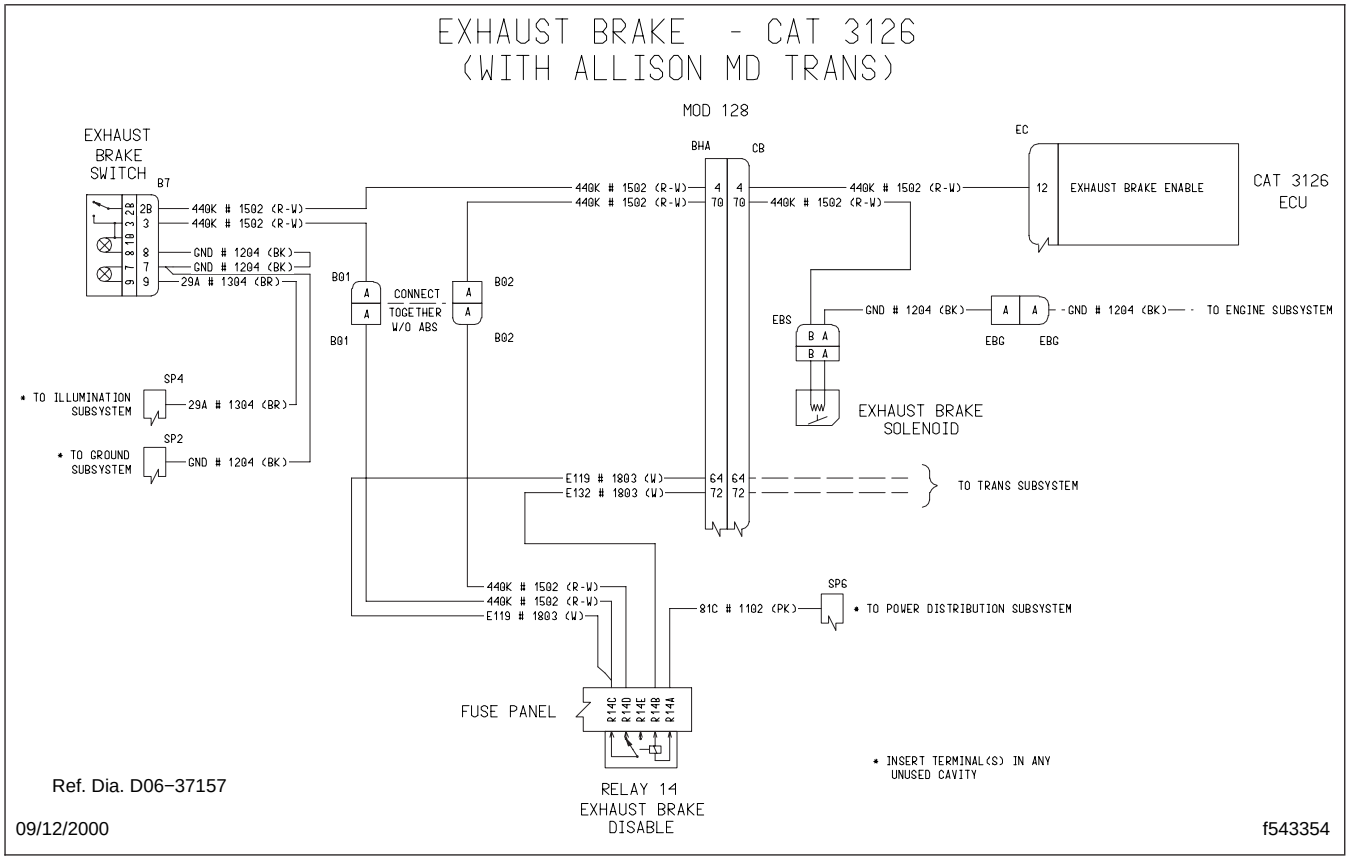


Fig. 1, Exhaust Brake Wiring for Caterpillar 3126B With Allison MD Transmission (full view)

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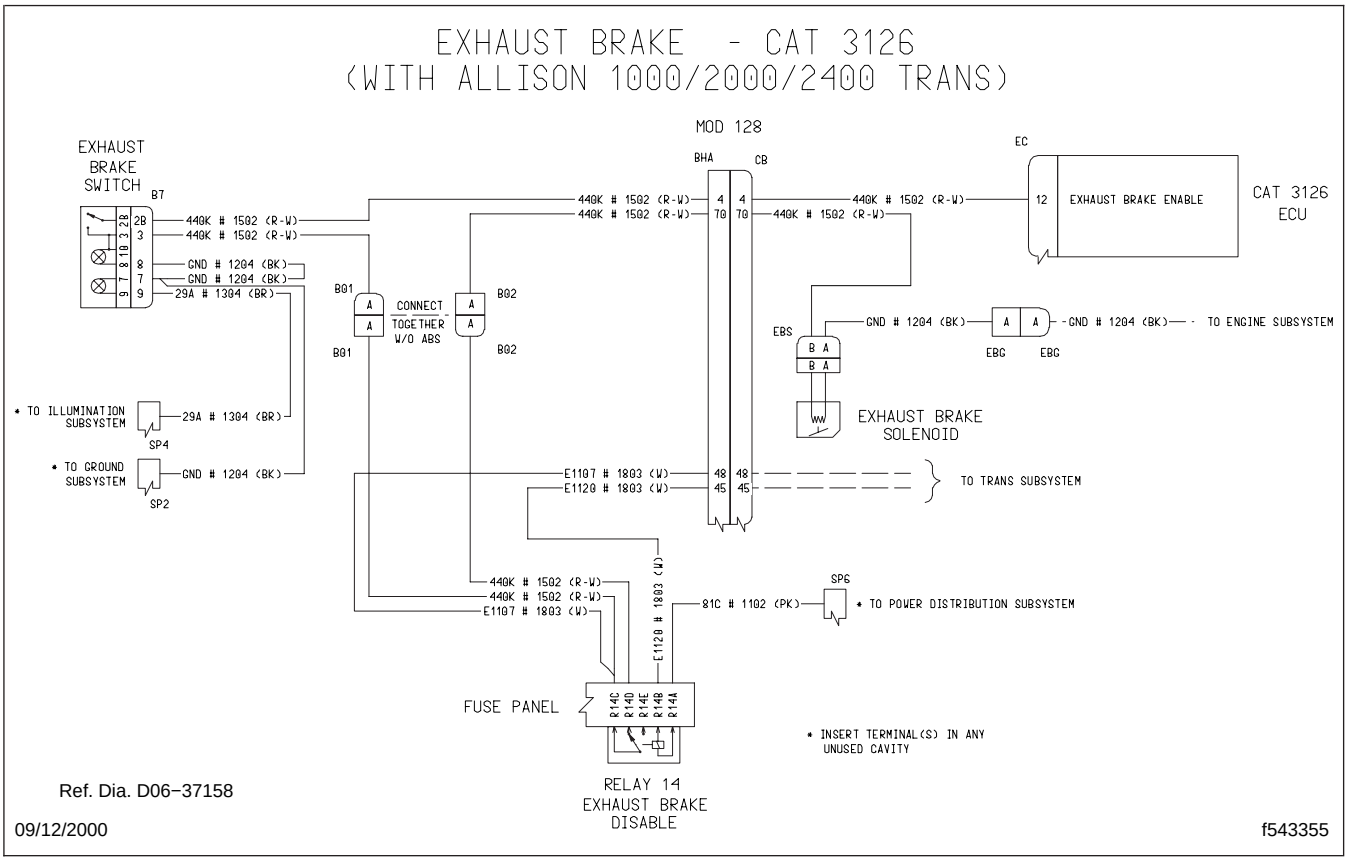


Fig. 2, Exhaust Brake Wiring for Caterpillar 3126B With Allison 1000, 2000 or 2400 Transmission (full view)

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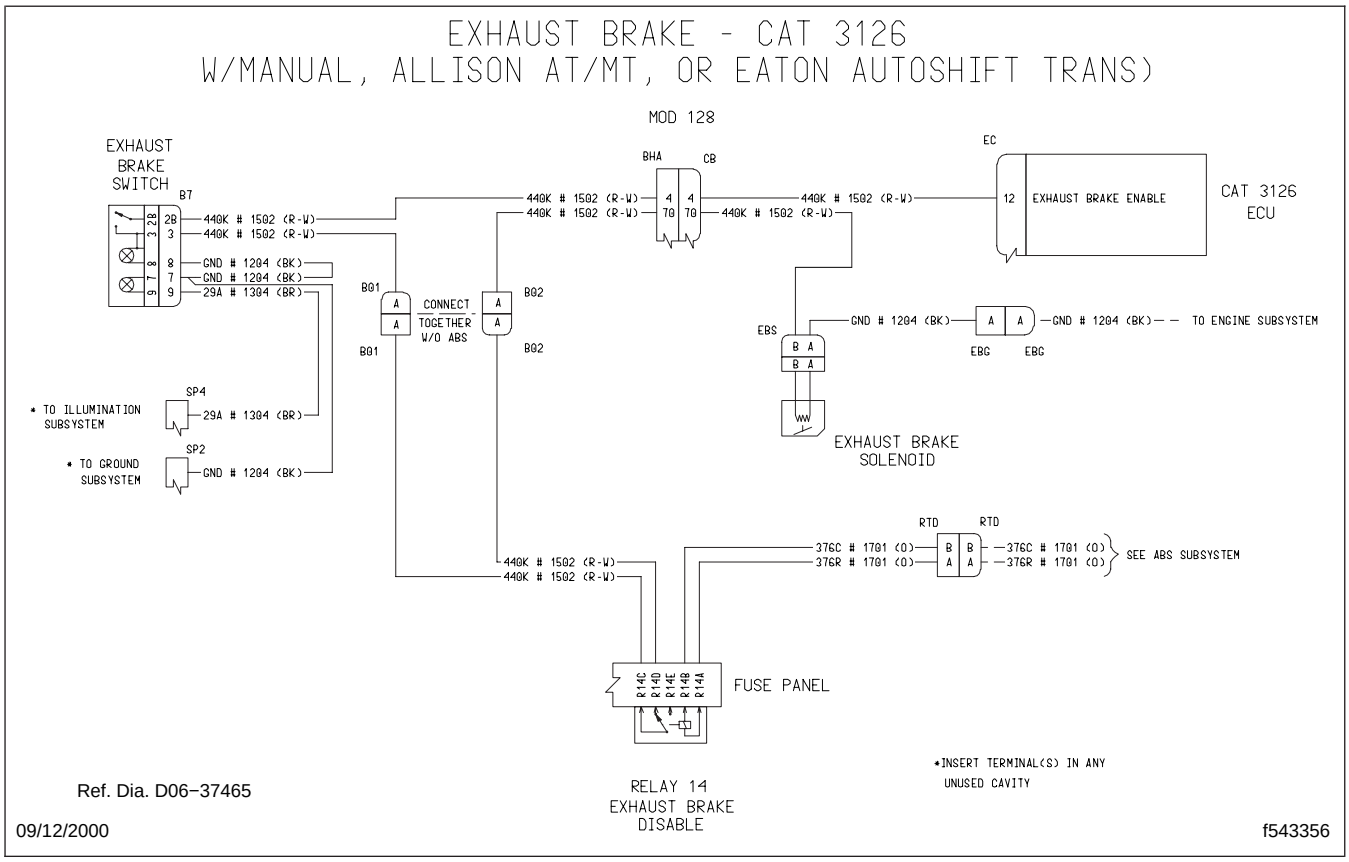


Fig. 3, Exhaust Brake Wiring for Caterpillar 3126B With Manual, Allison AT or MT, or Eaton AutoShift Transmission (full view)

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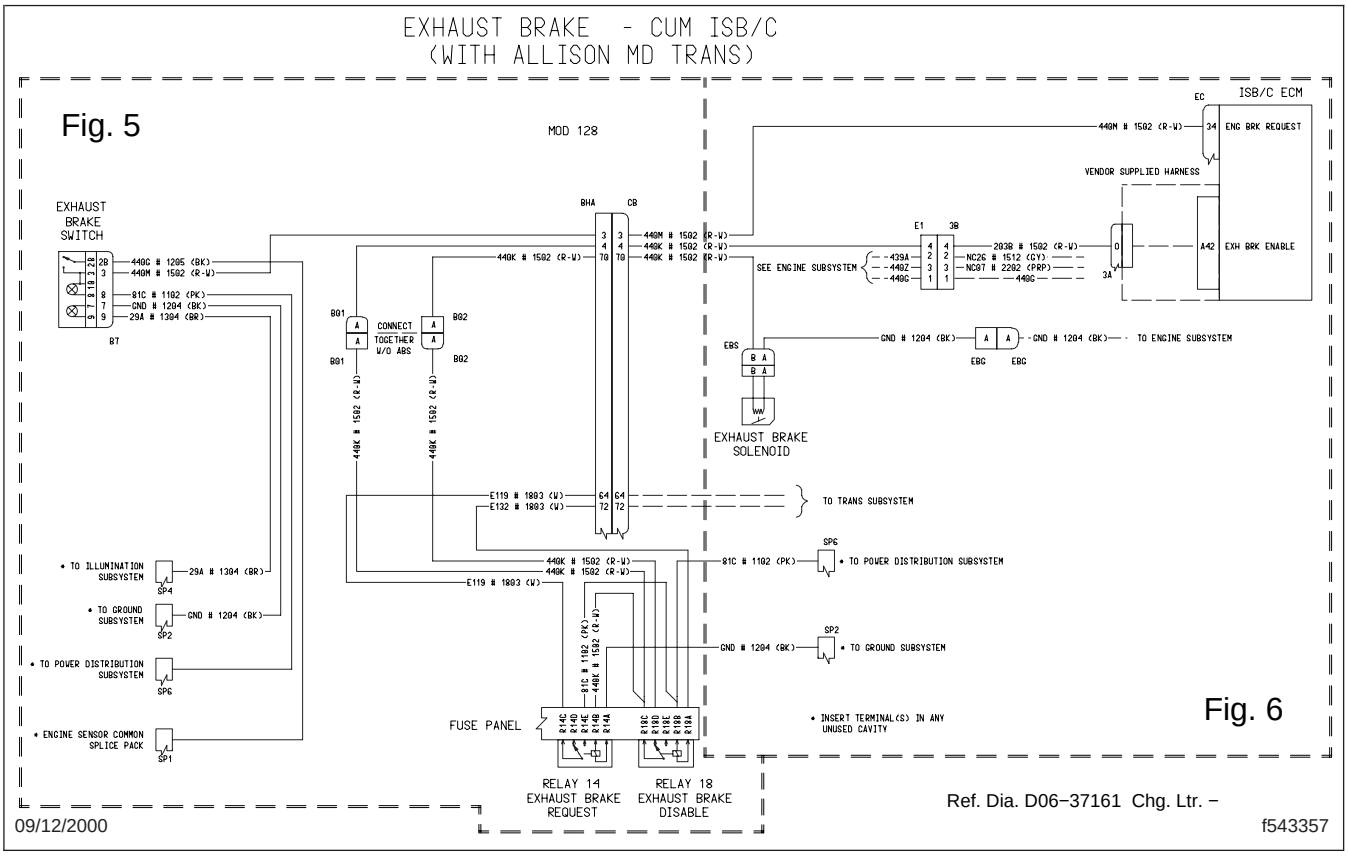


Fig. 4, Exhaust Brake Wiring for Cummins ISB or ISC With Allison MD Transmission (full view)

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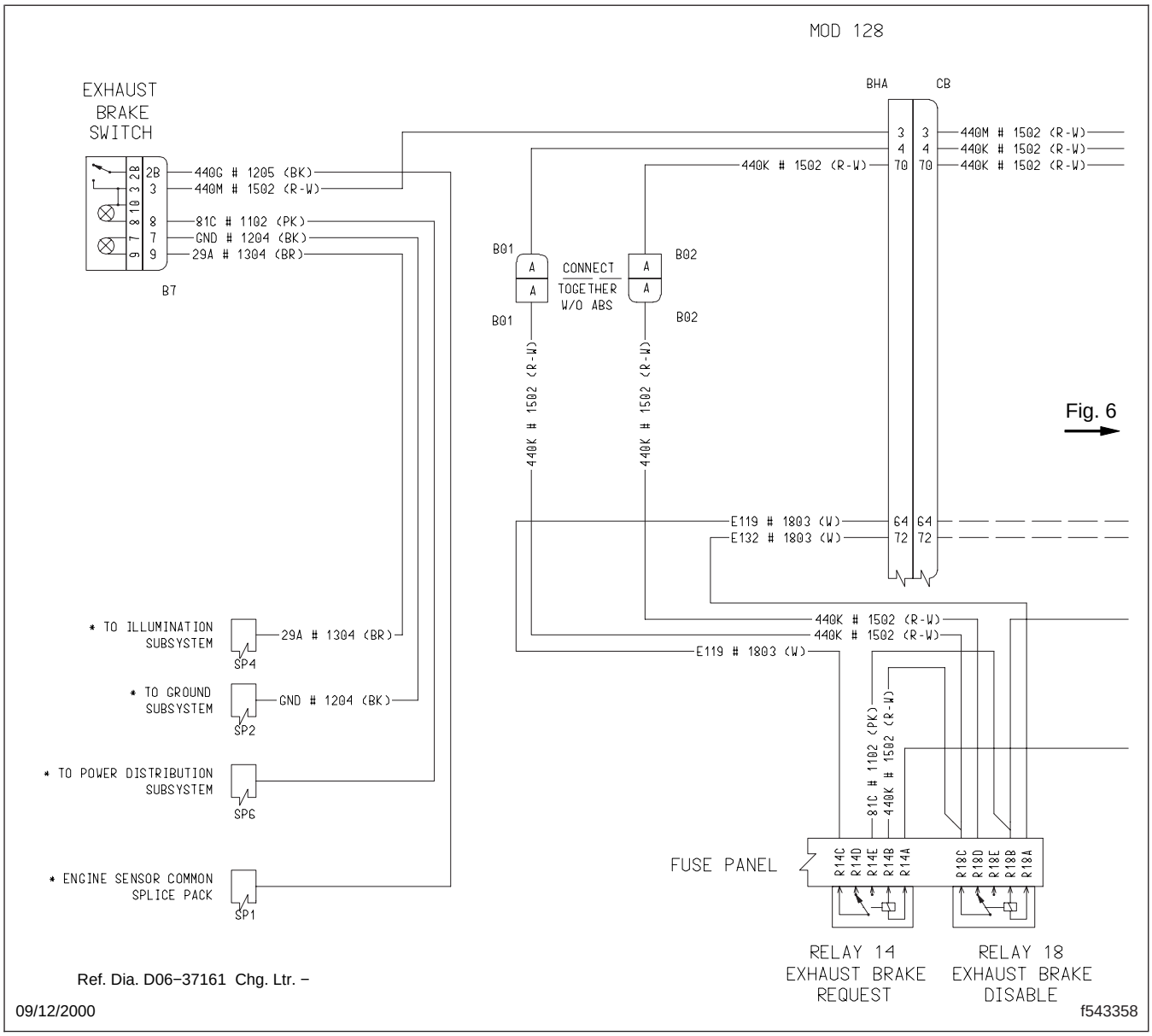


Fig. 5, Exhaust Brake Wiring for Cummins ISB or ISC With Allison MD Transmission (partial view)

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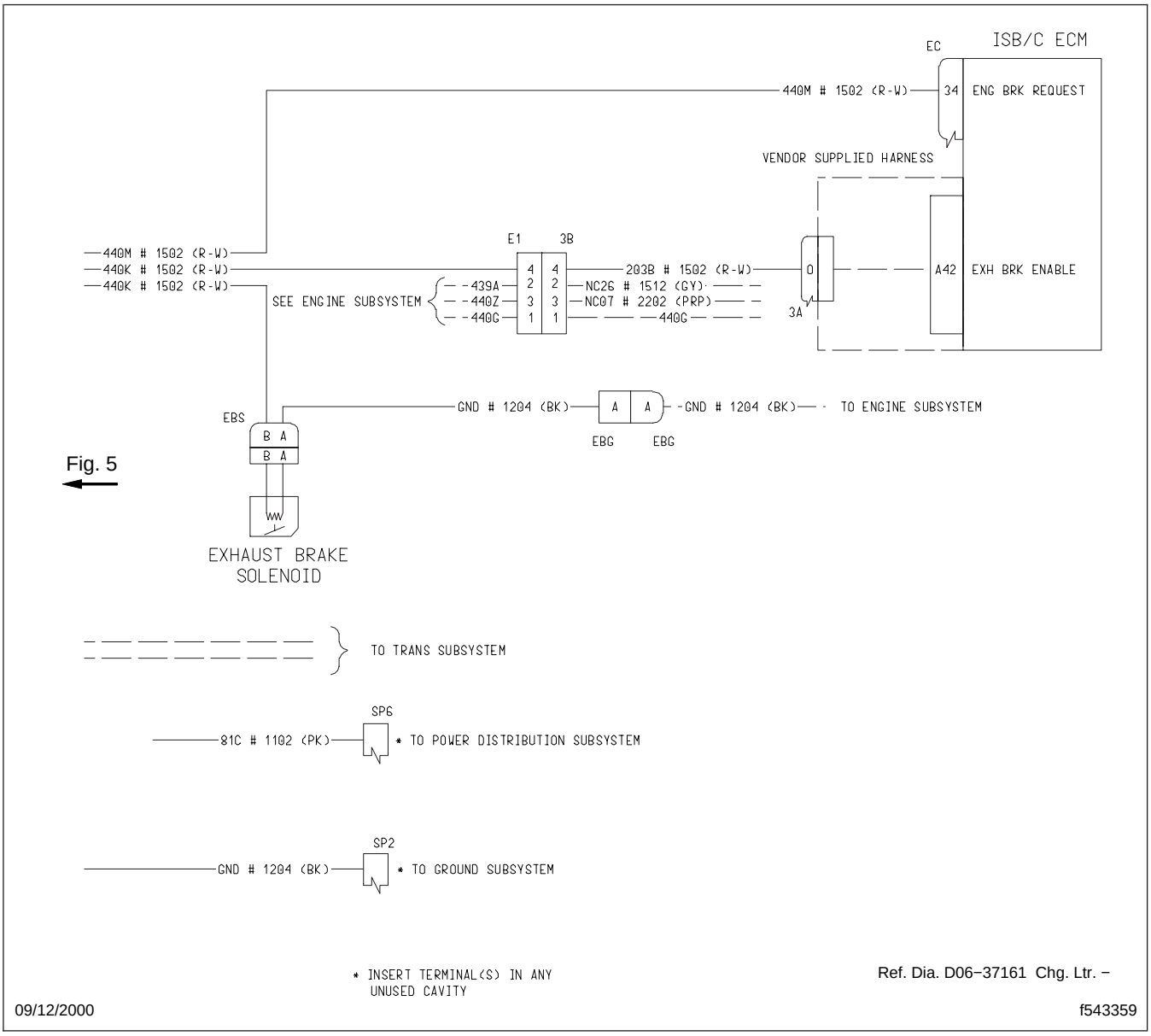


Fig. 6, Exhaust Brake Wiring for Cummins ISB or ISC With Allison MD Transmission (partial view)

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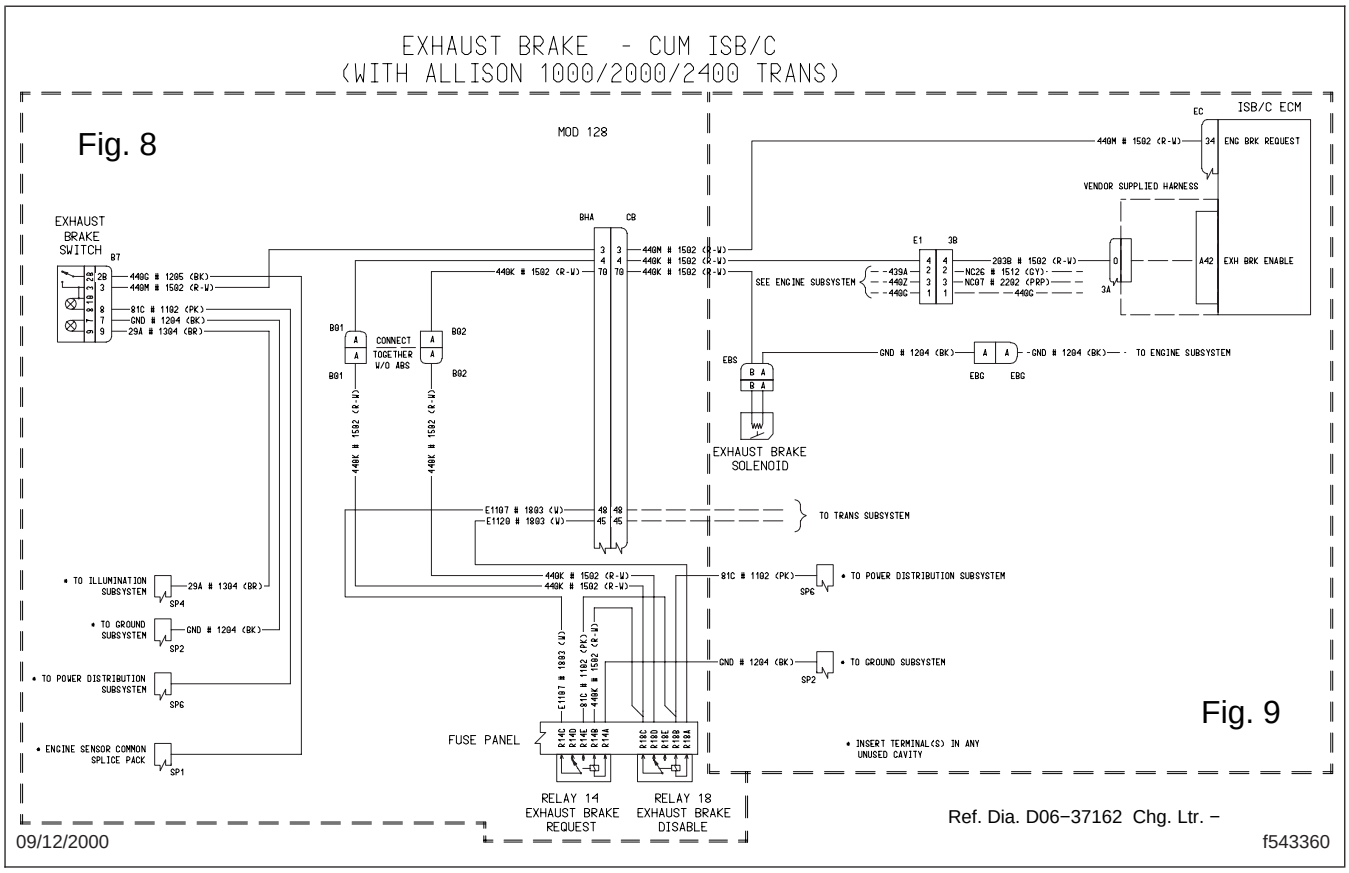


Fig. 7, Exhaust Brake Wiring for Cummins ISB or ISC With Allison 1000, 2000 or 2400 Transmission (full view)

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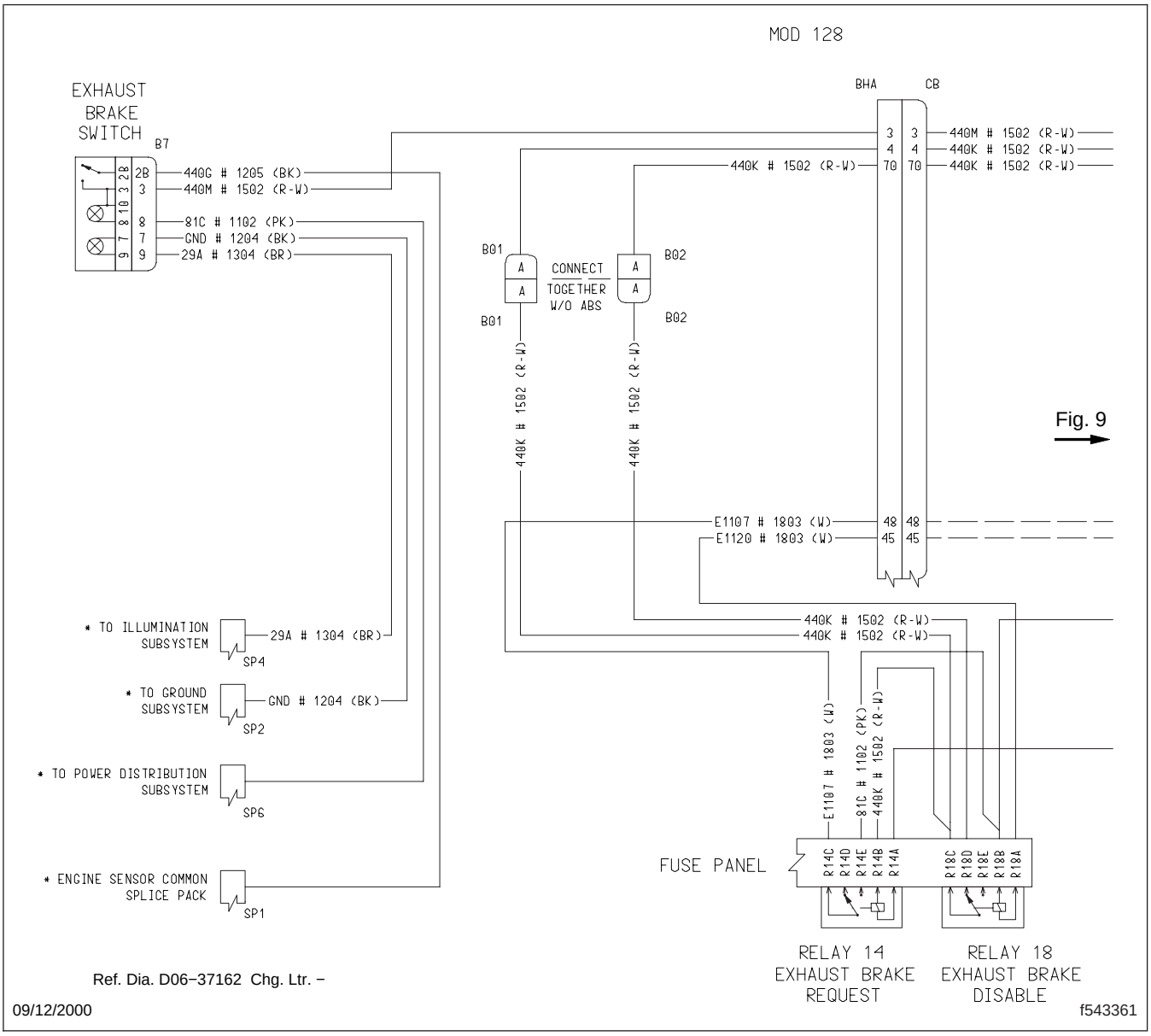


Fig. 8, Exhaust Brake Wiring for Cummins ISB or ISC With Allison 1000, 2000 or 2400 Transmission (partial view)

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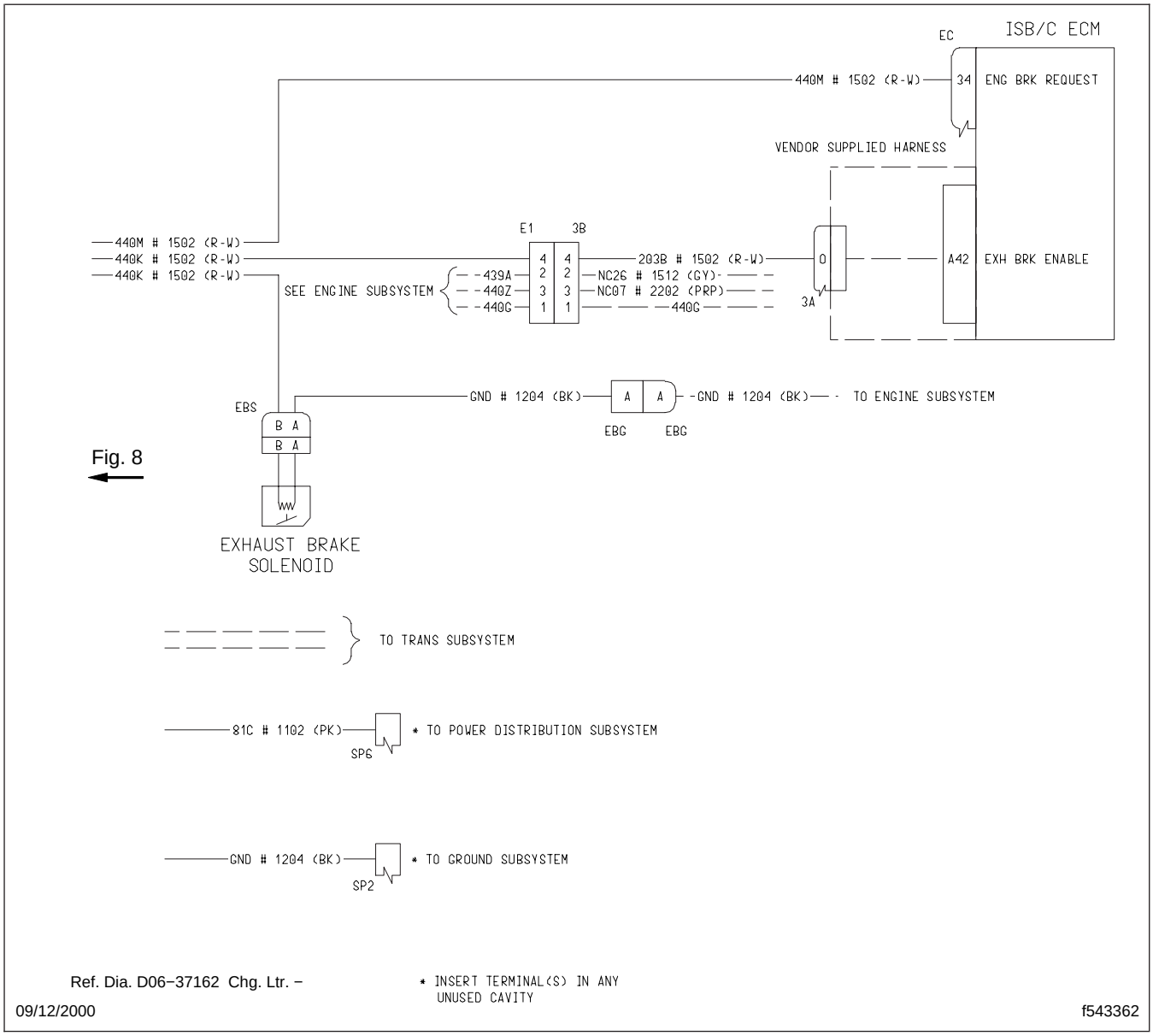


Fig. 8

Fig. 9, Exhaust Brake Wiring for Cummins ISB or ISC With Allison 1000, 2000 or 2400 Transmission (partial view)

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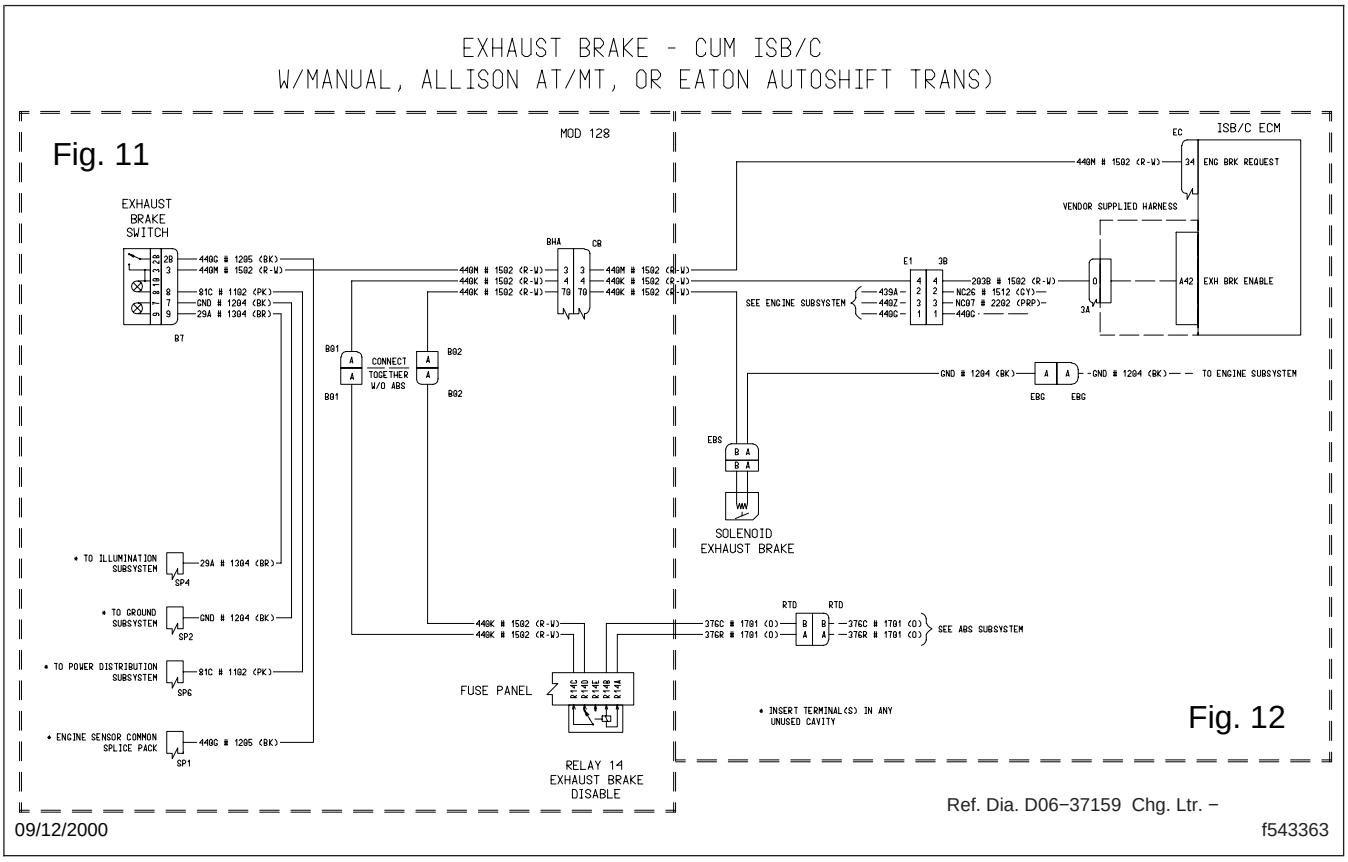


Fig. 10, Exhaust Brake Wiring for Cummins ISB or ISC With Manual, Allison AT or MT, or Eaton AutoShift Transmission (full view)

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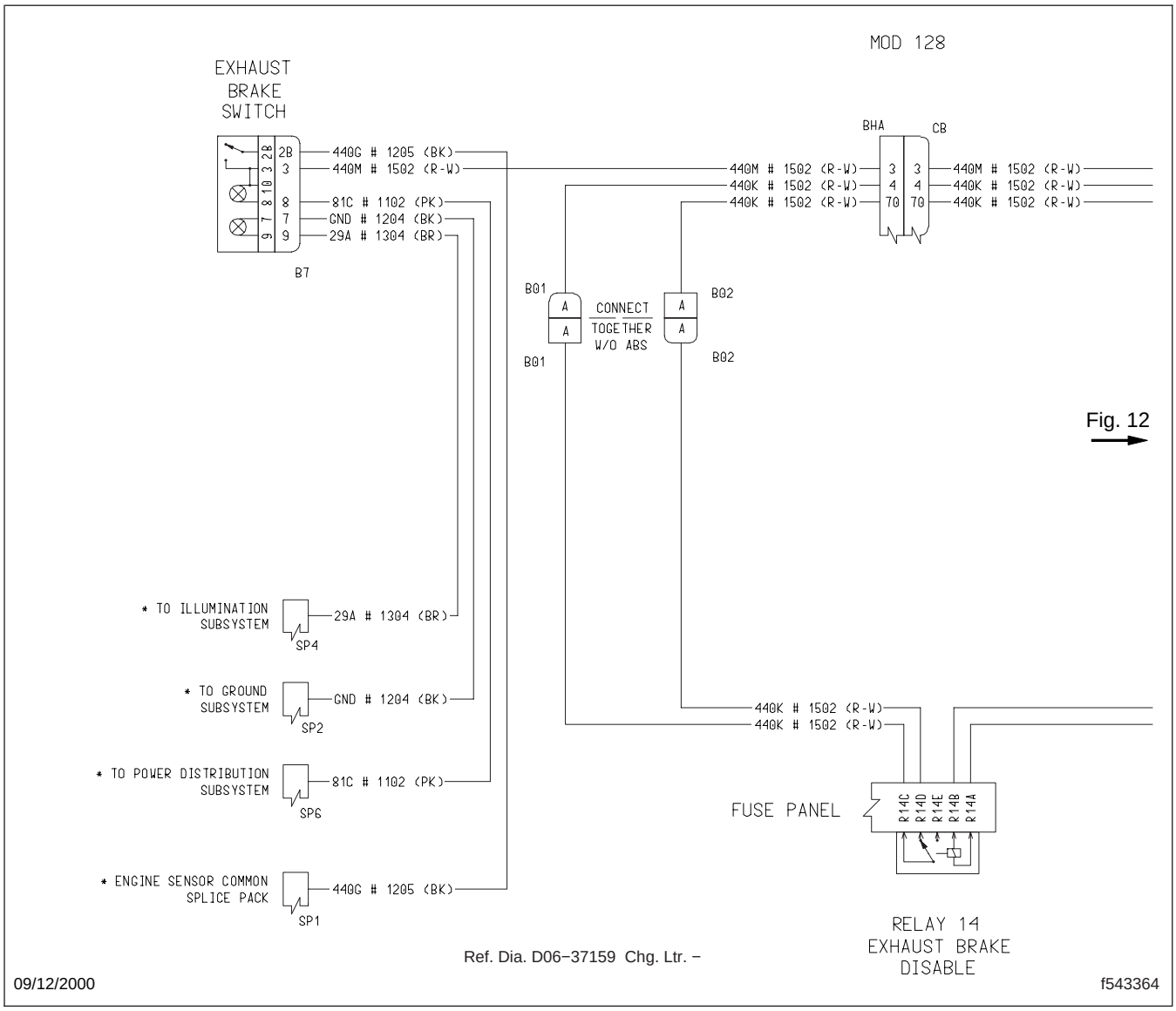


Fig. 11, Exhaust Brake Wiring for Cummins ISB or ISC With Manual, Allison AT or MT, or Eaton AutoShift Transmission (partial view)

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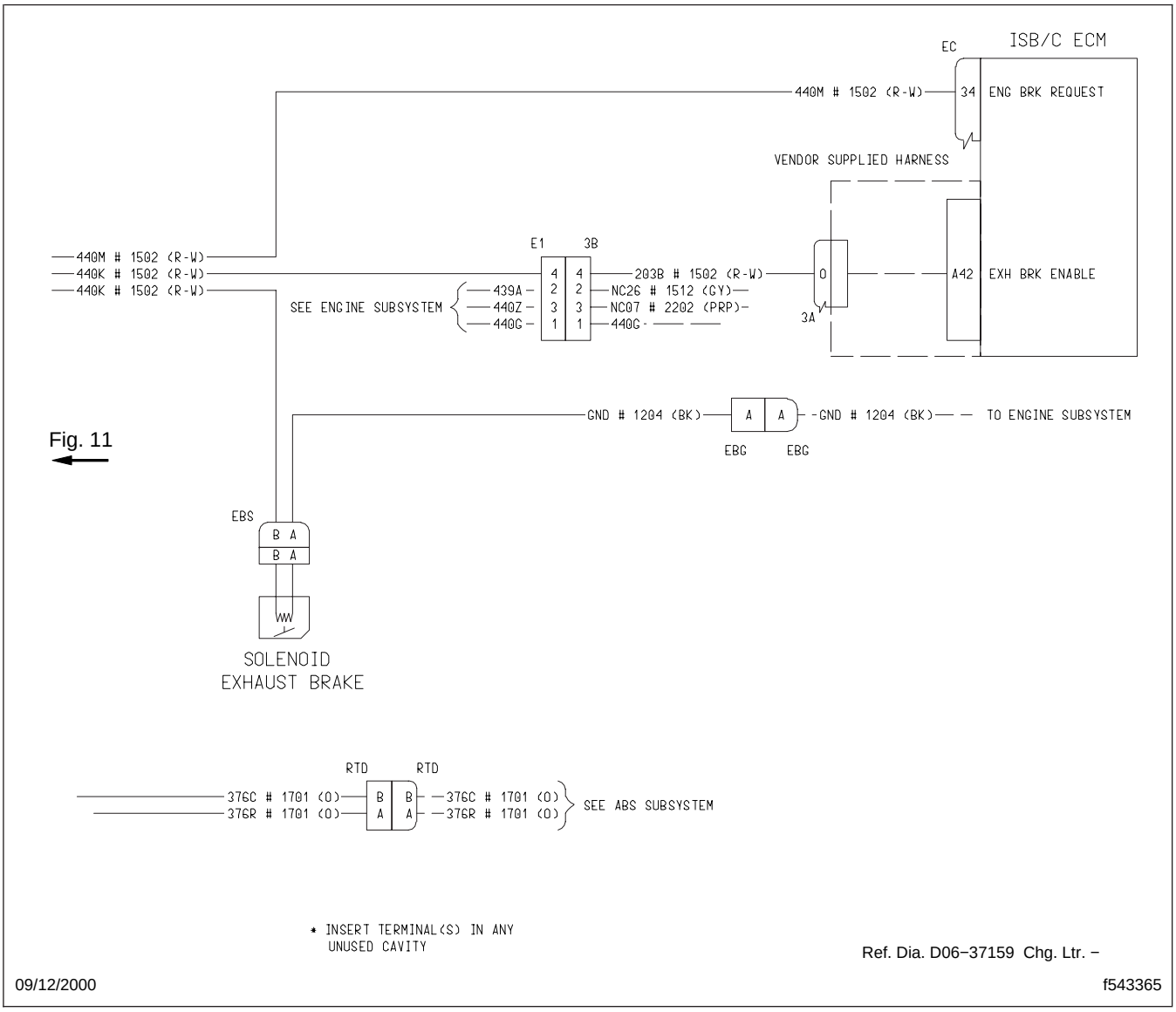


Fig. 12, Exhaust Brake Wiring for Cummins ISB or ISC With Manual, Allison AT or MT, or Eaton AutoShift Transmission (partial view)

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General Information

Modern electronic engines do not normally require special starting aids. At low temperatures, intake air preheaters, manifold preheaters, or water jacket heaters are sometimes used to assist in starting.

The grid heater starting aid system consists of the following:

- starter switch
- electronic controller
- engine oil pressure (EOP) switch
- glow plug relay
- fuel solenoid valve
- indicator lamp

The electric grid heater system electronically controls two grid heater elements in the air intake manifold. The electric grid heater system operates in two modes. The preheat mode heats the intake air prior to starting the engine. The post-heat mode heats the intake air after starting to improve cold engine running. This system can be used on naturally aspirated and Turbocharged engines.

The grid heater system benefits include:

- Quicker starting
- Smooter engine running after starting
- Replacement of ether as a starting aid
- Extended starter and battery life through less cranking.

The grid heater starting aid will not operate unless the intake manifold temperature sensor senses a temperature below 45°F (7°C). This system is compatible with a 12-volt electrical system only. Current draw is 95 amperes per element.

To prevent excessive drain on the batteries, the electric grid heater controller will interrupt the post-heat cycle, preventing further drain on the batteries. This battery protection feature is activated only on vehicles with weak or drained batteries.

The following is a summary of normal operations:

A. Turn the key switch to on (intake manifolrd temperature sensor must read a temperature below 45°F [7°C]).

B. While the grid heater indicator llight is on, the grid heater system is in the preheat mode; see **Table 1**.

C. When the grid heater indicator light goes out, the engine is ready to start.

D. Start the engine within 10 seconds after the grid heater sytems indicator light goes out.

E. After the engine starts, the grid heater system is in the post-heat mode.

Grid Heater System Operation

Temperature °F (°C)	Mode	Elements	Duration seconds	Duty Cycle % On/% Off
Below –2 (–19)	Preheat	Both	30	Continuous
	Post-Heat	Both	15	Continuous
		One	15	Continuous
		One	40	50/50
		One	106	25/75
–2 to 17 (–19 to –8)	Preheat	Both	20	Continuous
	Post-Heat	One	20	Continuous
		One	20	Continuous
		One	40	50/50
		One	106	25/75

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General Information

Grid Heater System Operation				
Temperature	**Mode**	**Elements**	**Duration**	**Duty Cycle**
°F (°C)			**seconds**	**% On/% Off**
17 to 46 (–8 to 8)	Preheat	Both	10	Continuous
	Post-Heat	One	10	Continuous
		One	40	Continuous
		One	106	Continuous
Above 45 (7)	Preheat	None	—	—
	Post-Heat	None	—	—

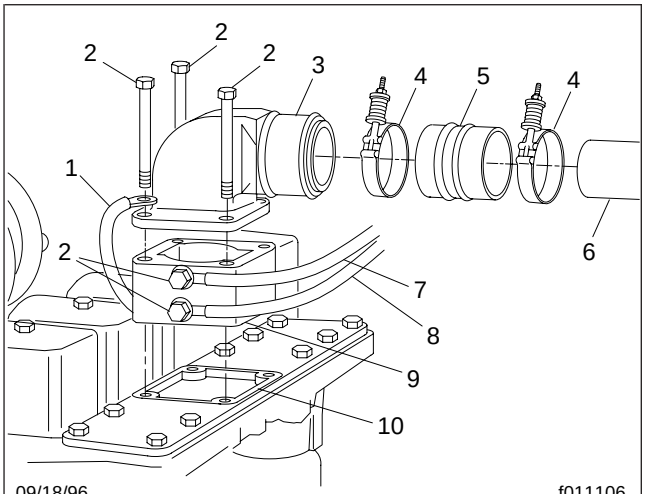
Table 1, Grid Heater System Operation

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Grid Heater Replacement

NOTE: During replacement refer to **Fig. 1**.

1. Set the parking brake, shut down the engine, and chock the tires.
2. Open the hood.
3. Disconnect the negative leads from the batteries.
4. Remove the air intake tube from the intake elbow by loosening the clamps (see Ref. 4).



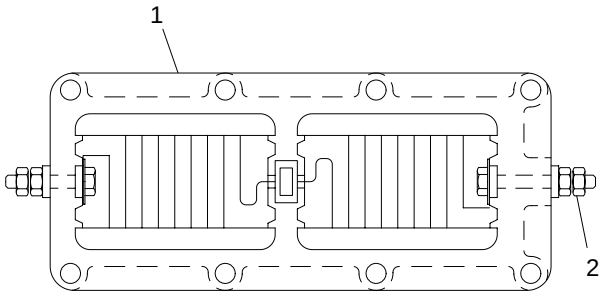
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1. Ground Cable
2. Capscrews
3. Intake Elbow
4. Clamp
5. Intake Couple
6. Intake Tube
7. Positive Element Cable #1
8. Positive Element Cable #2
9. Grid Heater Block
10. Manifold Mounting Surface

Fig. 1, Air Intake Grid Heater Assembly (single grid heater block shown, dual similar)

IMPORTANT: Note the orientation of the grid heater block before replacement, to ensure correct replacement.

5. Disconnect all three electrical cables from the grid heater block by removing the retaining capscrews.
6. Remove the eight mounting capscrews, then remove the intake elbow and the grid heater block (see **Fig. 2**). It may be necessary to pry between the grid heater block and the manifold to break the seal between them.



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1. Air Intake Grid Heater
2. Wire Connection

Fig. 2, Air Intake Grid Heater Block (dual shown, single similar)

7. Place a clean cloth in the intake manifold opening to prevent any contaminants from entering.
8. Clean any gasket material or sealant from the grid heater mounting surface, also clean any gasket material from the grid heater to intake elbow mounting surface.
9. Remove the cloth from the intake manifold and carefully check the manifold to ensure that there are no foreign objects remaining.
10. Place a new gasket on the grid heater block mounting surface.
11. Position a new grid heater block on the mounting surface and place a gasket on the grid heater block.

IMPORTANT: Be sure to secure the negative grid heater block cable (see **Fig. 1**, Ref. 1, ground cable) under a capscrew.

12. Place the intake elbow on the grid heater block and secure it with the mounting capscrews. Torque the mounting capscrews to 18 lbf·ft (24 N·m).
13. Connect the positive electrical cables to the grid heater block. The electrical cables should be secured within 6 inches of any connection to avoid connector or terminal ring damage.

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14. Position the intake tube on the intake elbow, with the intake couple and clamps in place. Torque the clamps 75 lbf·in (800 N·cm).

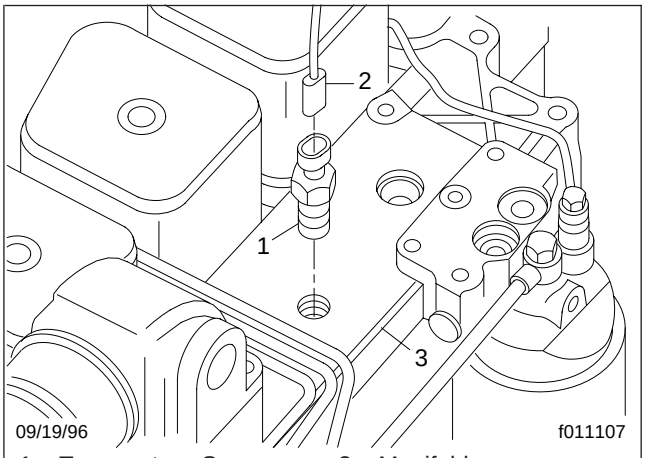
IMPORTANT: On vehicles equipped with a grid heater system, wait until the GRID HEATER indicator goes out before attempting to start the engine.

15. Connect the negative leads to the batteries and test the grid heater system for proper operation.
16. Remove the chocks from the tires.

Temperature Sensor Replacement

NOTE: During replacement refer to **Fig. 3**.

1. Set the parking brake, shut down the engine, and chock the tires.
2. Disconnect the negative leads from the batteries.
3. Disconnect the wire terminal from the sensor.
4. Unscrew the sensor from the grid heater manifold.



1. Temperature Sensor
2. Wire Terminal
3. Manifold

Fig. 3, Temperature Sensor

5. Screw the new temperature sensor in the grid manifold. Tighten to 25 lbf·in (282 N·cm).
6. Connect the wire to the sensor.
7. Connect the negative leads to the batteries and test the grid heater system for proper operation.
8. Remove the chocks from the tires.

Air Intake Heater Control Module Replacement

NOTE: During removal refer to **Fig. 4**.

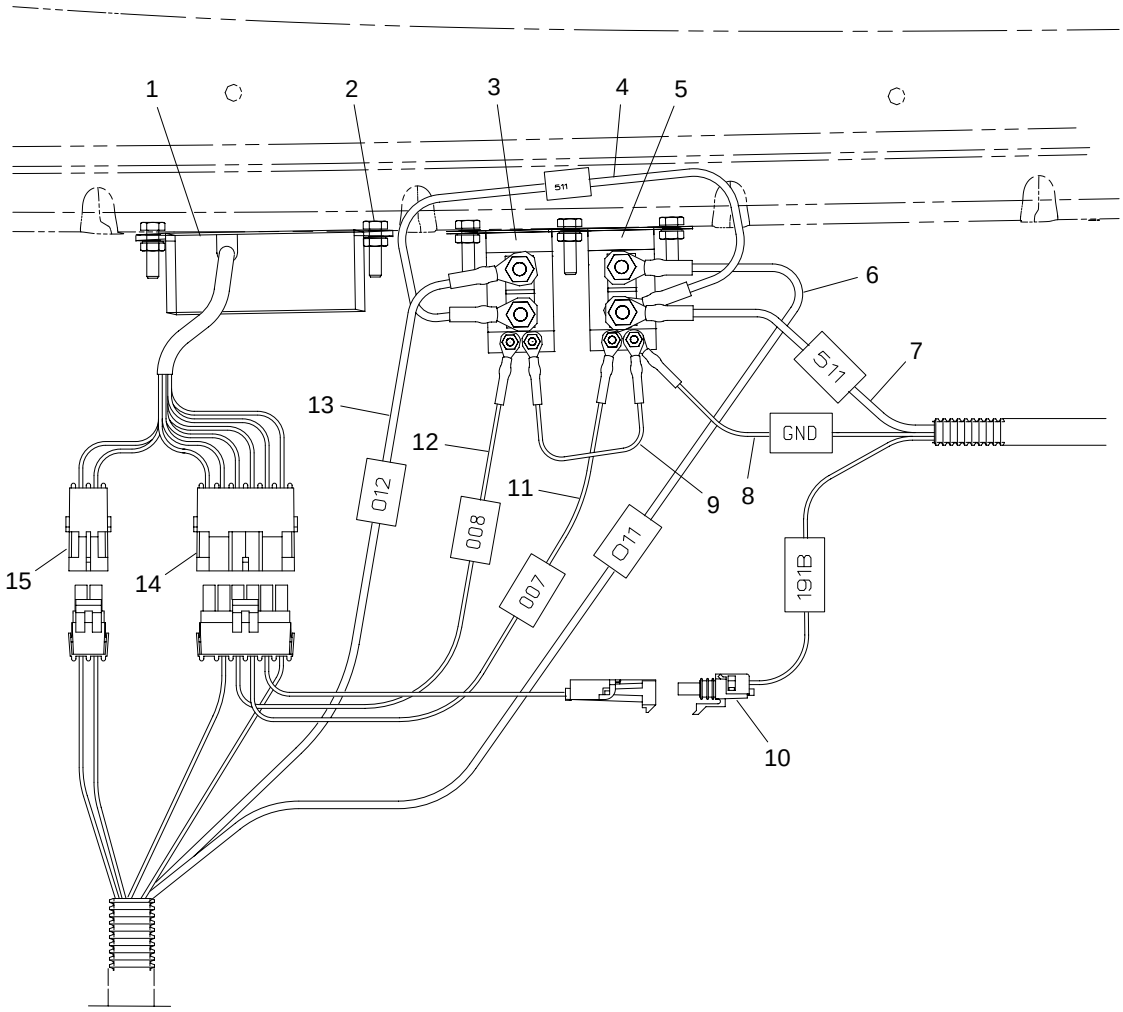
1. Set the parking brake, shut down the engine, and chock the tires.
2. Disconnect the negative leads from the batteries.
3. Working under the hood, disconnect the main module connector (see **Fig. 4**, Ref. 14) and the temperature sensor connector (see Ref. 15) at the grid heater module.
4. Remove the module by removing the mounting fasteners (see Ref. 2).
5. Position the new grid heater control module on the air intake tray. Secure it with the mounting fasteners.
6. Connect the main module connector and the temperature sensor connector to the module.
7. Connect the negative leads to the batteries and test the grid heater system for proper operation.
8. Remove the chocks from the tires.

Grid Heater Relay #1 Replacement

NOTE: During removal refer to **Fig. 4**.

1. Set the parking brake, shut down the engine, and chock the tires.
2. Disconnect the negative leads from the batteries.
3. Open the hood.
4. Disconnect the cables (see **Fig. 4**, Ref. 4, 6, 7, 8, and 9) and the controller module wire (see Ref. 11) from the relay.
5. Remove the relay by removing the locknuts that attach the wire assembly to the grid heater relay.
6. Remove the capscrews that secure the grid heater relay to the engine, and remove the grid heater relay.
7. Position the new relay on the grid heater relay tray, and install the capscrews. Tighten the capscrews securely.

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1. Heater Control Module
2. Mounting Fastener
3. Relay # 2
4. 12-Volt Power Jumper Wire
5. Relay #1
6. Grid #1 Power Cable
7. 12-Volt Power Cable
8. Heater Harness Ground Cable
9. Ground Jumper Cable
10. Wait-To-Start Light Connector
11. Controller Module to Relay #1
12. Controller Module to Relay #2
13. Grid #2 Power Cable
14. Main Module Connector
15. Temperature Sensor Connector

Fig. 4, Grid Heater Wiring Connections

8. Connect the cables (see **Fig. 4**, Ref. 4, 6, 7, 8, and 9) and the wire (see Ref. 11) to the relay.
9. Connect the negative leads to the batteries and test the grid heater system for proper operation.
10. Close the hood.
11. Remove the chocks from the tires.

Grid Heater Relay #2 Replacement

NOTE: During removal refer to **Fig. 4**.

1. Set the parking brake, shut down the engine, and chock the tires.
2. Disconnect the negative leads from the batteries.

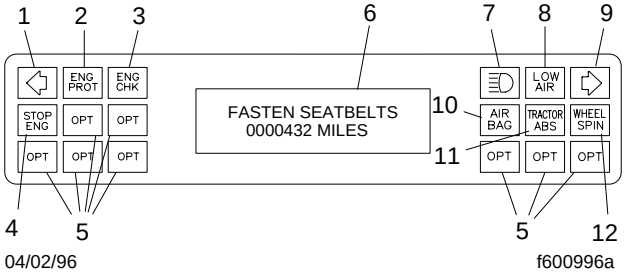
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3. Working under the hood, disconnect the cables (see **Fig. 4**, Ref. 4, 9, and 13) and the controller module wire (see Ref. 12) from the relay.
4. Remove the relay by removing the mounting fasteners.
5. Position the new relay on the air intake tray, and install the fasteners.
6. Connect the cables (see **Fig. 4**, Ref. 4, 9, and 13) and the wire (see Ref. 12) to the relay.
7. Connect the negative leads to the batteries and test the grid heater system for proper operation.
8. Remove the chocks from the tires.

Grid Heater Indicator Replacement

NOTE: During removal refer to **Fig. 5**.

1. Set the parking brake, shut down the engine, and chock the tires.



1. Left Turn Indicator
2. Engine Protection Warning Lamp
3. Check Engine Indicator
4. Stop Engine Warning
5. Optional Indicator (Grid Heater Indicator)
6. Message Display Screen
7. Hi-Beam Indicator
8. Low Air Warning
9. Right Turn Indicator
10. Air Bag Warning (Optional)
11. Tractor ABS Warning
12. Wheel Spin Indicator

Fig. 5, Driver Message Center, Level III ICU

2. Disconnect the negative leads from the batteries.
3. Loosen the dash panel (at the instrument cluster; see Ref. 5) by removing the mounting screws. Being careful not to damage the connecting wires, allow the panel to come away from the dashboard.
4. Disconnect the wires at the grid heater grid.
5. Remove the ICU3 light assembly by removing the mounting screws. See **Fig. 5**.

NOTE: Instruments and controls and their locations may vary from those shown.

6. Position a new grid heater indicator in the dash opening and secure it with the mounting screws.
7. Connect the wire to the grid heater indicator.
8. Install the dash panel and secure it with the mounting screws.
9. Connect the negative leads to the batteries and test the grid heater system for proper operation.
10. Remove the chocks from the tires.

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Troubleshooting |

Inspection and Verification

1. Visually inspect each component for a condition that may prevent system operation. Refer to the following list:
   - Blown fuse
   - Damaged wiring
   - Loose or corroded connections
2. If a visual inspection does not isolate a condition preventing system operation, go to the "On-Board Diagnostics (OBD)" procedure.

On-Board Diagnostics (OBD)

NOTE: Vehicle information and service diagnostics are shown on the message display screen on a one-line display. The message display screen will display service diagnostics, if the vehicle has this option.

1. Place the diagnostic switch in the "On" position. The switch is located under the instrument panel. Turn the ignition switch to the "Run" position. Place the diagnostic switch in the "Off" position. Wait one second and place the switch in the "On" position.
2. The indicator light should come on for 10 seconds and then go out. If the light does not come on, go to the problem charts in this section.
3. The indicator light should flash for 10 seconds at a rate of four flashes per second, indicating the controller has entered the system self test.
4. At the end of the self test, the indicator light will flash four times per second. indicating that the controller has reached the start signal input test. Start the engine for several seconds. If the controller receives a start signal, the indicator light will go out, ending the self test.
5. If a fault has occurred, the indicator light will flash one of the following codes. See **Table 1**for Diagnostic Test Codes.
6. See "Grid Heater Troubleshooting Circuit Tests" if the engine is a Caterpillar CFE/3126. For all engines, go to "Fault Code Troubleshooting Procedures".

Diagnostic Test Code Chart		
Flash Code	**Code**	**Fault**
1/2-second flash "On", 1/2-second flash "Off" with a 2 second delay before the next set of code flashes.	1	Relay Coil Output
Two 1/2-second flashes "On" with a 2 second "Off" delay between sets of code flashes.	2	Fuel Solenoid Output
Three 1/2-second flashes "On" with a 2 second "Off" delay between sets of code flashes.	3	Oil Pressure Switch Input
Four 1/2-second flashes "On" with a 2 second "Off" delay between sets of code flashes.	4	Temperature Sensor Input
Five 1/2-second flashes "On" with a 2 second "Off" delay between sets of code flashes.	5	Battery Feed to Glow Plugs

Table 1, Diagnostic Test Code Chart

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Grid Heater Troubleshooting Circuit Tests

IMPORTANT: The tests listed below apply to the **Caterpillar CFE/3126** engine only.

The grid heater circuit tests are to be used if there is an active or easily repeatable grid heater open circuit or grid heater short circuit diagnostic code. Also use this procedure to check the grid heater, the grid heater relay, and the grid heater lamp operation.

The electronic system response to an open or short in the circuit would be that the ECM is unable to turn on the heater. The grid heater will not turn on even when the ECM determines the conditions indicate it should.

The engine response to an open or short in the circuit would be that the engine may have white smoke in the exhaust and/or an increase in cranking time before starting with cold temperatures.

Test #1: Electrical Connectors and Wiring

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the rear tires.
2. Thoroughly inspect the ECM engine harness connector J2/P2, grid heater relay connector J501/P501, the grid heater lamp connector J648/P648, and the terminal connections to the intake heater relay.
3. Perform a 10 lb (45 N) pull test on each engine harness wire that is associated with the grid heater (terminal-8).
4. Check the ECM connector (Allen screw) for proper torque. Check the harness and wiring for abrasion and pinch points from the sensor back to the ECM. Repair or replace any wiring or connectors as necessary.
5. Ensure that all seals are in place and that the connectors are properly mated.
6. Verify that any repair made eliminates the original problem.

Test #2: Grid Heater Power-Up Test

1. Turn the ignition key switch on, but keep the engine shut down. The grid heater lamp should activate for two seconds and then shut off.
2. Connect an electronic service tool to the data link connector.
3. Access the grid heater enable special test on the electronic service tool.

IMPORTANT: Do not leave the grid heater enable special test on longer than is required, and avoid unnecessary cycling to prevent battery drain. The grid heater enable special test has a built in one minute timer to disable the test after the time expires.

NOTE: The relay is located on the front left side of the engine.

4. Begin the grid heater enable special test while listening for the relay to click. You may need to be near the engine to hear the relay click.

Test #3: Grid Heater Relay Contacts Voltage Check

1. Make sure the ignition key switch is turned to the off position.
2. Disconnect the wire at the grid heater relay terminal that routes to the grid heater.
3. Fabricate two jumper wires with Deutsche sockets on one end and Deutsche pins on the other end. Strip a small amount of insulation from the middle of one jumper wire.
4. Disconnect J501/P501 and insert the jumper wires in the electrical connectors. Pin 2 should have the jumper wire with the removed insulation.
5. Connect the voltage meter from the disconnected relay terminal to the jumper wire that is connected to J501 and P501 terminals.
6. Turn the ignition key switch on, but keep the engine shut down.

IMPORTANT: Do not leave the grid heater enable special test on longer than is required, and

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avoid unnecessary cycling to prevent battery drain. The grid heater enable special test has a built in one minute timer to disable the test after the time expires.

7. Access the grid heater enable special test on the electronic service tool and begin the test while watching the volt meter.
8. If voltage is detected, the relay and the positive battery connections are good. Leave the relay terminal wire disconnected, and do "Test #6: Wiring Check To and From Grid Heater".
9. If no voltage is detected or remains constant, reconnect the wire to the relay terminal and do "Test #7: Relay Contact Check at Positive Battery Terminal Connection".

Test #4: Grid Heater Relay Voltage Check at Connector P501

1. Disconnect the grid heater relay connector P501.
2. Be sure that the grid heater lamp connector J648/P548 is still connected.
3. Connect a voltage meter to the two terminals of the engine harness side (P501) of the grid heater relay connector.
4. Turn the ignition key switch on, but keep the engine shut down.
5. Access the grid heater enable special test on the electronic service tool and begin the test while watching the voltage meter.

IMPORTANT: Do not leave the grid heater enable special test on longer than is required, and avoid unnecessary cycling to prevent battery drain. The grid heater enable special test has a built in one minute timer to disable the test after the time expires.

6. If voltage is detected, the ECM and harness wiring to the grid heater relay connector P501 are good. Replace the grid heater relay and retest. Verify the condition has been resolved and connect J501/P501.
7. If no voltage is detected or remains constant, connect the wire to the relay terminal and connect J501/P501, and do "Test #8: Battery Voltage Check to Grid Heater Lamp Connector J648".

Test #5: Grid Heater Lamp Voltage Check

1. Make sure the ignition key switch is turned to the off position. Verify that connector J648/P548 and J501/P501 are still connected.
2. Locate the grid heater lamp in the dash. Remove the lamp from the dash.
3. Connect a voltage meter between the two terminals of the lamp socket.
4. Turn the ignition key switch on. The engine remains shut down.
5. Access the grid heater enable special test on the electronic service tool and begin the test while watching the voltage meter.

IMPORTANT: Do not leave the grid heater enable special test on longer than is required, and avoid unnecessary cycling to prevent battery drain. The grid heater enable special test has a built in one minute timer to disable the test after the time expires.

6. If no voltage is detected, replace the grid heater lamp. Verify that the original condition has been resolved.
7. If voltage is detected and then lost, the voltage lamp is working properly. If no voltage is detected or remains constant, reconnect the wire to the relay terminal and do "Test # 9: Voltage Check at Grid Heater Lamp Connector J648/P648".

Test #6: Wiring Check To and From Grid Heater

1. Make sure the ignition key switch is turned to the off position.
2. Disconnect both wires from the grid heater.
3. Use a digital multimeter to measure the resistance between the two ends of the wire that connects the grid heater to the grid heater relay.
4. Measure the resistance from the engine ground stud to the other end of the grid heater wire that connects to the ground stud.

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5. If the grid heater measures greater than 20 ohms, replace the grid heater. Verify that the original condition has been resolved.
6. If the heater ground wire measures greater than 20 ohms, replace the wire. Verify that the original condition has been resolved.

Test #7: Relay Contact Check at Positive Battery Terminal Connection

1. Make sure the ignition key switch is turned to the off position.
2. Connect the positive lead of the voltage meter to the positive lead of the relay contact terminal that connects to the grid heater circuit protector.
3. Connect the negative lead of the voltage meter to the engine ground stud.
4. Turn the ignition key switch on. The engine remains shut down.
5. If voltage is detected when the ignition key switch is turned to the on position, repair or replace the wiring from the grid heater lamp to the splice in the wire to the grid heater lamp connector J648 terminal-B. Verify that the original condition has been resolved.
6. If no voltage is detected when the ignition key switch is turned to the on position, inspect the grid heater circuit protection and wiring; repair or replace as necessary. Verify that the original condition has been resolved.

Test #8: Battery Voltage Check to Grid Heater Lamp Connector J648

1. Make sure the ignition key switch is turned to the off position.
2. Disconnect the grid heater lamp connector J648/P648.
3. Connect a voltage meter positive lead to J648 terminal-A
4. Connect a jumper wire to the ground stud, and connect the voltage meter negative lead to the jumper wire.
5. Turn the ignition key switch on. The engine remains shut down.
6. If voltage is detected and remains constant while the voltage meter is connected between J648 terminal-A and the ground stud, do "Test #10: Battery Voltage Check to Grid Heater Relay Connector P501".
7. If no voltage is detected while the voltage meter is connected between J648 terminal-A and the ground stud, inspect the following:
    - the circuit protection
    - the wiring from the circuit protection
    - the wiring from the battery to the circuit protection
8. Repair or replace as necessary.
9. Verify that the original condition has been resolved.

Test #9: Voltage Check at Grid Heater Lamp Connector J648/P648

1. Make sure the ignition key switch is turned to the off position.
2. Disconnect the grid heater lamp connector J648/P648.
3. Connect the voltage meter positive lead to the grid heater connector J648 terminal-A, and the negative lead to the engine ground stud.
4. Turn the ignition key switch on. The engine remains shut down.
5. If voltage is detected, repair or replace the wiring from the grid heater lamp to the splice in the wire to the grid heater lamp connector J648 terminal-B. Verify that the original condition has been resolved.
6. If no voltage is detected, repair or replace the wiring from the grid heater lamp to the grid heater lamp connector J648 terminal-A. Verify that the original condition has been resolved.

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Test #10: Battery Voltage Check to Grid Heater Relay Connector P501

1. Make sure that the ignition key switch is turned to the off position.
2. Be sure that the grid heater lamp connector J648/P648 is connected.
3. Disconnect the grid heater relay connector J501/P501.
4. Connect the voltage meter positive lead to the grid heater relay connector P501 terminal-1, and the negative lead to the ground stud.
5. Turn the ignition key switch on. The engine remains shut down.
6. If the voltage remains constant when the ignition key switch is in the on position, do "Test # 11: Check the ECM".
7. If no voltage is detected when the ignition key switch is in the on position, repair or replace the wiring from P648 terminal-A to P501 terminal-1. Verify that the original condition has been resolved.

Test #11: Check the ECM

1. Make sure that the ignition key switch is turned to the off position.
2. Disconnect the grid heater lamp connector J648/P648.
3. Disconnect the ECM harness Connector J2/P2 and install a 70-terminal breakout T to the ECM connector J2 only.
4. Connect the voltage meter positive lead to the grid heater lamp connector J648 terminal-A, and the negative lead to the breakout terminal-8.
5. Turn the ignition key switch on. The engine remains shut down.

IMPORTANT: Do not leave the grid heater enable special test on longer than is required, and avoid unnecessary cycling to prevent battery drain. The grid heater enable special test has a built in one minute timer to disable the test after the time expires.

6. Access the grid heater enable special test on the electronic service tool and begin the test while watching the voltage meter.

NOTE: When the ECM engine harness connector J2/P2 is disconnected with the ignition key switch on, an open circuit diagnostic code will be active/logged for all of the engine sensors and the grid heater open circuit. This is normal.

7. If voltage is detected or remains constant with the grid heater enable special test, repair or replace the wiring from the grid heater relay connector P501 to the ECM connector P2.
8. Remove the breakout T and connect the ECM engine harness connector J2/P2.
9. Verify that the original problem has been resolved.
10. If no voltage is detected, shut off the grid heater enable special test, and do "Test #12: Battery Voltage Check to ECM".

Test #12: Battery Voltage Check to ECM

1. Make sure that the ignition key switch is turned to the off position.
2. Disconnect the ECM vehicle harness connector J1/P1 and install a 70-terminal breakout T.
3. Connect the voltage meter's positive lead between breakout T terminal-52 (unswitched positive battery) and the voltage meter's negative lead at terminal-65 (negative battery).
4. Turn the ignition key switch on. The engine remains shut down. Note the voltage reading on the voltmeter.
5. Turn the ignition key switch off.
6. Connect the voltmeter between breakout T terminal-53 (unswitched positive battery) and terminal-67 (negative battery).
7. Turn the ignition key switch on, but keep the engine shut down, note the voltage reading on the voltmeter.
8. If the voltage readings were between 11 volts and 13.5 volts while the ignition key was switched on, the ECM is receiving the correct voltage but is not turning on the lamp.

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9. Replace the ECM. Verify that this corrects the original problem.
10. If either voltage reading is not between 11 volts and 13.5 volts, the problem may be in the vehicle wiring. See **Section 54.00** for vehicle wiring.

Fault Code Troubleshooting Procedures

IMPORTANT: The following procedures are to be used when troubleshooting Diagnostic Test Codes.

Relay Coil Output Fault (Code 1)

1. Check for continuity at the relay coil. Measure the resistance between the relay coil terminals. If the resistance is greater than 5 ohms, replace the relay. Test the system for normal operation. If the resistance is less than 5 ohms, check circuit 514 (BL) for an open.
2. Measure the resistance between connector 156, Terminal D, Circuit 514 (BL), and the relay terminal. If the resistance is greater than 5 ohms, repair the open in Circuit 514 (BL). Test the system for normal operation. If the resistance is less than 5 ohms, check Circuit 57 (BK) for an open.
3. Measure the resistance between the relay ground Circuit 57 (BK) and a clean chassis ground. If there is continuity in the circuit, replace the controller. Teste the system for normal operation. If there is no continuit, repair the open in Circuit 57(BK). Test the system for normal operation

Fuel Solenoid Fault (Code 2)

1. Check Circuit 455 (GR/R) for an open. Measure the resistance between connector C156, Terminal D and the solenoid feed wire Circuit 455 (GR/R). If the resistance is greater than 5 ohms, repair the open in Circuit 455 (GR?R). Test the system for normal operation. If the resistance is less than 5 ohms, check the fuel solenoid ground.
2. Measure the resistance between the solenoid case and a clean chassis ground. If the resistance is greater than 5 ohms, clean the solenoid to ground surface. Test the system for normal operation. If the resistance is less than 5 ohms, check the fuel solenoid function.
3. Connect a wire between the solenoid battery feed terminal and the battery positive (+) post. Connect a wire between a clean chassis ground and the solenoid ground terminal. If the solenoid clicks, replace the controller. Test the system for normal operation. If the solenoid does not click, replace the fuel solenoid. Test the system for normal operation.

Oil Pressure Switch Fault (Code 3)

1. Check for continuity at the oil pressure switch. Start the engine. Measure the resistance between the pressure switch terminals. If the resistance is greater than 5 ohms, replace the oil pressure switch. Test the system for normal operation. If the resistance is less than 5 ohms, check Circuit 868 (R/BR) for an open.
2. Measure the resistance between connector C155, Terminal C, Circuit 868 (R/BR) and the oil pressure switch connector. If the resistance is greater than 5 ohms, check Circuit 937 (BK) for an open.
3. Measure the resistance between connector C156, Terminal B and the oil pressure switch Circuit 937 (BK). If the resistance is less than 5 ohms, replace the controller. Test the system for normal operation. If the resistance is greater than 5 ohms, repair the open in Circuit 937 (BK). Test the system for normal operation.

Temperature Sensor Fault (Code 4)

1. Check the temperature sensor. Install a 1000-ohm resistor between the temperature sensor connector terminals. Measure the voltage at the glow plugs. If battery voltage is present, replace the temperature sensor. Test the system for normal operation. If battery voltage is not present, check Circuit 354 (GN/W) for an open.
2. Measure the resistance between controller connector C155, Terminal D and the sensor feed terminal Circuit 354 (GN/W). If the resistance is greater than 5 ohms, repair the open in Circuit

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354 (GN/W). Test the system for normal operation. If the resistance is less than 5 ohms, check Circuit 937 (BK) for an open.

3. Measure the resistance between connector C156, Terminal B and the sensor feed terminal Circuit 937 (BK). If the resistance is less than 5 ohms, replace the controller. Test the system for normal operation. If the resistance is greater than 5 ohms, repair the open in Circuit 937 (BK). Test the system for normal operation.

Battery Feed to Glow Plugs Fault (Code 5)

1. Check Circuit 37 (BK/Y) for an open. Measure the voltage at the glow plug relay, Circuit 37 (BK/Y). If the battery voltage is less than 10 volts, repair the open in Circuit 37 (BK/Y). Test the system for normal operation. If the voltage is greater than 10 volts, check the relay.
2. Connect a 6-gauge wire between Circuit 37 (BK/Y) and the glow plug terminal Circuit 118 (R). Measure the voltage at the glow plugs. If voltage is greater than 10 volts, replace the relay. Test the system for normal operation. If the voltage is less than 10 volts, check circuit 118 (R).
3. Measure the resistance between the relay terminal Circuit 118 (R) and the glow plug wiring terminal Circuit 118 (R). If the resistance is greater than 5 ohms, repair the open on Circuit 118 (R). Test the system for normal operation. If the resistance is less than 5 ohms, check the glow plug ground Circuit 57 (BK).
4. Measure the resistance between the glow plug case and a clean chassis ground. If the resistance is less than 5 ohms, replace the glow plug. If the resistance is greater than 5 ohms, repair the open in Circuit 57 (BK). Test the system for normal operation.

System Inoperative, Wait-to-Start Light Does Not Come On

1. Check the wait-to-start light. Connect a jumper between the controller connector Terminal F of connector C156 and a clean chassis ground.
2. If the wait-to-start light does not come on, check Circuit 709 (W/BL). Replace the wait-to-start bulb with a known good bulb. Connect a jumper wire between connector C156, Terminal F, Circuit 709 (W/BL) and a clean chassis ground. If the wait-to-start light comes on, run a self test to verify normal operation. If the wait-to-start light does not come on, check for continuity on Circuit 709 (W/BL). Measure the resistance between connector C156, Terminal F, Circuit 709 (W/BL) and the wait-to-start bulb socket terminal. If there is continuity, repair the open in the battery feed to the bulb. Test the system for normal operation. If there is no continuity, repair the open on Circuit 709 (W/BL). Test the system for normal operation.
3. If the wait-to-start light comes on, check for battery voltage at Circuit 717 (BL/R). Measure the voltage at connector C155, Terminal A, Circuit 717 (BL/R). If the voltage is greater than 10 volts, check Circuit 25 (BK/O) for an open. Measure the resistance between connector C156, Terminal C, Circuit 25 (BK/O) and a clean chassis ground. If there is no continuity, repair the open in Circuit 25 (BK/O). Test the system for normal operation. If there is continuity, check for battery voltage on Circuit 32 (R/BL). Measure the voltage at connector C155, Terminal B, Circuit 32 (R/BL) while cranking the engine. Measure the voltage at connector C155, Terminal B, Circuit 32 (R/BL). If battery voltage is present, replace the controller. Test the system for normal operation. If battery voltage is not present, repair the open in Circuit 37 (R/LB). Test the system for normal operation.
4. If the voltage is less than 10 volts, check for battery voltage to Fuse 7. Measure battery voltage at Fuse 7 battery feed terminal. If the voltage is less than 10 volts, repair the open in the battery feed to Fuse 7. Test the system for normal operation. If the voltage is greater than 10 volts, check Circuit 717 (BL/R) for an open. Measure the resistance between connector C155, Terminal A, Circuit 717 (BL/R) and the Fuse 7 terminal. If the resistance is less than 5 ohms, replace the controller. Test the system for normal operation. If the resistance is greater than 5 ohms, repair the open in Circuit 717 (BL/R). Test the system for normal operation.

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Troubleshooting

Engine Crank Signal Fault

1. Measure the voltage at connector C155, Terminal B, Circuit 32 (R/BL). If battery voltage is greater than 10 volts, replace the controller. Test the system for normal operation.
2. If the battery voltage is less than 10 volts, repair the open in Circuit 32 (R/BL). Test the system for normal operation.

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See **Fig. 1** for a full view of the grid heater wiring (Cummins engines). See **Fig. 2** and **Fig. 3** for partial views of the grid heater wiring.

See **Fig. 4** for a full view of the grid heater wiring (Mercedes-Benz MBE 900 engine). See **Fig. 5** and **Fig. 6** for partial views of the grid heater wiring.

See **Fig. 7** for a full view of the grid heater wiring (Caterpillar 3126 engine).

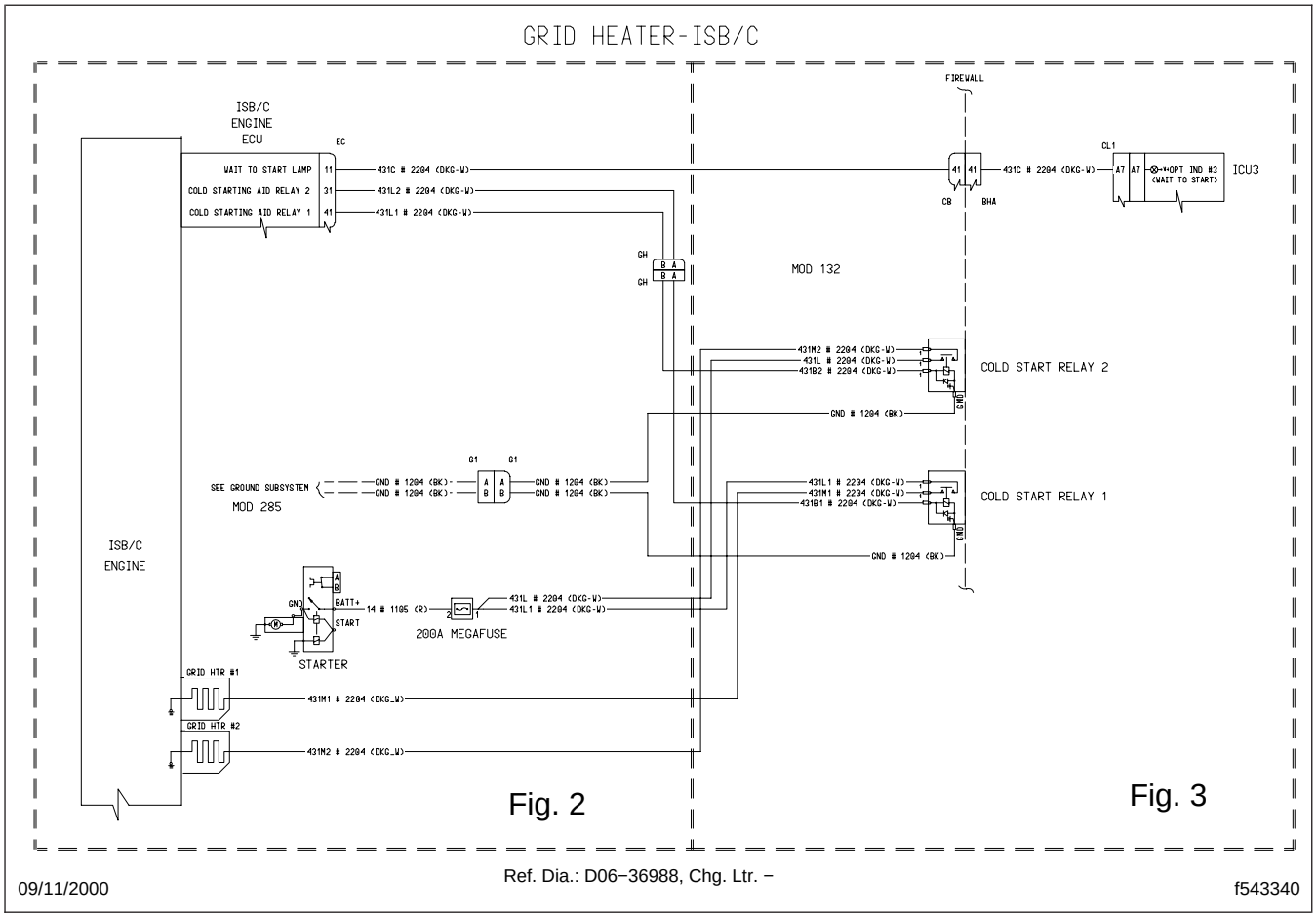


Fig. 1, Grid Heater Wiring, Cummins Engines (full view)

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Specifications

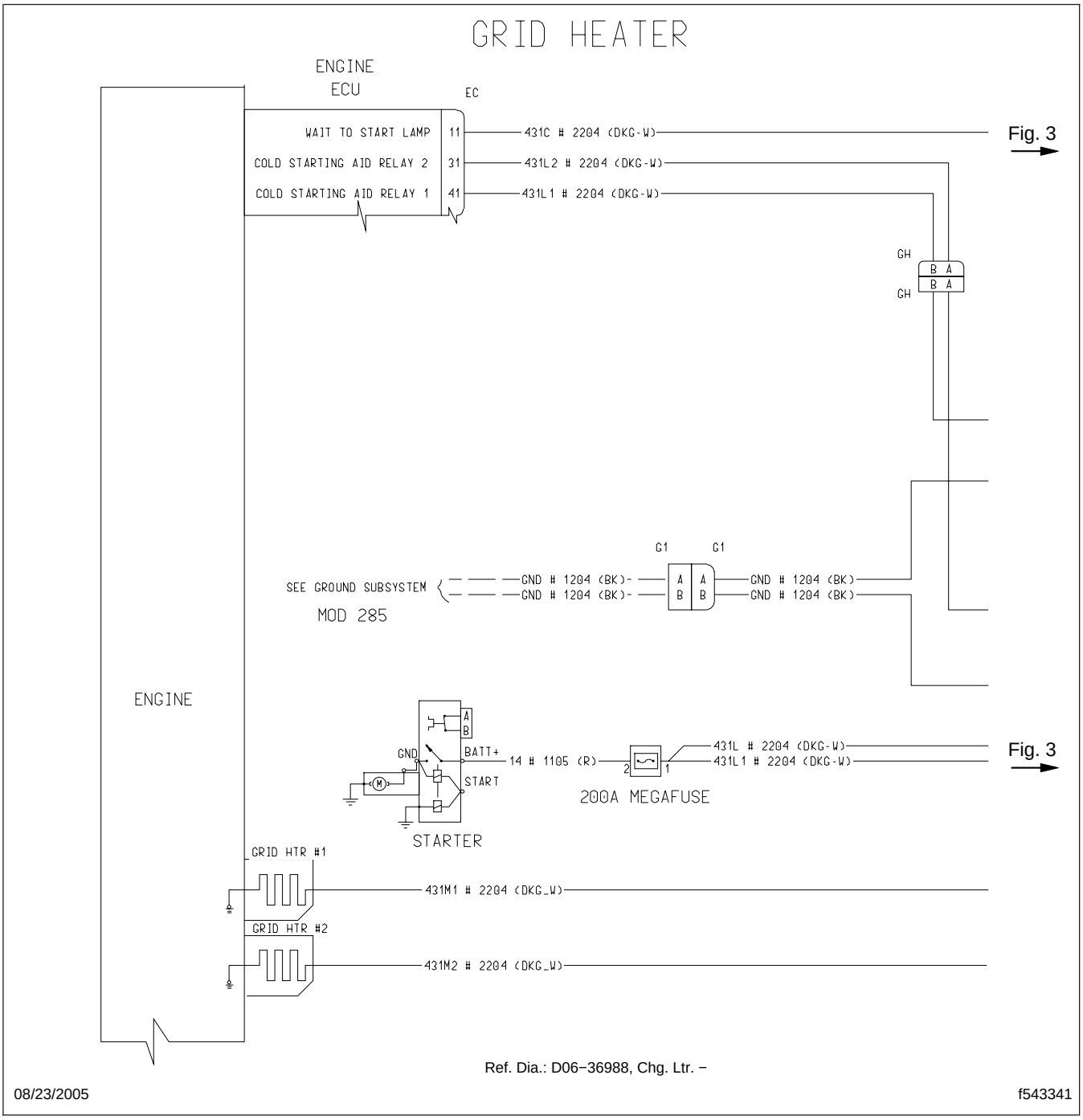


Fig. 2, Grid Heater Wiring, Cummins Engines (partial view)

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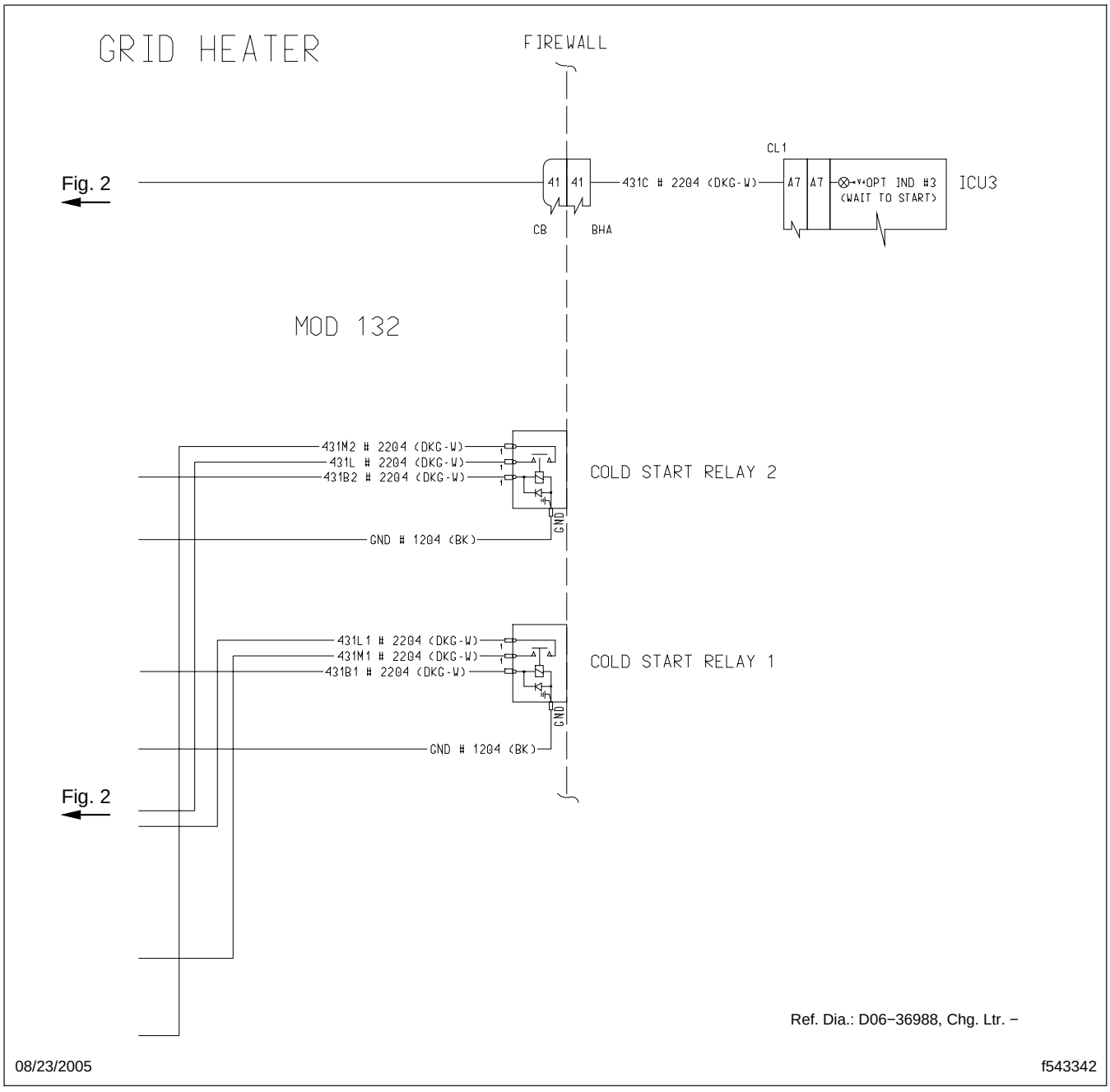


Fig. 3, Grid Heater Wiring, Cummins Engines (partial view)

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Specifications

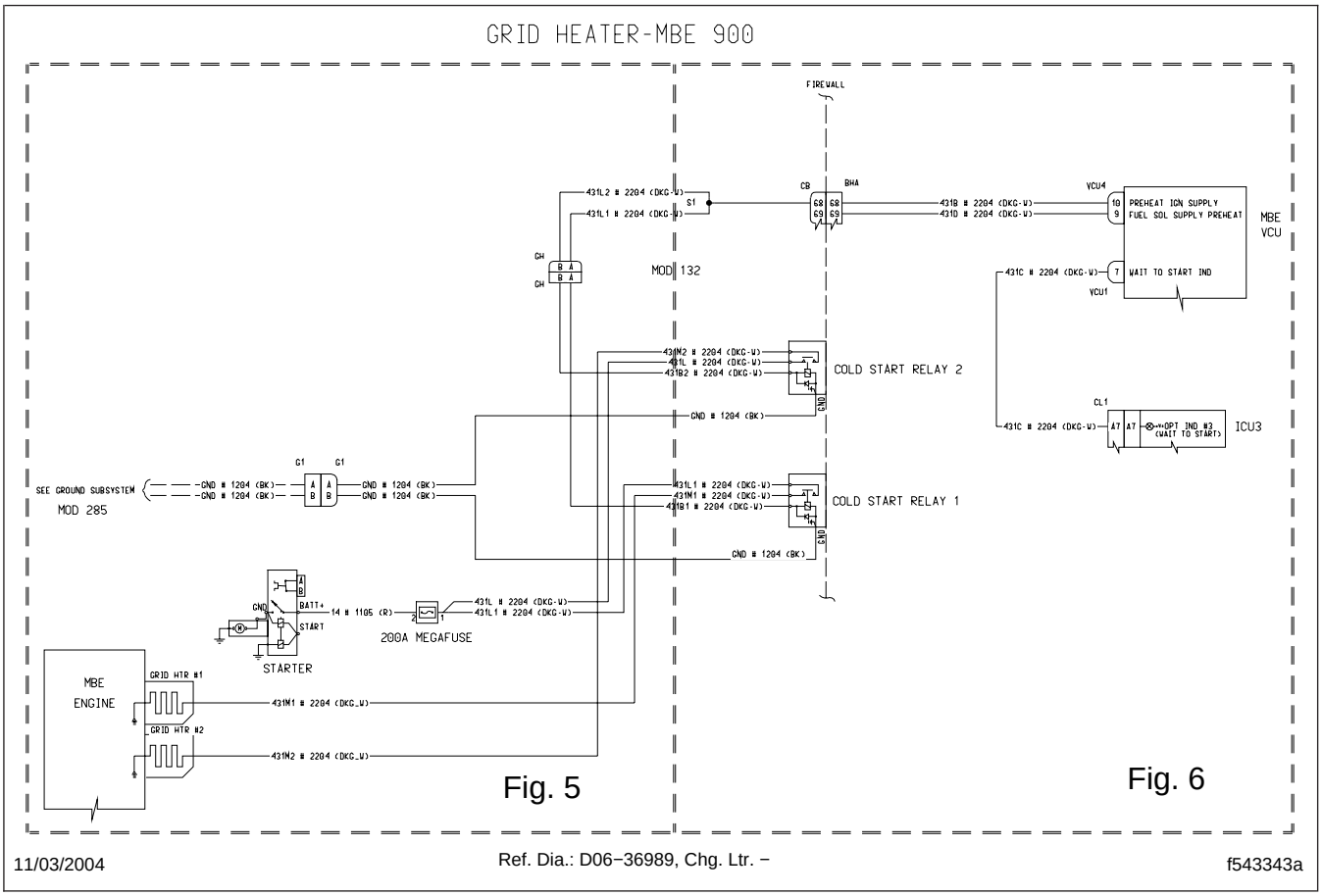


Fig. 4, Grid Heater Wiring, Mercedes-Benz Engines (full view)

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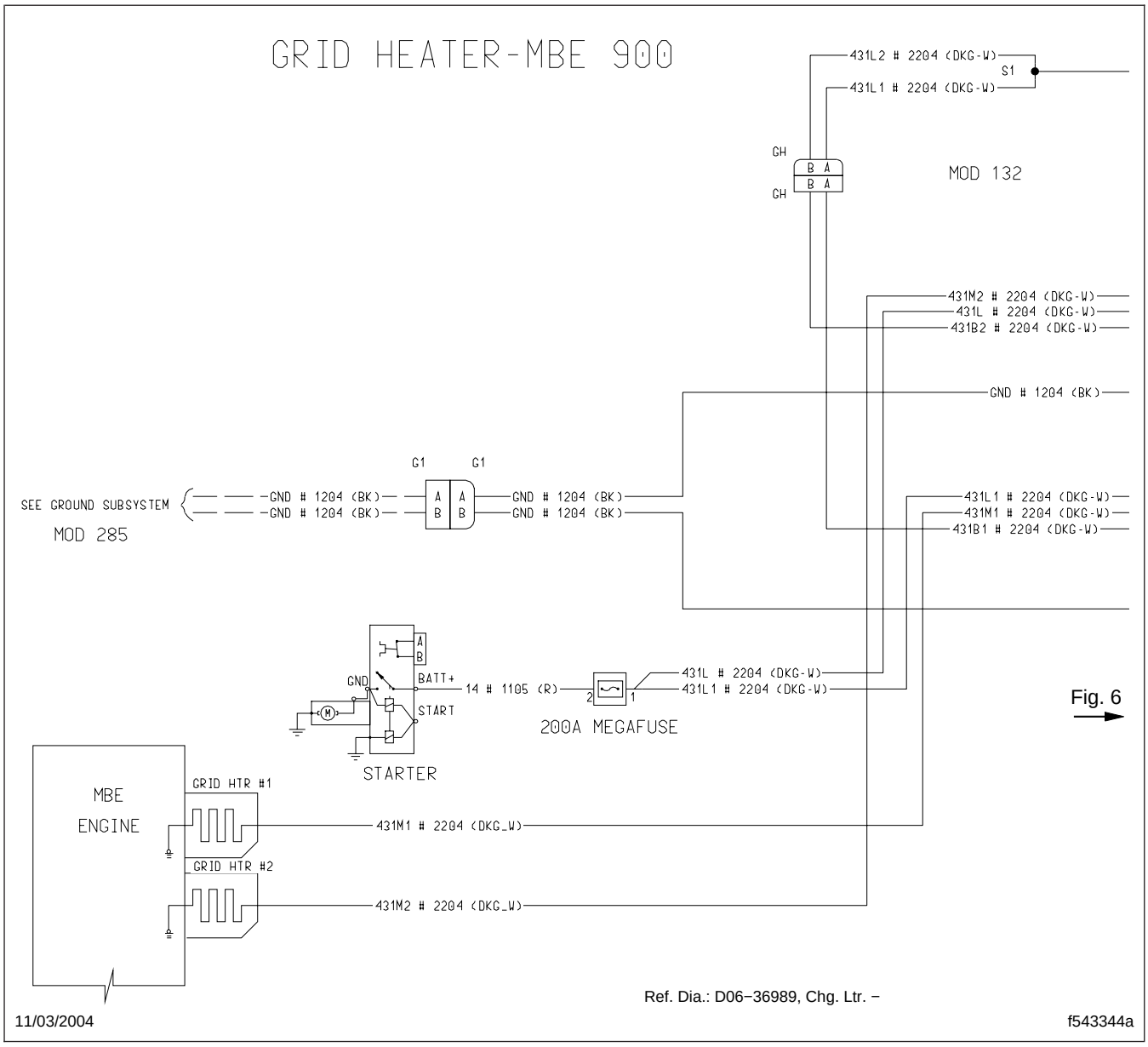


Fig. 5, Grid Heater Wiring, Mercedes-Benz Engines (partial view)

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Specifications

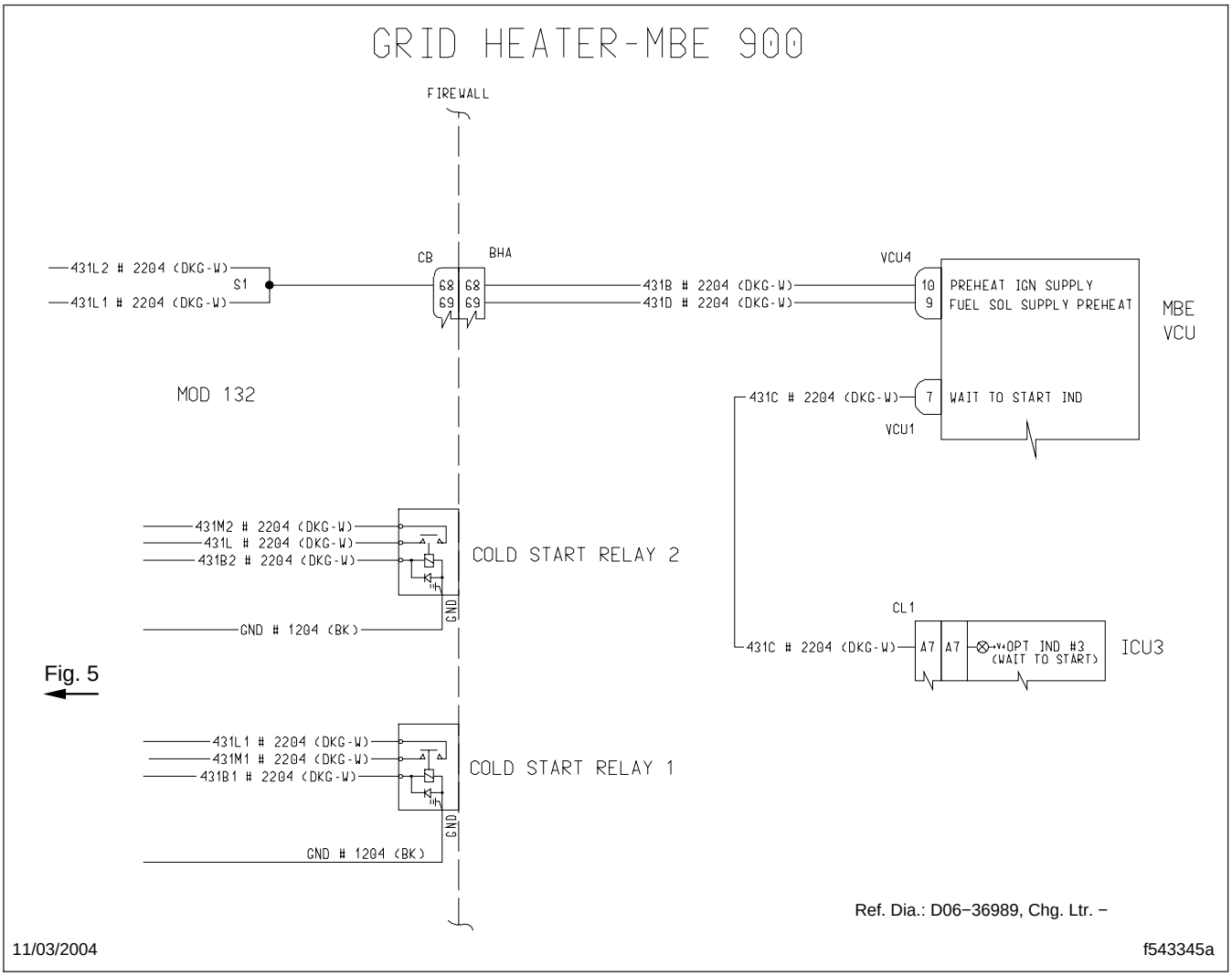


Fig. 6, Grid Heater Wiring, Mercedes-Benz Engines (partial view)

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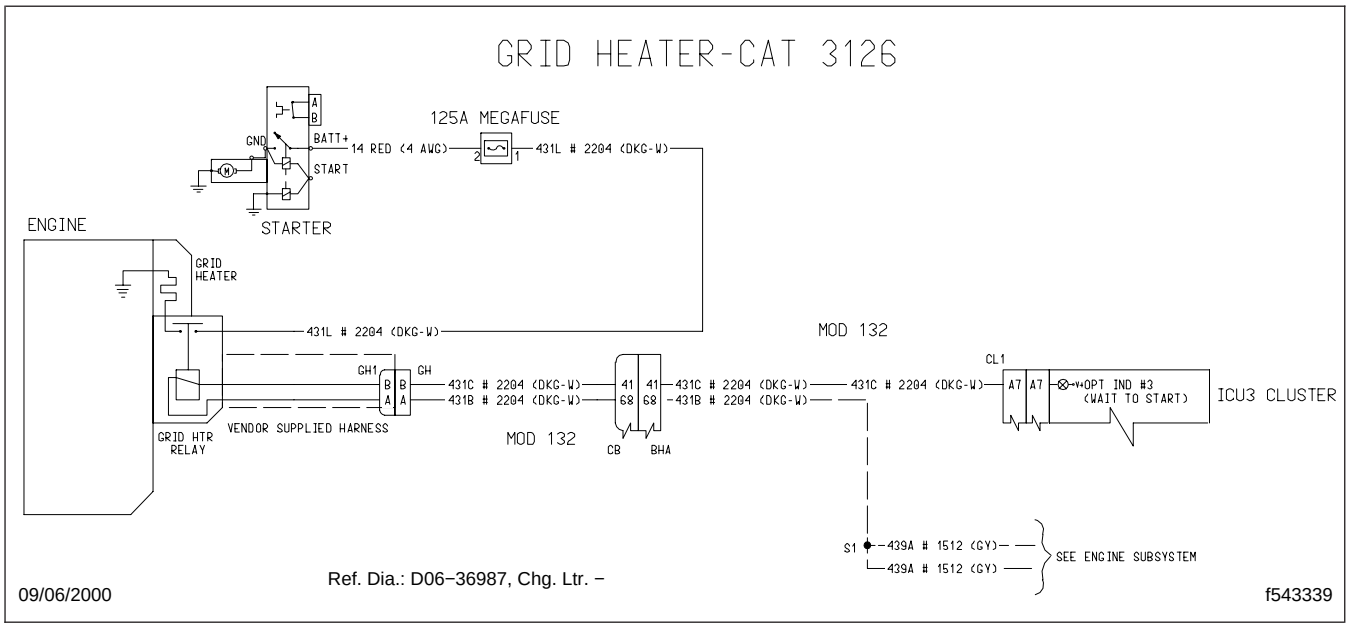


Fig. 7, Grid Heater Wiring, Caterpiller 3126B (full view)

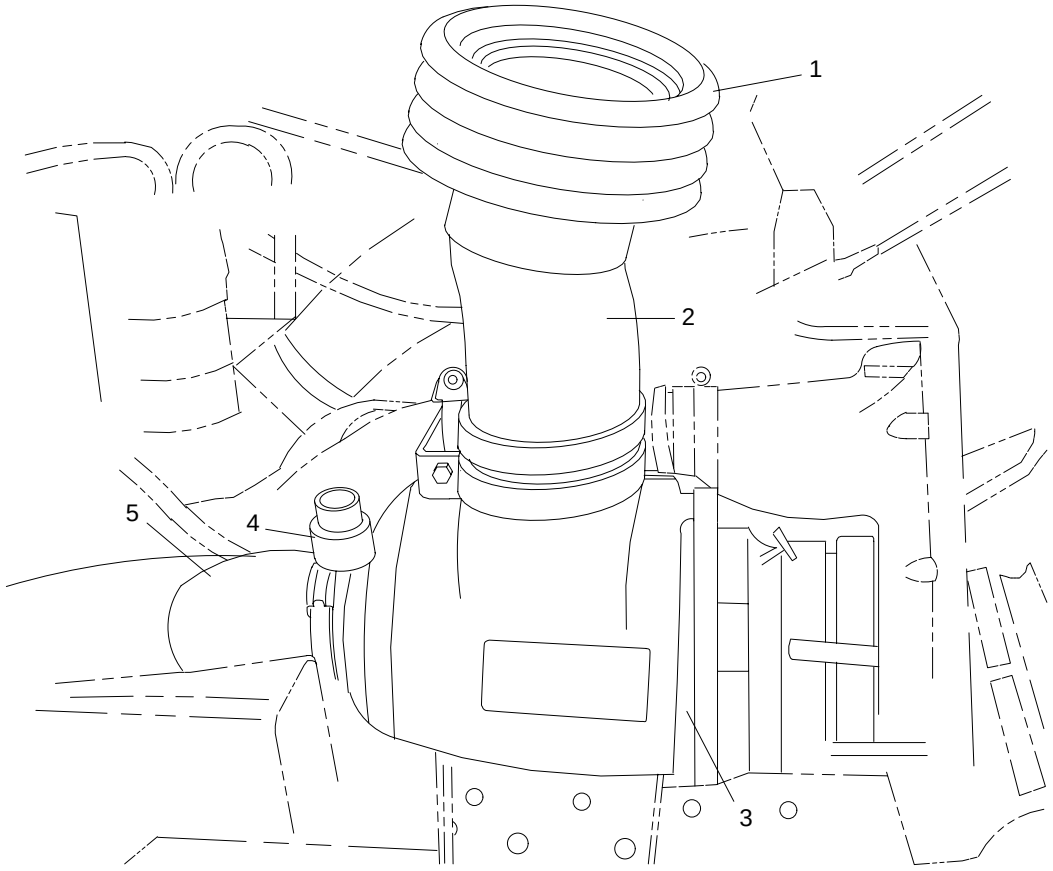
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General Information

An average diesel engine needs over 10,000 gallons (38 000 liters) of clean air for each gallon (3.8 liters) of fuel burned. In order for complete combustion to occur in each engine cylinder, more clean air than is needed is present in each cylinder. The air intake system routes this supply of outside air through an air cleaner, which filters out dirt, dust, abrasive particles, and other foreign material from the intake air, without restricting air flow. From there, the air intake ducting routes this clean air to the engine turbocharger.

The air intake ducting consists of a high-temp plastic housing for the air cleaner, followed by aluminum tubes and neoprene hoses. Stainless steel hose clamps fasten all the components together. See **Fig. 1**.

On some engines, a lock-up air restriction indicator is attached to the intake ducting near the air cleaner. See **Fig. 2**. As an option, an air restriction indicator or gauge mounts in the dashboard. Nylon tubing connects the remote-mounted indicator or gauge to the ducting. The air restriction indicator or gauge indicates when the air cleaner element needs to be replaced. The amount of allowable air restriction varies with engine type.



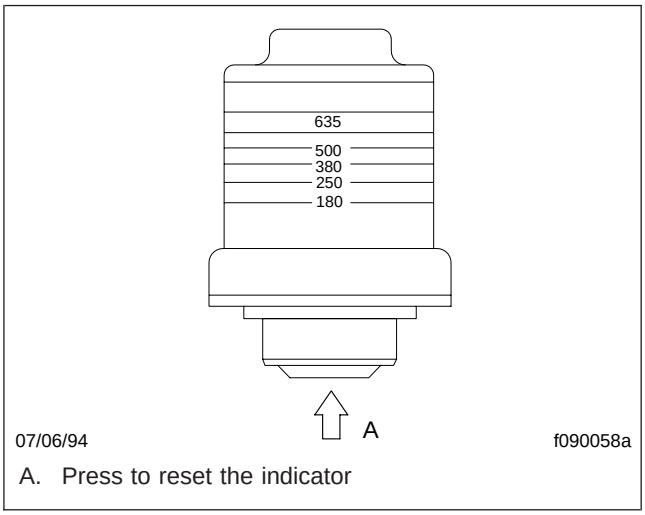
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1. Boot
2. Air Intake Pipe
3. Air Cleaner
4. Air Restriction Indicator
5. Elbow

Fig. 1, Air Intake Ducting

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General Information



A. Press to reset the indicator

Fig. 2, Air Restriction Indicator

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Air Intake Ducting Removal and Installation

WARNING

Do not operate the engine with any under-hood component of the air intake system removed; serious physical injury can occur if the turbocharger impeller is touched when it is rotating.

All air intake components and connections must be air-and water-tight. Dirt or dust entering the engine can cause internal engine damage. Much of the dirt and dust are silicates, which fuse into abrasive glass-like particles when exposed to engine combustion. These particles can grind piston rings, pistons, and cylinder liners.

IMPORTANT: Replace damaged components with new, identical parts. Neoprene hoses and nylon ducts that have been enlarged, extended or otherwise modified are not acceptable for installation between the air cleaner and the engine.

To avoid chafing, air intake ducting must not contact other parts.

Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Disassemble the air intake ducting.
   - 3.1 Loosen the clamp that holds the boot to the top of the air intake pipe and remove the boot. See **Fig. 1**.
   - 3.2 Loosen the clamps that hold the air intake pipe to the top of the air cleaner and remove the pipe from the cleaner.
   - 3.3 Loosen the clamp that holds the elbow to the back of the air cleaner. Remove the three hexhead capscrews, flatwashers and hexnuts that hold the air cleaner to the frame-mounted bracket. Remove the air cleaner. See **Fig. 2**.
   - 3.4 Loosen the clamp that holds the elbow to the pipe and remove the elbow. See **Fig. 3**.
   - 3.5 Remove the fitting for the air hose to the air compressor from the pipe. Loosen the clamp that holds the pipe to the turbocharger boot and remove the pipe. See **Fig. 4**.
   - 3.6 Loosen the clamp that holds the boot to the turbocharger. Remove the boot from the turbocharger. See **Fig. 3**.

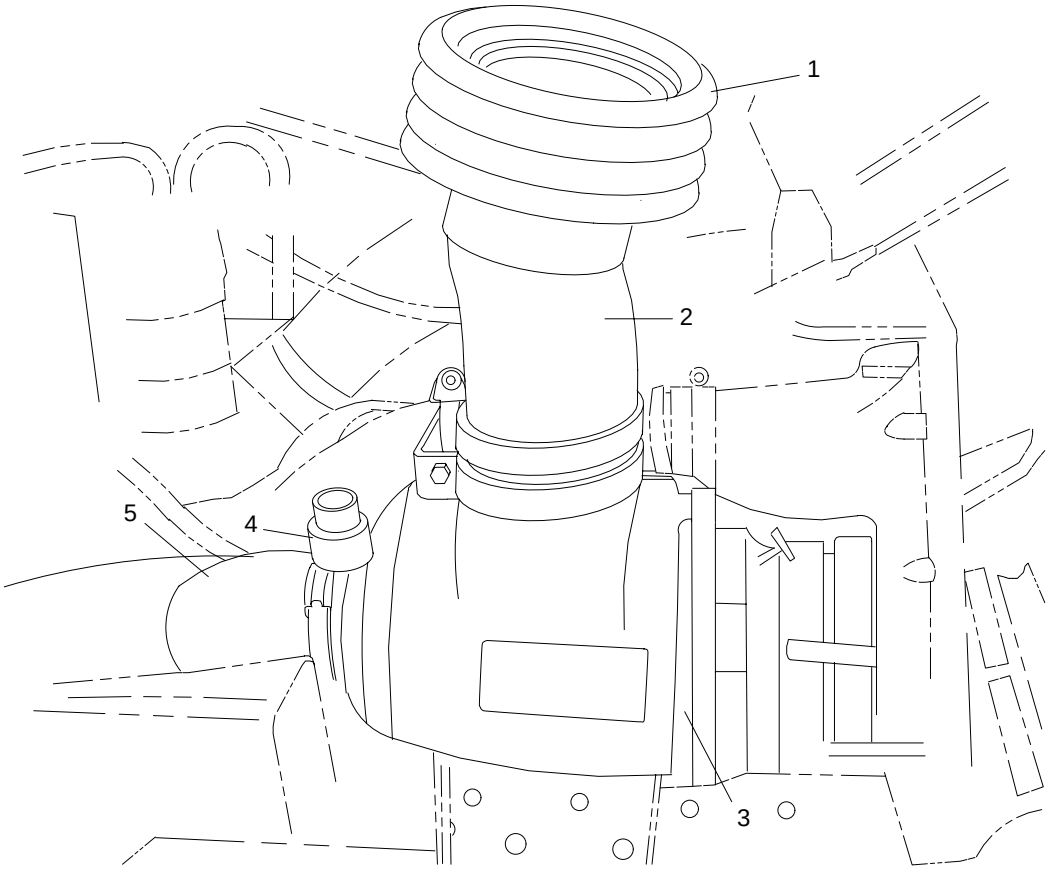
Installation

NOTE: Replace any damaged parts with new identical parts.

1. Assemble the air intake ducting.
   - 1.1 Install the new or undamaged boot on the turbocharger and install the clamp.
   - 1.2 Install the new or undamaged pipe on the turbocharger boot and install the clamp. Install the fitting for the hose to the air compressor.
   - 1.3 Install the new or undamaged elbow on the pipe and install the clamp.
   - 1.4 Install the new or undamaged air cleaner on the frame-mounted bracket using the three hexhead capscrews, flatwashers and hexnuts. Tighten the hexnuts 28 lbf·ft (38 N·m).
   - 1.5 Install the clamp that connects the elbow to the air cleaner.
   - 1.6 Install the air intake pipe on the top of the air cleaner and install the clamps.
   - 1.7 Install the boot on the air intake pipe and install the clamp.
2. Close and latch the hood.
3. Remove the chocks from the rear tires.

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Air Intake Ducting Removal and Installation



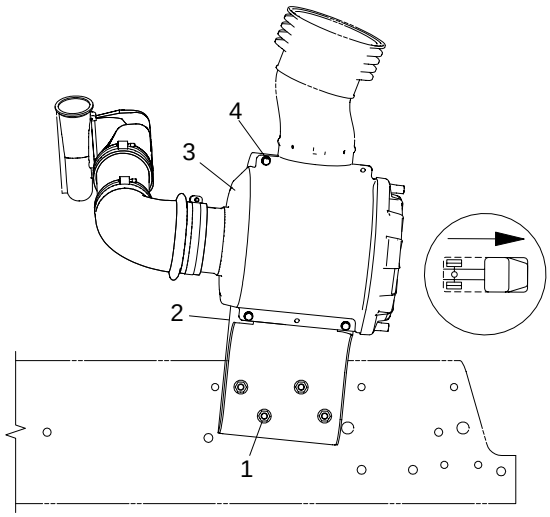
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1. Boot
2. Intake Pipe
3. Air Cleaner
4. Air Restriction Indicator
5. Elbow

Fig. 1, Air Intake Ducting

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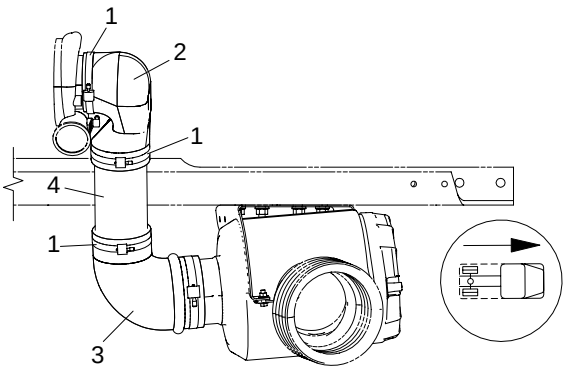
Air Intake Ducting Removal and Installation



01/31/2000 f090317

1. Hexhead Capscrew, 1/2–13 x 1.25
2. Air Cleaner Bracket
3. Air Cleaner
4. Hexhead Capscrew, 5/16–18

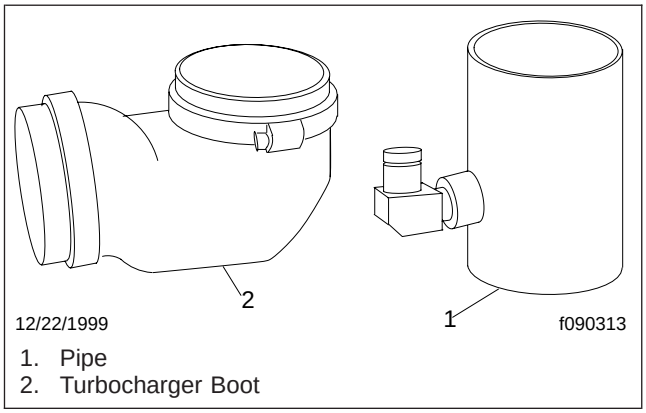
Fig. 2, Air Intake Ducting, Side View



01/31/2000 f090318

1. Clamp
2. Turbocharger Boot
3. Elbow
4. Pipe

Fig. 3, Air Intake Ducting, Overhead View



12/22/1999 f090313

1. Pipe
2. Turbocharger Boot

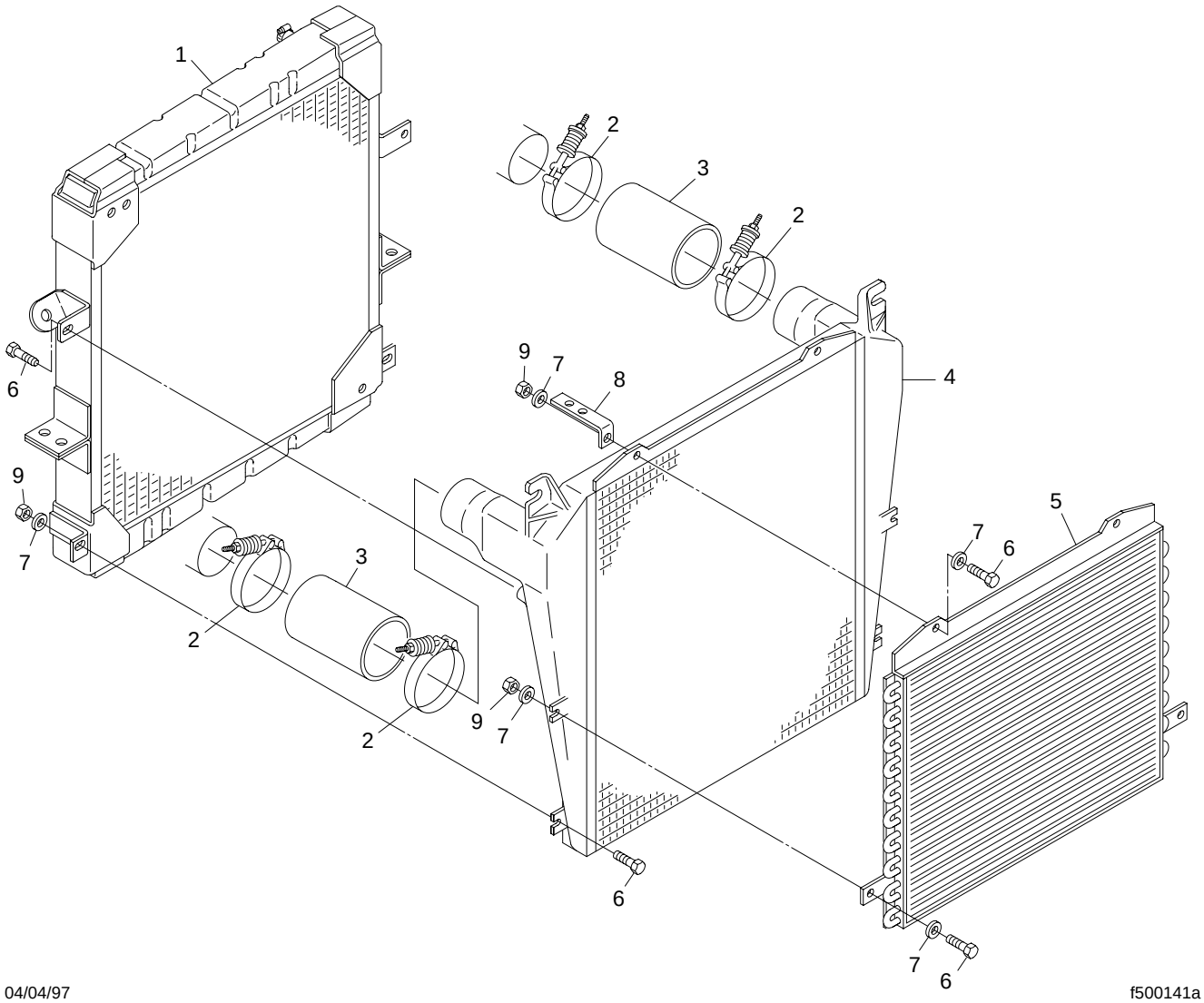
Fig. 4, Air Intake Ducting Components

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General Information

The charge air cooler (CAC) is attached to the front of the radiator, behind the condenser. See **Fig. 1**. It is similar to a radiator: outside ambient air passing through the CAC core cools the engine's intake air charge.

Air leaving the turbocharger is compressed, which heats it to about 275 to 325°F (135 to 162°C), depending on the ambient temperature. The CAC reduces this temperature to the engine manufacturer's specified air intake temperature before the air reaches the engine intake manifold. Lower tempera-



1. Radiator
2. Constant Tension Hose Clamp
3. Convoluted Hose
4. CAC
5. Condenser
6. Bolt
7. Washer
8. Stand-Off Bracket
9. Nut

Fig. 1, CAC Installation (typical)

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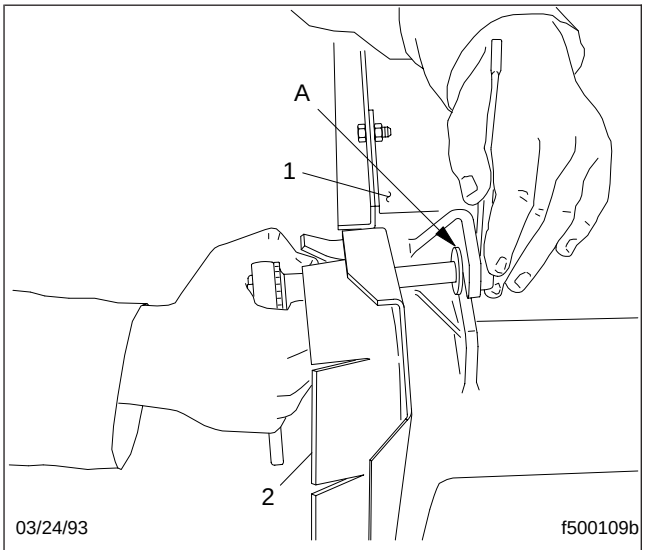
General Information

tures reduce exhaust emissions, improve fuel economy, and increase horsepower.

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Removal

1. Apply the parking brakes and chock the tires.
2. Remove the hood. For instructions, see **Group 88**.
3. With the refrigerant hoses connected, move the condenser aside as follows.
   - 3.1 Remove the air recirculation shields from either side of the condenser. See **Fig. 1**.
   - 3.2 Remove the clamp that secures the refrigerant hoses to the radiator support strut.
   - 3.3 Remove the four bolts that attach the condenser and move the condenser to one side. See **Fig. 2**. Wrap it in a protective blanket and secure it out of the way.
4. Remove the hood cable brackets from the radiator. See **Fig. 3**.
5. Disconnect the air inlet and outlet hoses from the CAC.
6. Remove the four CAC mounting bolts. See **Fig. 4**. Remove the CAC from the radiator.



A. Air Recirculation Shield Removal

1. CAC
2. Air Recirculation Shield

Fig. 1, Air Recirculation Shield

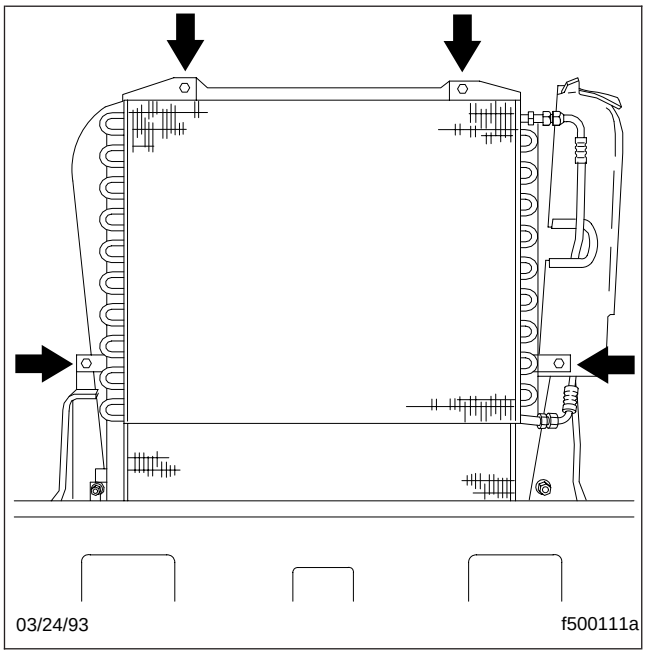
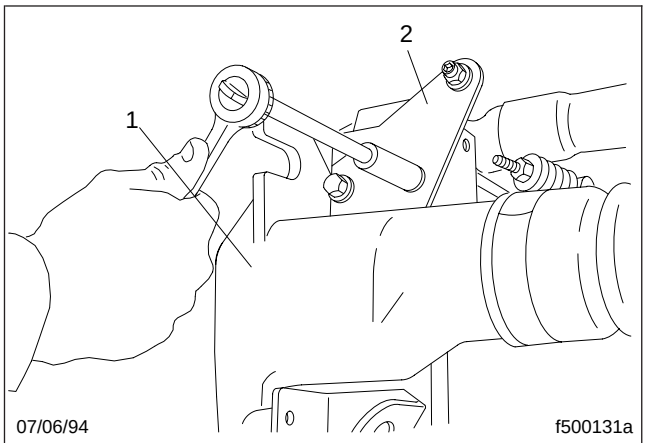


Fig. 2, Condenser Mounting Bolts



1. CAC
2. Hood Cable Bracket

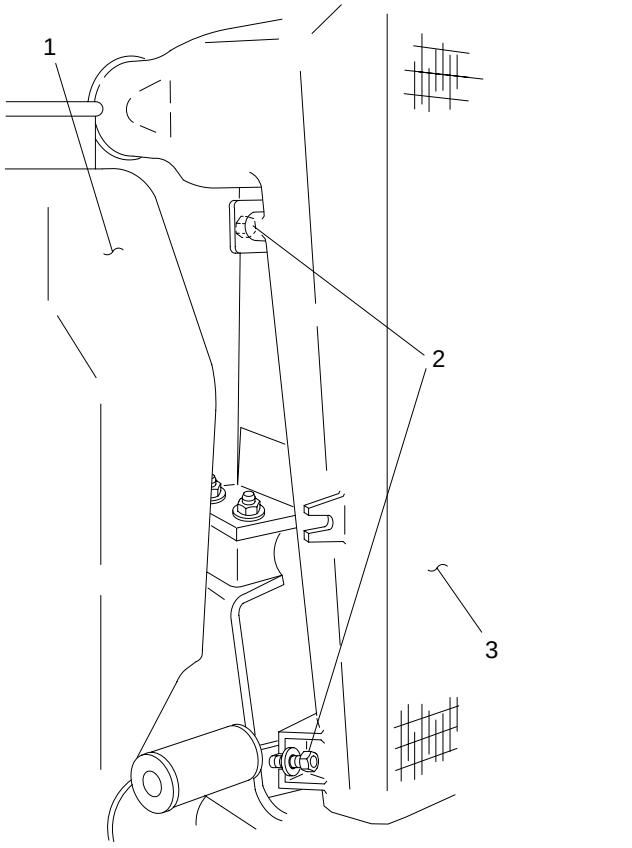
Fig. 3, Hood Cable Bracket

Installation

1. Position the CAC on the radiator and secure it with the four mounting bolts. See **Fig. 4**. Tighten the bolts 15 lbf·ft (20 N·m).
2. Connect the convoluted hoses to the CAC. See **Fig. 5** for the Mercedes-Benz MBE900 engine,

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CAC Removal and Installation



1. Air Cleaner
2. Right-Side Mounting Bolts
3. CAC

Fig. 4, CAC Mounting

Fig. 6 for the Cummins ISB engine, **Fig. 7** for the Cummins ISC engine, or **Fig. 8** for the Caterpillar 3126B engine.

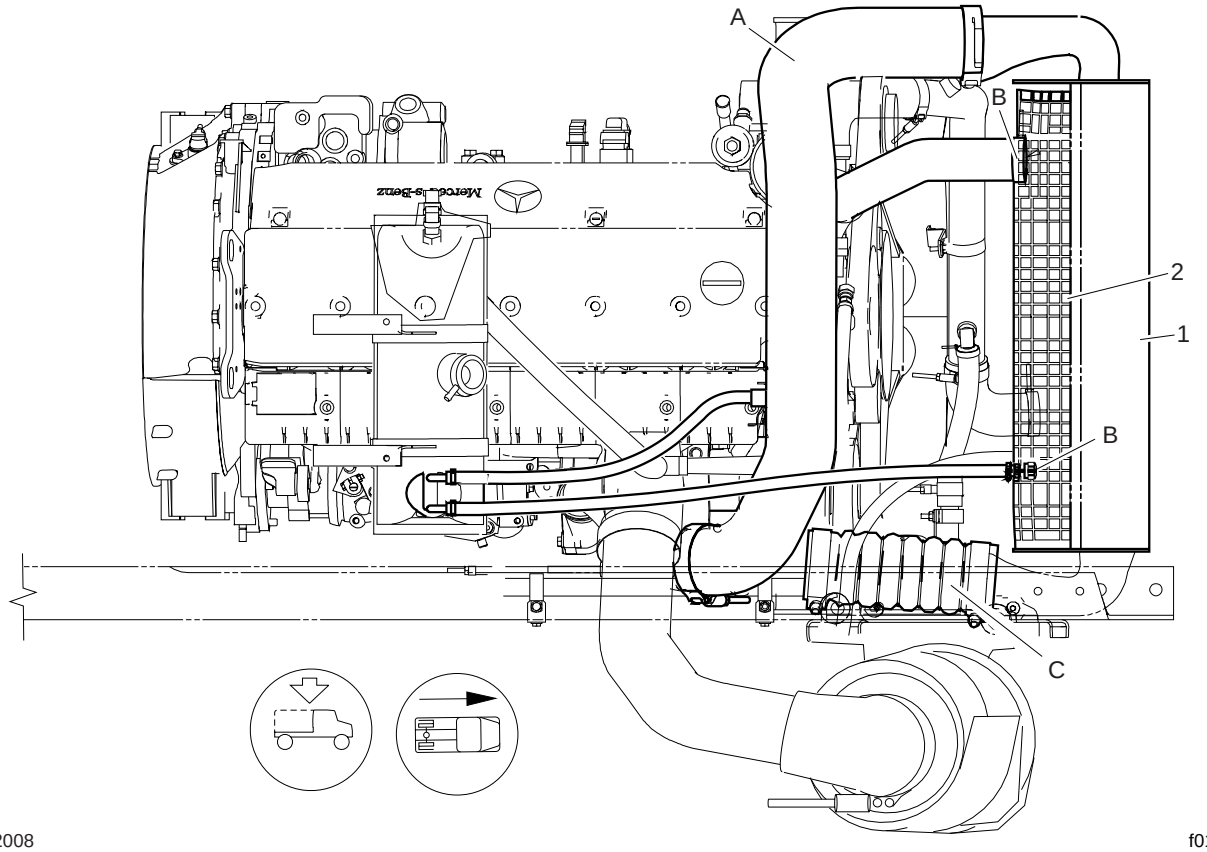
Turn the constant tension hose clamps so their tightening screws are under the hoses or facing inboard. Tighten the clamp screws 45 lbf·in (500 N·cm).

IMPORTANT: Vehicles built on or after February 26, 2007, have modified constant tension clamps that adjust to changes in diameter at the hose connection. When installing a new clamp or reinstalling a modified clamp, tighten the fastener 98 lbf·in (1100 N·cm). Do not retighten the clamp unless the measured torque drops below 50 lbf·in (560 N·cm), at which time it should be tightened again 98 lbf·in (1100 N·cm).

3. Install the hood cable brackets on the radiator. See **Fig. 3**. Tighten the bracket bolts 48 lbf·in (540 N·cm).
4. Position the condenser on the CAC and secure it with the four mounting bolts. See **Fig. 2**. Tighten the bolts 15 lbf·ft (20 N·m).
5. Clamp the refrigerant hoses to the left radiator support strut.
6. Install the air recirculation shields on the radiator. See **Fig. 1**. Tighten the shield bolts 15 lbf·ft (20 N·m).
7. Install the hood. For instructions, see **Group 88**.

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CAC Removal and Installation

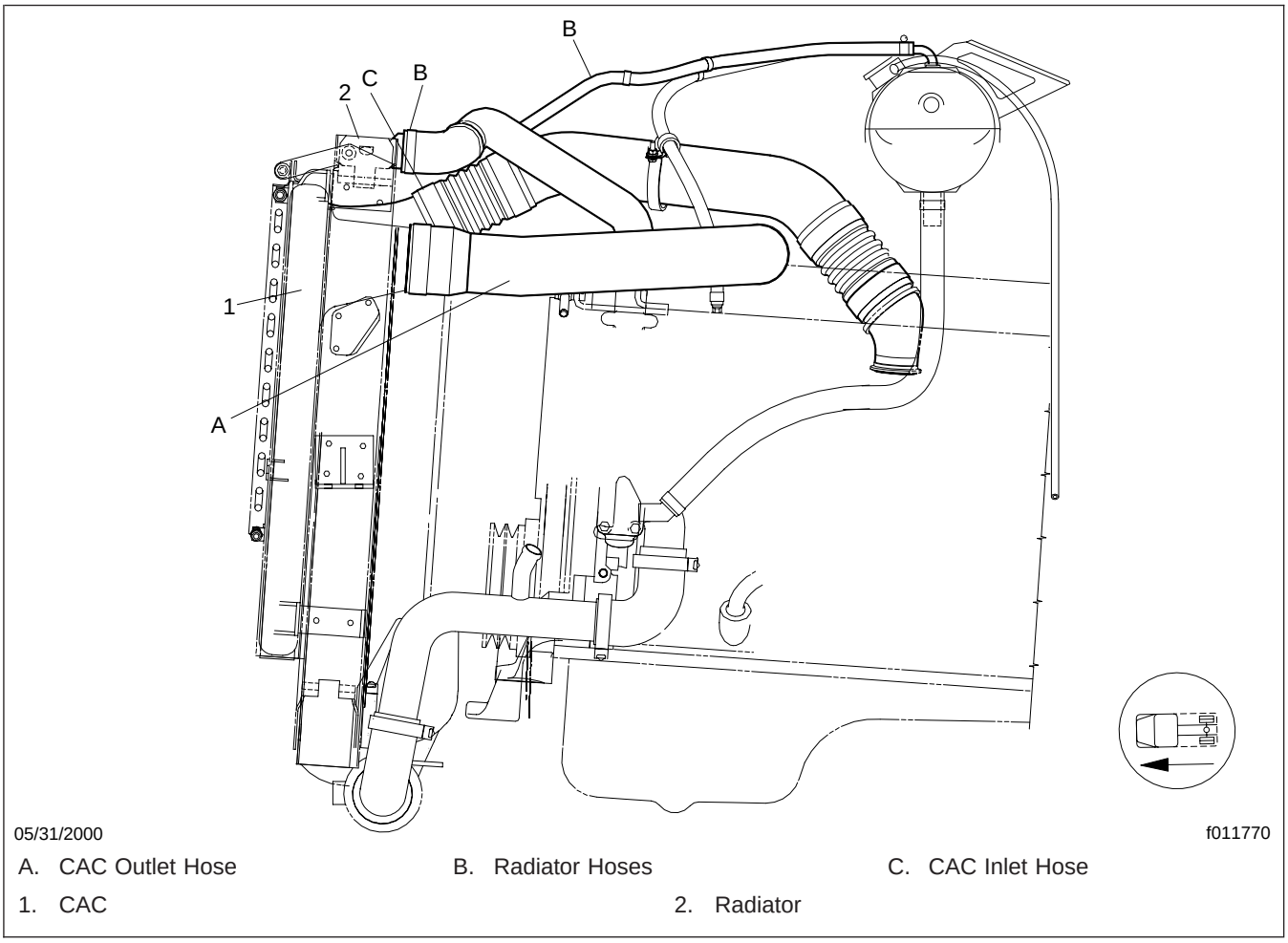


A. CAC Outlet Hose
B. Radiator Hose
C. CAC Inlet Hose
1. CAC
2. Radiator

Fig. 5, CAC and Radiator Hose Connections, Mercedes-Benz MBE900 Engine

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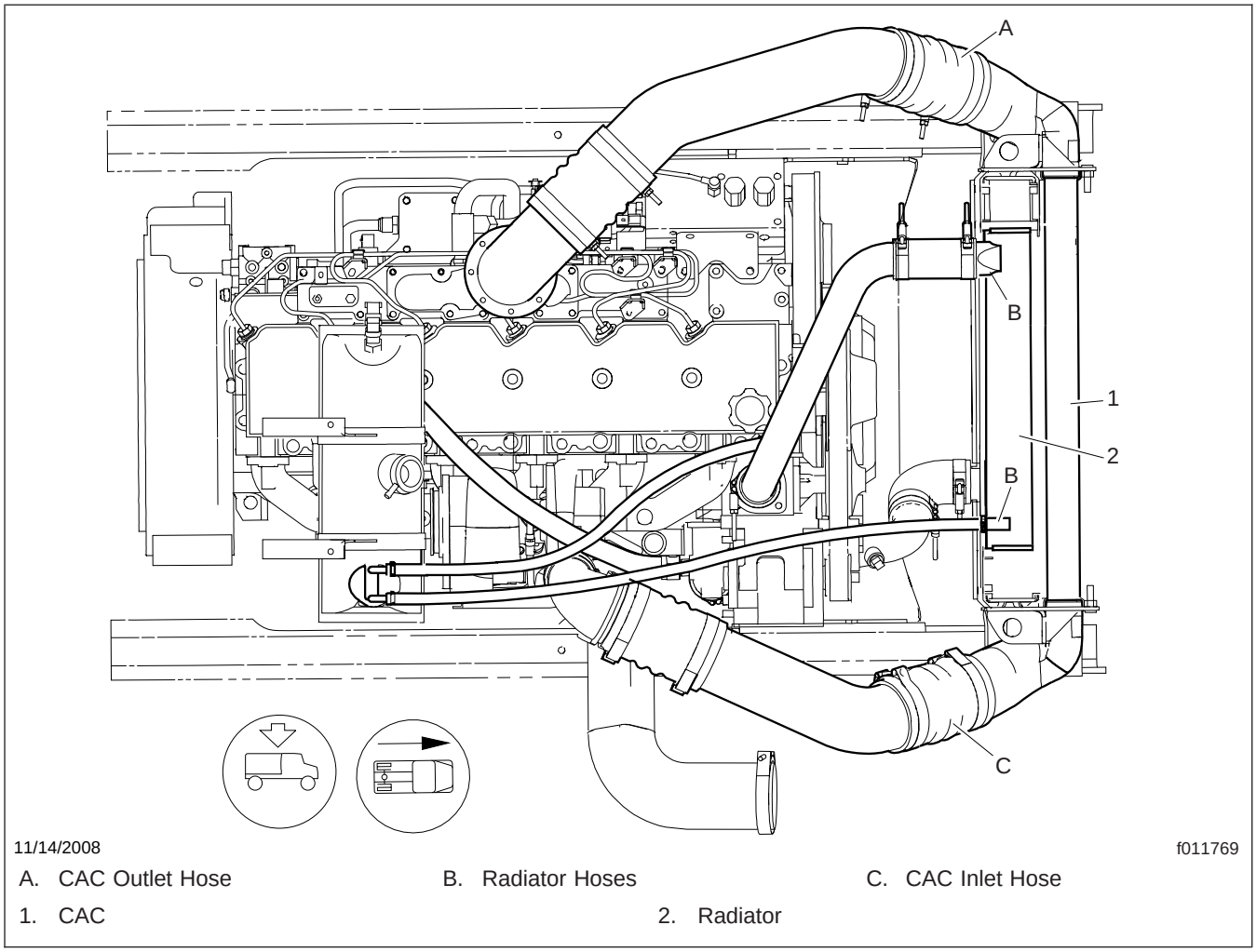
CAC Removal and Installation



A. CAC Outlet Hose
B. Radiator Hoses
C. CAC Inlet Hose
1. CAC
2. Radiator

Fig. 6, CAC and Radiator Hose Connections, Cummins ISB Engine

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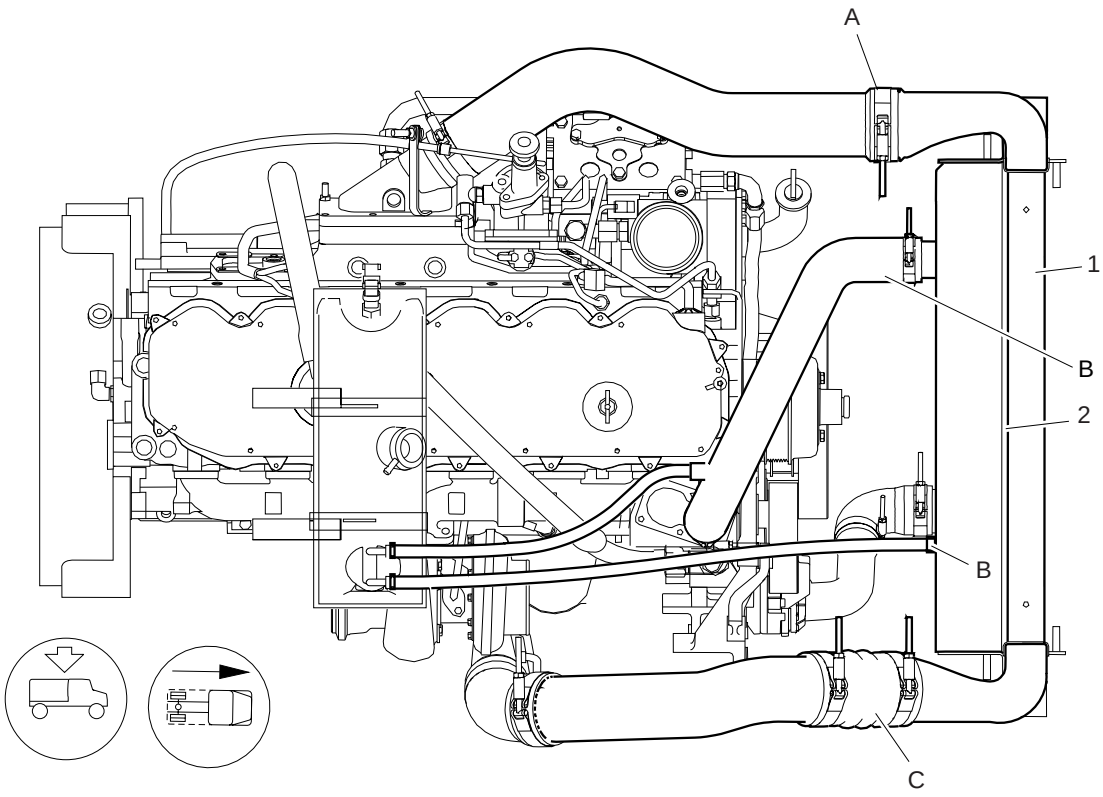


A. CAC Outlet Hose
B. Radiator Hoses
C. CAC Inlet Hose
1. CAC
2. Radiator

Fig. 7, CAC and Radiator Hose Connections, Cummins ISC Engine

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CAC Removal and Installation



11/14/2008 f011768

A. CAC Outlet Hose
B. Radiator Hoses
C. CAC Inlet Hose
1. CAC
2. Radiator

Fig. 8, CAC and Radiator Hose Connections, Caterpillar 3126B Engine

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CAC Inspection and Leakage Test

Inspection

1. Apply the parking brakes and chock the tires.
2. Check the charge air cooler (CAC) convoluted hoses and the inlet and outlet piping for holes or other damage. Also, check for loose or damaged constant tension hose clamps. Replace damaged parts. If hose clamps are loose, turn them so their tightening screws are under the hoses or facing inboard. Tighten the screws 45 lbf·in (500 N·cm).

IMPORTANT: Vehicles built on or after February 26, 2007, have modified constant tension clamps that adjust to changes in diameter at the hose connection. When installing a new clamp or reinstalling a modified clamp, tighten the fastener 98 lbf·in (1100 N·cm). Do not retighten the clamp unless the measured torque drops below 50 lbf·in (560 N·cm), at which time it should be tightened again 98 lbf·in (1100 N·cm).

3. Check the CAC core fins. If the fins are bent, use a small pair of needlenose pliers or a small screwdriver to straighten them.
4. Check the CAC core for clogged fins. Use compressed air or water to dislodge any material restricting airflow through the core.
5. Perform the "CAC Core Leakage Test."

CAC Core Leakage Test

Charge air coolers are designed in such a way that they may leak an insignificant amount of air. The allowable leakage listed in **Table 1** represents a loss of less than 0.1 percent of charge airflow. Based on this rate, there should be no measurable loss of performance.

Leakage Rate Specifications		
Engine	**Pressure Drop in 15 Seconds: psi (kPa)**	**Start Pressure: psi (kPa)**
Caterpillar	5 (34)	30 (207)
Cummins	7 (48)	30 (207)
Detroit Diesel	5 (34)	25 (172)

Table 1, Leakage Rate Specifications

The CAC core leakage test should be performed using a CAC test kit, part number 5039, which can be purchased from Kent-Moore/SPX at 1-800-328-6657.

1. Apply the parking brakes and chock the tires.
2. Connect the test equipment to the CAC core as follows. See **Fig. 1**.
   - 2.1 Remove the inlet and outlet air piping from the convoluted hoses that attach them to the CAC air inlet and air outlet.
   - 2.2 Slip a safety ring with thumbscrew over each convoluted hose, and onto the CAC air inlet and air outlet. Turn the rings so the thumbscrews are facing outboard and the safety chains are inboard. Tighten the thumbscrews securely.
   - 2.3 Install an additional constant tension hose clamp on each convoluted hose.
   - 2.4 Install the test plug without an adapter in the CAC air inlet, and turn the plug so the safety chain is inboard. Tighten both of the rearmost constant torque hose clamps 72 lbf·in (810 N·cm).
   - 2.5 Install the test plug with adapter in the CAC air outlet, and turn the plug so the safety chain is inboard. Tighten each constant tension hose clamp 72 lbf·in (810 N·cm).

⚠ WARNING

Always secure the test plugs with the safety rings. Test pressures could blow out an unsecured test plug at high speed, possibly causing eye injury or other serious personal injury.

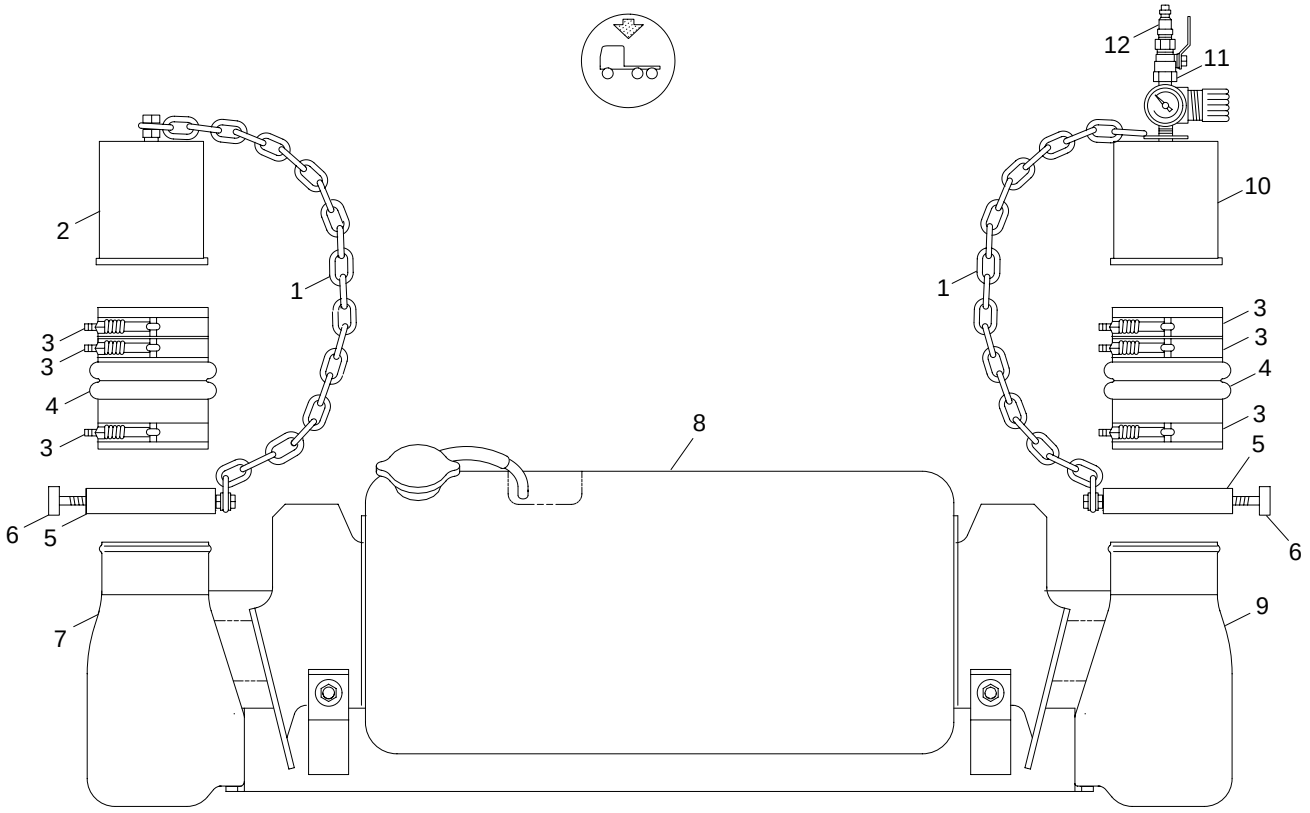
   - 2.6 If not already installed, install a test valve/gauge assembly and air chuck in the test plug with adapter.
   - 2.7 Attach a pressurized air line to the air chuck on the pressure regulator valve.
3. Test the CAC core as follows.

⚠ WARNING

Always wear safety glasses when doing this procedure. Do not stand in front of the test plugs while the core is pressurized. A plug could sud-

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CAC Inspection and Leakage Test



1. Safety Chain
2. Test Plug
3. Constant Tension Hose Clamp
4. Convoluted Hose
5. Safety Ring
6. Thumbscrew
7. CAC Air Inlet
8. Radiator Surge Tank
9. CAC Air Outlet
10. Test Plug with Adapter
11. Test Valve/Gauge Assembly
12. Air Chuck

Fig. 1, CAC Core Testing

denly release debris at high speed, possibly resulting in eye injury or other serious personal injury.

3.1 Open the test valve, then slowly open the pressure regulator valve and allow the CAC to gradually fill with air to the start pressure. See **Table 1**.

3.2 Close the test valve, and watch the gauge for 15 seconds. If there is more than the specified drop in the CAC pressure in 15 seconds, replace the CAC. See **Table 1**.

IMPORTANT: Do not attempt to repair the CAC.

3.3 When testing is completed, reduce the pressure on the pressure regulator valve to bleed air from the CAC.

4. Remove the test equipment (and the additional constant tension hose clamps) from the convoluted hoses.
5. Pull the convoluted hoses and constant tension hose clamps rearward until the hoses cover about 1-1/2 inches (38 mm) of the CAC air inlet and air outlet piping.
6. Turn the clamps so their tightening screws are under the hoses or facing inboard. Tighten the screws 45 lbf·in (500 N·cm).

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CAC Inspection and Leakage Test

IMPORTANT: Vehicles built on or after February 26, 2007, have modified constant tension clamps that adjust to changes in diameter at the hose connection. When installing a new clamp or reinstalling a modified clamp, tighten the fastener 98 lbf·in (1100 N·cm). Do not retighten the clamp unless the measured torque drops below 50 lbf·in (560 N·cm), at which time it should be tightened again 98 lbf·in (1100 N·cm).

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Flushing

If the charge air cooler (CAC) is suspected of being contaminated, flush the CAC.

1. Apply the parking brakes and chock the tires.
2. Remove the CAC. For instructions, see **Subject 100**.
3. Set the CAC in a horizontal position with the inlet and outlet ports facing up.

IMPORTANT: Use only naphtha or mineral spirits to clean the charge air cooler. Do not use caustic solutions such as those that are commonly used in radiator shops. Do not use steam or high-temperature cleaning operations. Caustic solutions, steam, and high-temperature cleaning operations will damage the RTV that seals the charge air cooler tubes to the headers, which may result in leaking.

4. Pour a filtered naphtha or mineral spirits solution into the CAC until it is 40 percent full.
5. Cap the inlet and outlet ports on the CAC.
6. Rock the CAC back and forth so that the solvent travels from one tank, through the tubes, to the other tank and back. Repeat this process ten times.

NOTE: Do not leave the solvent in the CAC for more than 10 minutes.

7. Remove the caps from the inlet and outlet ports.
8. Drain the CAC and properly dispose of the solvent.
9. Leave the caps off and allow the residual solvent to evaporate.
10. Install the CAC. For instructions, see **Subject 100**.

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Restriction Test

After flushing the charge air cooler (CAC) because of turbocharger or engine damage, test the pressure drop across the CAC and air piping, as follows:

1. Remove the pipe plug from the tapped hole in the turbocharger air outlet elbow.

   Remove the pipe plug, or the nylon tube and atomizer for the ether start system (if so equipped), or the air line to the turbocharger air-pressure gauge (if so equipped), from the tapped hole in the rear left-hand side of the intake manifold.

   Install an air pressure gauge in each tapped hole.

2. Operate the engine at rated speed and horsepower; there is no need to operate the engine at its peak torque rating. While operating the engine, read both air pressure gauges.

   Because of air turbulence at the turbocharger outlet, subtract 0.3 inHg (1 kPa) from the pressure measurement taken at this point, to make it a true reading.

   From that reading, subtract the reading taken at the intake manifold. This is the pressure drop of the CAC.

   If the pressure drop is more than 5 inHg (17 kPa), flush or replace the CAC as needed.

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Specifications

Fastener Torque Values		
Description	**Torque**	
	lbf·ft (N·m)	**lbf·in (N·cm)**
CAC to Radiator Mounting Bolt	15 (20)	—
Hood Cable Bracket Bolts	—	48 (540)
Constant Tension Hose Clamps (vehicles built before February 26, 2007)	—	45 (500)
Constant Tension Hose Clamps (vehicles built on or after February 26, 2007)	—	98 (1100)
Condenser Mounting Bolts	15 (20)	—
Air Recirculation Shield Bolt	15 (20)	—

Table 1, Fastener Torque Values

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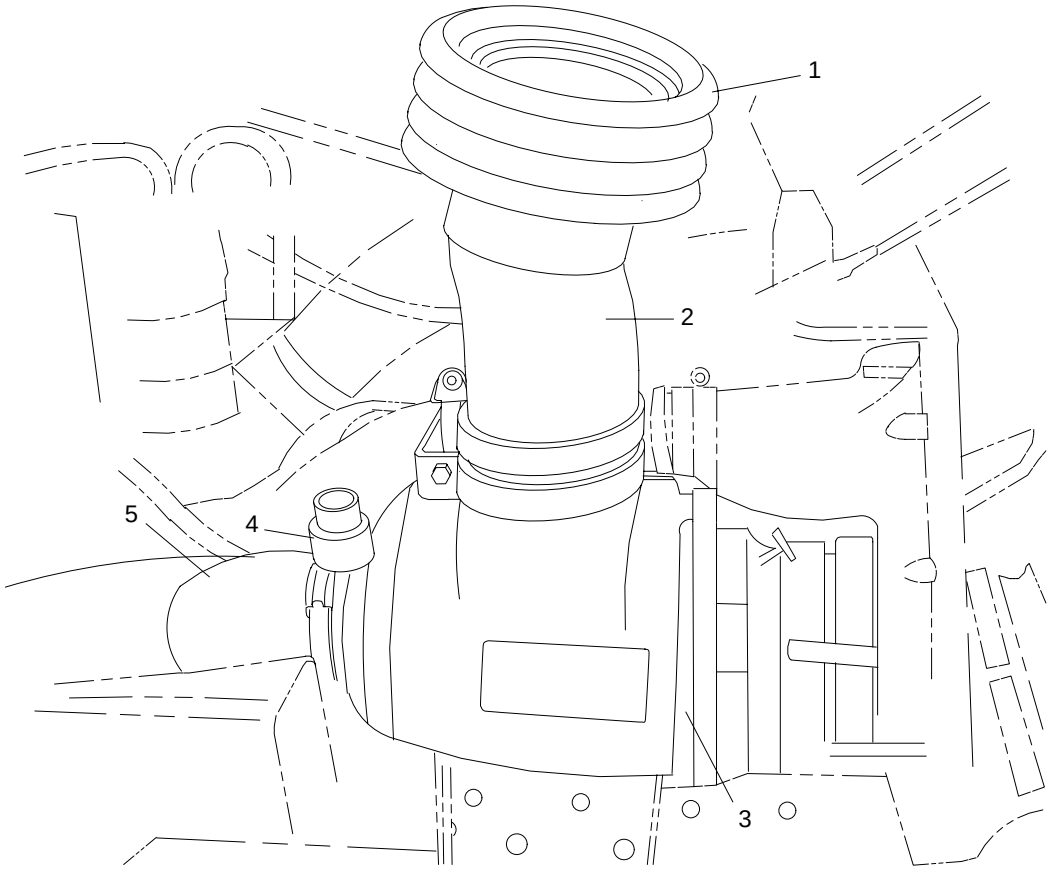
General Information

The air cleaner is horizontally mounted on the outside of the right frame rail, directly behind the bumper. See **Fig. 1**. Air enters through the grill and is diverted into the air cleaner housing where it passes from the outside to the inside of a replaceable, moisture-resistant, fine-mesh paper filter element. See **Fig. 2**. Filtered air exits the air cleaner through an outlet port at the back of the housing.

An air restriction gauge indicates how much air filter capacity has been used and how much remains. See **Fig. 3**. It registers the actual maximum restriction of the filter element (or elements, if two air cleaners are installed) when the engine is operating at full load. The yellow indicator inside the air restriction gauge retains the reading so that the remaining capacity can be read even after the engine is shut down.

NOTICE

Use the air intake restriction gauge rather than visual inspection to determine if servicing the air filter element is necessary. Removal of the air filter element can cause damage to the primary seal, which may allow contaminants into the engine, potentially causing engine damage.



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1. Boot
2. Intake Pipe
3. Air Cleaner
4. Air Restriction Gauge
5. Elbow

Fig. 1, Air Cleaner

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General Information

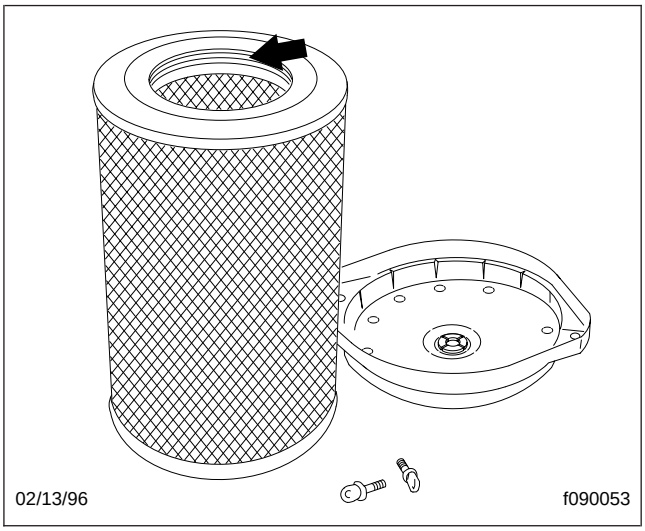


Fig. 2, Air Cleaner Filter

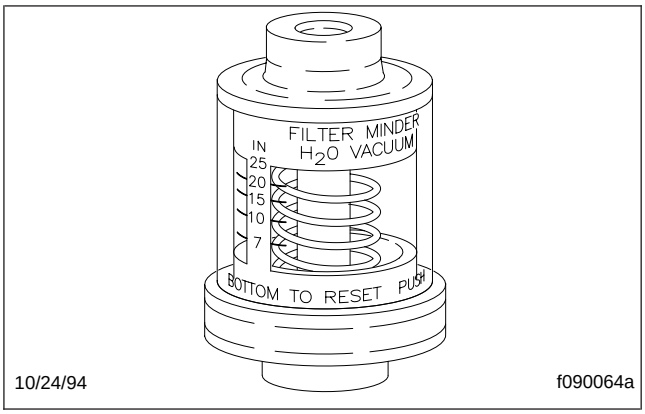


Fig. 3, Air Restriction Gauge

NOTE: The air restriction gauge and tap fittings sometimes become plugged from moisture or engine vapors, possibly causing an incorrect reading.

IMPORTANT: Most engine degreasers are harmful to the polycarbonate (Lexan) plastics that are used in air restriction gauges. When cleaning an engine or other components, avoid getting degreaser on these plastic parts.

A lock-up air restriction gauge is mounted on the air intake pipe. See **Fig. 1**. The gauge has a push-type reset button located at the end opposite the mounting fitting. As an optional location, the air restriction gauge can be mounted in the dashboard. See **Fig. 4**.

Nylon tubing connects the remote-mounted gauge to the air intake piping.

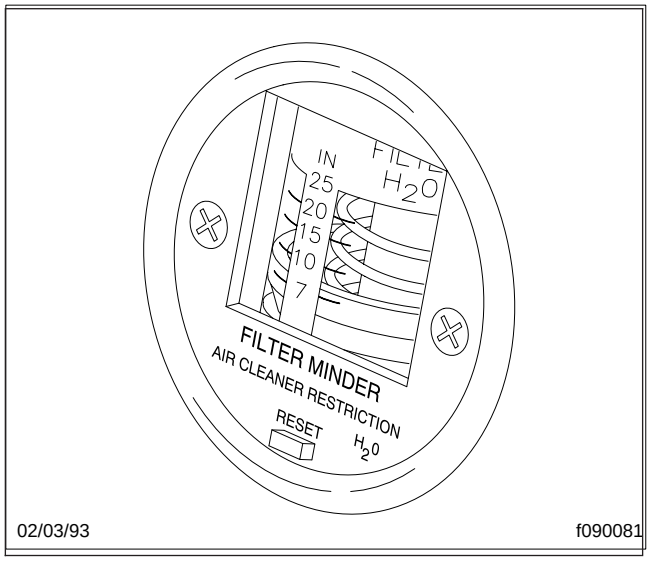


Fig. 4, Air Restriction Gauge, Dash-Mounted

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Air Cleaner Element Replacement

Replacement

NOTE: Replace the air cleaner element only when it reaches the maximum restriction level allowed by the engine manufacturer. See **Subject 120**.

NOTICE

Do not operate the engine with the air filter element or any intake component removed as damage to the engine could occur.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Check the seams around the air cleaner inlet and outlet ports. Check the outer surface of the cleaner housing for cracks, dents or damage. If there are signs of leaks or damage, repair or replace the parts.
4. Remove the two thumb screws from the front of the housing. Remove the cover.
5. Grip the base of the filter element firmly. Gently twist and pull the filter element out of the housing.

NOTICE

Do not clean or reuse air filter elements. Cleaning and reusing the elements increases the chances of dirt entering the engine. Always replace with a new one.

6. Inspect the element and clean the housing.
   - 6.1 Check the filter element for soot or oil. If soot is present, check for leaks in the engine exhaust system and for exhaust from other equipment. If the element is oily, check for fumes escaping from the engine crankcase breather. Excessive oil mist shortens the life of any dry-type filter; correct the cause.
   - 6.2 Inspect the filter element radial seal surface for dust trails (from gasket leakage). See **Fig. 1**. Check the cleaner housing for damage or dirt build-up that may cause sealing problems. If there is leakage or damage, repair or replace the parts.

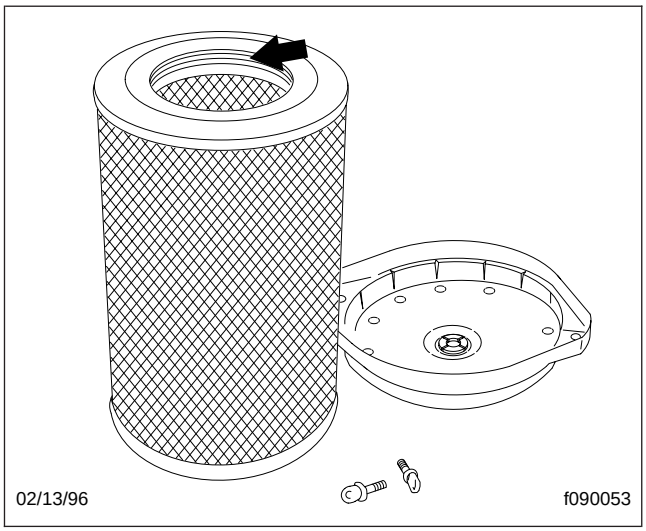


Fig. 1, Radial Seal Surface of Filter Element

   - 6.3 Wipe the inside of the cleaner housing with a clean damp cloth.

NOTICE

Remove any dirt in the cleaner housing. Failure to do so could cause dirt to be drawn into the engine, causing damage.

7. Inspect the new filter element before installing it. See **Fig. 1**.
   - 7.1 Inspect the element for radial seal surface damage and dented metal parts. If the radial seal surface is damaged to the extent that dust might bypass it, do not use the element.
   - 7.2 Place a bright light inside the element, and rotate the element while looking through it from the outside. The light will reveal, by a bright spot, any hole or rupture. Any hole in the element will allow dust to enter the engine. Do not use the element if it is damaged.
8. Position the filter element in the air cleaner housing. Push the element into place until only about 1 inch (2.5 cm) still extends out of the housing.
9. Place the cover over the element and secure the cover with the two thumb screws.
10. Check all clamps for tightness, and all ducting and hoses for leaks; repair as necessary.

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Air Cleaner Element Replacement

11. Close and latch the hood.
12. Remove the chocks from the rear tires.

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Replacement

NOTICE

All air intake components and connections must be air- and water-tight. Dirt or dust entering the engine can cause internal engine damage. Much of the dirt and dust are silicates, which fuse into abrasive glass-like particles during engine combustion. These particles can grind piston rings, pistons, and cylinder liners. Do not operate the engine with the air filter element or any air intake component removed.

IMPORTANT: Do not modify air cleaners or air intake ducting.

If the air cleaner housing has been dented or damaged, immediately check all ducting and connections to the air cleaner for leakage. Adjust or replace parts as necessary. If needed, replace the air cleaner as follows:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Remove the air cleaner. See **Fig. 1**.
   - 3.1 Remove the two thumb screws securing the housing cover and remove the cover.
   - 3.2 Remove the filter element from the housing. See **Subject 100**.
   - 3.3 Loosen the hose clamps holding the pipe to the top of the housing. Remove the pipe and clamps from the top of the housing.
   - 3.4 Loosen the hose clamp connecting the elbow to the back of the air cleaner housing. Remove the air cleaner housing from the elbow and cover the open end of the elbow.
   - 3.5 Remove the three bolts, washers and nuts that secure the housing to its mounting bracket.
   - 3.6 Take the air cleaner off its mounting bracket.
4. Install the new air cleaner.
   - 4.1 Position the air cleaner housing on its mounting bracket. Secure the housing with the three bolts, washers and nuts. Tighten them 28 lbf·ft (38 N·m).
   - 4.2 Uncover the elbow and connect it to the air cleaner housing. Tighten the hose clamp.
   - 4.3 Connect the pipe to the top of the new housing. Tighten the hose clamps.
   - 4.4 Check all clamps for tightness, and all ducting and hoses for leaks; repair as necessary.

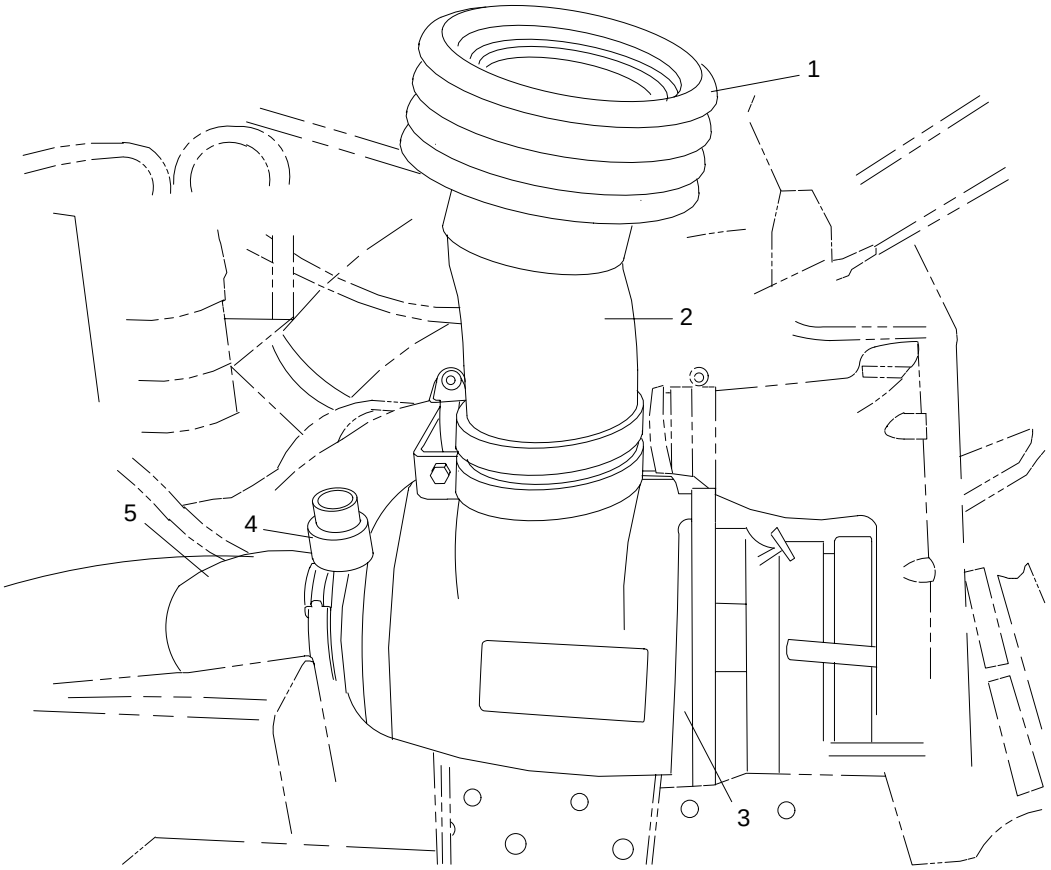
NOTICE

Do not clean or reuse air filter elements. Cleaning and reusing the elements increases the chances of dirt entering the engine. Always replace with a new one.

5. Inspect a new filter element and install it in the new air cleaner. See **Subject 100**.
6. Close and latch the hood.
7. Remove the chocks from the rear tires.

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Air Cleaner Replacement



1. Boot
2. Intake Pipe
3. Air Cleaner
4. Restriction Indicator
5. Elbow

Fig. 1, Air Cleaner

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Element Restriction Check

The restriction of air flow through the air cleaner element is measured at the tap in the air transfer tube joined to the cleaner outlet.

On vehicles with an intake-duct-mounted restriction indicator (manual- or automatic-reset), the indicator is mounted in a safety fitting in the air intake piping.

On vehicles with a dash-mounted restriction indicator (manual-reset) (**Fig. 1**) or air restriction gauge (automatic-reset) (**Fig. 2**), a hose connects the indicator or gauge to the safety fitting in the air intake piping.

NOTICE

Use the air intake restriction gauge rather than visual inspection to determine if servicing the air filter element is necessary. Removal of the air filter element can cause damage to the primary seal, which may allow contaminants into the engine, potentially causing engine damage.

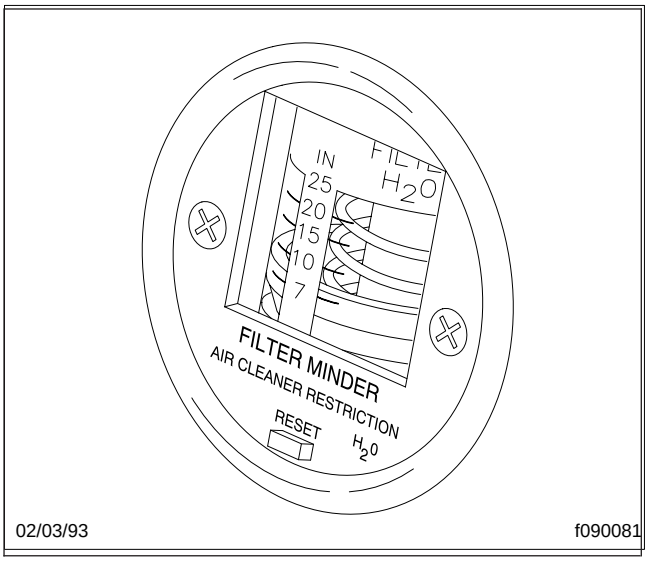


Fig. 1, Optional Dash-Mounted Manual-Reset Air Restriction Indicator

On vehicles *without* an indicator or gauge, a water manometer or a service gauge must be connected to the air intake ducting to check element restriction.

- For a vehicle with a manual-reset air restriction indicator, check the indicator with the engine off to see if air restriction equals or exceeds the value shown in **Table 1** for maximum air restriction at *full-load* and governed rpm. If air restriction is at or above the maximum, push the reset button on the dash-mounted or intake-duct-mounted indicator, then operate the engine at *no-load* and governed rpm, and compare the indicator reading with the value shown in **Table 1** for maximum air restriction at *no-load* and governed rpm.
- For a vehicle with an air restriction gauge, or a restriction indicator that resets automatically when the engine is shut down, operate the engine at *no-load* and governed rpm, and compare the gauge/indicator reading with the value shown in **Table 1** for maximum air restriction at *no-load* and governed rpm.
- For a vehicle without a gauge or indicator, test restriction with a water manometer or a service gauge. Refer to the test equipment manufacturer's literature for test procedures. Operate the engine at *no-load* and governed rpm, and compare the reading with the value shown in **Table 1** for maximum air restriction at *no-load* and governed rpm.

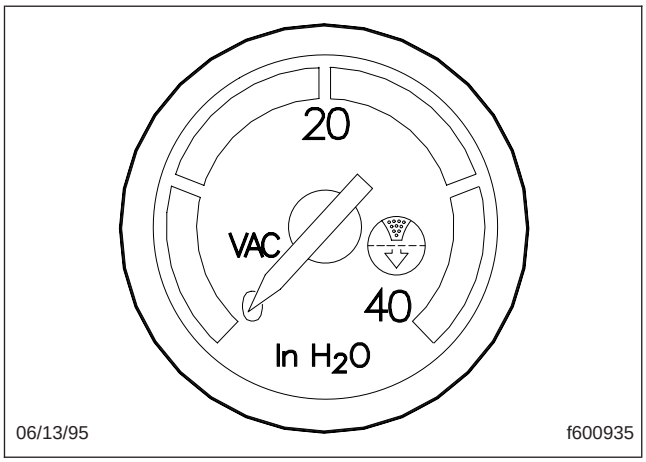


Fig. 2, Optional Dash-Mounted Automatic-Reset Air Restriction Gauge

If air restriction equals or exceeds the value shown in **Table 1** for maximum air restriction at *no-load* and governed rpm, replace the air cleaner element. See **Subject 100**.

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Air Cleaner Element Restriction Check

Maximum Air Restriction in Inches of Water (inH $_2$O)		
Engine	**At Full-Load and Governed RPM**	**At No-Load and Governed RPM**
Mercedes-Benz	20	10
Cummins	25	12
Caterpillar™	25	12

Table 1, Maximum Air Restriction in Inches of Water (inH $_2$O)

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Specifications

Fastener Torques			
Description	**Grade**	**Size**	**Torque lbf·ft (N·m)**
Air Cleaner Mounting Nuts	5	3/8–16	28 (38)

Table 1, Fastener Torques

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General Information

The Bendix Tu-Flo 550 and 750 are two cylinder, single-stage, reciprocating air compressors, which supply compressed air to the vehicle air system. The Tu-Flo 550 has a rated displacement of 13.2 cfm (374 L/min) of air at 1250 rpm. The Tu-Flo 750 has a rated displacement of 16.5 cfm (468 L/min) of air at 1250 rpm.

The compressor draws air from the air intake pipe, compresses the air, and delivers it to the air system supply reservoir. The compressor runs continuously but has "loaded" and "unloaded" modes which are regulated by the air governor and the compressor loading assembly. When the governor sends an air signal to the unloader assembly, the unloader assembly holds the compressor air intake valve open so that no more compressed air is forced into the air system. As air in the system is used, its pressure drops, and at 90 psi (620 kPa), the air governor stops the signal to the compressor. Without the signal, the unloader assembly automatically closes the compressor air intake valve to force more air into the system.

On vehicles with air dryers, when the system reaches the cut-out pressure of 120 psi (825 kPa), the air governor also sends an air signal to open the sludge ejector in the air dryer.

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Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Open the hood.
3. Drain the air system.

⚠ WARNING

Wear goggles when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

4. Using a cleaning solvent, remove road dirt and grease from the outside of the compressor. Dry the compressor with compressed air.
5. Drain the radiator coolant; see **Group 20** in this manual for instructions.
6. Loosen the constant-torque hose clamps at both ends of the charge air cooler outlet air piping. Remove the piping to access the air compressor.
7. Marking their locations and positions, disconnect all air, coolant, and oil lines attached to the compressor. Remove tie straps as needed to move the lines out of the way.

NOTE: On vehicles with combined air dryers and air reservoir modules, the air governor is mounted on the module not the air compressor.

8. If the air governor is mounted on the compressor, remove it and the governor mounting gasket.
9. Remove the compressor support bracket, if so equipped.
10. Support the compressor, and remove the bolts that attach it to the auxiliary drive housing, accessory drive, or timing gear plate. Remove the compressor, gasket, and splined coupling.
11. Discard all mounting gaskets.

Installation

IMPORTANT: Be sure the gasket surfaces are cleaned and not damaged.

1. Install the splined coupling (if so equipped) and a new compressor gasket. Hold the compressor in place, and install the bolts that attach it to the auxiliary drive housing, accessory drive, or timing gear plate. See the engine shop manual or rebuild manual for final torque specification.
2. Install the compressor support bracket, if so equipped.
3. If applicable, use a new air governor mounting gasket. Install the air governor on the compressor.
4. Identify and connect all air, coolant, and oil lines to the compressor. Secure the lines as needed with tie straps.
5. Install the charge air cooler outlet air piping. Tighten the constant-torque hose clamp screws 45 lbf·in (500 N·cm).
6. Fill the engine cooling system; see **Group 20** in this manual for instructions.
7. Operate the engine and check for leaks.
8. Return the hood to the operating position.
9. Remove the chocks from the tires.

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Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Drain the air from all air reservoirs.
3. Remove the air compressor from the engine. For instructions, see **Subject 100**.
4. Remove the cylinder head from the crankcase. See **Fig. 1**.

   4.1 Scribe an alignment mark across the cylinder head and the crankcase for assembly alignment.

   IMPORTANT: Do not use a marking method, such as chalk, that can be wiped off during assembling.

   4.2 Note the position of any attached components. Remove the cylinder head capscrews.

   4.3 Tap the cylinder head with a soft mallet to break the gasket seal. Remove the cylinder head.

Installation

1. Scrape off any gasket material from the cylinder head and the crankcase.

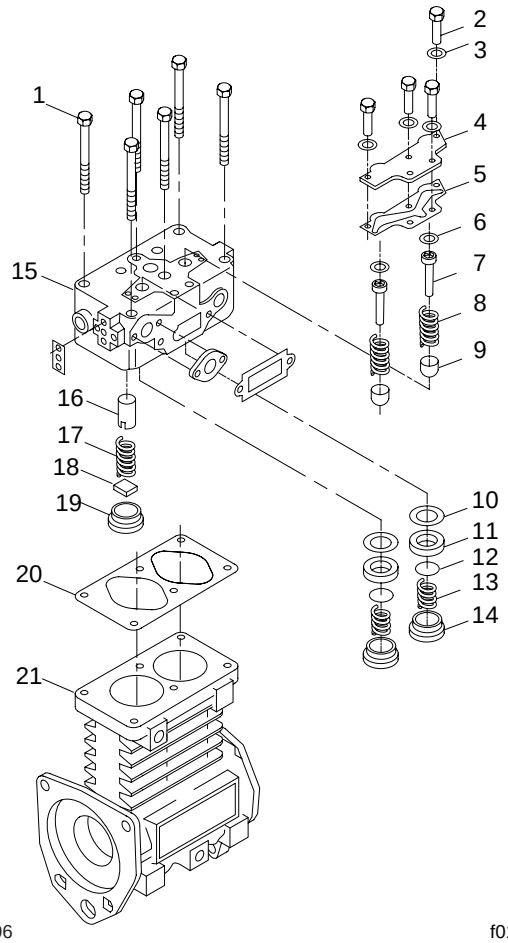
⚠ WARNING

Wear goggles when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

2. Using compressed air, blow dirt particles or gasket material from all cylinder cavities.
3. Install the cylinder head on the compressor crankcase.

   3.1 Place a new cylinder head gasket on the crankcase. If the cylinder head gasket has a bead on one side, install the gasket with the bead side up.

   3.2 Using the previously marked alignment, position the cylinder head on the crankcase.



1. Cylinder Head Capscrew
2. Unloader Plate Capscrew
3. Unloader Plate Lockwasher
4. Unloader Plate
5. Unloader Plate Gasket
6. O-Ring
7. Unloader Piston
8. Spring
9. Unloader Bushing
10. Gasket
11. Inlet Valve Seat
12. Inlet Valve
13. Inlet Valve Spring
14. Inlet Valve Stop
15. Cylinder Head
16. Discharge Valve Stop
17. Discharge Valve Spring
18. Discharge Valve
19. Discharge Valve Seat
20. Cylinder Head Gasket
21. Crankcase

Fig. 1, Cylinder Head, Exploded View

   3.3 Position on the cylinder head any brackets, spacers, or clamps that were removed. Install the cylinder head cap-

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Cylinder Head Removal and Installation

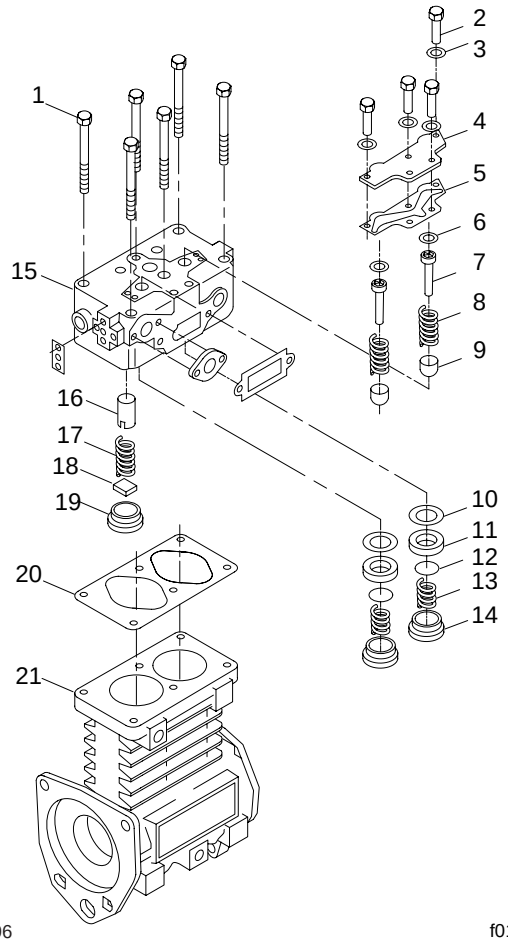
screws and tighten them evenly, in a cross pattern 37 to 42 lbf·ft (50 to 57 N·m).

4. Connect the air discharge line and the water lines to the cylinder head.
5. Install the air compressor on the engine. For instructions, see **Subject 100**.
6. Operate the engine and make sure there are no coolant leaks.
7. Remove the chocks from the tires.

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Cylinder Head Disassembly, Cleaning and Inspection, and Assembly

Disassembly (See Fig. 1)



1. Cylinder Head Capscrew
2. Unloader Plate Capscrew
3. Unloader Plate Lockwasher
4. Unloader Plate
5. Unloader Plate Gasket
6. O-Ring
7. Unloader Piston
8. Spring
9. Unloader Bushing
10. Gasket
11. Inlet Valve Seat
12. Inlet Valve
13. Inlet Valve Spring
14. Inlet Valve Stop
15. Cylinder Head
16. Discharge Valve Stop
17. Discharge Valve Spring
18. Discharge Valve
19. Discharge Valve Seat
20. Cylinder Head Gasket
21. Crankcase

Fig. 1, Cylinder Head, Exploded View

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the compressor from the vehicle. For instructions, see **Subject 100**.
3. Place the compressor on a suitable work surface. Remove the cylinder head from the crankcase. For instructions, see **Subject 110**.
4. Remove the unloader mechanism.
   - 4.1 Remove the unloader plate capscrews, lockwashers, and the unloader plate. Scrape off any gasket material from the unloader plate and the cylinder head.
   - 4.2 Remove and discard the unloader pistons, O-rings, and springs.
5. Check the unloader piston bushings. If damaged or worn excessively, replace the compressor.

NOTE: Before disassembling the discharge valve mechanism, measure and record the discharge valve travel from closed to completely open. If the measurement exceeds 0.046 inch (1.17 mm), replace the compressor. If the measurement is within 0.046 inch, proceed to the next step.

6. Using a 9/16-inch Allen wrench, remove and discard the discharge valve seats, discharge valves, and discharge valve springs.
7. Remove and discard the inlet valve stops and springs, along with the inlet valves, inlet valve seats, and gaskets.

Cleaning and Inspection

1. Remove carbon deposits from the discharge cavity, rust and scale from the cooling cavities.
2. Clean carbon and dirt from the inlet and unloader passages.
3. Scrape all foreign material from the body surfaces.

⚠ WARNING

Wear goggles when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

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Cylinder Head Disassembly, Cleaning and Inspection, and Assembly

4. Using solvent, thoroughly clean all metal parts removed from the cylinder head. Using shop air, blow the dirt particles from the cavities and passages.
5. Check that all cavities and passages are clear, including the inlet and unloader.
6. Check that all mating surfaces are clean of old gasket material. Remove any old material.
7. Inspect the cylinder head for cracks or damage.
8. With the cylinder head and head gasket secured to a flat surface or to the crankcase, apply shop air pressure to one of the coolant ports with all other ports plugged.
9. Check for leaks by applying a soap solution to the exterior of the body. If leakage is detected, replace the compressor.

Assembly (See Fig. 1)

1. Install the unloader mechanism.
   - 1.1 With the unloader pistons being prelubricated from the manufacturer, install the new unloader springs, and the new unloader pistons. The unloader piston O-rings are pre-installed on the unloader pistons.
   - 1.2 Install the new unloader plate gasket and the unloader plate.
   - 1.3 Install the unloader plate lockwashers and capscrews. Tighten the capscrews 15 to 18 lbf·ft (20 to 25 N·m) in a cross pattern.
2. Install the inlet valve mechanism.
   - 2.1 Install the new inlet valve gaskets, new inlet valve seats, new inlet valves, and the new inlet valve springs into their bores.
   - 2.2 Install the new inlet valve stops and tighten 70 to 90 lbf·ft (95 to 122 N·m).
3. Install the new discharge valve springs, new discharge valves, and the new discharge valve seats into their bores. Tighten the seats 70 to 90 lbf·ft (95 to 122 N·m). The discharge valve travel should be 0.030 inches to 0.046 inch (0.762 mm to 1.17 mm).
4. Test for leakage at the discharge valves by applying 100 psi (690 kPa) through the cylinder head discharge port and apply soap solution to the discharge valve and seat. Leakage in the form of soap bubbles is permissible.

   If there is extreme leakage, leave the air pressure applied and with a hardwood dowel and a hammer, tap the discharge valves off of their seats several times. This will improve the seal between the discharge valve and the valve seat and should reduce leakage.

   If there is still extreme leakage, replace the discharge valve seats.

   With the air pressure still applied at the discharge port of the cylinder head, check for leakage around the discharge valve stop on top of the cylinder head. No leakage is permitted.
5. Install the compressor cylinder head. For instructions, see **Subject 110**.
6. Tighten the unloader plate capscrews 15 to 18 lbf·ft (20 to 25 N·m).
7. Install the compressor on the engine. For instructions, see **Subject 100**.
8. Remove the chocks from the tires.

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Crankcase Disassembly, Cleaning and Inspection, and Assembly

Disassembly

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the compressor from the vehicle and place it on a suitable work surface. For instructions, see **Subject 100**.
3. Remove the air compressor cylinder head. For instructions, see **Subject 110**.
4. Before disassembling the compressor, use a metal scribe to mark the parts with matching numbers or lines.

IMPORTANT: Do not use a marking method, such as chalk, that can be wiped off during assembling.

5. Remove the pistons and connecting rods. See **Fig. 1**.
   - 5.1 Remove the base plate capscrews.
   - 5.2 Tap the base plate with a soft mallet to break the gasket seal.
   - 5.3 Scrape off any gasket material from the crankcase and base plate.
   - 5.4 Remove the connecting rod bolts and connecting rod caps.
   - 5.5 Push the pistons and connecting rods out through the cylinder bore of the crankcase. Discard the pistons and connecting rod assemblies including the connecting rod caps and the connecting rod bolts.
6. Remove the crankshaft.
   - 6.1 Remove the key or keys from the crankshaft and any burrs from the crankshaft where the key or keys were removed.

   NOTE: Some compressors may have a crankshaft key at each end.

   - 6.2 Remove the end-cover capscrews, the end cover, end-cover seal, and the rear thrustwasher.
   - 6.3 If the compressor has sleeve bearings, remove and discard the sleeve bearings from the crankcase and the end cover.
   - 6.4 If the compressor has a ball-type main bearing, remove the rear snap ring (if so equipped). Press the crankshaft and ball bearing from the crankcase. Press the ball bearing from the crankshaft.
   - 6.5 Remove and discard the front and rear thrustwashers.

Cleaning and Inspection

1. Scrape off any gasket material from the top and bottom of the crankcase.

⚠ WARNING

Wear goggles when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

2. Clean all parts with solvent before inspecting them and dry the parts with compressed air.
3. Clean all oil passages through the crankshaft, crankcase, end cover, and base plate. Inspect the passages with a wire to be sure they are clear.
4. Check the fit of the new pistons, piston rings, and connecting rods.
   - 4.1 The pistons for the Tu-Flo 750 compressor are similar to the Tu-Flo 550 and may be identified by the distance from the center of the wrist pin to the top of the piston. See **Fig. 2**.
   - 4.2 To check the ring gap, place the ring in the top of the cylinder bore and, using a piston, push the ring to mid-point of the cylinder bore and check the ring gap. The gap for compression rings must be 0.002 to 0.013 inch (0.050 to 0.330 mm).

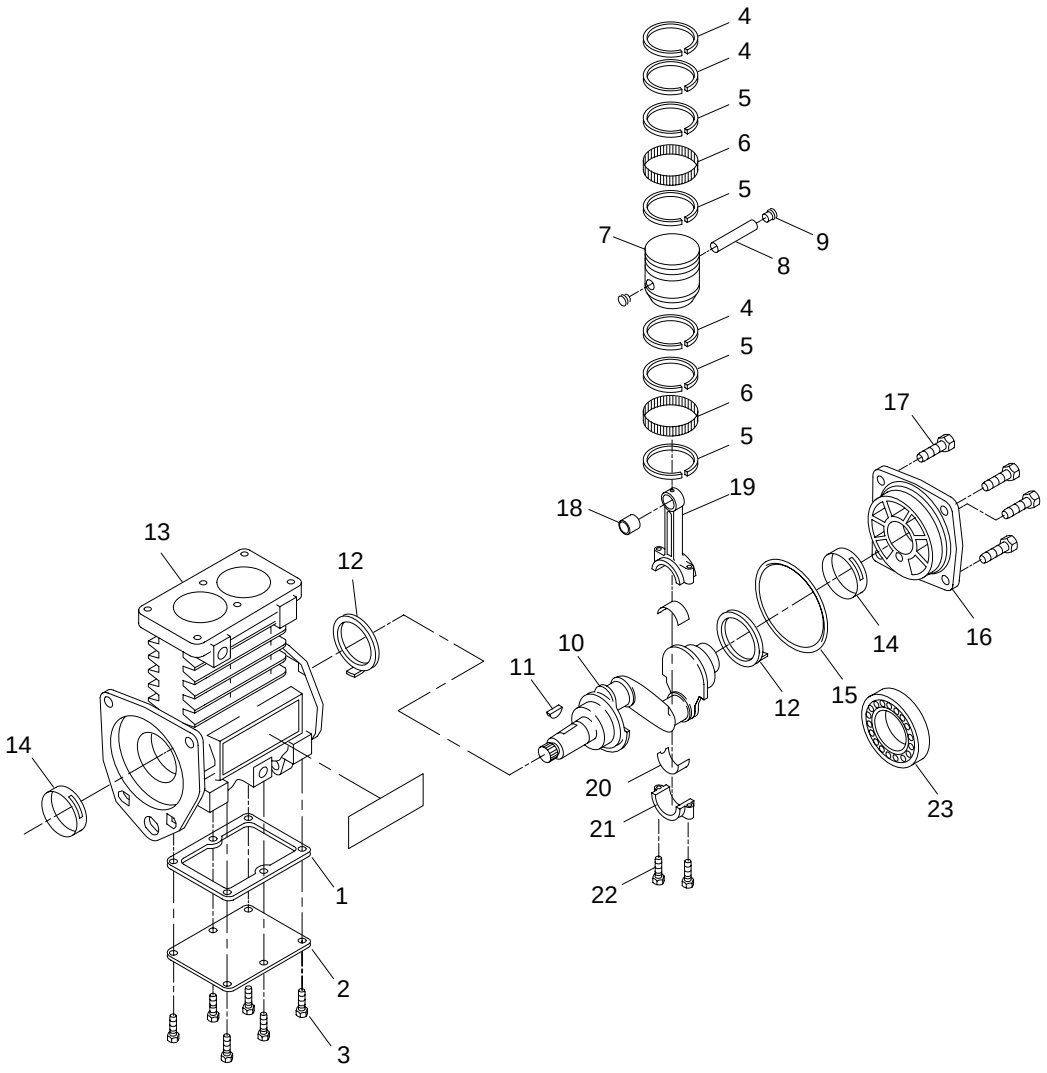
     The gap for oil ring and expander ring must be 0.010 to 0.040 inch (0.254 to 1.016 mm). See **Fig. 3** and **Table 1**.

Allowable End Gap	
Ring	**End Gap in Inch (mm)**
Compression	0.002–0.013 (0.050–0.330)
Oil and Expander	0.010–0.040 (0.254–1.016)

Table 1, Allowable End Gap

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Crankcase Disassembly, Cleaning and Inspection, and Assembly



1. Base Gasket
2. Base Plate
3. Base Plate Capscrew
4. Compression Ring
5. Oil Ring
6. Expander Ring
7. Piston
8. Wrist Pin
9. Wrist Pin Button
10. Crankshaft
11. Crankshaft Key
12. Thrust Washer
13. Crankcase
14. Sleeve Bearing
15. End Cover Seal
16. End Cover
17. End Cover Capscrew
18. Wrist Pin Bushing
19. Connecting Rod
20. Connecting Rod Bearing (Sets)
21. Connecting Rod Cap
22. Connecting Rod Bolt
23. Ball Bearing

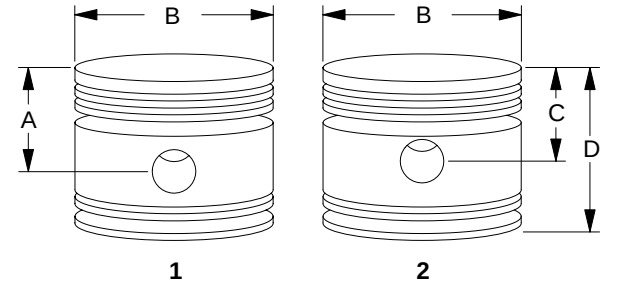
Fig. 1, Crankcase, Exploded View

4.3 Check the fit of the piston rings in the piston ring grooves. Groove clearance for the compression ring is 0.002 to 0.004 inch (0.051 to 0.101 mm). Groove clearance for the expander and oil rings is 0.000 to 0.006 inch (0.000 to 0.152 mm).

5. Inspect the crankcase.

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Crankcase Disassembly, Cleaning and Inspection, and Assembly



A. 1.25 in (31.75 mm)
B. 2.78 in (70.61 mm)
C. 1.06 in (26.92 mm)
D. 2.17 in (55.12 mm)
1. Tu-Flo 550 Compressor Piston
2. Tu-Flo 750 Compressor Piston

Fig. 2, Piston Comparison

5.1 Check the crankcase surfaces for cracks and damage.

5.2 On compressors where main ball bearings are used, the difference between the outside diameter of the ball bearing outer race and the inside diameter of the crankcase bore should be 0.0003 inch (0.008 mm) tight to 0.0023 inch (0.058 mm) loose. This will maintain a correct fit. Replace the compressor if the fit is too loose.

5.3 Check the end cover for cracks and damage. Replace them as necessary.

5.4 Check the cylinder bore with an inside micrometer or with calipers. Cylinder bores which are scored, out-of-round, or tapered more than 0.0005 inch (0.013 mm) should be rebored and honed oversize. Oversized pistons and piston rings are available in 0.010 inch (0.254 mm), 0.020 inch (0.508 mm), and 0.030 inch (0.762 mm).

6. Inspect the crankshaft.

6.1 Check the crankshaft splines, gear teeth, tapered ends, and all machined and ground surfaces for wear, scoring, or damage. Repair the damage, or replace the crankshaft if needed.

6.2 Check the crankshaft connecting rod journals for extreme scoring, and measure them for out-of-round wear. Standard crankshaft journals are 1.1242 to 1.1250 inches (28.555 to 28.575 mm) in diameter. If the crankshaft is extremely scored or worn out-of-round, and cannot be reground, replace it.

NOTE: If the crankshaft needs to be reground or replaced, do so before proceeding to the next step. For compressors having reground crankshafts, connecting rod bearing inserts are available in 0.010 inch (0.254 mm), 0.020 inch (0.508 mm), and 0.030 inch (0.762 mm) undersize.

Assembly (See Fig. 1)

1. For a compressor with sleeve bearings, install the crankshaft and end cover.

1.1 Press the new sleeve bearings into the end cover and crankcase. Make sure the slots in the bearings line up with the oil passages in the end cover and crankcase.

If there is no oil passage present in the crankcase, press the sleeve bearing into the crankcase with the slot located 90 degrees from vertical.

1.2 Install the new front thrustwasher with the tang inserted in the slot toward the flange.

1.3 Insert the crankshaft and the rear thrustwasher with the tang toward the end cover of the compressor.

1.4 Place the end-cover seal on the boss of the end cover.

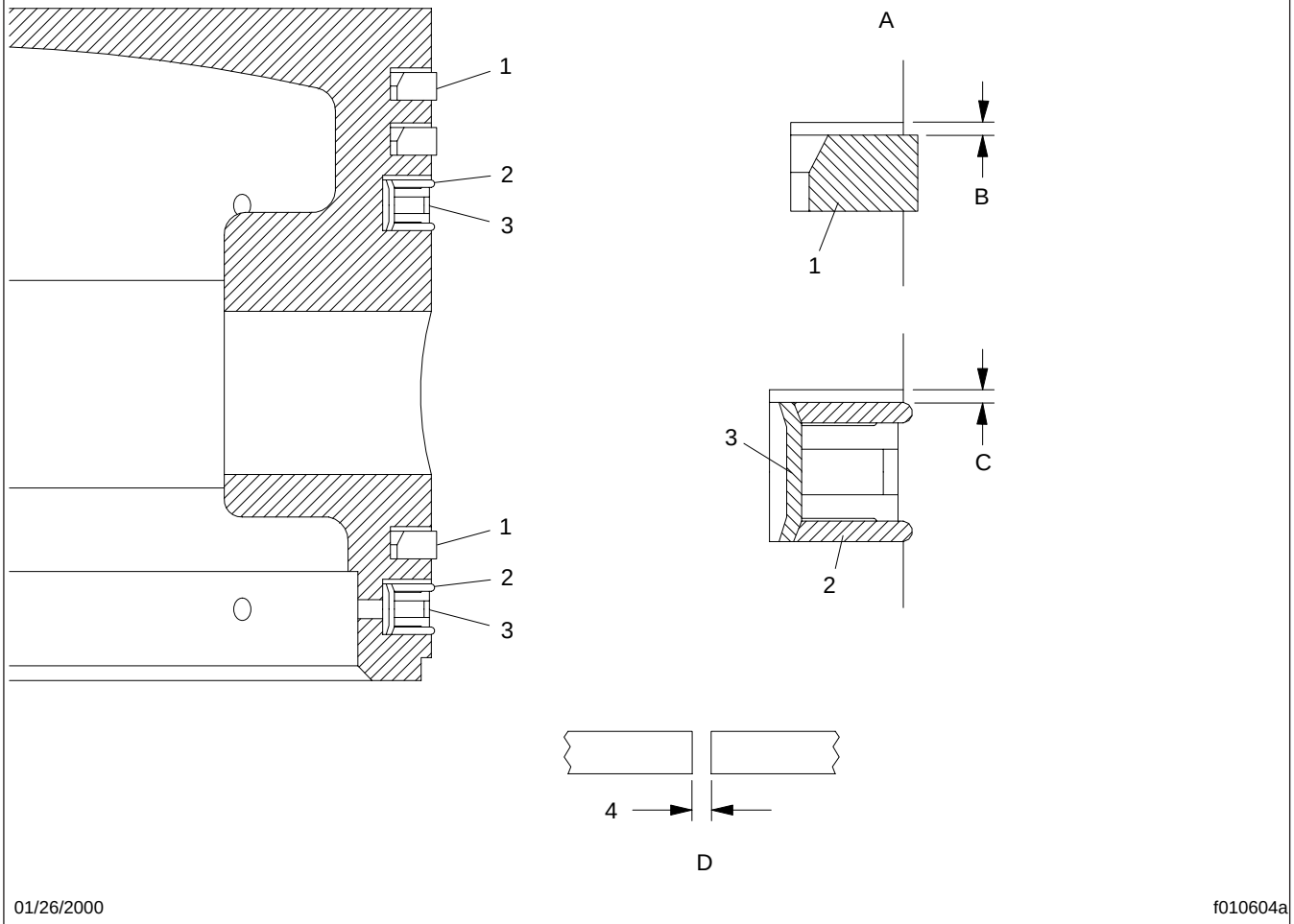
1.5 Install the end cover making sure not to pinch the end cover seal. Make sure the tang of the rear thrustwasher is inserted in the slot of the end cover. Install the capscrews and tighten the capscrews 15 to 18 lbf·ft (20 to 25 N·m) in a cross pattern.

2. If one end of the compressor uses a ball-type main bearing, install the crankshaft and endcovers.

2.1 Press the new sleeve bearings into the crankcase. Make sure the slots in the

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Crankcase Disassembly, Cleaning and Inspection, and Assembly



A. Side Clearance
B. 0.002 to 0.013 in (0.05 to 0.33 mm)
1. Compression Ring
2. Oil Ring
C. 0.01 to 0.04 in (0.254 to 1.016 mm)
D. Ring End Gap With Ring in the Cylinder Bore
3. Expander Ring
4. End Gap

Fig. 3, Piston Specifications

bearings line up with the oil passage in the end cover and crankcase.

If there is no oil passage present in the crankcase, press the sleeve bearing into the crankcase with the slot located 90 degrees from vertical.

2.2 Install the new front thrustwasher with the tang inserted in the slot toward the flange.

2.3 Press the ball bearing onto the correct end of the crankshaft so that the drive end of the crankshaft will be positioned in the crankcase as marked before disassembly. Using an arbor press, carefully press the ball bearing and the crankshaft into the crankcase. Install the retainer ring, if so equipped.

3. Assemble the new piston rings on the new pistons.

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Crankcase Disassembly, Cleaning and Inspection, and Assembly

IMPORTANT: To properly test a compressor under operating conditions, a test rack is necessary for correct mounting, cooling, lubricating, and driving the compressor.

NOTE: Install the piston rings on the pistons starting at the center of the piston and moving outward. Rotate the piston rings in their respective grooves so that the end gap is at least 90 degrees from the previous ring's end gap.

3.1 Install the expander ring in the piston groove. The ends of the expander ring must butt and must not overlap.

3.2 Install the bottom oil ring by inserting one end below the expander ring in the ring groove, and wind the ring into position. Install the top oil ring in the same manner above the expander ring making sure the gap is staggered from the bottom oil ring and the expander ring.

3.3 Install the compression rings in the correct grooves, with the bevel or "pip" mark (if any) toward the top of the piston.

4. Assemble the new connecting rods on the new pistons.

4.1 Lubricate the wrist pins and the wrist pin bushings in the connecting rods with clean engine oil.

4.2 Position the connecting rods in the pistons and press in the wrist pins. Secure the wrist pins by installing the wrist pin buttons in the ends of the wrist pins.

5. Install the new pistons and new connecting rods.

5.1 Apply clean engine oil to both pistons, the piston rings, the wrist pins, the connecting rod caps and the new connecting rod bearings.

5.2 Turn the crankshaft so its number-one rod journal (the one nearer the drive end) is down and centered.

5.3 Using a piston ring compressor, insert the number-one connecting rod and piston through the top of the number-one cylinder bore.

NOTE: The connecting rods and connecting rod caps are matched sets, therefore the caps must not be switched or rotated end for end.

5.4 Install the connecting rod bearings on the connecting rod and connecting rod cap.

5.5 Tighten the new connecting rod bolts evenly in increments of 11 to 13 lbf·ft (15 to 17 N·m).

5.6 Turn the crankshaft so its number-two connecting rod journal is in the downward, center position.

5.7 Install the number-two connecting rod and piston in the same manner as described above.

6. Before replacing the cylinder head on the crankcase, ensure that the correct pistons have been used by turning the crankshaft one complete revolution such that each piston moves to its maximum upward stroke. At the upward stroke position, each piston should move to the top of the crankcase. If the piston does not approach the top of the crankcase, the piston is incorrect and, if not replaced, could result in compressor damage.

7. Install the base plate.

7.1 Position the gasket on the crankcase. Install the base plate on the crankcase as marked before disassembly.

7.2 Tighten the six capscrews 15 to 18 lbf·ft (20 to 25 N·m) in a cross pattern.

8. Install the cylinder head on the crankcase. For instructions, see **Subject 110**.

9. Install the compressor on the engine. For instructions, see **Subject 100**.

10. Operate the engine and check for leaks.

11. Remove the chocks from the tires.

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Troubleshooting Tables

Problem—Excessive Oil Passage

Problem—Excessive Oil Passage	
Possible Cause	**Remedy**
Restricted air intake	Check the engine air filter and replace it if necessary. Check the compressor air inlet for kinks and excessive bends. Repair as needed.
Restricted oil return line to engine	Check for excessive bends, kinks, and restrictions in the oil return line. The return line must descend from the compressor to the engine crankcase. Repair as needed.
Damaged oil seal ring or loose end cover	Inspect the oil seal ring for wear or damage. Repair as needed. Check the end cover capscrew torques and tighten as necessary.
Insufficient compressor cooling (compressor runs hot)	Remove grease, grime, or dirt from the cooling fins of the compressor. Check for damaged cooling fins. Replace damaged components. Check for correct coolant line sizes. Check the coolant flow through the compressor. The minimum allowable flow is 2.5 gallons per minute at maximum engine governed speed, and minimum allowable flow is 0.5 gallons per minute at engine idle. If low, inspect the coolant lines for rust scale, kinks, and restrictions. Repair or replace as necessary.
Compressor runs loaded an excessive amount of time	Check air lines and connections for leakage. Repair or replace lines and connections until leakage is eliminated.
Back pressure from the engine crankcase	Check for excessive engine crankcase pressure. Repair or replace ventilation components as necessary. NOTE: An indication of crankcase pressure is a loose or partially lifted dipstick.
Excessive engine oil pressure	Check the engine oil pressure with a test gauge, and compare the reading to the engine specification. Do not restrict the compressor oil supply line.
Malfunctioning compressor	Replace or repair the compressor after making certain none of the preceding conditions exist.

Problem—Noisy Compressor Operation

Problem—Noisy Compressor Operation	
Possible Cause	**Remedy**
Loose drive coupling or gear (as indicated)	Inspect the fit of the drive coupling and gear on the compressor crankshaft. Tighten or replace the components. If the crankshaft keyway is damaged, replace the compressor.
Compressor cylinder head or discharge line restrictions	Inspect the compressor discharge port and discharge line for carbon build-up. If carbon is detected, remove the carbon and check for proper coolant flow to the compressor. Inspect the discharge line for kinks and restrictions. Replace the discharge line as necessary.
Air compressor bearing damaged or worn	Replace the bearings.
Malfunctioning compressor	Rebuild or replace the compressor after making certain none of the preceding conditions exist.

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Troubleshooting

Problem—Excessive Build-Up and Recovery Time

Problem—Excessive Build-Up and Recovery Time	
Possible Cause	**Remedy**
Restricted air intake	Check the engine air filter and replace it if necessary. Check the compressor air inlet for kinks and excessive bends. Repair as needed.
Restricted discharge or compressor discharge cavity	Inspect the compressor discharge port and line for restrictions and carbon build-up. If carbon is detected, remove the carbon. Check for proper cooling to the compressor. Inspect the discharge line for kinks and restrictions. Replace the discharge line as necessary.
Slipping drive components	Check for faulty drive gears and coupling, and replace as necessary.
Excessive air system leakage (not including the air compressor)	Check all valves, air lines, and connections for leakage. Repair or replace valves and lines until leakage is eliminated.
Unloader pistons seized	Check the operation of the unloading mechanism. Check for corrosion and contamination of unloader pistons. Check for correct operation of the compressor air governor. If the governor is operating properly, repair or replace the unloading mechanism.
Malfunctioning compressor	Rebuild or replace the compressor after making certain none of the preceding conditions exist.

Problem—Compressor Fails to Unload

Problem—Compressor Fails to Unload	
Possible Cause	**Remedy**
Faulty or worn unloader pistons or bores	Inspect for worn, dirty, or corroded unloader pistons and bores. Replace as necessary.
Malfunctioning governor	Check the setting with an accurate test gauge. Repair or replace the air governor.
Unloader air lines from governor damaged	Inspect the air lines to, and from, the governor for kinks or restrictions. Repair or replace the air lines.

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Torque Values

Fastener Torque Values	
Description	**Torque: lbf·ft (N·m)**
Cylinder Head	37–42 (50–57)
Unloader Cover Plate	15–18 (20–25)
Discharge Valve Seat	70–90 (95–122)
Inlet Valve Stop	70–90 (95–122)
End Cover	15–18 (20–25)
Connecting Rod	11–13 (15–17)
Bottom Cover	15–18 (20–25)
Inlet Fitting	15–18 (20–25)
Discharge Fitting	15–18 (20–25)
Governor or Governor Adaptor	15–18 (20–25)

Table 1, Fastener Torque Values

Compressor Specifications

Compressor Specifications	
Description	**inches (mm)**
Discharge Valve Travel (minimum/maximum)	0.030/0.046 (0.762/1.168)
Fit Between Crankcase Bore and Ball-Type Main Bearing (minimum/maximum)	0.0003/0.0023 (0.008/0.058)
Clearance for Crankshaft Main Journals to i.d. of Sleeve-Type Main Bearing (maximum)	0.005 (0.13)
Crankshaft Main Journal Standard Diameter	1.1242–1.1250 (28.555–28.575)
Clearance Between Crankshaft Rod Journals and Connecting Rod Bearing (minimum/maximum)	0.0003/0.0021 (0.008/0.053)
Crankshaft Rod Journal Standard Diameter *	1.1242–1.1250 (28.555–28.575)
Cylinder Bore Out-of-Round (maximum)	0.0005 (0.013)
Cylinder Bore Taper (maximum)	0.0005 (0.013)
Clearance Between Cylinder Bore and Cast Iron Piston (minimum/maximum) †	0.002/0.004 (0.050/0.101)
Clearance Between Wrist Pins and Connecting Rod Bushings (maximum)	0.0007 (0.0178)
Compression Ring Groove Clearance	0.002–0.004 (0.050–0.101)
Oil and Expander Ring Groove Clearance	0.00–0.006 (0.00–0.152)
Compression Ring Gap (installed in cylinder)	0.002–0.013 (0.050–0.330)
Oil and Expander Ring Gap (installed in cylinder)	0.010–0.040 (0.254–1.016)

* For compressors having reground crankshafts, undersize connecting rod bearing inserts are available in 0.010 inch (0.254 mm), 0.020 inch (0.508 mm), and 0.030 inch (0.762 mm).

† Oversized pistons and piston rings are available in 0.010 inch (0.254 mm), 0.020 inch (0.508 mm), and 0.030 inch (0.762 mm).

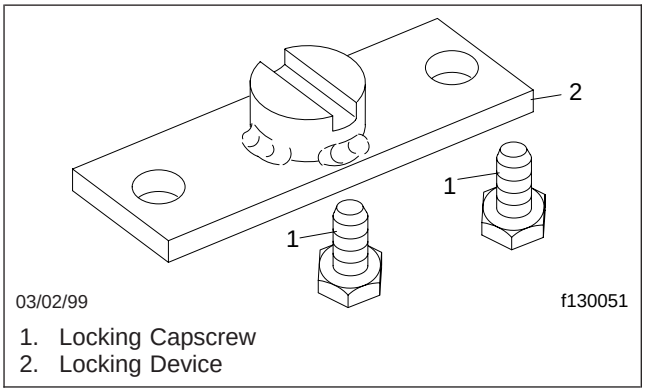
Table 2, Compressor Specifications

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Air Compressor Removal, Inspection and Installation

Removal

NOTE: A special tool is need for this procedure, Kent-Moore KM 904 589 03 63 00, air compressor locking device. See **Fig. 1**.



1. Locking Capscrew
2. Locking Device

Fig. 1, Air Compressor Locking Device

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.

⚠ WARNING

To prevent scalding, do not drain the coolant when the coolant temperature is above 122°F (50°C).

2. Drain the coolant. For detailed procedures, see Group 20 in the *Acterra Maintenance Manual*.
3. Remove the two capscrews attaching the power steering pump to the air compressor. See **Fig. 2**.

IMPORTANT: Do not remove the power steering lines. Tie up the lines and the pump out of the way.

4. Remove the cross plate between the compressor and the power steering pump. See **Fig. 3**.
5. Remove the coolant delivery line and coolant return line. See **Fig. 3**.

NOTE: The coolant delivery line is attached to the crank angle position sensor wire with a tie strap. Cut the tie strap and remove the coolant delivery line.

6. Remove the three air lines. See **Fig. 4**.

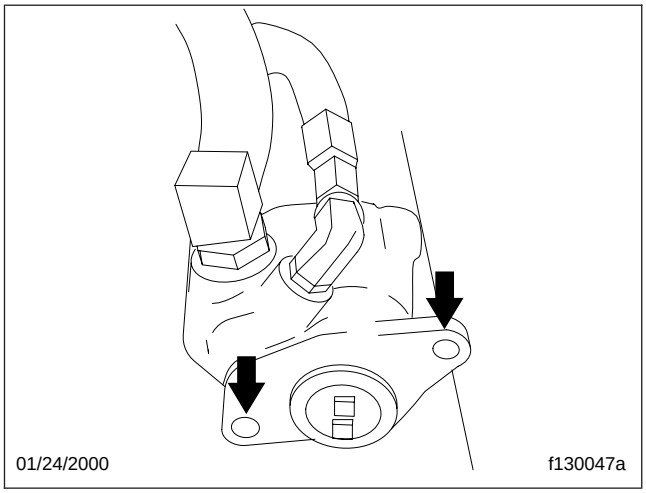


Fig. 2, Power Steering Pump Capscrews

6.1 Remove the discharge (compressed air) line. Check the fittings for damage and replace if necessary. Check inside the discharge line for carbon deposits. If deposits are found, replace the discharge line.

6.2 Remove the unloader line. Check the fittings for damage and replace if necessary.

6.3 Loosen the hose clamp and remove the intake (suction) air line.

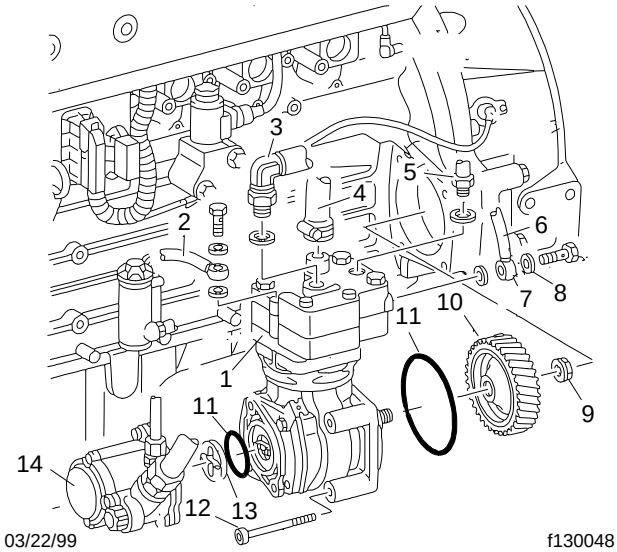
7. Remove the four mounting capscrews attaching the air compressor to the crankcase. See **Fig. 3**.
8. Slide the drive gear away from the flywheel. Catch any oil that runs out and dispose of it properly.

Inspection

1. Inspect the O-rings on the fittings at the air system ports and replace if necessary. If the O-rings are damaged, replace the fittings also.
2. Replace the O-ring between the power steering pump and the air compressor.
3. Install the Kent-Moore locking device on the air compressor at the end of the drive shaft where it connects to the power steering pump. This locks the drive shaft to allow removal of the drive nut. See **Fig. 1**.

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Air Compressor Removal, Inspection and Installation



1. Air Compressor
2. Coolant Return Line
3. Discharge Line
4. Intake Air Line
5. Unloader Air Line
6. Coolant Delivery Line
7. Banjo Fitting
8. Copper Washer
9. Drive Nut
10. Drive Gear
11. O-Ring
12. Mounting Capscrew (4 qty.)
13. Cross Plate
14. Power Steering Pump

Fig. 3, Air Compressor Mounting

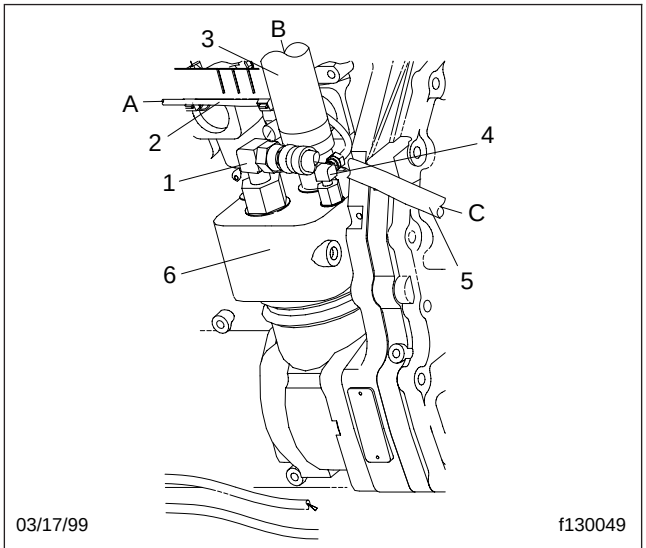
4. Install the two locking capscrews on the locking device and tighten them until the air compressor drive is locked and incapable of movement. See **Fig. 5**.

5. Remove the drive gear from the air compressor. See **Fig. 6**.

   5.1 Place the air compressor in a vise. Make sure it is tightly secured and cannot slip or slide out of the vise.

   5.2 Place an impact wrench on the drive nut and pull the drive nut off the drive gear.

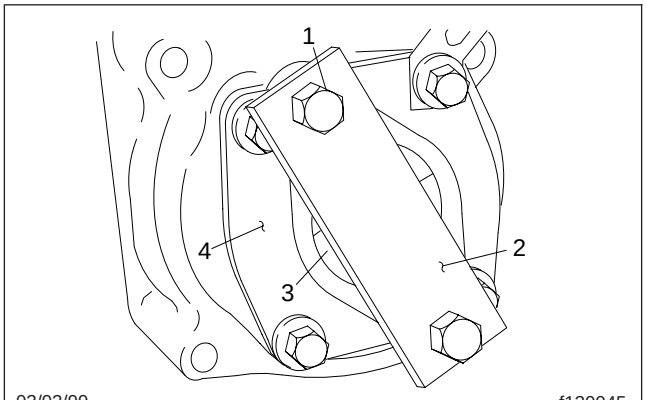
   5.3 Remove the drive gear from the air compressor with a gear puller, if necessary.



A. To Air Governor
B. From Intake Side of Turbocharger
C. To Wet Tank (or air dryer, if installed)

1. Discharge Port
2. Unloader Air Line
3. Intake Air Line
4. Unloader Port
5. Discharge Air Line
6. Air Compressor

Fig. 4, Air Line Attachments



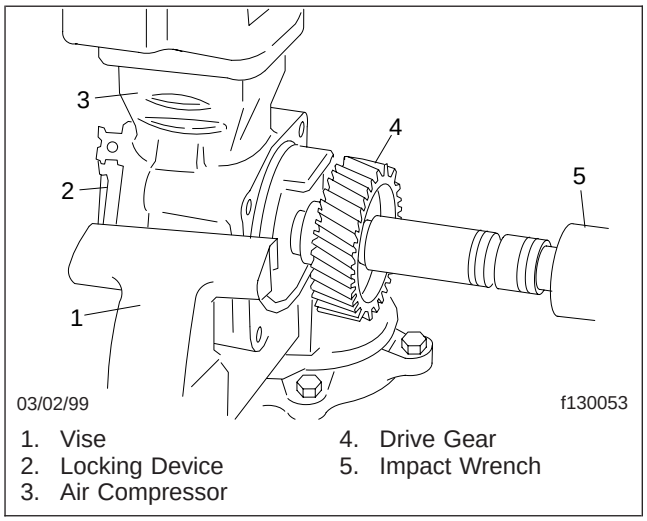
1. Locking Capscrew
2. Locking Device
3. End of Drive Shaft
4. Air Compressor

Fig. 5, Locking the Air Compressor Drive

6. Inspect the drive gear for worn or broken teeth, spalling and corrosion. Replace the drive gear if necessary.

7. Install the drive gear and drive nut on the drive shaft of the air compressor. Tighten the drive nut 200 lbf·ft (270 N·m).

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1. Vise
2. Locking Device
3. Air Compressor
4. Drive Gear
5. Impact Wrench

Fig. 6, Pulling the Drive Gear

8. Remove the locking device from the air compressor and release the air compressor from the vise.

Installation

1. Install the air compressor.
2. Install the four air compressor mounting capscrews. Tighten each capscrew 30 lbf·ft (40 N·m).
3. Install the three air lines. See **Fig. 4**.
   - 3.1 Install the discharge line. Make sure the O-ring is properly installed on the fitting. Tighten the fitting 74 lbf·ft (100 N·m).
   - 3.2 Install the unloader line. Make sure the O-ring is properly installed on the fitting.
   - 3.3 Install the intake air line and tighten the hose clamp.
4. Install the two coolant lines.
   - 4.1 Pay particular attention to the coolant delivery line at the rear of the air compressor. It is difficult to line up the bolt and fitting correctly.

   IMPORTANT: If necessary to line up the banjo bolt, loosen the coolant line that attaches to the rear of the engine.

   NOTE: Attach the coolant delivery line to the crank angle position sensor wire with a tie strap.

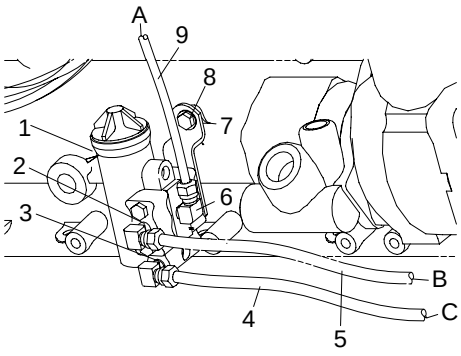
   - 4.2 Tighten the banjo bolts on the coolant delivery and return lines 30 lbf·ft (40 N·m).
5. Install the cross plate. Use grease to hold it in place while installing the power steering pump.
6. Install the two capscrews attaching the power steering pump to the air compressor. Tighten the capscrews 30 lbf·ft (40 N·m). See **Fig. 2**.
7. Fill the radiator with coolant. For detailed procedures, see Group 20 in the *Acterra Maintenance Manual*.
8. Top off the engine oil.
9. Remove the chocks from the rear tires.

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Air Governor Removal and Installation

Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Release system air pressure.
3. Remove and mark the three air line fittings. See **Fig. 1**. Inspect all fittings for damage and replace if necessary.



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A. From Air Compressor (unloader port)
B. To Air Dryer (if installed)
C. To Wet Tank
1. Air Governor
2. Unloader Port, Air Dryer
3. Reservoir Port
4. Supply Air Line
5. Air Dryer Control Line
6. Unloader Port, Air Compressor
7. Mounting Bracket
8. Mounting Capscrew, M8
9. Unloader Air Line

Fig. 1, Air Governor Installation

4. Remove the mounting capscrew and remove the mounting bracket from the vehicle, with the air governor attached.
5. Remove the two capscrews holding the air governor to the mounting bracket.

Installation

1. Install the air governor on the mounting bracket, using the two capscrews, as removed.
2. Install the mounting bracket, with the air governor attached, on the engine. Tighten the M8 mounting capscrew 12 lbf·ft (16 N·m).
3. Coat each air line fitting with pipe thread sealant at the air governor port. For approved compounds, see **Specifications, 400**.

IMPORTANT: Coat the surface between the fitting and port on the air governor. Do not put sealant on the surfaces between the fitting and the air line.

4. Install the three air line fittings, as removed. Make sure all fittings are tight.
5. Remove the chocks from the rear tires.

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Air Compressor Torque Values	
Description	**lbf·ft (N·m)**
Air Compressor Mounting Capscrews	30 (40)
Discharge Line Fitting	74 (100)
Coolant Line Banjo Bolts	30 (40)
Drive Nut	200 (270)
Power Steering Pump Mounting Capscrews	30 (40)

Table 1, Air Compressor Torque Values

Air Governor Torque Values	
Description	**lbf·ft (N·m)**
Air Governor Mounting Capscrew, M8	12 (16)

Table 2, Air Governor Torque Values

Approved Pipe Thread Sealants	
Protectant Material	**Approved Brand**
Pipe Thread Sealant (49-00094-108)	Loctite® 567
	Henkel 790 Pipegrip
	Perma-Lok LH-150

Table 3, Approved Pipe Thread Sealants

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General Information

⚠ WARNING

Avoid contact with the air compressor discharge line. Compressed air directly from the air compressor is hot enough to burn the skin.

The air compressor is a one cylinder, single-stage, reciprocating air compressor, which supplies compressed air to the vehicle air system. It has a rated displacement of 15.2 or 18.7 cfm (430 or 530 L/min).

The air compressor is:

- Lubricated by the engine lubrication system;
- Cooled by the engine coolant system;
- Controlled by a governor that may be attached or remotely mounted.

All models of the Cummins air compressor are the same design except for the drive gear, mounting arrangement, rear drive through, and porting on the heads.

The ISC engine was first available with the Cummins air compressor in July, 1998. The ISB engine offered it starting in January, 1999.

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Air Compressor Removal and Installation

Removal

NOTE: Depending on engine model, Cummins engines may have either a fuel pump or a power steering pump mounted to the back of the air compressor.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Release system air pressure.
3. Drain the engine coolant.
4. Disconnect the following lines:
   - intake and discharge air lines
   - two coolant lines
   - control line at or from the governor
5. If the power steering pump is mounted to the compressor:
   - 5.1 Remove the power steering pump mounting bolts. See **Fig. 1**.

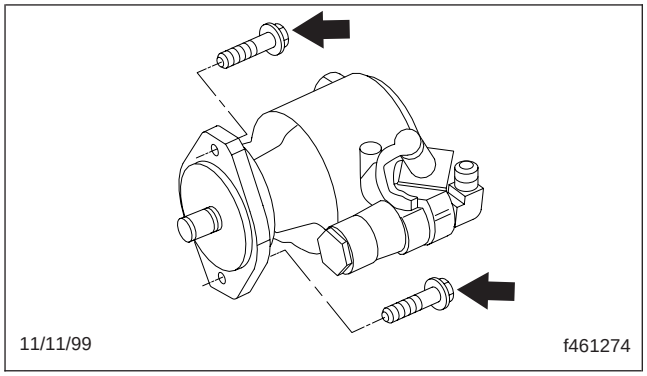


Fig. 1, Power Steering Pump Mounting Bolts

   - 5.2 Remove the power steering pump and gasket from the engine. Tie the pump and lines out of the way.
6. If the fuel pump is mounted to the compressor:
   - 6.1 Disconnect the fuel line from the fuel filter.
   - 6.2 Disconnect the fuel return line from the fuel pump.
   - 6.3 Disconnect the fuel outlet line from the fuel pump.
   - 6.4 Disconnect the electrical wire from the fuel pump solenoid.
   - 6.5 Remove the support bracket from the engine block to the fuel pump.
   - 6.6 Remove the fuel pump and filter assembly from the air compressor.

IMPORTANT: An assistant is necessary to remove the air compressor from the engine compartment.

7. Slide the air compressor off the studs and lift it out of the engine compartment. See **Fig. 2**.

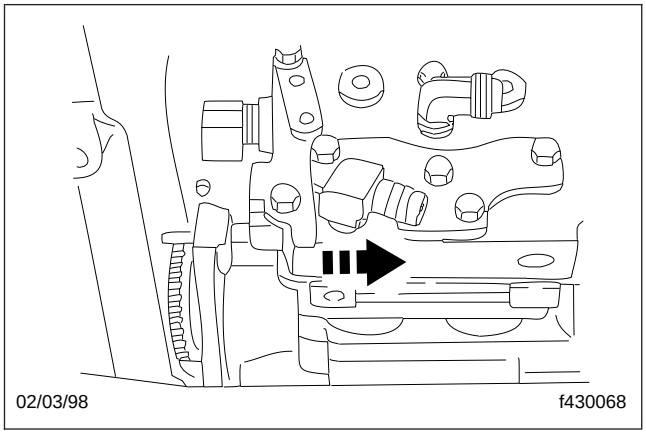


Fig. 2, Compressor and Studs

Installation

IMPORTANT: See the timing instructions in **Subject 140**.

1. Remove the dirt and grease from the air compressor mounting surfaces and compressor lines.
2. Install a new gasket and slide the air compressor onto the studs.
3. Tighten the retaining bolts and fittings 30 to 46 lbf·ft (41 to 62 N·m). See **Fig. 3**.
4. If the power steering pump is mounted to the compressor:
   - 4.1 Position the power steering pump.
   - 4.2 Install the mounting bolts. Tighten the bolts 30 to 46 lbf·ft (41 to 62 N·m). See **Fig. 1**.
5. If the fuel pump is mounted to the compressor:

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Air Compressor Removal and Installation

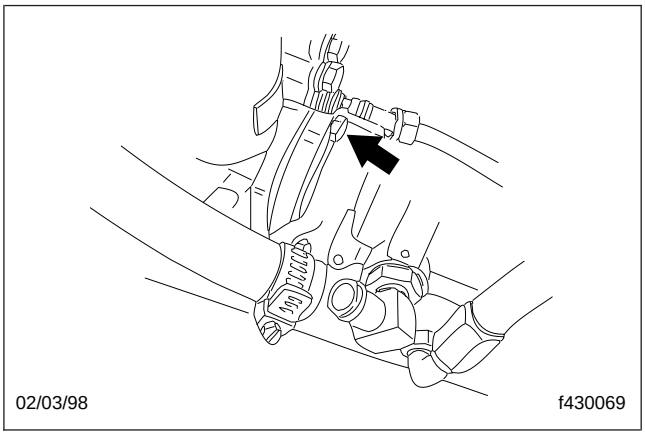


Fig. 3, Retaining Bolt

5.1 Install the fuel pump and filter assembly onto the air compressor.

5.2 Install the support bracket from the engine block to the fuel pump.

5.3 Connect the electrical wire to the fuel pump solenoid.

5.4 Connect the fuel outlet line to the fuel pump.

5.5 Connect the fuel return line to the fuel pump.

5.6 Connect the fuel line to the fuel filter.

6. Connect the following lines to the air compressor:
   - intake and discharge air lines
   - two coolant lines
   - control line at or from the governor
7. Fill the engine cooling system. For instructions, see **Group 20**.
8. Remove the chocks from the tires.

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Air Compressor Disassembly and Assembly

Disassembly

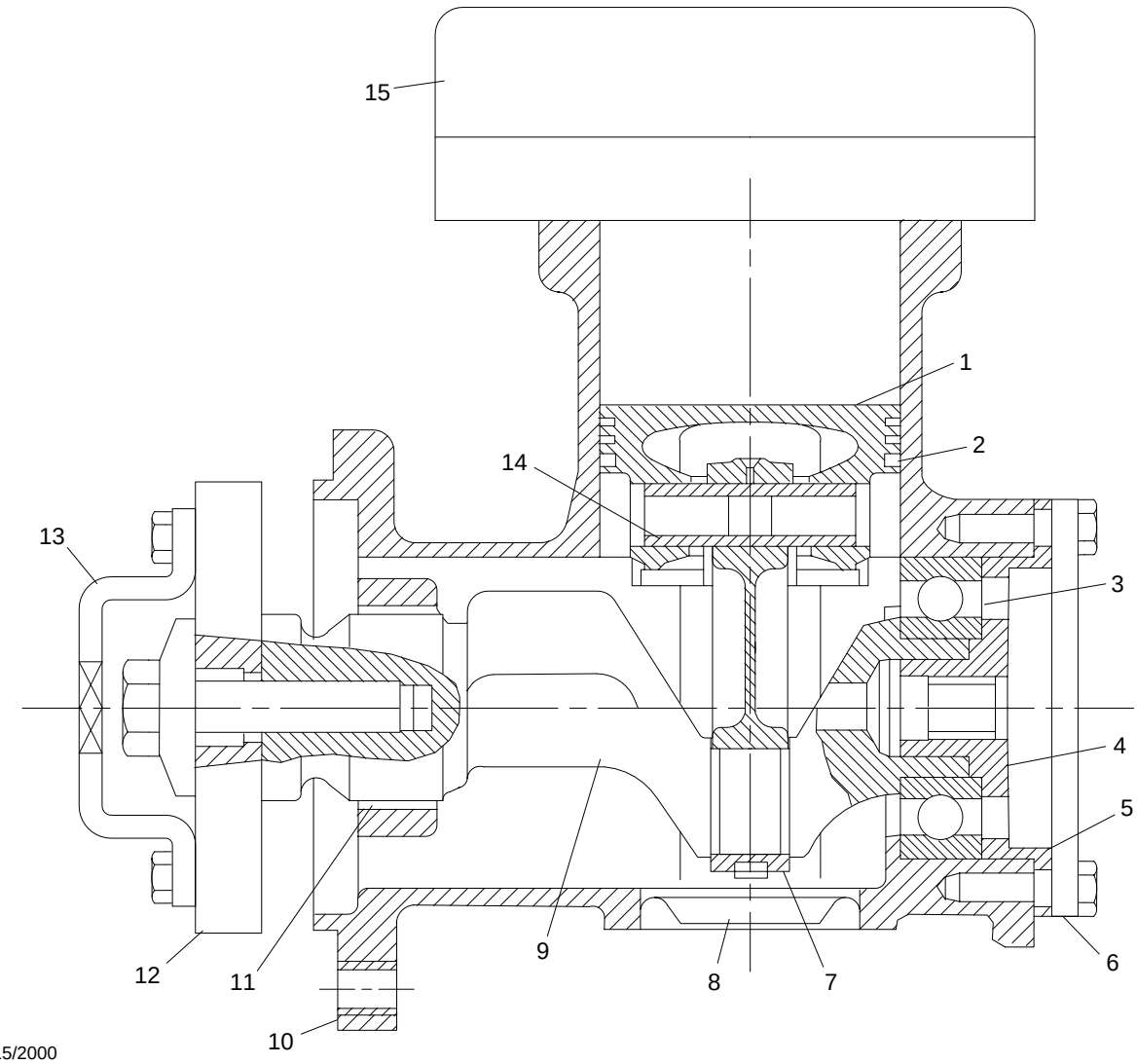
1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the air compressor. For instructions, see **Subject 100**.
3. Remove the drive gear. See **Fig. 1**.
4. Remove the rear cover, gasket, and adapter ring (if equipped).
5. Remove the four 13-mm head bolts. Discard the bolts.
6. Remove the head, valve, and gasket. Note the position of these parts in respect to the crankcase for assembly. A paint marker can be used to mark the positions.
7. Using a large screwdriver or similar device, knock the sump plug out of the crankcase via the cast slot.
8. Align the crankshaft to position the rod cap in the access hole.
9. Remove the two torx head 30 rod bolts.
10. Pull the rod cap off of the rod and crankshaft.
11. Push the piston and rod assembly out of the top of the crankcase with a wooden dowel or hammer handle, pushing on the bottom of the rod.
12. Position the crankshaft in the top-dead-center position (the gear alignment pin will also be in the top-dead-center position) and press the crankshaft out of the rear of the crankcase. This requires approximately 3000 lbs (1360 kg) of force.
13. If the front bearing bushing is in good condition, do not remove it. See **Subject 120** for the permissible maximum diameter.
14. Clamp the crankshaft by the counterweight and remove the bearing retaining nut. It will require a high removal torque in the counterclockwise direction. A section of splined shaft can be used as a tool.
15. Remove the bearing from the shaft. A press is required.

Assembly

1. Press the ball bearing on to the rear crankshaft journal and assemble the retainer. The retainer has a spline in the center. Tighten 332 to 369 lbf·ft (450 to 500 N·m).
2. Press a front bushing into the crankcase to a depth of 0.7 inches (18 mm) below the machined flange.
3. Assemble the crankshaft into the crankcase making sure the rod throw is in the top-dead-center position and will enter through the cast clearance slot.
4. Press the assembly in until it securely bottoms on the shoulder.
5. Assemble the rings on the piston. Insure the rings are in the correct orientation. Stagger the end gaps.
6. Coat the wrist pin, rod bore, and piston bores with light oil. Assemble the rod, wrist pin, and retainers. Make sure the retainers are secure in the grooves. The rod should move freely.
7. Coat the piston bore with light oil. Using a ring compressor, install the piston into the crankcase. Align the rod to match up to the crankshaft. The piston and rod have no fore or aft preference.
8. Apply light oil to the crankshaft rod journal and assemble the rod cap. Tighten the bolts 48 to 58 lbf·in (540 to 660 N·cm). Rotate the bolts an additional 65 to 85 degrees.
9. Check that the crankshaft rotates without binding or excessive torque. The maximum torque is 53 lbf·in (600 N·cm).
10. Apply red Loctite® sealant to the sealing surface of the sump plug and press it in the crankcase until the flange seats.
11. Assemble the gasket/valve assembly and head to the crankcase. Make sure the guide pins are in the correct direction to enter the larger diameters in the valve and crankcase. If orientation marks were applied during disassembly, simply align them and proceed. Assemble and tighten the four head bolts 13 to 16 lbf·ft (18 to 22 N·m). Rotate the bolts an additional 85 to 105 degrees. Complete the torque sequence by alternating corners.

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Air Compressor Disassembly and Assembly



1. Piston
2. Rings
3. Bearing
4. Retainer
5. Adapter
6. Rear Cover
7. Connecting Rod
8. Sump Plug
9. Crankshaft
10. Crankcase
11. Bushing
12. Drive Gear
13. Barring Adapter
14. Wrist Pin
15. Head

Fig. 1, Air Compressor

12. Press the gear on the crankshaft supporting the rear end of the crank.
13. Assemble and tighten the bolt 111 to 114 lbf·ft (150 to 155 N·m). Rotate the bolt an additional 180 to 190 degrees.
14. Install the air compressor. For instructions, see **Subject 100**.
15. Remove the chocks from the tires.

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Cleaning

Parts cleaning can be done by most commercial methods used for cleaning ferrous metals and aluminum parts.

Soak the parts in a kerosene emulsion-based cleaner designed to remove carbon. The cleaner must have a 9.5 pH or less to avoid turning the aluminum parts black. The cleaner manufacturer or supplier can be contacted about solution concentration, temperature, and soak time. If using a hot caustic cleaning process, do not immerse aluminum parts.

NOTE: Do not use a scraper to remove carbon and scale. The sealing surfaces can be damaged. The parts can be scrubbed with a stiff nonmetallic brush. Avoid the use of abrasive products similar to Scotch Brite because of damage and the abrasive grit left behind by these products.

Inspection

Any evidence of heavy wear or deformation on any component as if it was overstressed, disqualifies the part for reuse. See **Fig. 1**.

Head

Inspect the valve elements for breakage and cracks. Any signs of damage renders the parts unusable.

Inspect the sealing seats for wear and deformations due to debris. Anything more than a polishing of the seat renders the part unusable.

Crankcase

Inspect the top surface and sump plug bore. They should be smooth and free of scratches to enable resealing on assembly.

The front bearing bushing may not have been removed during the disassembly procedure. If it was not removed, inspect it in place for wear and galling. The maximum allowable diameter is 2 inches (51 mm). The surface should be smooth and free of galling or damage from debris.

The bearing bores should be free of heavy scratches and not show any deformation of material so that the assembly of the bearings will be smooth and tight.

The piston bore should not be scratched or show evidence of aggressive wear. Polished wear is acceptable in the ring areas. The bore should not exceed 3 inches (76 mm) in diameter. Evidence of galling or operation with debris disqualifies the crankcase for reuse.

Crankshaft

Inspect the machined diameters for damage and wear. The front bearing journal and rod journal can show polished wear. The wear limit on the front journal is 2 inches (51 mm). The wear limit on the rod journal is 1.25 inches (32 mm). The rear bearing journal may show phantom contact from the bearing assembly and removal. Any galled material or deformation disqualifies it for reuse.

Inspect the thread in the front and rear to make sure they have not been stripped or deformed.

Piston

Inspect the ring grooves for wear and damage. Polished wear is normal, but a step at the base of the groove indicates excessive wear. Groove width limits are:

- 0.08 inches (2.03 mm) for the compression ring groove;
- 0.16 inches (4.06 mm) for the oil ring groove.

Inspect the outside diameter for excessive wear. The piston is not reusable if the machining marks are worn off the skirt.

Inspect the wrist pin bores. The maximum diameter is 0.75 inches (19.05 mm).

If the top of the piston has dents, it is best to replace the piston.

Rod

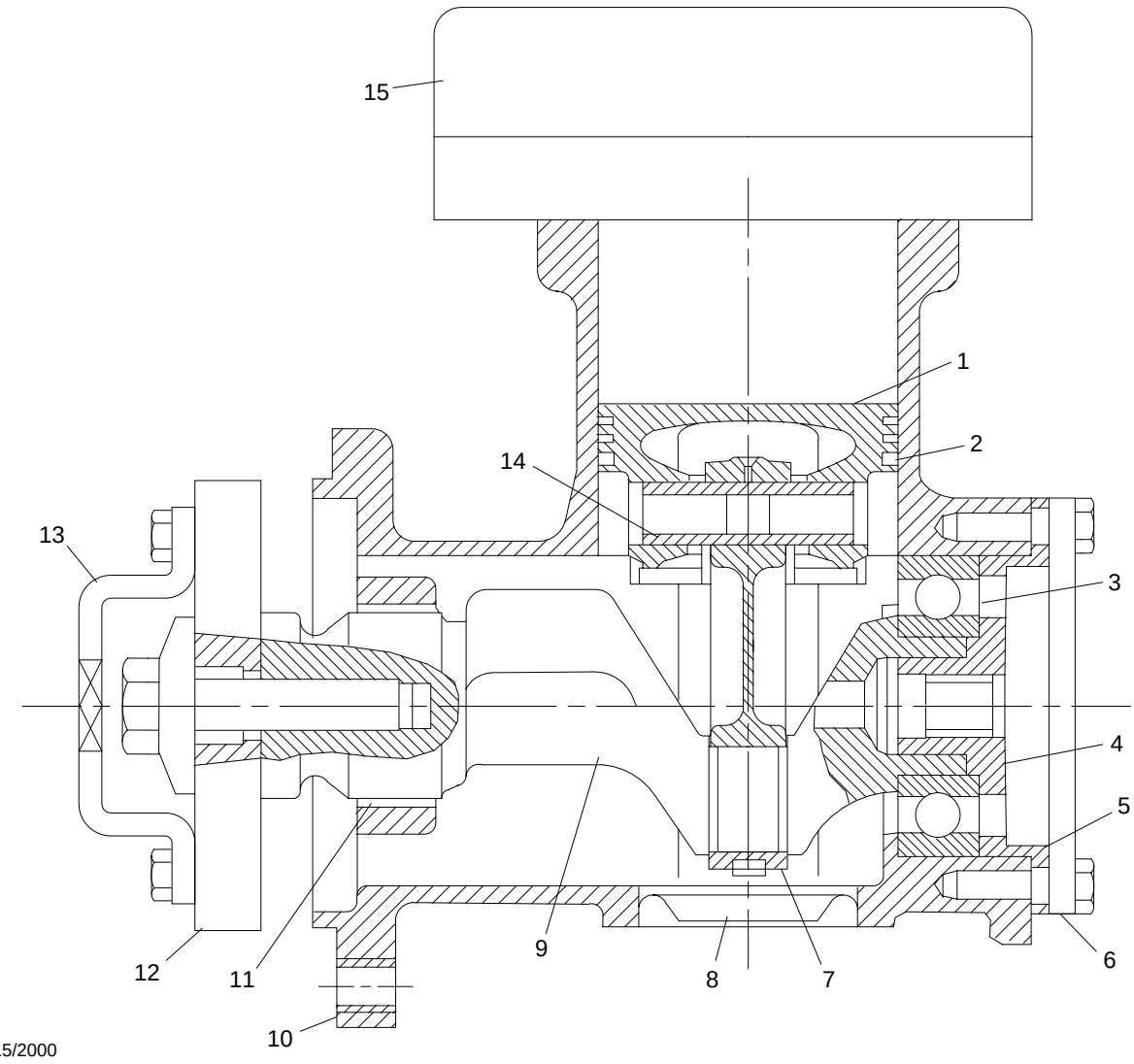
Inspect the wrist pin bores. The maximum diameter is 0.75 inches (19.05 mm).

Inspect the lower bore with the rod cap assembled. The maximum diameter is 1.25 inches (32 mm).

The finish should appear smooth with no evidence of galling.

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Air Compressor Cleaning and Inspection



1. Piston
2. Rings
3. Bearing
4. Retainer
5. Adapter
6. Rear Cover
7. Connecting Rod
8. Sump Plug
9. Crankshaft
10. Crankcase
11. Bushing
12. Drive Gear
13. Barring Adapter
14. Wrist Pin
15. Head

Fig. 1, Air Compressor

Wrist Pin

Inspect the surface and make sure it is smooth and free of damage. The maximum diameter is 0.75 inches (19.05 mm) for reuse.

There may be phantom areas of smoothness on the wrist pin that came in contact with the rod and piston bores. These should show no perceptible depth.

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Rear Ball Bearing

This bearing should always be changed during rebuild.

Crankcase Preparation for Reuse

If the crankcase is being reused and new rings are being installed, the bore should be honed lightly with 220 grit honing stones and stroked up and down to produce a cross-hatch pattern in the bore that has an approximate included angle of 30 degrees. The honing process is used to produce a visual pattern on the bore and remove as little material as possible.

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Bench Testing

On a bench, use a wrench to turn the compressor over. Check to make sure:

- Moving parts are not binding;
- The intake port is drawing some vacuum indicating the inlet valve is seated;
- The exhaust port is passing some air demonstrating the exhaust valve is seated.

Using shop air, pressurize the exhaust port to make sure there is good exhaust valve seating.

Using shop air, cycle the unloader piston.

Apply a tank with a vacuum of 20 to 30 inHg (68 to 101 kPa) to check inlet valve seating. A small drop in vacuum indicates good seating.

Using shop air, pressurize a water port (with the other port plugged) to make sure gaskets and castings are leak proof.

Vehicle Testing

Install the compressor on a vehicle and check for the following:

- The system pressure should build from 85 to 100 psi (586 to 689 kPa) in 25 seconds or less.
- The compressor should unload as the system pressure comes up to 120 psi (827 kPa).
- Bleed the air down with the brakes. The compressor should load again at approximately 100 psi (689 kPa).
- Check for audible air leaks during the load cycle.
- Check for small leaks by applying a soap solution to the exterior of the compressor.
- Check for any coolant leaks.
- Check for any oil leaks.

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Timing

ISB and ISC Engines

NOTE: On ISC engines, compressors with a build date of January 1, 1999 to April 1, 1999 do not have the gear timed to the compressor. To determine the build date of a compressor, locate the data tag on the rear of the compressor, just below the cylinder head. The build date code is a 4-digit number such as 0999. The first 2 digits represent the week it was built and the last 2 digits represent the year the compressor was built. A build date code of 0999 indicates the ninth week of 1999, or the week of February 22 through 26, 1999.

IMPORTANT: The engine must be at top-dead-center when timing the air compressor to the engine.

1. Remove the air compressor. For instructions, see **Subject 100**.
2. Position the air compressor so it can be viewed from the gear end.
3. Rotate the gear as necessary to position the timing mark ("I") in the 3 o'clock position. The air compressor has a divot on the housing at the 3 o'clock position.
4. Install the air compressor. For instructions, see **Subject 100**.

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Troubleshooting Tables

Problem—Excessive Oil Passage

Problem—Excessive Oil Passage	
Possible Cause	**Remedy**
Restricted air intake	Check the engine air filter and replace if necessary. Check the compressor air inlet for kinks and excessive bends. Repair as needed.
Restricted oil return line to engine	Check for excessive bends, kinks, and restrictions in the oil return line. The return line must descend from the compressor to the engine crankcase. Repair as needed.
Damaged oil seal ring or loose end cover	Inspect the oil seal ring for wear or damage. Repair as needed. Check the end cover capscrew torques and tighten as necessary.
Compressor runs loaded an excessive amount of time	Check air lines and connections for leakage. Repair or replace lines and connections until leakage is eliminated.
Back pressure from the engine crankcase	Check for excessive engine crankcase pressure. Repair or replace ventilation components as necessary. NOTE: An indication of crankcase pressure is a loose or partially lifted dipstick.
Excessive engine oil pressure	Check the engine oil pressure with a test gauge and compare the reading to the engine specification. Do not restrict the compressor oil supply line.
Malfunctioning compressor	Replace the compressor after making certain none of the preceding conditions exist.

Problem—Noisy Compressor Operation

Problem—Noisy Compressor Operation	
Possible Cause	**Remedy**
Loose drive coupling or gear (as indicated)	Inspect the fit of the drive coupling and gear on the compressor crankshaft. Tighten or replace the components. If the crankshaft keyway is damaged, replace the compressor.
Compressor cylinder head or discharge line restrictions	Inspect the compressor discharge port and discharge line for carbon build-up. If carbon is detected, remove the carbon and check for proper coolant flow to the compressor. Inspect the discharge line for kinks and restrictions. Replace the discharge line as necessary.
Air compressor bearing damaged or worn	Replace the bearings.
Malfunctioning compressor	Replace the compressor after making certain none of the preceding conditions exist.

Problem—Excessive Build-Up and Recovery Time

Problem—Excessive Build-Up and Recovery Time	
Possible Cause	**Remedy**
Restricted air intake	Check the engine air filter and replace if necessary. Check the compressor air inlet for kinks and excessive bends. Repair as needed.

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Troubleshooting

Problem—Excessive Build-Up and Recovery Time	
Possible Cause	**Remedy**
Restricted discharge or compressor discharge cavity	Inspect the compressor discharge port and line for restrictions and carbon build-up. If carbon is detected, remove the carbon. Check for proper cooling to the compressor. Inspect the discharge line for kinks and restrictions. Replace the discharge line as necessary.
Slipping drive components	Check for faulty drive gears and coupling, and replace as necessary.
Excessive air system leakage (not including the air compressor)	Check all valves, air lines, and connections for leakage. Repair or replace valves and lines until leakage is eliminated.
Unloader pistons seized	Check the operation of the unloading mechanism. Check for corrosion and contamination of unloader pistons. Check for correct operation of the compressor air governor. If the governor is operating properly, repair or replace the unloading mechanism.
Malfunctioning compressor	Replace the compressor after making certain none of the preceding conditions exist.

Problem—Compressor Fails to Unload

Problem—Compressor Fails to Unload	
Possible Cause	**Remedy**
Faulty or worn unloader pistons or bores	Inspect for worn, dirty, or corroded unloader pistons and bores. Replace as necessary.
Malfunctioning governor	Check the setting with an accurate test gauge. Repair or replace the air governor.
Damaged unloader air lines from governor	Inspect the air lines to and from the governor for kinks or restrictions. Repair or replace the air lines.

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Specifications

Torque Specifications		
Description	**lbf·ft (N·m)**	**lbf·in (N·cm)**
Compressor Retaining Bolts and Fittings	30–46 (41–62)	—
Power Steering Pump Mounting Bolts	30–46 (41–62)	—
Ball Bearing Retainer	332–369 (450–500)	—
Rod Cap Bolts	—	48–58 (540–660)
Head Bolts	13–16 (18–22)	—
Drive Gear Retaining Bolt	111–114 (150–155)	—
Barring Adapter	33–37 (45–50)	—

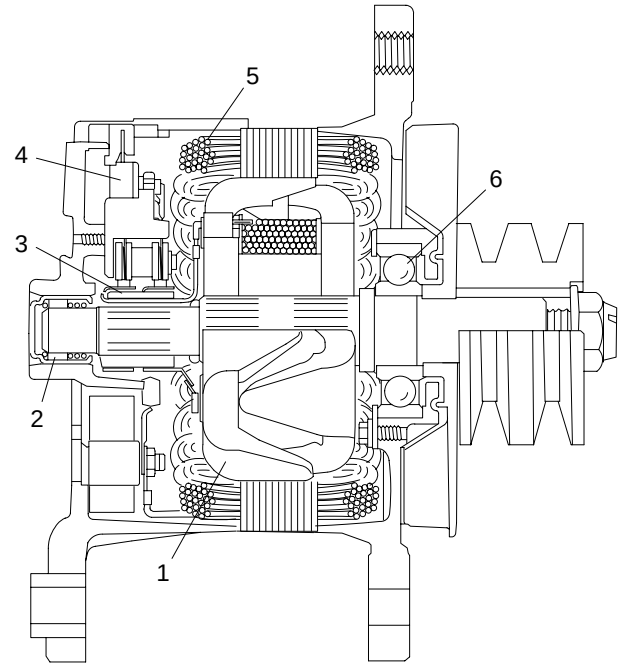
Table 1, Torque Specifications

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General Information

Delco Remy SI-series alternators feature solid-state regulators mounted inside their end frame; see **Fig. 1**. The rotor is the only moving part in the alternator. It runs in a ball bearing at the drive end, and a roller bearing at the rectifier end.

As the rotor turns, the magnetism within it produces AC current in the stator windings. The internally mounted diodes convert that AC current to DC, to charge the batteries and supply the rest of the vehicle with usable electric current.



1. Rotor
2. Roller Bearings
3. Brushes
4. Regulator
5. Field Windings
6. Ball Bearings

Fig. 1, 24-SI Alternator Components

All SI-series bearings are sealed, so that no lubrication is required. The current-carrying conductors are stationary, as are the field-winding stator components. The regulator and diodes are enclosed in a sealed compartment.

Alternators for EPA07 and Later

Delco Remy 24-SI alternators (see **Fig. 2**) are brush-type; the 35-SI and 36-SI are brushless models. Alternators designed for EPA07 and later, are designed to function in underhood temperatures up to 221°F (105°C). The 36-SI generates 100 amps at idle engine speed, to power auxiliary devices with minimum emissions and maximum fuel efficiency.

Models from the 24-, 35-, and 36-SI may be equipped with Remote Sense (see **Fig. 3**), a fourth terminal on the alternator. That terminal connects to the batteries to monitor battery voltage and adjust alternator output accordingly, keeping the batteries at optimum charge.

In most alternators, a fan on the belt drive end draws cooling air through the alternator housing from the rear. Some alternators such as the 24-SI now have twin fans in the center of the housing, designed to draw air from both ends, and exhaust it through vents around the center of the housing.

Fig. 4 shows three types of alternator mounts. The pad mount is favored in later applications, for its stability, durability, and resistance to vibration.

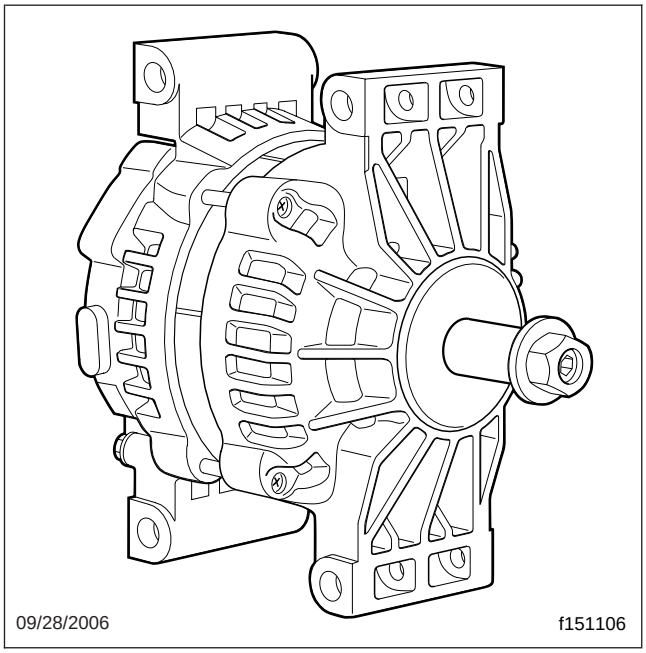
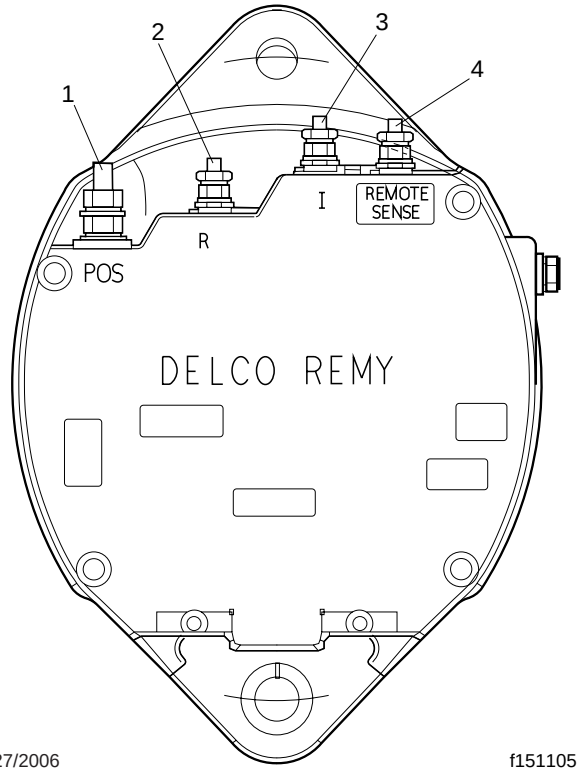


Fig. 2, 24-SI Pad-Mount Alternator

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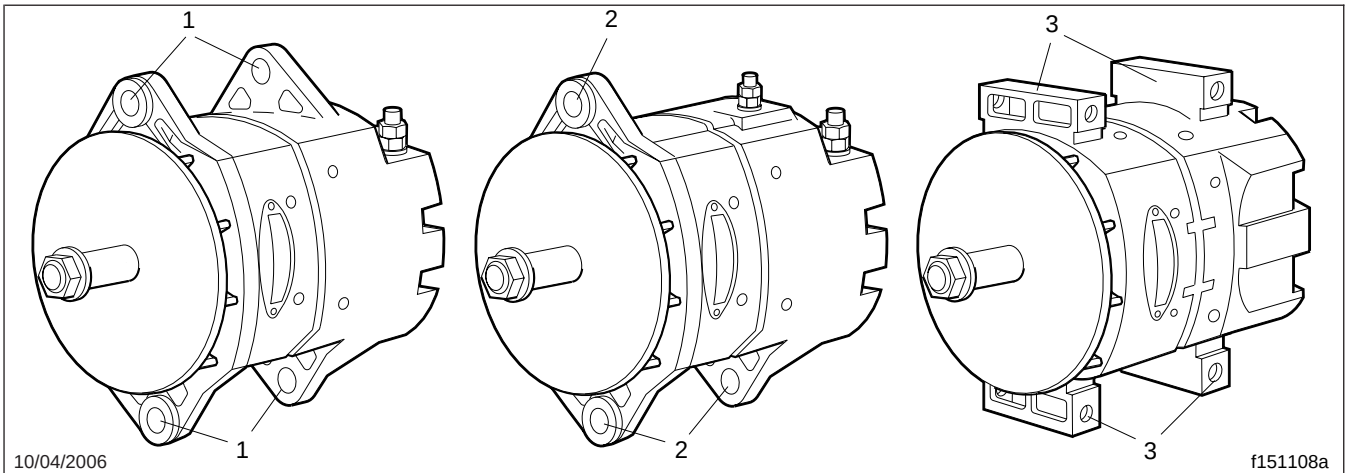
General Information



1. Positive (Battery) Terminal
2. Relay Terminal
3. Indicator Terminal
4. Remote Sense Terminal

Fig. 3, Alternator Terminals with Remote Sense (35-SI Shown)

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1. DR Quad Mount
2. J-180 Hinge Mount
3. Pad Mount

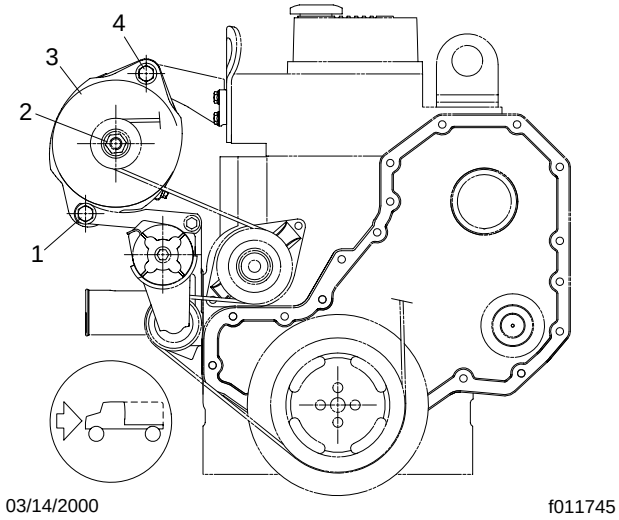
Fig. 4, Alternator Mounts

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Removal and Installation, Cummins and Caterpillar™ Engines

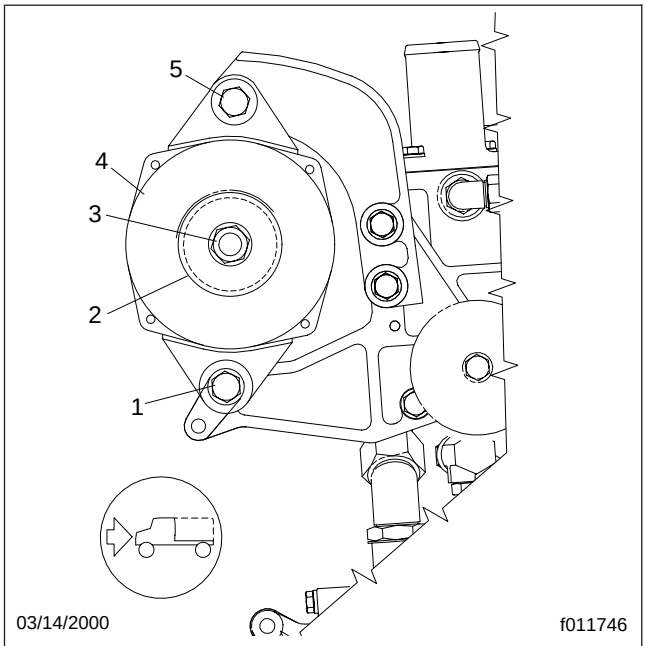
Removal

1. Apply the parking brake, shut down the engine, and chock the rear tires.
2. Open the hood.
3. Disconnect the batteries, or (if equipped) turn off the battery shutoff switch.
4. Disconnect the wires from the alternator terminals. Label them for reassembly. See **Fig. 1** or **Fig. 2**.
5. Remove the alternator belt, as follows:
   - 5.1 Insert a 1/2" breaker bar in the belt tensioner, and rotate the tensioner up off the belt.
   - 5.2 Holding the tensioner up, remove the belt from the alternator pulley.
   - 5.3 Slowly release the belt tensioner, and remove the breaker bar.
6. Remove a hinge-mount alternator as follows:
   - 6.1 Remove the bolt that attaches the lower alternator mount to the link.



1. Bolt, 1/2–13 x 1.25
2. Pulley Nut
3. Alternator
4. Pivot Bolt, 1/2–13 x 6.5

Fig. 1, Alternator Mounting, Cummins ISB



1. Bolt, 1/2–13 x 6.5
2. Alternator Pulley
3. Pulley Nut
4. Alternator
5. Pivot Bolt, 1/2–13 x 1.75

Fig. 2, Alternator Mounting, Caterpillar 3126B

   - 6.2 Remove the pivot bolt nut and washer.
   - 6.3 Support the alternator to prevent it from falling, and remove the pivot bolt.
   - 6.4 Remove the alternator from the vehicle.
7. Remove the pulley from the alternator, to use on the new one.

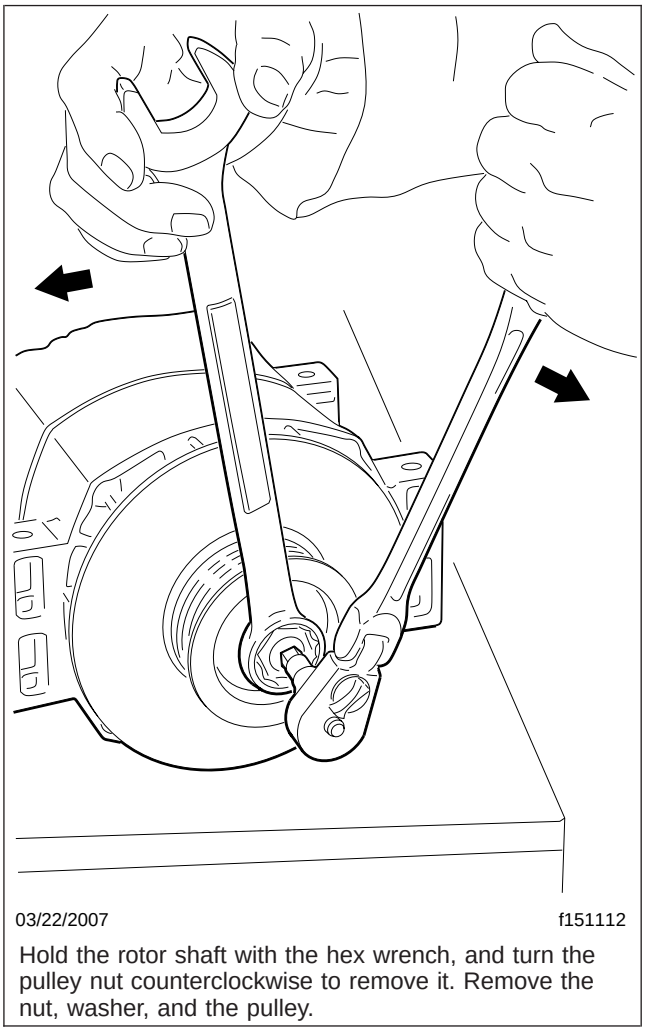
   If the alternator is a Delco Remy:
   - 7.1 Hold the alternator pulley retaining nut with a box-end wrench.
   - 7.2 Insert a 5/16-inch hex wrench into the hex fitting in the end of the rotor shaft; see **Fig. 3**.
   - 7.3

Installation

1. Install the pulley on the new alternator, reversing the removal steps. The torque for the pulley nut is stamped on the front of the alternator fan.

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Removal and Installation, Cummins and Caterpillar™ Engines



Hold the rotor shaft with the hex wrench, and turn the pulley nut counterclockwise to remove it. Remove the nut, washer, and the pulley.

Fig. 3, Loosening a Delco Remy Alternator Pulley Nut

2. Position the alternator on the mount.
3. Insert the pivot bolt through the alternator and mount.
4. Install the washer and nut on the pivot bolt.
5. Install the bolt to secure the lower alternator mount. Tighten the nut on the pivot bolt. See **Specifications, 400** for torque values.
6. Install the belt on the alternator, as follows:
   - 6.1 Insert a breaker bar in the belt tensioner, and rotate the tensioner up while installing the belt on the alternator pulley. Make sure the belt is aligned on all pulleys.
   - 6.2 Ease the tensioner onto the belt. It automatically tightens the belt to the correct tension.
   - 6.3 Remove the breaker bar from the tensioner.
7. Connect the wires to the alternator terminals. If the wires are not labeled, see the wiring diagram in **Specifications, 400**.
8. Connect the batteries, or (if equipped) turn on the battery shutoff switch.
9. Close and latch the hood, and remove the tire chocks.

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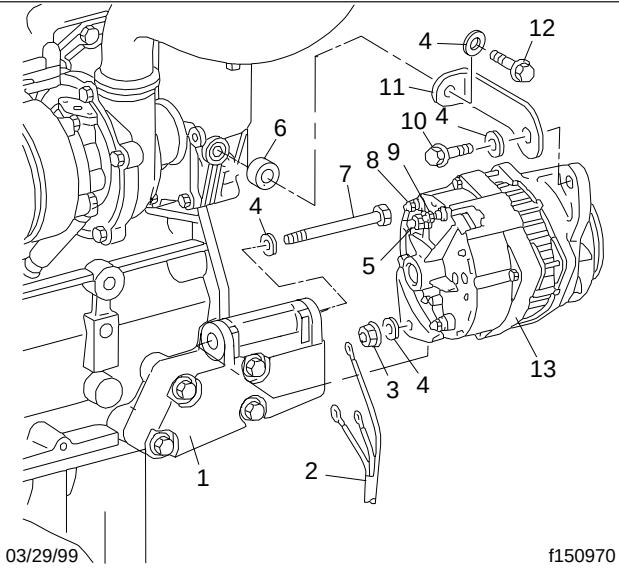
Removal and Installation, Detroit Diesel and Mercedes-Benz Engines

Removal

1. Apply the parking brake, shut down the engine, and chock the rear tires.
2. Open the hood.
3. Disconnect the batteries, or (if equipped) turn off the battery shutoff switch.

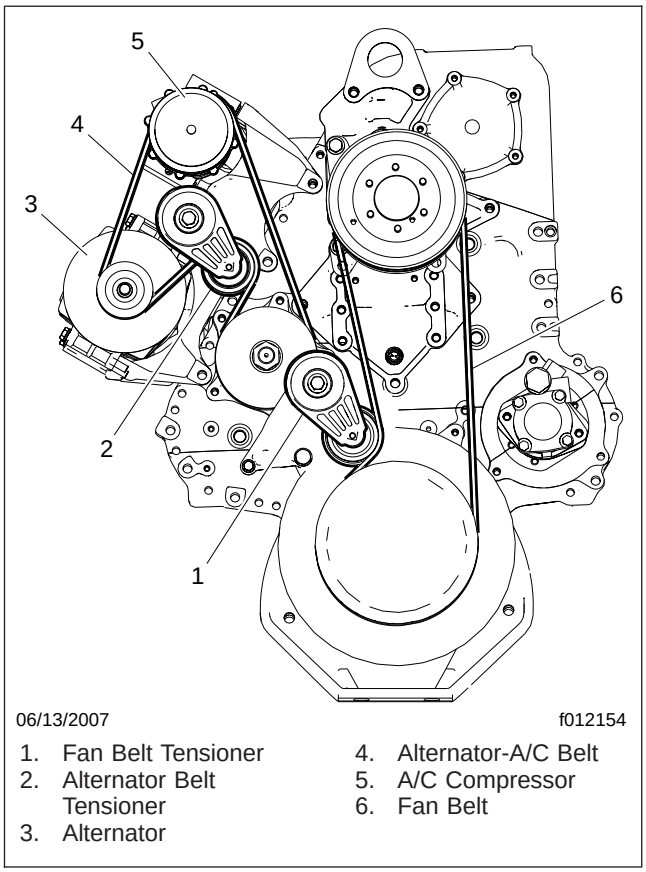
NOTE: Early model vehicles may have an SAE J180 hinge-mount alternator as shown in **Fig. 1**, but later models have pad-mount alternators as shown in **Fig. 2**.

4. Release the tension on the belt, and remove the belt from the alternator pulley; see **Fig. 1** or **Fig. 2**.



1. Alternator Bracket
2. Wiring Harness
3. Lower Alternator Mounting Hexnut
4. Washer
5. Output (BAT) Terminal
6. Spacer
7. Lower Alternator Mounting Bolt
8. Ground (G) Terminal
9. Indicator Light (I) Terminal
10. Upper Alternator Mounting Capscrew
11. Mounting Strap
12. Strap Mounting Capscrew
13. Alternator

Fig. 1, Hinge-Mount Alternator Installation, Mercedes-Benz Engine



1. Fan Belt Tensioner
2. Alternator Belt Tensioner
3. Alternator
4. Alternator-A/C Belt
5. A/C Compressor
6. Fan Belt

Fig. 2, Pad-Mount Alternator Installation, Detroit Diesel Series 60 Engine

5. Disconnect the wiring harness at the alternator. Note the wire positions on the terminals, for correct installation.
6. From underneath the vehicle, remove the lower alternator mounting bolt, hexnut, and washers.
7. Remove the strap mounting capscrew. Remove the mounting strap and alternator, as an assembly.
8. Remove the upper mounting capscrew and washer. Remove the mounting strap.
9. Remove the pulley, for use on the new alternator. If the alternator is a Delco Remy:

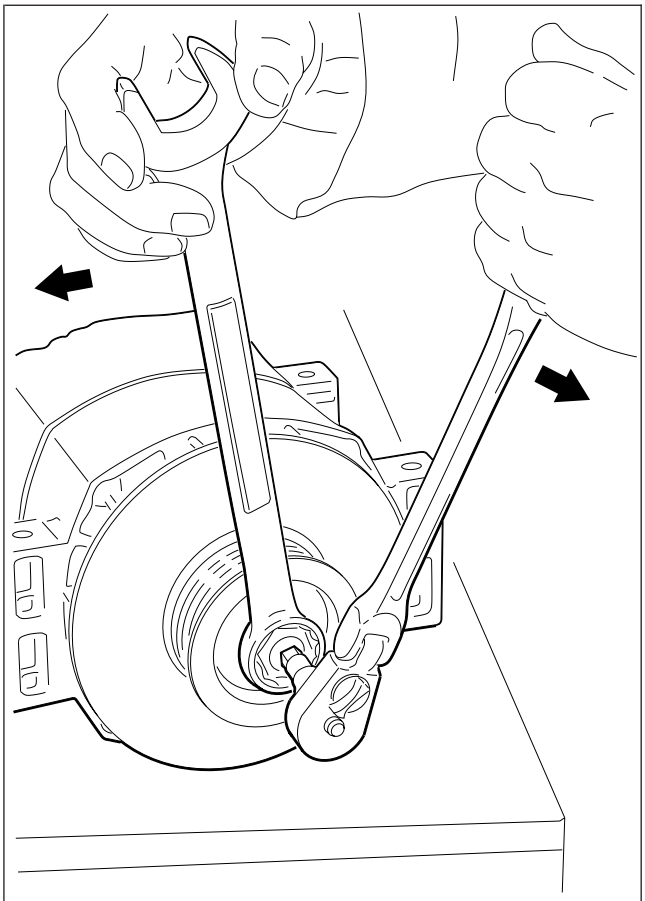
    9.1 Hold the alternator pulley retaining nut with a box-end wrench.

    9.2 Insert a 5/16-inch hex wrench into the hex fitting in the rotor shaft.

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Removal and Installation, Detroit Diesel and Mercedes-Benz Engines

9.3 Hold the rotor shaft with the hex wrench, and turn the pulley nut counterclockwise to remove it. See **Fig. 3**. Remove the nut, washer, and pulley.



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Hold the rotor shaft with the hex wrench, and turn the pulley nut counterclockwise to remove it. Remove the nut, washer, and the pulley.

Fig. 3, Loosening a Delco Remy Alternator Pulley Nut

10. Check the belt's condition; if it is questionable, replace it with a belt of the correct size and length.

Installation

1. Install the pulley on the new alternator, reversing the steps listed under **Removal**. Tighten the pulley hexnut 75 lbf·ft.
2. If the alternator is a hinge-mount:
   - Position the mounting strap on the alternator (see **Fig. 1**), and install the upper alternator mounting capscrew and washer.
   - Tighten the hexnut 48 lbf·ft (65 N·m).
   - Position the other end of the mounting strap, and install the strap mounting capscrew and washer. Tighten the capscrew 30 lbf·ft (40 N·m).
   - Position the alternator on the mounting bracket, and install the lower alternator mounting bolt, hexnut and washers. Tighten the hexnut 37 lbf·ft (50 N·m).
3. If the alternator is a pad-mount:
   - Position the alternator on the engine and start the mounting capscrews. Tighten 35 lbf·ft (48 N·m).
   - Relax the belt tensioner and place the alternator drive belt in position. The correct belt tension is set automatically.
4. Connect the wiring harness to the alternator, as it was before. Tighten the output terminal hexnut 100 lbf·in (1140 N·cm). Tighten the ground terminal hexnut 65 lbf·in (734 N·cm). Tighten the other terminals' hexnuts 20 lbf·in (220 N·cm).
5. Spray exposed terminal connectors with dielectric red enamel.
6. Connect the batteries or (if equipped), turn on the battery shutoff switch.
7. Connect the batteries, or turn on the battery shutoff switch.
8. Close and latch the hood, and remove the tire chocks.

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The Electrical System

Alternators are very reliable, if:

- the alternator has sufficient capacity for the electrical load, including equipment that may have been added
- the alternator is properly installed, with fasteners tightened to the correct torque
- drive belts are properly adjusted, neither too tight, nor slipping
- connections are clean and tight
- cables are of sufficient size, and in good repair
- the batteries are not too old and are clean, with uncorroded terminals and no conductive dirt layers from the top of the battery to ground
- the alternator is protected from sources of extreme heat, such as exhaust leaks
- the alternator is clean, with no heat-trapping dirt inside or out

The alternator must be seen as part of an electrical **system**, including all vehicle electrical components. The condition and demands placed on any one component may affect the other components.

When the engine is running, a vehicle's alternator output is generally sufficient to supply all of a vehicle's standard electrical needs, but adding to the electrical load (such as fitting many running lights or electrical devices) can make it necessary to install a larger alternator.

Alternators are not designed to charge discharged batteries. A properly specified alternator will use most of its capacity running the vehicle, and have little excess capacity available to charge the batteries. Being forced to charge the batteries can overwork an alternator, causing it to overheat, which increases its internal resistance, further lowering its output. This can lead to problems in several parts of the electrical system, just as problems elsewhere can cause damage to the alternator.

IMPORTANT: Discharged batteries should be charged with external battery chargers. Do not rely on the alternator to charge a depleted battery.

Bad batteries, poor connections, faulty wiring, or faulty components can cause excessive current drain in the system and can damage the alternator.

Corroded or dirty connections, conductive dirt on the battery top, deteriorated cables, and many other factors can give false indications of alternator problems, and can ultimately cause alternator failure. Alternator troubleshooting should also consider the condition of the batteries, cables, and connections. A voltage drop test can often point to a faulty connection or bad component that is causing problems elsewhere in the system.

Causes of Alternator Damage

A drive belt slipping on the alternator pulley generates heat, which radiates up the rotor shaft and damages internal components, in addition to destroying the belt. The heat can destroy the rotor bearings and diodes, leading to alternator failure.

The drive belt must be of the correct size and length, particularly on vehicles equipped with automatic belt tensioners.

Glazed or deteriorated belts should be replaced immediately, and the tension properly adjusted. If a hinge-mount alternator is in use, the fasteners should be tightened in the proper order (first, tensioner fasteners, then mounting fasteners) to the correct torque values, and the belt tension double-checked. Pad-mount alternators do not provide for tension adjustment; that is done by an external tensioner mounted on the engine.

Engine fluid leaks or blow-by may be drawn in by the alternator cooling fan, and create a film that attracts, and holds, a coating of dirt on, and inside the alternator. This is most common in engines with high idle times, operating without frequent use of the engine fan. Dirt and oil buildup inhibit cooling and free movement; alternators should be kept clean. Oil and soot deposits should not be allowed to build.

Alternators made dirty by other parts of the vehicle, such as oil vapor from blow-by, may be misdiagnosed as having leaked their bearing lubricants. This can lead to erroneous replacement of a functioning alternator.

NOTE: Delco Remy alternator bearings use a very small amount of grease that will not contaminate the alternator, or surrounding engine surfaces.

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Troubleshooting

Alternators should not be cleaned with high-pressure spray, which can damage internal parts. If caustic cleaning agents get into electrical connections, they can cause serious long-term problems with hidden corrosion; caustic agents should not be used on any electrical components.

Troubleshooting Procedures

IMPORTANT: Many good alternators are mistakenly replaced, although they are working properly and the problem lies elsewhere in the system. Correct testing and accurate diagnosis help prevent such costly mistakes.

Before testing, make sure:

- all belts are correctly tightened
- the wiring and terminals are clean, and in good condition
- all terminal nuts are tightened and properly protected.

The Intelli-Check Alternator Analyzer is widely available through Delco Remy dealers. See **Fig. 1**. This tool (DR 10457848, a single tester, or DR 10457865, a four-pack of testers) performs a quick check of the alternator, to see if it is working correctly.

NOTE: If a total vehicle charging system analysis is required, see "Alternator/Charging System Testing."

Intelli-Check Alternator Analyzer

The following information includes a pre-test procedure and operating instructions for the Delco Intelli-Check Tester, and is similar to the procedures provided by Delco with the Intelli-Check Tester.

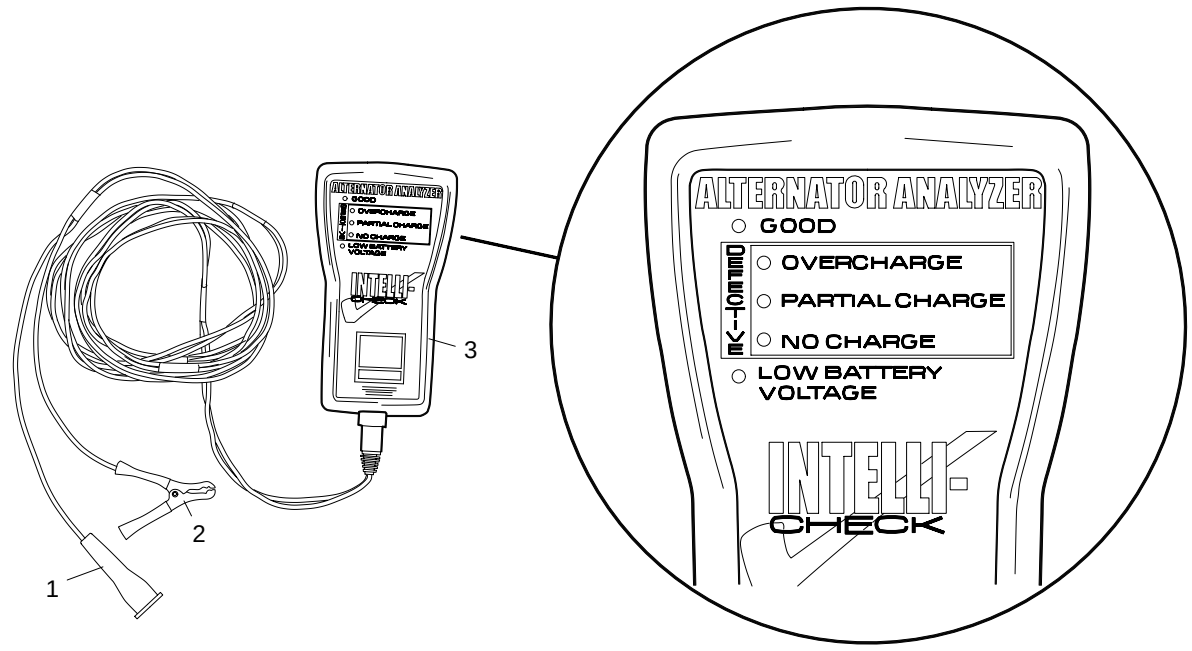
Pre-Test Procedure (Engine Off)

1. Inspect the alternator connections, to be sure they are all secure and tight. Verify that the sense wire is connected to the sense terminal, on vehicles equipped with remote-sense alternators.
2. With the engine off, connect the red alligator clip to the output terminal of the alternator. Connect the black alligator clip to the alternator ground. An optional ground connection is to the body of the alternator. The tester LEDs will illuminate, then go off, as it performs a self-test.
3. After 4 seconds, the tester will activate. The following LEDs may illuminate, depending on the condition of the batteries:
    - **GOOD** (green) LED indicates the battery voltage is above 12.8, and has a surface charge. The surface charge must be removed before proceeding with the alternator test. To remove the surface charge, do the following:
        A. Turn on the headlights and blower motor for 2 minutes, without restarting the engine.
        B. Reset the tester by disconnecting, then reconnecting, the tester alligator clips. The analyzer will perform its self-test again.
        C. Repeat the applicable steps of the Pre-Test Procedure.
    - A **NO CHARGE** (red) LED indicates the battery voltage is below 12.8. This LED should illuminate for most tests. Proceed with the alternator test.
    - A **LOW BATTERY VOLTAGE** (blue) LED indicates the battery voltage is below 12.35. If the batteries will start the vehicle, proceed with the alternator test. However, after completing the Intelli-Check alternator test, perform the procedures under "Alternator/Charging System Testing" to determine the condition of the rest of the charging system.

Intelli-Check Operating Instructions (Engine Running)

1. Start the engine using onboard batteries only. If the batteries will not start the engine, they must be charged before a valid test can be performed.
2. Verify the engine is at idle, and all electrical loads are off.
3. Accelerate the engine to governed speed, hold for 10 seconds, then return to idle.
    - If the **GOOD** (green) LED illuminates, proceed to the next step.

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1. Red Alligator Clip
2. Black Alligator Clip
3. Hand-Held Alternator Analyzer

Fig. 1, Delco Remy Intelli-Check Alternator Analyzer

- If any LEDs illuminate indicating overcharge, partial charge, or no charge (the three red lights in the **DEFECTIVE** section), replace the alternator, and run the complete test again.
- If the **LOW BATTERY VOLTAGE** (blue) LED illuminates, evaluate the charging system using the instructions in "Alternator/ Charging System Testing."

4. With the engine running, turn on all electrical loads.
5. Accelerate the engine to governed speed, hold for 10 seconds, then return to idle.
6. If the **GOOD** (green) LED illuminates, the alternator is OK, and the test is complete.

NOTE: If the alternator tests OK in the above tests, and the customer's complaint is reduced battery or headlight life, see "Alternator/ Charging System Testing" to analyze the charging system.

7. If any LEDs illuminate indicating overcharge, partial charge, or no charge (the three red lights in the **DEFECTIVE** section), replace the alternator, then run the complete test again.
8. If the **LOW BATTERY VOLTAGE** (blue) LED illuminates, evaluate the charging system using the instructions in "Alternator/Charging System Testing".

Alternator/Charging System Testing

Battery Open Circuit Voltage Test, Alternator Output Voltage Test and Alternator Amperage Output Test

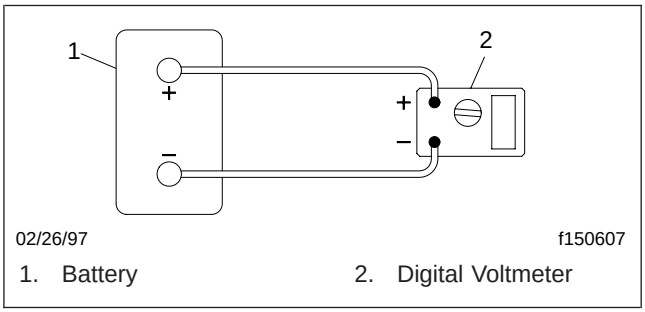
1. Use a digital volt-ohmmeter (VOM) set on the 2–20VDC (or similar) scale to test the battery open circuit voltage (OCV). With the engine shut down and the voltmeter set up as shown in **Fig. 2**, check for voltage of 12.4 volts or more.

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Troubleshooting

If the OCV is 12.4 volts or more, turn on the vehicle headlights for approximately 3 minutes.

If the OCV is less than 12.4 volts, charge the batteries properly. For instructions, see **Group 54**.



1. Battery
2. Digital Voltmeter

Fig. 2, Setup 1: Battery Open Circuit Voltage (and alternator amperage output)

IMPORTANT: Be sure to disconnect the batteries, or remove them from the vehicle, before charging.

2. Check the alternator output without a load. See **Fig. 3**.

   2.1 Start the engine and run it at 1500 rpm for 3 to 5 minutes, to stabilize the system before proceeding to the next step.

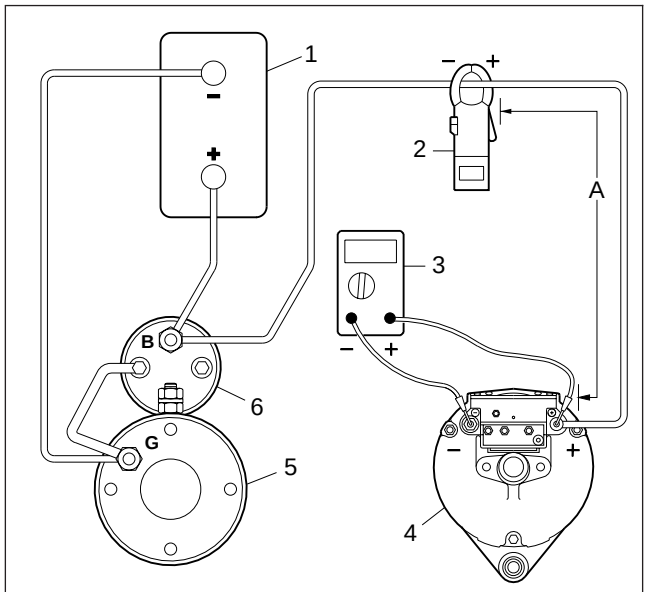
   2.2 Connect the positive (+) lead of the digital voltmeter (still set on the 2–20VDC or similar scale) to the alternator (battery) terminal. Connect the negative (–) lead of the voltmeter to the alternator negative (–) ground terminal. See **Fig. 3**.

   2.3 If the voltmeter reads from 13.8 to 14.2 volts, record this reading (V1) and go to the next step. If the alternator can not make acceptable output, replace it.

3. Check the alternator output under load. See **Fig. 3**.

   3.1 Attach a clamp-on induction ammeter around the positive (+) wire, at least 6 inches (15 cm) away from the alternator. See **Fig. 3**.

   3.2 With the engine still running at 1500 rpm, turn on the following electrical accessories to load the alternator, until the ammeter reads 60 to 75 amps.



A. Locate the ammeter at least 6 inches (15 cm) away from the alternator.

1. Battery
2. Ammeter
3. Digital Voltmeter
4. Alternator
5. Cranking Motor
6. Solenoid

Fig. 3, Setup 2: Alternator Output Test

- Both front and rear heater blowers (on HIGH)
- Headlights (high beams)
- Road lights
- Interior lights

NOTE: As an alternate method of putting load on the alternator, connect a carbon pile tester and set it to 60 to 75 amps.

   3.3 Keep the voltmeter connected as in the previous step; positive (+) lead connected to the alternator positive (+) terminal; negative (–) lead connected to the alternator negative (–) terminal.

   3.4 If the voltmeter reads from 13.6 to 14.2 volts, record this reading (V2), and go to the next step.

   If the voltmeter reads less than 13.6 volts, replace the alternator.

4. Perform an alternator amperage output test.

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4.1 Connect a carbon pile tester across the vehicle batteries, as shown in **Fig. 2**.

NOTE: **Figure 2** shows a voltmeter, but the connections for the carbon pile tester are the same.

4.2 Attach a clamp-on induction ammeter around the alternator output wire, at least 6 inches (15 cm) away from the alternator. See **Fig. 3**.

4.3 Start the engine, and make sure all vehicle electrical accessories are turned off. Run the engine at fast speed, and adjust the tester to the alternator maximum current output. Record this output value.

NOTE: Ensure that the alternator is turning at maximum available rpm, and keep adjusting the tester dial until the ammeter reads its highest value. Record this reading.

4.4 Turn off the tester, and shut down the engine.

Multiply the output reading by 0.85. For example, if the output reading is 90 Amps, 90 x 0.85 = 76.5 Amps.

4.5 If the output value recorded is less than 85 percent of the rated amperage output, repeat the test.

4.6 If the output value recorded is still less than 85 percent of the rated amperage output, replace the alternator.

4.7 If the output is more than 85 percent of the rated output, the alternator is good.

4.8 Make sure that all test instruments are removed, and that the vehicle wiring is routed and connected in its normal configuration.

5. To identify other problem areas within the vehicle, check the operation of the charging system. Set up the voltmeter as shown in **Fig. 2** and **Fig. 3**.

NOTE: For any load at 1500 rpm or more, battery voltage must be within 0.5 volts of the alternator voltage.

5.1 If readings at the batteries are within 0.5 volts of the readings at the alternator, the charging system is working correctly. Check other areas of the vehicle to locate the problem.

5.2 If the reading at the batteries is more than 0.5 volts lower than the reading at the alternator, do the next step.

6. Check charging system connections, cables, and terminals.

6.1 Check all connections between the battery, starter, and alternator for tightness and signs of corrosion. Tighten and clean as necessary.

6.2 Check all cables for breaks or partial breaks. Repair or replace as necessary.

6.3 Check each ring terminal for breakage at the point where it attaches to its wire or cable.

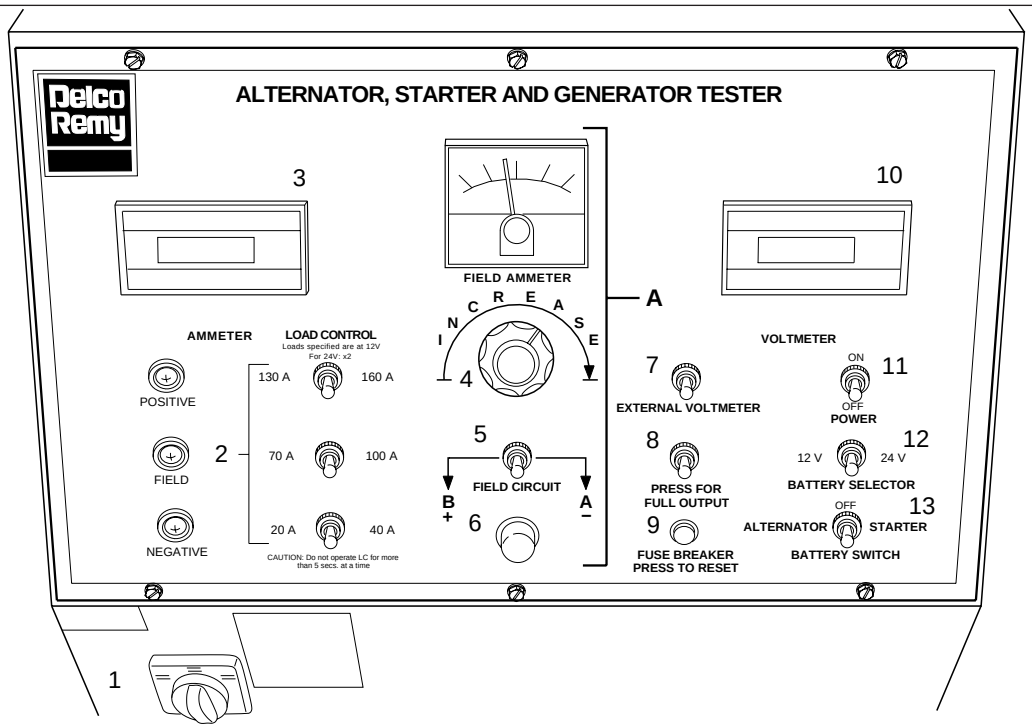
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Required Equipment

See **Fig. 1** for a standard Delco Remy Tester.

NOTE: This equipment and the following tests may also be used to test Leece Neville alternators.

- Delco Remy alternators require a 2-1/2 inch V-belt pulley, p/n DR 10503932 (supplied with the Delco Remy tester).
- Leece-Neville alternators require a 3-1/2 inch V-belt pulley, p/n LN 107 22, and a 5/8-inch washer, p/n LN 120 129.



A. These controls are not used when testing alternators with internal voltage regulators.

1. Motor Switch: Forward–Off–Reverse
2. Load Control Switches
3. Ammeter
4. Variable Field Control
5. Field Selector Switch
6. DTL Lamp
7. External Voltmeter Switch
8. Full Field Switch
9. Circuit Breaker (Press to Reset)
10. Voltmeter
11. Power Switch
12. 12–24-Volt Selector
13. Alternator/Battery Test Switch

Fig. 1, Alternator Tester Control Panel (typical)

The tests in this subject require the following equipment:

- Alternator tester with the battery charged to at least 12.4 V (Delco Remy shown).
- Alternator to be tested.
- V-belt.
- Jumper lead to connect the BAT (+) alternator terminal to the remote sense terminal.
- Standard 5/8–18 hexnut, for mounting the pulley on the alternator. Use a standard hexnut, not the self-locking nut that is supplied with the alternator.

NOTICE

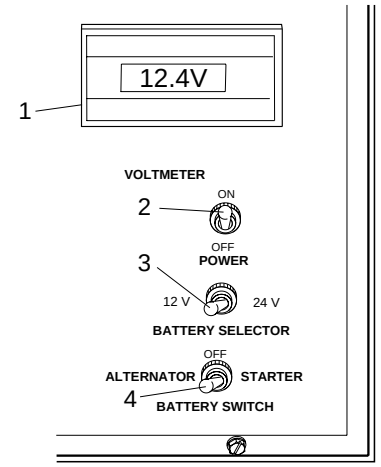
Repeatedly using self-locking nuts may damage the threads on the pulley shaft.

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Alternator Bench Testing

Test Preparation

1. Set the battery voltage selector switch to 12V. See **Fig. 2**.



1. Voltmeter
2. Power Switch
3. Battery Voltage Selector
4. Battery Switch

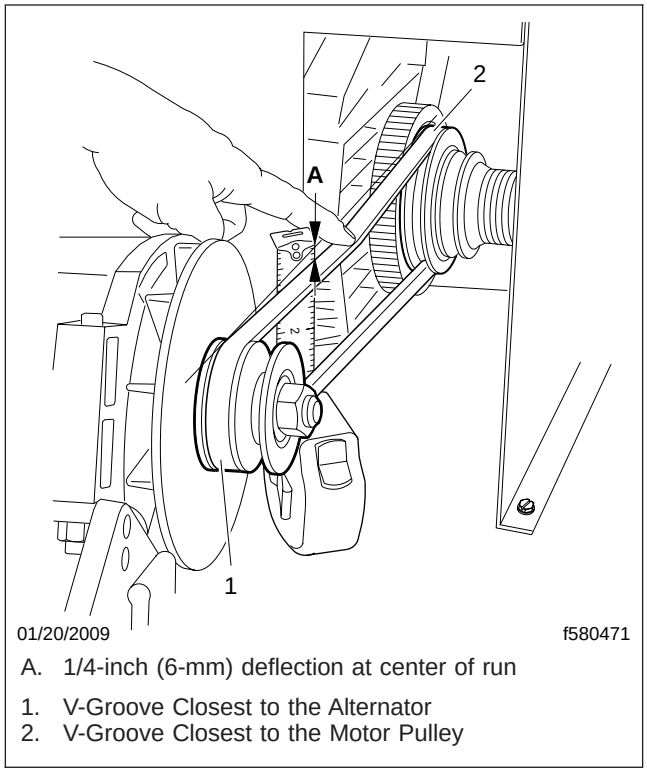
Fig. 2, Alternator Tester Power Switches

2. Set the battery switch to "Alternator." See **Fig. 2**.

NOTICE

The next step supplies battery voltage to the alternator tester power and ground cables. Ensure that they are separated and insulated from each other, and that they are not touching conductive materials. Failure to observe this precaution could cause component damage.

3. Turn the tester power switch ON. See **Fig. 2**. Check the battery voltage in the voltmeter on the tester. The tester battery voltage must be at least 12.4V; if it is below 12.4V, charge or replace the tester battery as necessary. Turn the power switch OFF.
4. Mount the appropriate manufacturer's pulley on the alternator.
5. Mount the alternator on the tester.
   - 5.1 Run the belt from the largest V-groove of the bench motor drive pulley to the V-groove closest to the alternator on the alternator pulley. See **Fig. 3**. Do not use the serpentine belt groove.



A. 1/4-inch (6-mm) deflection at center of run

1. V-Groove Closest to the Alternator
2. V-Groove Closest to the Motor Pulley

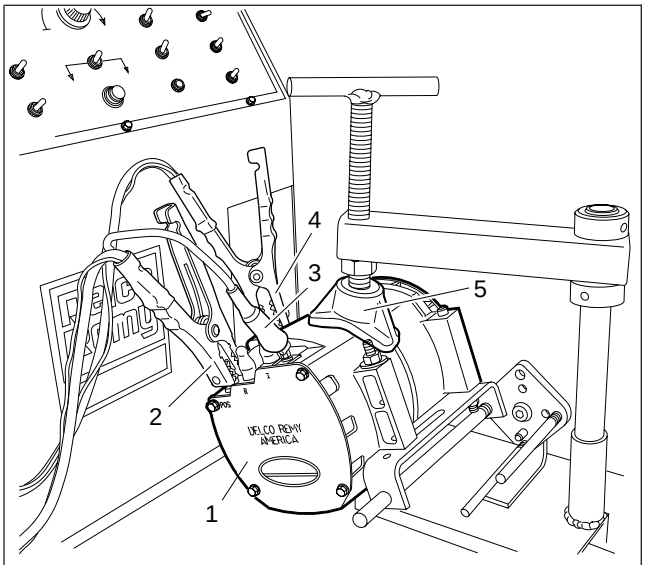
Fig. 3, Belt Deflection with Alternator Mounted on Tester

   - 5.2 Move the vise to align the pulleys, so that the belt runs straight between the V-groove on the motor pulley and the V-groove closest to the alternator.
   - 5.3 Tension the V-belt with the hand wheel, so that it deflects 1/4-inch (6 mm) under hand pressure at the center of the run, then clamp the alternator in position.
6. Connect the electrical leads from the tester to the alternator. See **Fig. 4**. Take care that the tester power and ground cables are separated and insulated from each other, and that they are not touching conductive materials.
   - 6.1 Connect the red positive lead from the tester to the output terminal (BAT or +) on the alternator.

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6.2 Connect the black negative lead from the tester to the output ground terminal (-) or to a mounting ear of the alternator.

7. Attach a jumper lead from the output terminal (BAT or +) to the remote sense terminal. Some testers have this jumper built-in on the positive lead, as shown in **Fig. 4**, Item 3; others may require a separate jumper as shown in **Fig. 5**.



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1. Alternator
2. Positive Lead
3. Remote Sense Jumper
4. Negative Lead
5. Clamp

Fig. 4, Alternator Clamped on Tester with Leads Connected

Voltage Test

NOTICE

Ensure that the alternator tester power and ground cables are separated and insulated from each other, and that they are not touching conductive materials. Failure to do so could cause damage to the tester.

1. Turn the tester power switch ON. See **Fig. 2**, Item 2.

⚠ WARNING

The following steps involve spinning the alternator with the open V-belt; be careful that all loose objects, garments, hair, and hands are well clear of the alternator and belt, and use safety shields properly, or serious personal injury may occur.

2. Turn the motor switch (located on the lower left-hand portion of the tester) to the FORWARD position, to start the alternator free-spinning. See **Fig. 1**, Item 1.

NOTE: The voltage output limit applies only to a non-loaded alternator. The purpose of this test is to ensure that the alternator produces the proper voltage with no load (free-spin).

3. Record the alternator voltage output during free-spin. See **Fig. 2**, Item 1.
   - If the alternator output is between 13.5V and 14.7V, the alternator is functioning properly; proceed to the *Load Test*.
   - If the alternator output is not between 13.5V and 14.7V, the alternator is faulty and must be replaced.

Load Test

1. Calculate the test load for the alternator being tested. The test load is 80 percent of the alternator-output rating.

   Multiply the alternator-output rating by **0.8**, to calculate the test load.

   For example, an alternator with 100-amp output rating has an 80-amp test load (100 x 0.8 = 80).

NOTE: Contact a Delco Remy or Leece-Neville representative if you are unsure of the calculation.

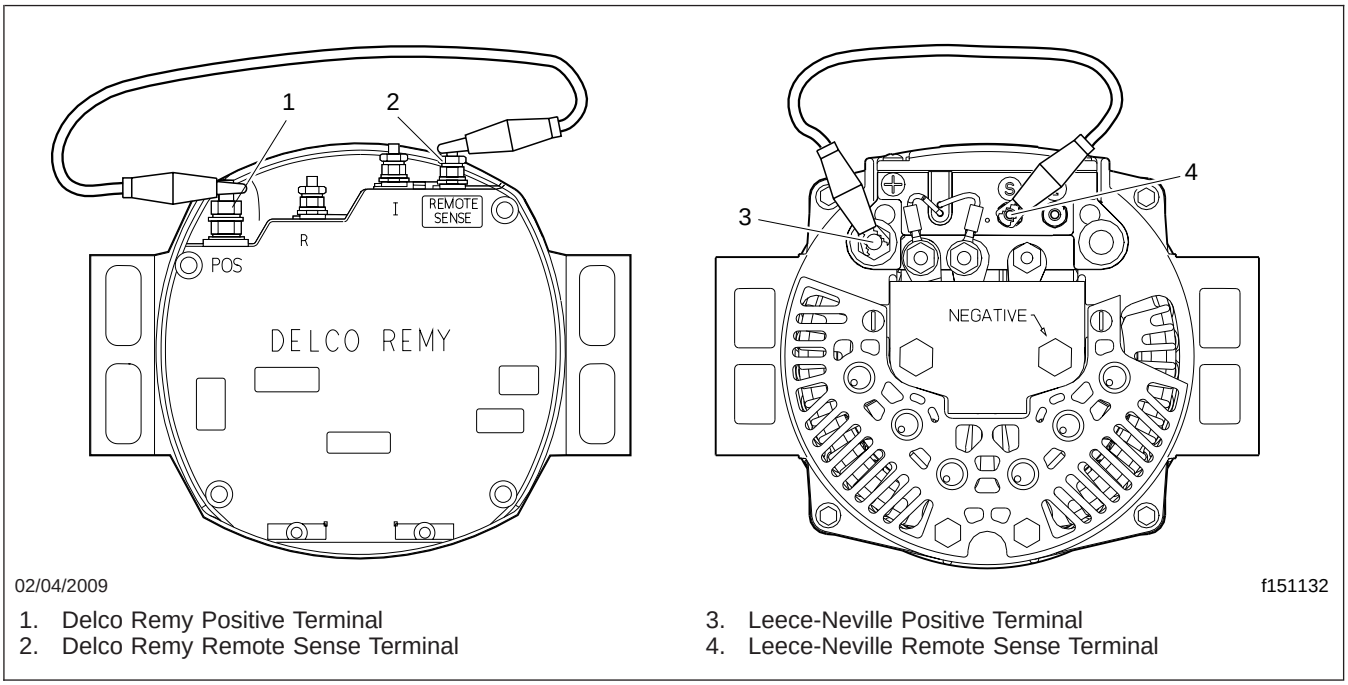
2. Determine the appropriate load-control-switch setting to use for the alternator being tested. See **Fig. 1**, Item 2.

   Use the load-control-switch setting **equal to, or the next level below** the test load calculation.

   For example, on this tester the available settings are 20/40, 70/100, and 130/160 amp. The load-control-switch setting for the 100-amp alternator

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Alternator Bench Testing



1. Delco Remy Positive Terminal
2. Delco Remy Remote Sense Terminal
3. Leece-Neville Positive Terminal
4. Leece-Neville Remote Sense Terminal

Fig. 5, Installed Jumper Leads (Typical)

would be 70 amp, because it is the available setting just below 80 amp.

NOTICE

Do not operate the alternator under load for more than 5 continuous seconds or damage to the alternator may occur.

3. Apply the appropriate load switch for 5 seconds then release.
4. Record the **difference** in voltage output between when the alternator is free-spinning, and under load.
   - For all alternators except Delco Remy 22SI, if the voltage difference between free-spin and loaded is more than 0.5V, the alternator is faulty and must be replaced. If the voltage difference between free-spin and loaded is less than 0.5V, the alternator is functioning properly.
   - For Delco Remy 22SI, if the voltage difference between free-spin and loaded is more than 1.0V, the alternator is faulty and must be replaced. If the voltage difference between free-spin and loaded is less than 1.0V, the alternator is functioning properly.
5. Turn the tester power switch OFF, then disconnect the electrical leads and jumper from the alternator.

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See **Fig. 1** for typical alternator wiring.

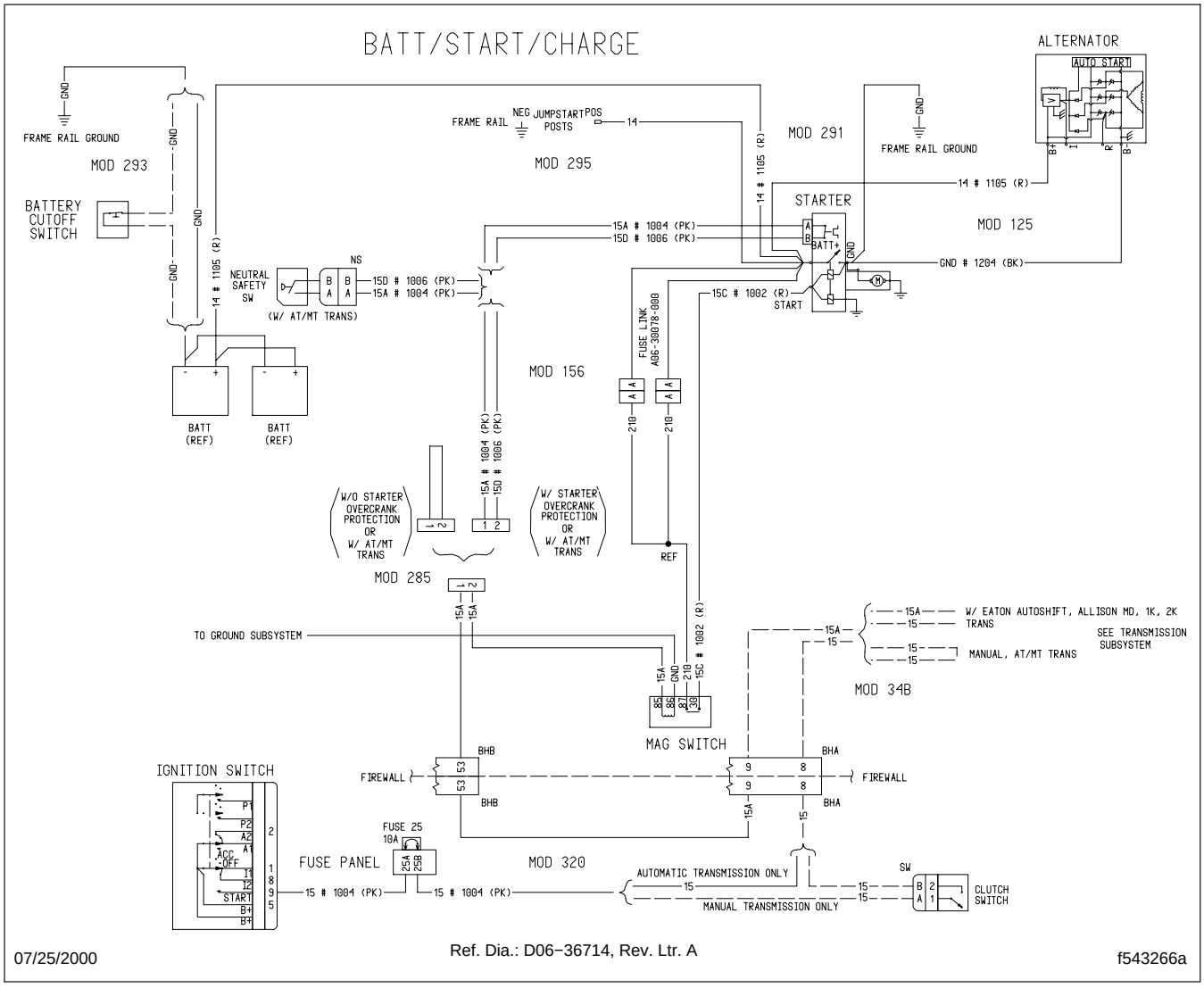


Fig. 1, Typical Alternator Wiring

Fastener Torque			
Size	**Type**	**Torque: lbf·ft (N·m)**	**Torque: lbf·in (N·cm)**
1/4–20	—	—	50–60 (560–680)
1/4–28	—	—	55–70 (620–780)
5/16–24	—	—	100–110 (1140–1240)
5/8–18	—	70–80 (95–108)	—
1/2–13	Phosphate & Oil	60–70 (81–95)	—
1/2–13	Zinc	50–60 (68–81)	—

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Specifications

Fastener Torque			
Size	**Type**	**Torque: lbf·ft (N·m)**	**Torque: lbf·in (N·cm)**
10 mm	Phosphate & Oil	30–38 (41–52)	—
10 mm	Zinc	24–31 (33–42)	—
10–24	—	—	15–25 (160–280)
Alternator Pulley Nut	—	75 (102)	—

Table 1, Fastener Torque

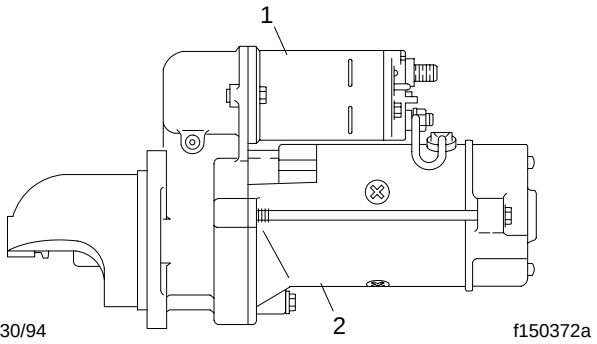
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General Information

The Delco Remy starter mounts at the forward face of the flywheel bell housing on the right side of the engine.

The starter assembly consists of two basic parts: the solenoid and the starter motor. See **Fig. 1**. The shift lever and wiring connect the two parts, and the lever, motor and solenoid are completely enclosed for protection from dirt, ice and splash. See **Fig. 2**. The starter features sealed bearings with lifetime lubrication.

The solenoid is wired to the starter relay, the alternator, and the batteries. Turning the key switch to start supplies power to the starter relay, and the relay activates the solenoid. Once activated, the solenoid plunger slides forward, moving the shift lever to engage the starter drive gear with the engine flywheel ring gear, and connecting the solenoid's battery terminal to the motor terminal.



1. Starter Solenoid
2. Starter Motor

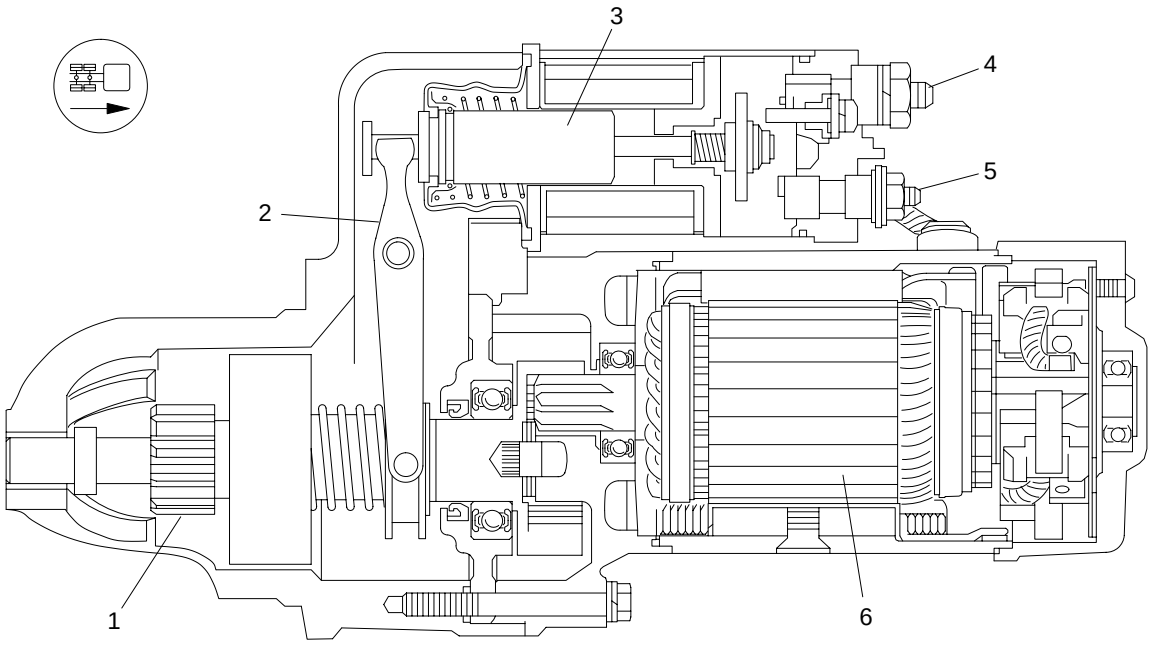
Fig. 1, Delco Remy Starter

The motor terminal is wired to the starter motor so power from the batteries activates the starter motor after the starter drive gear engages the engine flywheel.

Once the engine starts, and the ignition stops supplying power to the starter relay, the solenoid plunger retracts, disengaging the starter motor from the engine flywheel, and cutting battery power to the starter motor.

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General Information



1. Starter Drive Gear
2. Shift Lever
3. Solenoid Plunger
4. Battery Terminal
5. Motor Terminal
6. Starter Motor

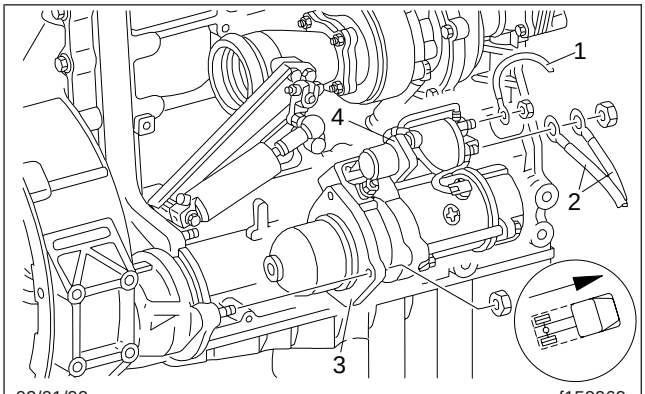
Fig. 2, Starter Components

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Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Disconnect the batteries or, if equipped, turn off the battery shutoff switch.
   - 3.1 Disconnect the battery ground cable at the vehicle frame.
   - 3.2 Disconnect the positive battery cable from the batteries.
4. Remove the starter from the engine.
   - 4.1 On Cummins ISB engines, disconnect the wires from the starter solenoid terminals and label them for reassembly. Remove the three capscrews that secure the starter to the engine.
   - 4.2 On Mercedes-Benz engines, disconnect the control cable and the starter cables at the solenoid. See **Fig. 1**. Remove the three nuts and remove the starter from the timing case of the engine.

     Inside the timing case, inspect the teeth of the flywheel ring gear for wear. If worn, replace the flywheel ring gear.



NOTE: Right-side mounting shown.

1. Control Cable
2. Starter Cables
3. Starter Motor
4. Solenoid

Fig. 1, Starter, Mercedes-Benz Engine

5. Inspect the starter pinion for wear. If worn, replace the starter.

Installation

1. Install the starter on the engine.
   - 1.1 On Cummins ISB engines, position the starter and secure it with the three capscrews. Tighten the capscrews 32 lbf·ft (43 N·m).

     Connect the wires to the starter terminals. If the wires were not labeled for reassembly, see the starter wiring diagram in **Specifications, 400**.
   - 1.2 On Mercedes-Benz engines, apply a light film of grease to the starter pinion and flywheel ring gear.

     Position the starter and secure it with the three nuts. Tighten the nuts 37 lbf·ft (50 N·m).

     Connect the starter cables and the control cable to the solenoid. See **Fig. 1**.
2. Connect the batteries or if equipped, turn on the battery shutoff switch.
   - 2.1 Connect the positive battery cable to the batteries.
   - 2.2 Connect the battery ground cable to the vehicle frame.
3. Close and latch the hood.
4. Remove the chocks from the tires.
5. Start the engine to test the starter.

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Troubleshooting

Problem—Starter Cranks Slowly or Not at All

Problem—Starter Cranks Slowly or Not at All	
Possible Cause	**Remedy**
Loose drive belt	Check the drive belt. See the drive belt subject in the appropriate engine section in **Group 01** for instructions. If necessary, tighten to the manufacturer's specifications. Start the engine and check the alternator voltage and output. See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
Damaged or missing drive belt	Check the drive pulleys for locked bearings. Repair or replace any damaged components. Replace the drive belt and start the engine. Check the alternator voltage and output. See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
Undercharged batteries	Do a load test on the batteries. See **Group 54** for instructions. Charge or replace batteries as needed. If the batteries were discharged, check the alternator voltage and output. See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
Battery cables do not deliver sufficient voltage to starter	Check the available cranking voltage. Go to "Available Cranking Voltage Test" for instructions.
Broken starter solenoid circuit	Check the starter solenoid circuit. Go to "Starter Solenoid Circuit Test" for instructions. Make repairs as needed. Start the engine to verify the repair.
Broken control circuit	Check the starter wiring. Go to "Starter Wiring Test" for instructions. Make repairs as needed. Start the engine to verify the repair.
Broken magnetic switch	Replace the magnetic switch.
Damaged starter ring gear or pinion gear	Visually check the ring and pinion gears. Go to "Ring and Pinion Gear Test" for instructions.
Starter does not stay engaged	Go to "Cold Weather Starting Test" for instructions.
Damaged starter	Replace the starter.
Mechanical problem in engine	See **Group 01** or the engine manufacturer's manuals.

STARTER TEST

1. Connect a voltmeter from solenoid "S" terminal to ground. Engage the start switch.

   If the voltmeter reads 6.0 volts or less, check and repair the magnetic switch circuit. If symptoms continue, proceed with the test.

2. If the voltmeter reads more than 6.0 volts or the symptoms continue after repairing the magnetic switch circuit, remove the starter and visually check the pinion.
3. If the pinion is milled, repair or replace the starter, but do not install the starter.
4. Visually check the ring gear. If the teeth are milled, replace the ring gear and check the flange to flywheel dimension.
5. Reinstall the starter and perform the "Available Cranking Voltage Test."

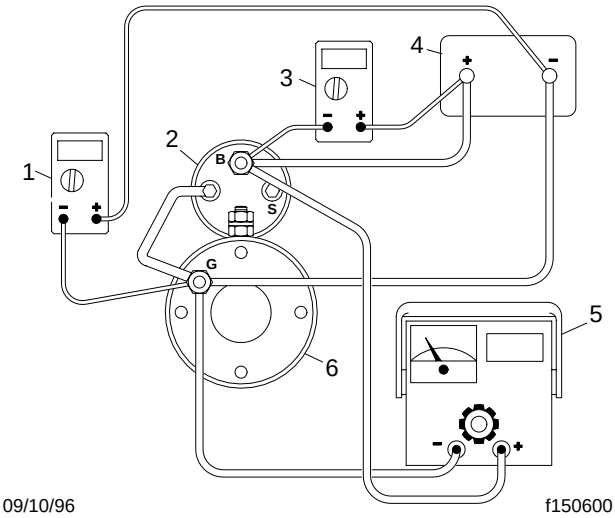
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Troubleshooting

AVAILABLE CRANKING VOLTAGE TEST

Battery Cable Test

1. Connect the positive lead of a carbon pile tester to the starter solenoid "B" (battery) terminal. Connect the negative lead of the carbon pile to the starter "G" (ground) terminal. See **Fig. 1**.



1. Voltmeter (recording V2, negative side voltage loss)
2. Cranking Motor
3. Voltmeter (recording V1, positive side voltage loss)
4. Battery
5. Carbon Pile
6. Starter Solenoid

Fig. 1, Battery Cable Test

IMPORTANT: Connect the voltmeter to the starter "B" terminal, not to the carbon pile clamp.

2. Set a digital voltmeter on the low scale (2V, 3V, or 4V, depending on type of meter) and connect the positive lead to the battery positive (+) terminal. Connect the negative lead to the starter "B" terminal.

3. Turn on the carbon pile and adjust it to a 500-amp load. Read and record the voltage (V1) on the voltmeter. Turn off the carbon pile.

4. Now connect the digital voltmeter (still set on the low scale) to the battery negative (–) terminal and the starter "G" (ground) terminal.

IMPORTANT: Connect the voltmeter to the starter "G" terminal, not to the carbon pile clamp.

5. Turn on the carbon pile again and adjust it to a 500-amp load, as before. Read and record the voltage (V2) on the voltmeter. Turn off the carbon pile.

NOTE: Ignore the minus (–) sign.

6. Add the positive (V1) and the negative (V2) voltage loss readings together. If the total voltage loss is 0.500 volts or less, the battery cables are OK.

   Add the positive (V1) and the negative (V2) voltage loss readings together. If the total voltage loss is more than 0.500 volts, repair or replace as necessary.

7. Disconnect the carbon pile and the voltmeter. Reconnect the magnetic switch to the starter "S" terminal.

Interconnecting Cable Test

1. This test requires two persons. While the first person cranks the engine, the second person uses a voltmeter to measure the voltage across the starter solenoid "B" (battery) and starter "G" (ground) terminals.

2. If the voltage is 9.0 volts or less while cranking, check the battery interconnecting cables.

   2.1 While cranking, measure the voltage across each battery.

   2.2 If the difference between any two batteries in the same battery box is more than 0.5 volt, check and replace the interconnecting cables as required.

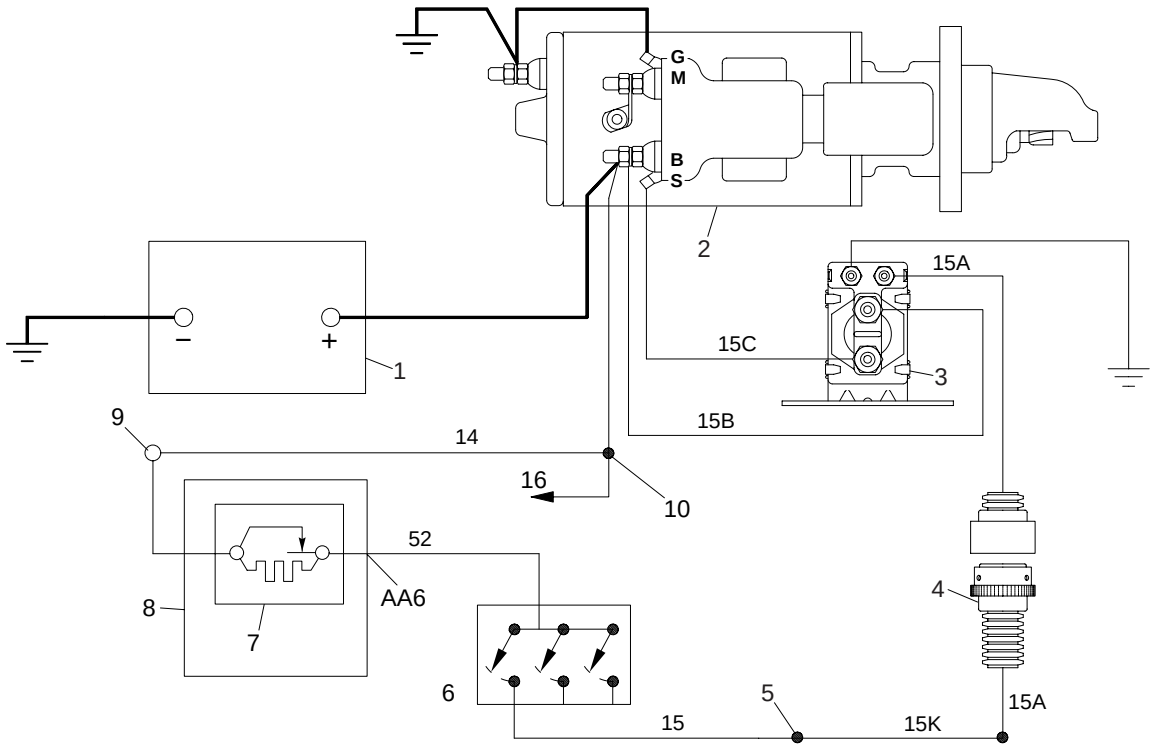
   2.3 If any cable or connection feels warm to the touch, check and replace the interconnecting cables as required.

3. If the starter still does not crank, go to "Ring and Pinion Gear Test."

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STARTER SOLENOID CIRCUIT TEST

The starter solenoid circuit includes the starter solenoid, cranking motor, magnetic switch and ignition switch. It is part of the cranking circuit. See **Fig. 2**.



NOTE: Wire 16 connects to the alternator.

1. Battery
2. Cranking Motor (top view)
3. Magnetic Switch
4. Frontwall Connector (Pin E1)
5. Splice Connector
6. Ignition Switch
7. 10-Amp Circuit Breaker
8. Cab/Firewall Power Stud
9. Engine Power Stud

Fig. 2, Cranking Circuit Wiring

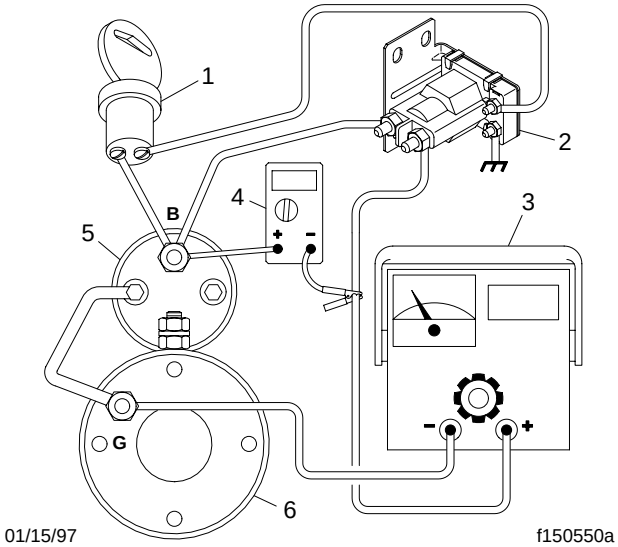
If there is excessive voltage loss in the starter solenoid circuit, the starter may not engage the flywheel at all, or it may drop out too soon when battery voltage goes down. Do the following test to check for excessive voltage loss in the starter solenoid circuit.

1. Disconnect, at the solenoid, the lead from the magnetic switch to the "S" terminal on the starter solenoid.
2. Use a small clamp or 8-gauge jumper wire to connect this lead to the positive lead of a carbon pile tester. Connect the negative lead of the carbon pile to the starter "G" (ground) terminal. See **Fig. 3**.
3. Set a digital voltmeter on the high (20V) scale and connect the positive lead to the starter "B" (battery) terminal. Connect the negative lead to the magnetic switch lead to which the carbon pile is already connected.
4. Read and record (as V3) the battery voltage shown on the meter, about 12.6V.

NOTE: This step requires two persons.

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Troubleshooting



1. Ignition Keyswitch
2. Magnetic Switch
3. Carbon Pile
4. Digital Voltmeter
5. Starter Solenoid
6. Cranking Motor

Fig. 3, Starter Solenoid Circuit Test

5. Have one person turn the ignition keyswitch to the START position while the other person listens for the clicking sound of the magnetic switch closing. Read the voltage on the voltmeter. It should read very low voltage, less than 0.1V.

IMPORTANT: If the magnetic switch does not close, do the "Magnetic Switch Circuit Test."

6. Check the starter solenoid circuit voltage loss.

   6.1 Turn the ignition key to the START position; then turn on the carbon pile and adjust it to a 100-amp load.

   6.2 Now read and record (as V4) the voltage on the voltmeter. Turn off the carbon pile.

   6.3 If the voltage drop (V4–V3) is 1.0V or less, the starter solenoid circuit is OK. Test the magnetic switch circuit.

   If the voltage drop (V4–V3) is more than 1.0V, the voltage loss is excessive. Go to "Starter Wiring Test."

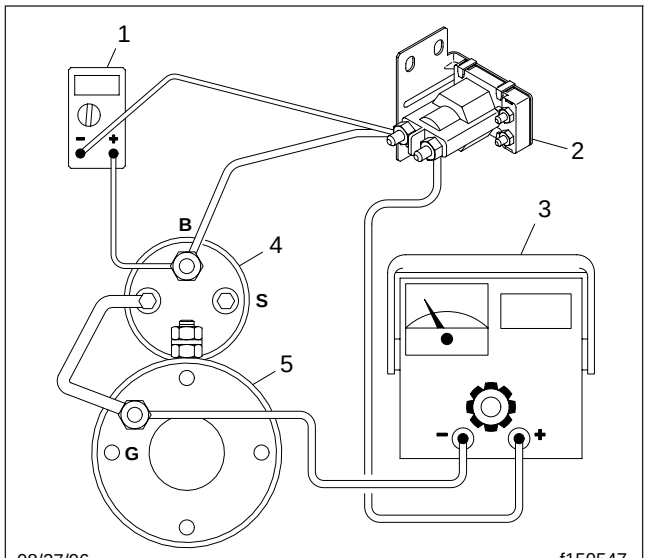
STARTER WIRING TEST

1. Disconnect the lead from the magnetic switch to the "S" terminal on the starter solenoid (leave as in "Starter Solenoid Circuit Test").

IMPORTANT: It is difficult to gain access to the starter "S" terminal. Avoid touching the starter "B" terminal at the same time as the "S" terminal, as this can cause an electric shock.

2. Connect this lead to the positive lead of a carbon pile tester. Connect the negative lead of the carbon pile to the starter "G" (ground) terminal (leave as in "Starter Solenoid Circuit Test").

3. Set a digital voltmeter on the low scale and connect the positive lead of the voltmeter to the starter solenoid "B" (battery) terminal. Connect the negative lead of the voltmeter to the large terminal of the magnetic switch that is connected to the starter "B" terminal (circuit 15B). See **Fig. 4**. If any voltage shows, reconnect to the other large terminal.



1. Digital Voltmeter
2. Magnetic Switch
3. Carbon Pile
4. Starter Solenoid
5. Cranking Motor

Fig. 4, Starter Wiring Test, First Wire Voltage Loss (V5)

NOTE: If desired, do a continuity check on the circuit to be sure that it is connected to the correct terminal. Low resistance indicates that the connections are correct.

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4. Have a second person start the engine momentarily.

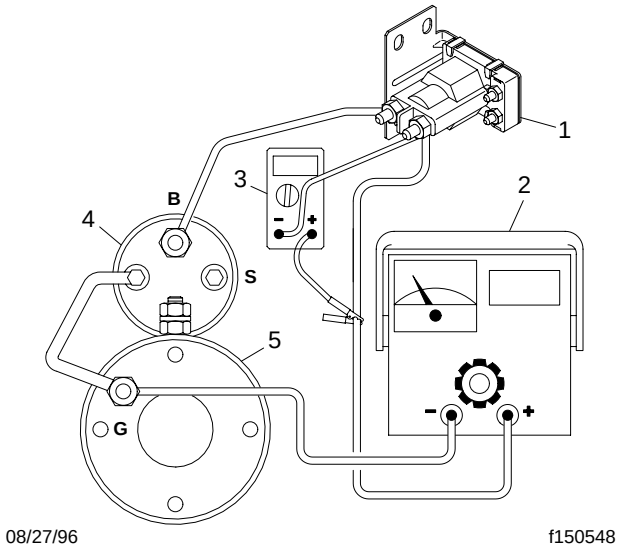
IMPORTANT: If the magnetic switch does not close, do the "Magnetic Switch Circuit Test."

5. Check the first wire voltage loss (V5).

   5.1 Turn the ignition key to the START position, then turn on the carbon pile and adjust it to a 100-amp load.

   5.2 Now read and record the voltage (V5) on the voltmeter. Turn off the carbon pile.

6. Now connect the positive lead of the digital voltmeter (still set on the low scale) to the magnetic switch lead which is already connected to the carbon pile (as in "Starter Solenoid Circuit Test"). Connect the negative lead of the voltmeter to the other large terminal on the magnetic switch (circuit 15C). See **Fig. 5**.



1. Magnetic Switch
2. Carbon Pile
3. Digital Voltmeter
4. Starter Solenoid
5. Cranking Motor

Fig. 5, Starter Wiring Test, Second Wire Voltage Loss (V6)

7. Have a second person start the engine momentarily.

8. Check the second wire voltage loss (V6).

   NOTE: Ignore the minus (–) sign.

   8.1 Turn the ignition key to the START position, then turn on the carbon pile and again adjust it to a 100-amp load.

   8.2 Now read and record the voltage (V6) on the voltmeter. Turn off the carbon pile.

   8.3 Add the two voltages (V5 and V6) together to get the total wire voltage loss. If the total wire voltage loss adds up to 0.8 volts or less, the wiring is OK. Replace the magnetic switch.

   If the total wire voltage loss adds up to more than 0.8 volts, check the wire connections for tightness and the terminals for corrosion. Repair or replace as necessary.

9. Disconnect the carbon pile and the voltmeter. Reconnect the magnetic switch to the starter "S" terminal.

10. Check all wiring and connections and repair or replace as needed.

MAGNETIC SWITCH CIRCUIT TEST

Before replacing the magnetic switch, or repairing or replacing any of the starting and charging circuits, do this test.

1. Apply the parking brakes and chock the tires.

2. Check the wiring and the magnetic switch for wear or damage. See **Fig. 2**.

3. Check the circuit between the magnetic switch and the starter "B" terminal (circuit 15B) for correct voltage.

   3.1 Disconnect the circuit running from the starter "S" terminal to the magnetic switch (circuit 15C).

   3.2 Connect a voltmeter to the magnetic switch terminal where the circuit from the starter "B" terminal is connected (circuit 15B).

   3.3 If the voltmeter reading is 0 volt, check for an open circuit.

   If the voltmeter reading is less than 12.0 volts, check for corroded or loose connections.

   If the voltmeter reading is 12.0 volts or more, go to the next step.

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Troubleshooting

3.4 Repair or replace any damaged wires.

4. Check the magnetic switch ground circuit.
   - 4.1 Connect an ohmmeter between the magnetic switch ground terminal and a known good ground.
   - 4.2 If the ohmmeter reading is more than 0.5 ohm, check for corroded or loose connections.
   - 4.3 Repair or replace any damaged wires.
5. Check the magnetic switch ignition wiring (circuit 15) for correct voltage.

   NOTE: This check requires two persons.

   - 5.1 Have one person turn on the ignition keyswitch and hold it in the "start" position.
   - 5.2 Have the other person connect a voltmeter between the magnetic switch terminal where the ignition circuit is connected (circuit 15A) and a known good ground.
   - 5.3 If the voltmeter reading is 0 volt, check for an open in circuit 15A.

     If the voltmeter reading is less than 11.0 volts, check for corroded or loose connections.

     If the voltmeter reading is 11.0 volts or more, go to the next step.
   - 5.4 Repair or replace any damaged wires, circuit breakers, or relays.
6. Check the circuit between the magnetic switch and the starter "S" terminal (circuit 15C) for correct voltage.

   NOTE: This check requires two persons.

   - 6.1 Have one person hold the ignition keyswitch in the "start" position.
   - 6.2 Have the other person connect a voltmeter between the magnetic switch terminal where the circuit from the starter "S" terminal is connected (circuit 15C) and a known good ground.
   - 6.3 If the voltmeter reading is less than 12.0 volts, replace the magnetic switch.
7. Check the voltage to the magnetic switch again. If the voltmeter reading is now eleven volts or more, disconnect the voltmeter, and remove the chocks from the tires. If the reading is still less than eleven volts, replace the magnetic switch.

RING AND PINION GEAR TEST

1. This test requires two persons. While the first person bars the engine over, the second person visually checks the entire flywheel ring gear and starter pinion gear visually (check all the teeth in both gears).
2. If the pinion teeth are damaged, replace the starter. If the ring gear teeth are damaged, replace the ring gear.

NOTE: For ring gear replacement procedures, see the engine manufacturer's manuals.

3. If the engine still does not crank properly after replacing the starter, look for a mechanical problem in the engine. For instructions, see **Group 01** or the engine manufacturer's manuals.

COLD WEATHER VOLTAGE TEST

In cold weather, the starter may fail to engage, even though it performed well at higher temperatures. Do the following test to check for cold weather voltage loss in the cranking circuit.

1. With the ignition keyswitch on, clamp a heavy battery jumper cable between the two large studs on the magnetic switch. Remove the jumper immediately to stop the engine from cranking.
2. If the engine starts with the jumper in place, do the "Starter Wiring Test." Repair/replace the wiring connections, terminals, and/or magnetic switch as necessary.
3. If the engine now starts properly, check the starter mounting bolts for tightness and do the "Alternator Wiring Test." See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
4. If the engine still does not start properly, go to "Available Cranking Voltage Test."

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Specifications

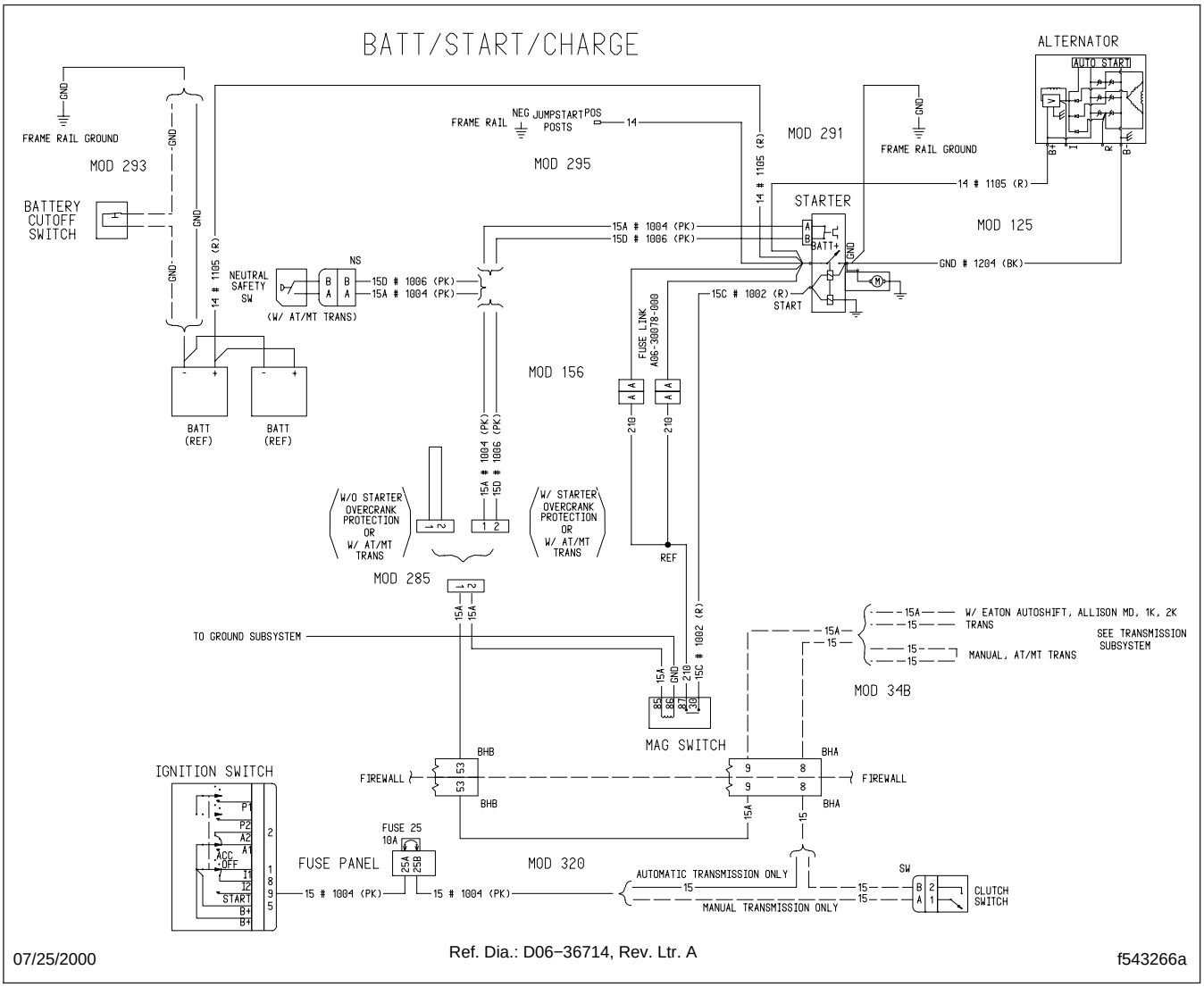
See **Fig. 1** for a starter wiring diagram.

Fastener Torques			
Description	**Grade**	**Size**	**Torque lbf·ft (N·m)**
Starter Mounting Capscrews, Cummins ISB Engines	8.8	M10 x 1.5	32 (43)
Starter Mounting Nuts, Mercedes-Benz Engine	—	—	37 (50)
Turbocharger Oil Return Pipe Mounting Bolts	10.9	M8 x 1.25	30 (40)

Table 1, Fastener Torques

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Specifications



07/25/2000 Ref. Dia.: D06−36714, Rev. Ltr. A f543266a

Fig. 1, Starter Wiring Diagram

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General Information

The Leece-Neville alternators are 14-volt, self-load-limiting alternators equipped with a three-step adjustable voltage regulator. See **Fig. 1**.

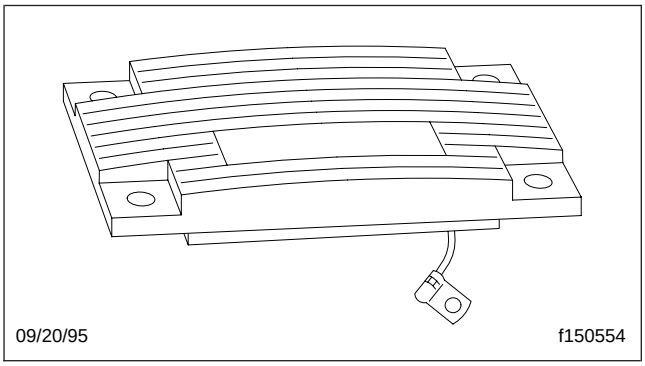


Fig. 1, Three-Step Adjustable Voltage Regulator

The SmartChek™ models feature a light-emitting diode (LED) that changes color to simplify troubleshooting. When the LED is green, the alternator is OK. When the LED is red, the alternator needs replacing.

Six silicon diodes mounted in heat sinks convert alternating current from the delta-wound stator into direct current. A capacitor connected between the heat sinks helps suppress transient voltage spikes, which could possibly damage the diodes.

The brushes and voltage regulator are located in a waterproof housing that may be removed for replacement or inspection. An external relay terminal is also provided.

The voltage regulator is also equipped with transient voltage protection and will withstand instantaneous opening of the charging circuit under full load conditions.

Current is produced by rotating a magnet inside a stationary winding. The rotating magnet is called a rotor and the stationary winding is called a stator. See **Fig. 2**.

The rotor is electrically magnetized by a small current flowing through the brushes, riding on smooth slip rings. See **Fig. 3**. Alternating current is then produced as the magnetic poles of the rotor pass the coil windings of the stator.

These alternators have 12 magnetic poles in the rotor and three separate windings in the stator. See

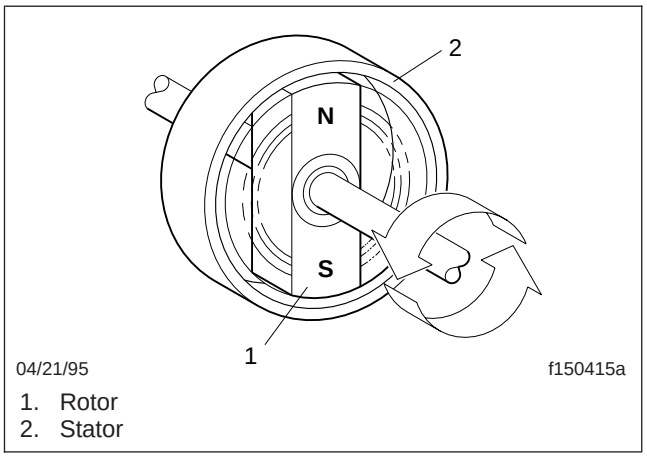


Fig. 2, Producing the Current

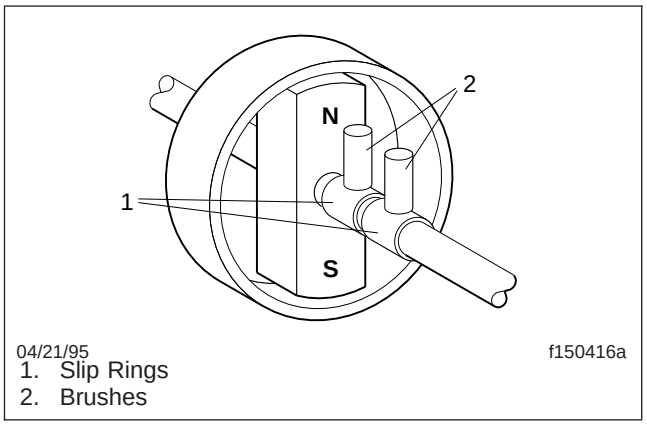


Fig. 3, Magnetizing the Rotor

Fig. 4 and **Fig. 5**. Since the rotor produces alternating current as it passes the coil windings of the stator, increased engine speed produces more current.

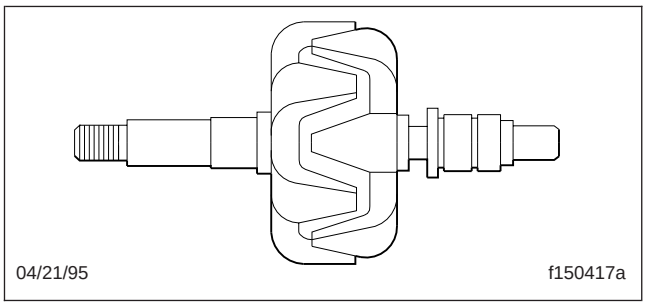


Fig. 4, Rotor

Rectifier assemblies convert alternating current to direct current for storage in the batteries. Rectifiers

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General Information

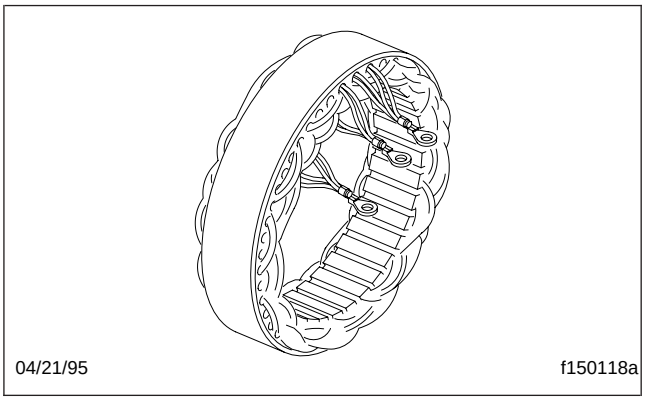


Fig. 5, Stator

consist of silicon diodes that work as electrical switches and permit current flow in only one direction. They are mounted in an aluminum casting, which is finned to dissipate heat. This is called a heat sink. See **Fig. 6**.

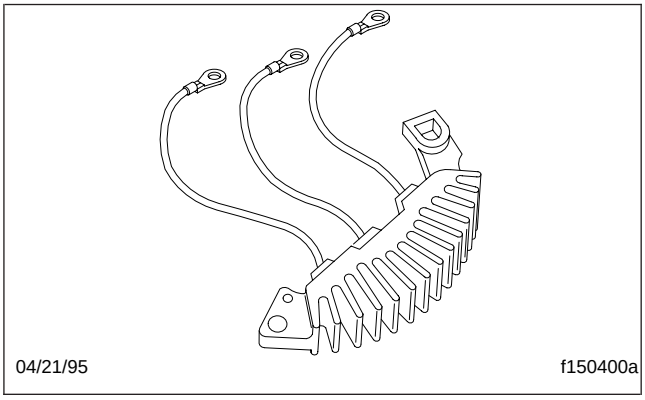


Fig. 6, Heat Sink

The voltage regulator controls the alternator output and the state of charge of the batteries. See **Fig. 1**. It is used in the charging system to regulate the battery voltage to the vehicle.

The diode trio converts a small amount of alternating current from the stator into direct current which is used as a signal to turn on the regulator.

When the battery is charged, the regulator reduces the field current flow to the rotor. Reducing the field current flow, in turn, reduces the alternator output. When the headlights or accessories place a load on the battery, the regulator increases the current flow to the rotor, and alternator output increases, to maintain voltage.

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Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Disconnect the battery ground cable.
4. Mark all electrical leads and disconnect them from the alternator. See **Fig. 1**.

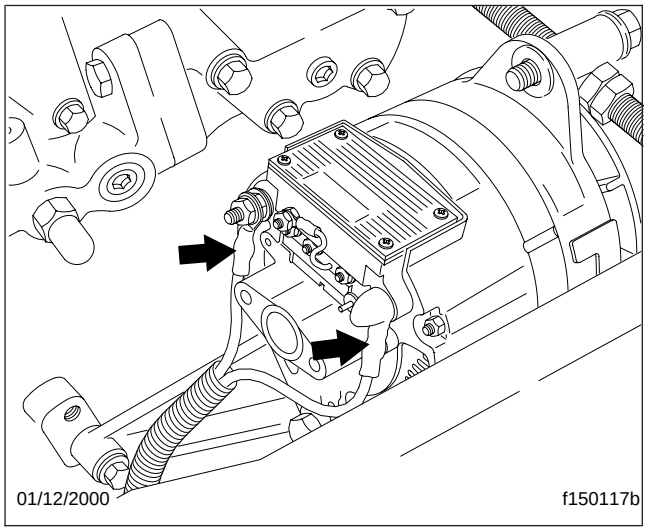
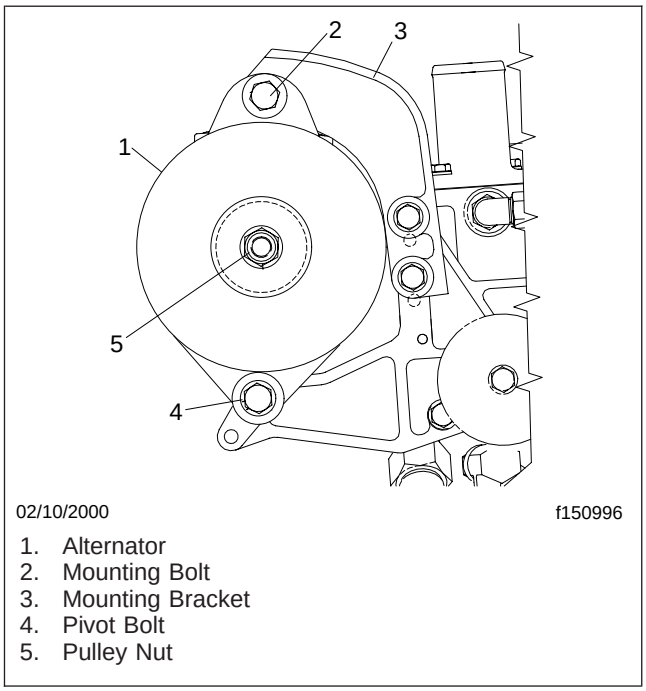


Fig. 1, Lead Connections

5. Remove the alternator belt from the alternator pulley.
   - 5.1 Insert a breaker bar in the belt tensioner and rotate the tensioner up and off the belt.
   - 5.2 Holding the tensioner up, take the belt off the alternator pulley.
   - 5.3 Slowly release the belt tensioner, and remove the breaker bar. It is not necessary to remove the belt from the vehicle.
6. Remove the alternator. See **Fig. 2** or **Fig. 3**.
   - 6.1 Remove the mounting bolt from the alternator.
   - 6.2 Securely hold the alternator to prevent it from falling and remove the long bolt that secures the alternator to the mounting bracket.



1. Alternator
2. Mounting Bolt
3. Mounting Bracket
4. Pivot Bolt
5. Pulley Nut

Fig. 2, Alternator Installation, Caterpillar 3126B Engine

   - 6.3 Remove the alternator from the vehicle.
7. Inspect the drive belt. For instructions, see **Section 01.02**.

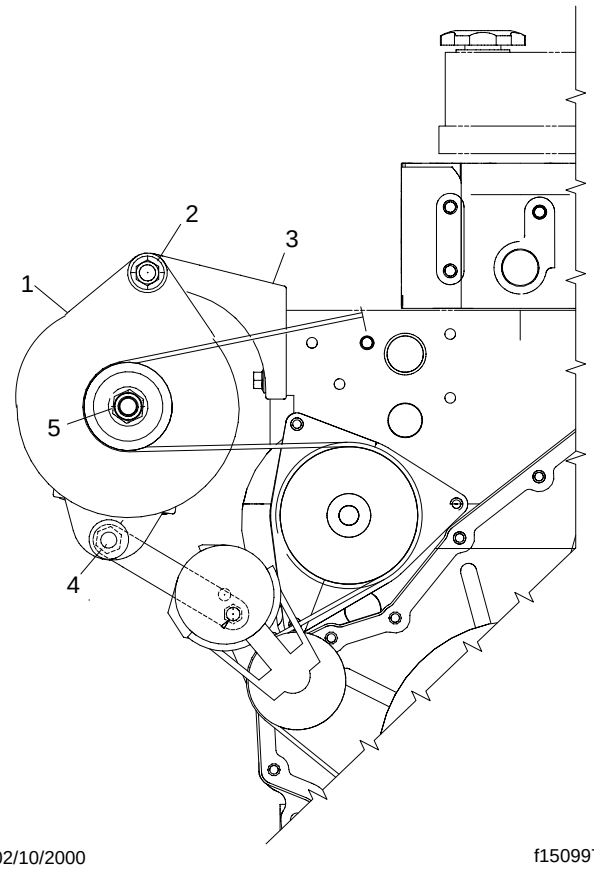
Installation

1. Install the alternator on the pivot bracket. See **Fig. 2** or **Fig. 3**.
   - 1.1 Position the alternator on the bracket.
   - 1.2 Insert the pivot capscrew through the alternator, the bracket and the brace.
   - 1.3 Install the washer and nut on the end of the pivot capscrew.
2. Install the alternator mounting capscrew and tighten. Tighten the pivot capscrew. See **Specifications, 400** for torque values.
3. Install the drive belt on the pulley as removed. If installing a new pulley or a new alternator, tighten the pulley nut 75 lbf·ft (102 N·m). Do not use an impact wrench.

NOTE: The belt tensioner automatically adjusts the drive belt to the correct tension. If the belt slips, repair or replace the tensioner. For in-

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Removal and Installation



1. Alternator
2. Pivot Bolt
3. Mounting Bracket
4. Mounting Bolt
5. Pulley Nut

Fig. 3, Alternator Installation, Cummins Engine

structions, see the engine manufacturer's service literature.

4. Connect all leads to the back of the alternator as removed. Tighten the output terminal nut 100 lbf·in (1140 N·cm). Tighten the ground terminal nut 65 lbf·in (740 N·cm).
5. Spray any exposed terminal connectors with dielectric red enamel. See **Table 1**.
6. Connect the batteries.
7. Before returning the vehicle to operation, test the alternator DC output voltage. For instructions, see **Troubleshooting, 300**.
8. Close and latch the hood.
9. Remove the chocks from the rear tires.

Approved Dielectric Red Enamel	
Protectant Material	**Approved Brands**
Spray-On Application	MMM 1602 IVI–Spray Sealer, Red Electric Grade; order from the PDC
Brush-On Application	Glyptal 1201EW– Low VOC, Red; order at **www.glyptal.com** or 1-800-GLP-1201

Table 1, Approved Dielectric Red Enamel

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Adjustment

NOTE: Before checking or adjusting the alternator voltage, check the wiring, connections and belt tension.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Turn off all accessories. Run the engine at fast idle (approximately 1200 rpm) and charge the batteries.
3. Connect an accurate voltmeter across the batteries to determine the charging voltage. If the voltage is below 13.8 volts, or above 14.2 volts, adjust the voltage regulator.
4. Shut down the engine.
5. If needed, adjust the charging voltage.
   - 5.1 Open the hood.
   - 5.2 Remove the small black cap on the regulator cover to expose the adjustment screw.
   - 5.3 Using a small screwdriver, turn the adjusting screw until the voltage is between 13.8 volts and 14.2 volts.
     - To increase the voltage, turn the adjusting screw clockwise.
     - To decrease the voltage, turn the adjusting screw counterclockwise.
6. Run the engine at fast idle (approximately 1200 rpm) and check the voltage again to make sure it has been properly adjusted. Readjust as necessary.

NOTE: If adjustment does not bring the voltage into the proper range, replace the voltage regulator.

7. Shut down the engine.
8. Replace the plastic cap on the access hole over the adjusting screw.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

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Troubleshooting

Many alternators have been replaced that later investigation reveals were working properly. This may be due to incorrectly diagnosing the problem.

IMPORTANT: Before testing, make sure:

- All belts are correctly tightened;
- The wiring and terminals are clean and in good condition;
- All terminal nuts are torqued and properly protected.

To troubleshoot the SmartChek™ diagnostic alternator perform the following steps:

1. With the engine off, clean the top of the regulator using a shop cloth until you can see the SmartChek indicator.
2. Start the engine. If the SmartChek indicator glows red, replace the alternator.

   If the indicator glows green, go to the next step.
3. Turn on several vehicle accessories, such as lights and heater fans. If the green indicator changes to red, replace the alternator.

   If the indicator continues to glow green, the alternator is OK. Check the other components of the electrical system.

Delco Remy has an alternator testing tool called the Intelli-Check Alternator Analyzer. See **Fig. 1**. This tool (DR 10457848, a single tester, or DR 10457865, a four-pack of testers) is to be used as a quick check of the alternator to see if it is working correctly.

NOTE: If you do not have the Delco Intelli-Check Tester, or if the alternator rated output is above 145 amps, or if a total vehicle charging system analysis is required, see "Alternator/Charging System Testing."

Intelli-Check Alternator Analyzer

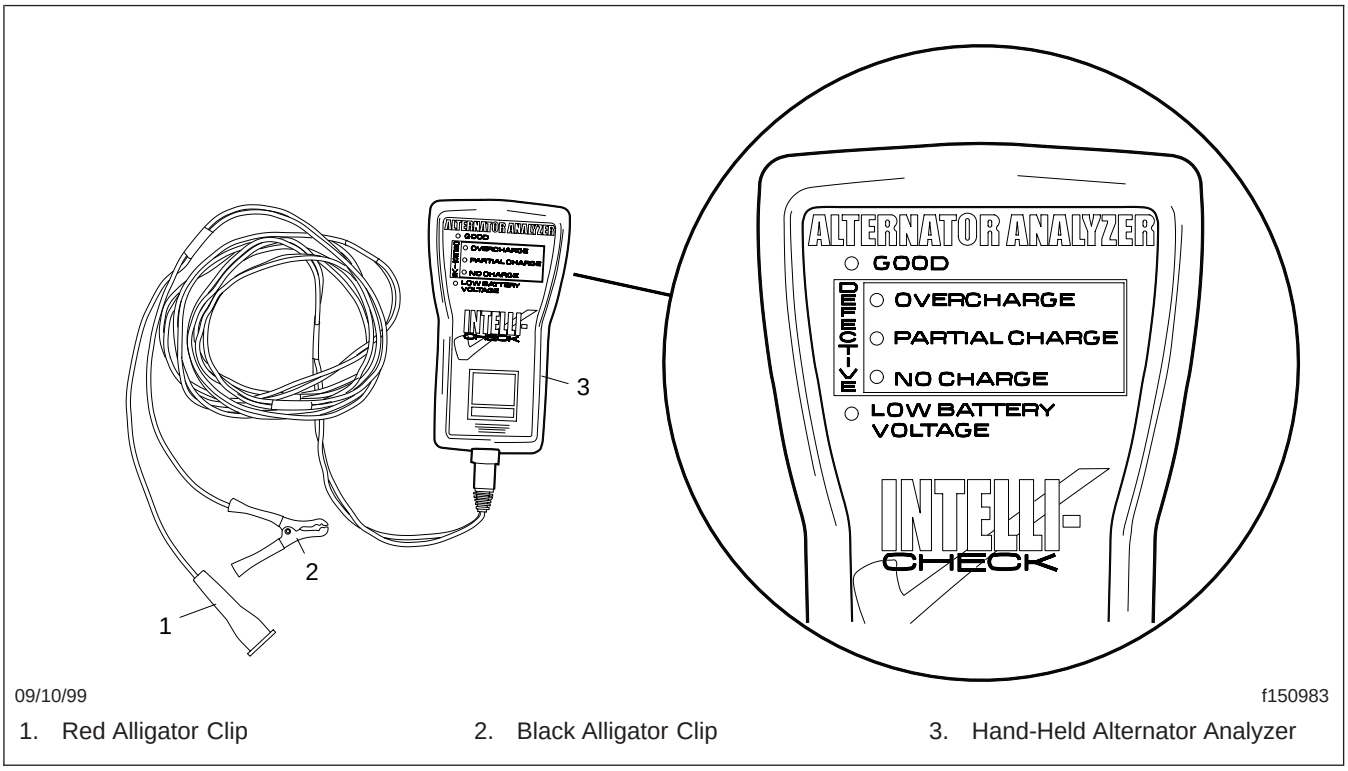
The following information includes a pre-test procedure and operating instructions for the Delco Intelli-Check Tester, and is similar to the procedures provided by Delco with the Intelli-Check Tester.

Pre-Test Procedure (Engine Off)

1. Inspect the alternator connections to verify that all terminals are secured and tight. Verify that the sense wire is connected to the sense terminal on vehicles equipped with remote-sense alternators.
2. With the engine off, connect the red alligator clip to the output terminal of the alternator. Connect the black alligator clip to the alternator ground. An optional ground connection is to the body of the alternator. The tester LEDs will illuminate and then go off as it performs a self-test.
3. After 4 seconds the tester will activate. The following LEDs may illuminate depending on the condition of the batteries:
   - **GOOD** (green) LED indicates the battery voltage is above 12.8 and has a surface charge. The surface charge must be removed before proceeding with the alternator test. To remove the surface charge, do the following:
     A. Turn on the headlights and blower motor for 2 minutes without restarting the engine.
     B. Reset the tester by disconnecting, then reconnecting the tester alligator clips. The analyzer will again perform its self-test.
     C. Repeat the applicable steps of the Pre-Test Procedure.
   - **NO CHARGE** (red) LED indicates the battery voltage is below 12.8. This LED should illuminate for most tests. Proceed with the alternator test.
   - **LOW BATTERY VOLTAGE** (blue) LED indicates the battery voltage is below 12.35. If the batteries will start the vehicle, proceed with the alternator test. However, after completing the Intelli-Check alternator test, perform the procedures under "Alternator/Charging System Testing" to determine the condition of the rest of the charging system.

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Troubleshooting



1. Red Alligator Clip
2. Black Alligator Clip
3. Hand-Held Alternator Analyzer

Fig. 1, Delco Remy Intelli-Check Alternator Analyzer

Tester Operating Instructions (Engine Running)

1. Start the engine using onboard batteries only. If the batteries will not start the engine, they must be charged for 2 hours. Start the test again after charging the batteries.
2. Verify the engine is at idle and all electrical loads are off.
3. Depress the accelerator to governed speed, hold for 10 seconds, then return to idle.
   - If the **GOOD** (green) LED illuminates, proceed to the next step.
   - If any LEDs illuminate indicating overcharge, partial charge or no charge (the three red lights in the **DEFECTIVE** section), replace the alternator and run the complete test again.
   - If the **LOW BATTERY VOLTAGE** (blue) LED illuminates, evaluate the charging system using the instructions in "Alternator/ Charging System Testing."
4. With the engine running, turn on all electrical loads.
5. Depress the accelerator to governed speed, hold for 10 seconds, then return to idle.
6. If the **GOOD** (green) LED illuminates, the alternator is OK and the test is complete.

NOTE: If the alternator tests OK in the above tests, and the customer's complaint is reduced battery or headlight life, see "Alternator/ Charging System Testing" to completely analyze the charging system.

7. If any LEDs illuminate indicating overcharge, partial charge or no charge (the three red lights in the **DEFECTIVE** section), replace the alternator and run the complete test again.
8. If the **LOW BATTERY VOLTAGE** (blue) LED illuminates, evaluate the charging system using the instructions in "Alternator/Charging System Testing."

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Alternator/Charging System Testing

Battery Open Circuit Voltage Test, Alternator Output Voltage Test and Alternator Amperage Output Test

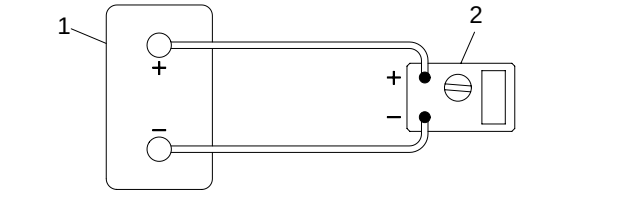
1. Use a digital volt-ohmmeter (VOM) set on the 2-20VDC (or similar) scale to test the battery open circuit voltage (OCV). With the engine shut down and the voltmeter set up as shown in **Fig. 2**, check for voltage of 12.4 volts or more.

   If the OCV is 12.4 volts or more, turn on the vehicle headlights for approximately 3 minutes.

   If the OCV is less than 12.4 volts, charge the batteries properly. For instructions, see **Group 54**.

IMPORTANT: Be sure to disconnect the batteries or remove them from the vehicle before charging.

2. Check the alternator output without a load. See **Fig. 3**.



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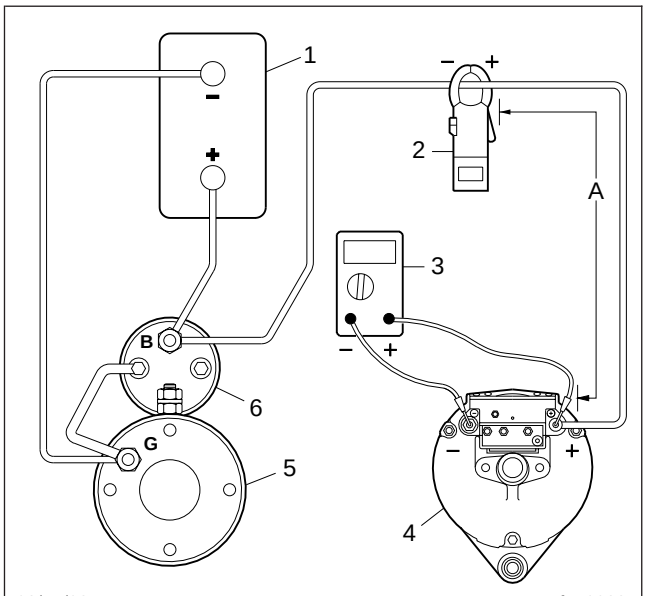
1. Battery
2. Digital Voltmeter

Fig. 2, Setup 1: Battery Open Circuit Voltage (and alternator amperage output)

2.1 Start the engine and run it at 1500 rpm for 3 to 5 minutes to stabilize the system before proceeding to the next step.

2.2 Connect the positive (+) lead of the digital voltmeter (still set on the 2-20VDC or similar scale) to the alternator (battery) terminal. Connect the negative (–) lead of the voltmeter to the alternator negative (–) ground terminal. See **Fig. 3**.

2.3 If the voltmeter reads from 13.8 to 14.2 volts, record this reading (V1) and go to the next step. If the alternator reads less than 13.8 volts and is adjustable, try to adjust the voltage regulator to 13.8 to 14.2 volts. If unable to obtain acceptable output, replace the alternator.



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A. Locate the ammeter at least 6 inches (15 cm) away from the alternator.

1. Battery
2. Ammeter
3. Digital Voltmeter
4. Alternator
5. Cranking Motor
6. Solenoid

Fig. 3, Setup 2: Alternator Output Voltage

3. Check the alternator output under load. See **Fig. 3**.

   3.1 Attach a clamp-on induction ammeter around the positive (+) wire. See **Fig. 3**.

   NOTE: Locate the ammeter at least 6 inches (15 cm) away from the alternator.

   3.2 With the engine still running at 1500 rpm, turn on the following electrical accessories to load the alternator until the ammeter reads 60 to 75 amps.

   - Both front and rear heater blowers (on HIGH)
   - Headlights (high beams)
   - Road lights
   - Interior lights

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Troubleshooting

NOTE: As an alternate method of putting load on the alternator, connect a carbon pile tester and set it to 60 to 75 amps.

3.3 Keep the voltmeter connected as in the previous step; positive (+) lead connected to the alternator positive (+) terminal; negative (–) lead connected to the alternator negative (–) terminal.

3.4 If the voltmeter reads from 13.6 to 14.2 volts, record this reading (V2) and go to the next step.

If the voltmeter reads less than 13.6 volts, replace the alternator.

4. Perform an alternator amperage output test.

4.1 Connect a carbon pile tester across the vehicle batteries as shown in **Fig. 2**.

NOTE: **Figure 2** shows a voltmeter, but the connections for the carbon pile tester are the same.

4.2 Attach a clamp-on induction ammeter around the alternator output wire. See **Fig. 3**.

NOTE: Locate the ammeter at least 6 inches (15 cm) away from the alternator.

4.3 Start the engine and make sure all vehicle electrical accessories are turned off. Run it at fast speed and adjust the tester to the alternator maximum current output. Record this output value.

NOTE: Ensure that the alternator is turning at maximum available rpms and keep adjusting the tester dial until the ammeter reads its highest value.

4.4 Turn off the tester and shut down the engine.

4.5 If the output value recorded is less than 85 percent of the rated amperage output, repeat the test. If the output value recorded is still less than 85 percent of the rated amperage output, replace the alternator.

4.6 Make sure that all test instruments are removed and that the vehicle wiring is returned to its operational state.

5. To identify other problem areas within the vehicle, check the operation of the charging system. Set up the voltmeter as shown in **Fig. 2** and **Fig. 3**.

NOTE: For any load at 1500 rpm or more, battery voltage must be within 0.5 volts of the alternator voltage.

5.1 If readings at the batteries are within 0.5 volts of the readings at the alternator, the charging system is working correctly. Check other areas of the vehicle to locate the problem.

5.2 If the reading at the batteries is more than 0.5 volts lower than the reading at the alternator, do the next step.

6. Check charging system connections, cables and terminals.

6.1 Check all connections between the battery, starter and alternator for tightness and signs of corrosion. Tighten and clean as necessary.

6.2 Check all cables for breaks or partial breaks. Repair or replace as necessary.

6.3 Check each ring terminal for breakage at the point where it attaches to its wire or cable.

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See **Fig. 1** for a charging circuit wiring diagram.

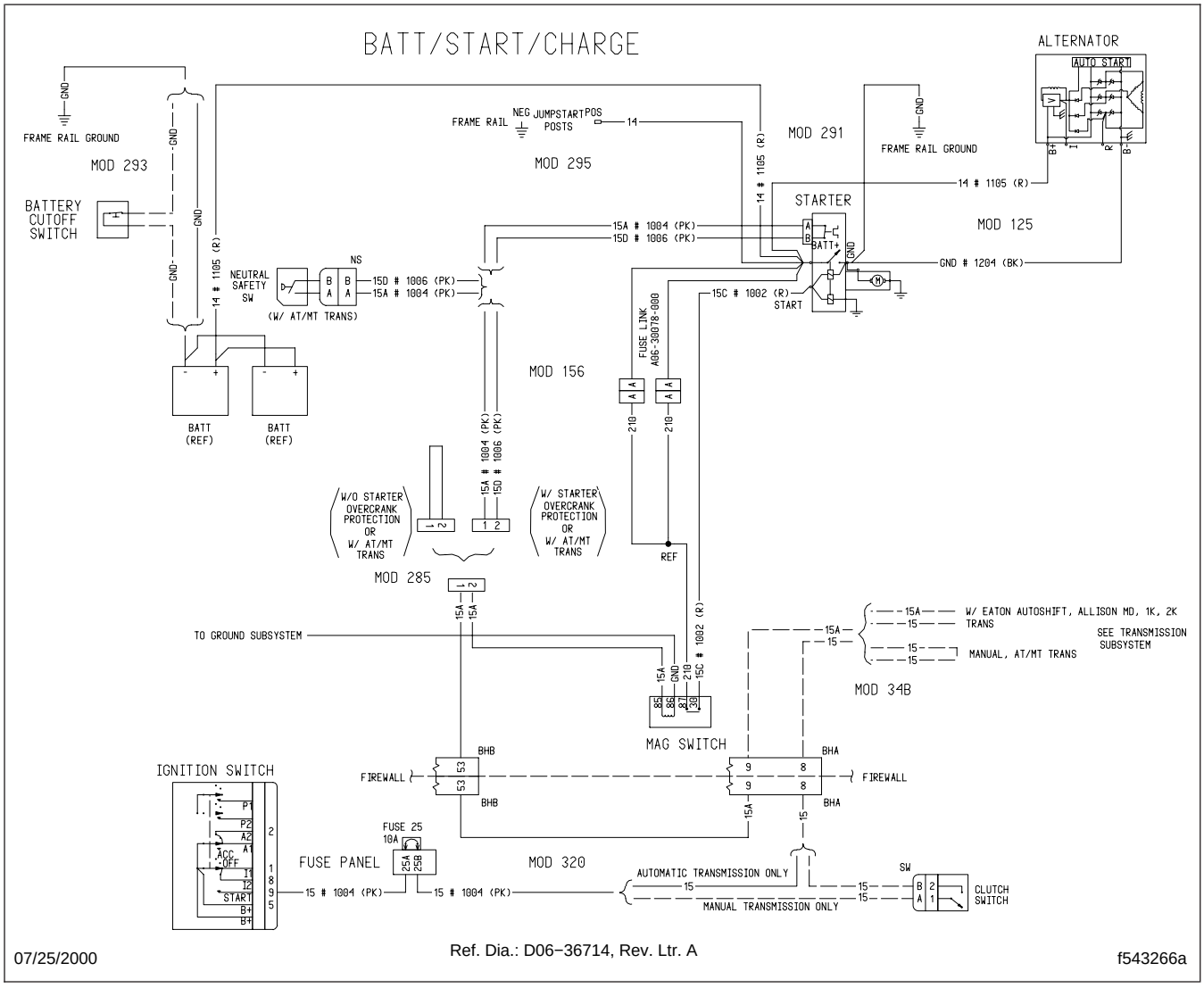


Fig. 1, Charging Circuit Wiring Diagram

Mounting Fastener Torques			
Description	**Type**	**Size**	**Torque: lbf·ft (N·m)**
Alternator Mounting Capscrew	Phosphate & Oil	1/2 in	60–70 (81–95)
	Zinc	1/2 in	50–60 (68–81)
	Phosphate & Oil	1/2 in	22–28 (30–38)
	Zinc	10 mm	18–23 (24–31)

Table 1, Mounting Fastener Torques

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Specifications

Terminal Fastener Torques			
Description	**Grade**	**Size**	**Torque: lbf·in (N·cm)**
Alternator Output ("BAT") Terminal Nut	5	5/16–18	100 (1140)
Alternator Ground ("G") Terminal Nut	5	1/4–20	65 (740)

Table 2, Terminal Fastener Torques

Pulley Nut Torque, All Engines			
Description	**Grade**	**Size**	**Torque: lbf·ft (N·m)**
Pulley Nut	8PO	1/2–20	75 (102)

Table 3, Pulley Nut Torque, All Engines

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General Information

The main function of a cooling system is to keep the engine at its optimum operating temperature. This results in the most efficient use of fuel and allows the engine oil to provide a good lubricating film. For the coolant plumbing on:

- A Cummins ISB or ISC engine, see **Fig. 1**;
- A Mercedes-Benz engine, see **Fig. 2**;
- A Caterpillar™ 3126B engine, see **Fig. 3**.

The cooling system is a high-flow design, where most of the coolant in a warm engine moves relatively quickly across the radiator in a single pass.

As the engine warms, the thermostat directs the coolant to the radiator. The thermostat keeps the engine temperature in the optimum range by controlling the two flows.

To prevent air and vapor from being trapped in the radiator or engine, vent lines rise from the high points where air and vapor would collect in those components. The vent lines carry any collected air to the surge tank.

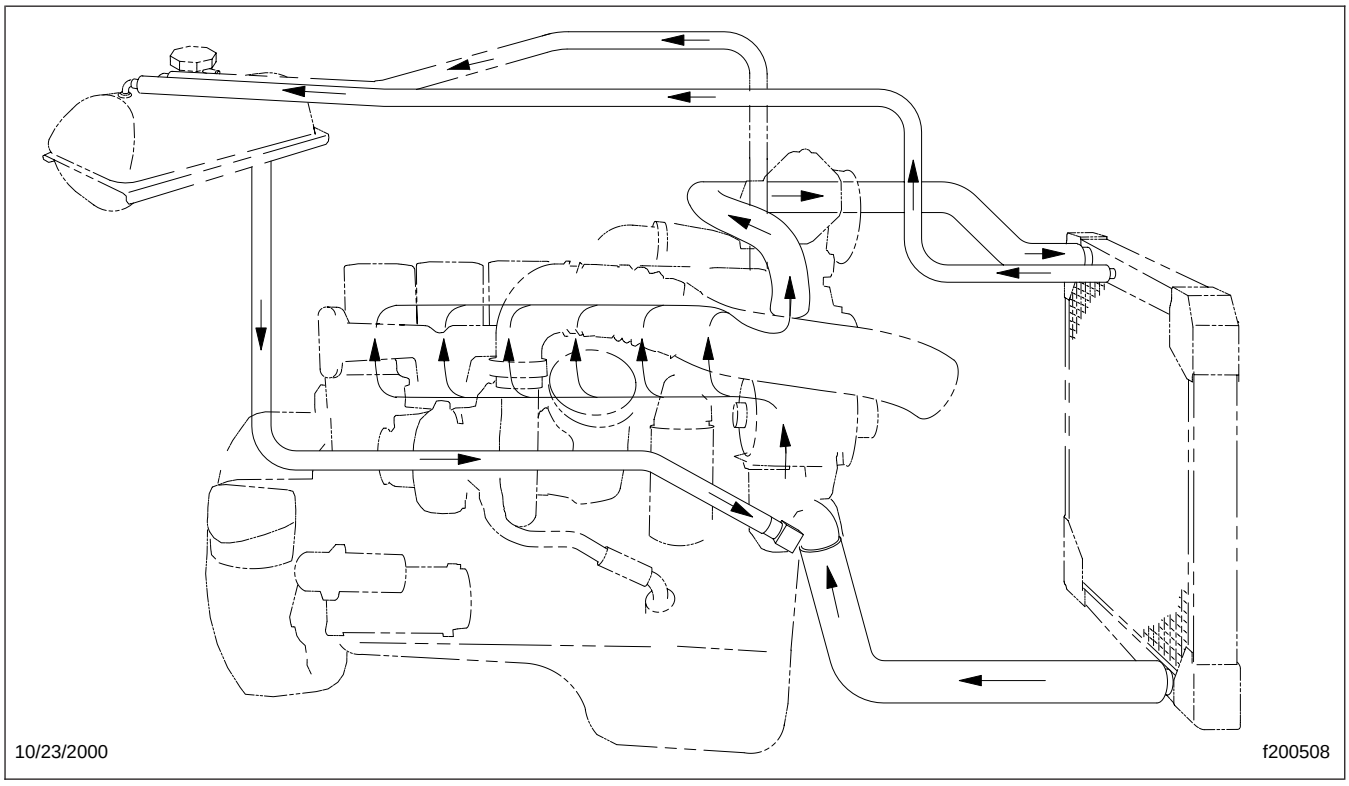


Fig. 1, Coolant Plumbing for Cummins ISB and ISC Engines

Coolant flows from the radiator to the water pump, which forces the coolant into the engine block. Inside the block, the coolant flows around and between the cylinders, and then up into the cylinder head. From the head, it flows to the temperature regulator (thermostat) housing. If the engine is cool, the thermostat directs the coolant back to the water pump, and the water pump forces the coolant back into the engine.

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General Information

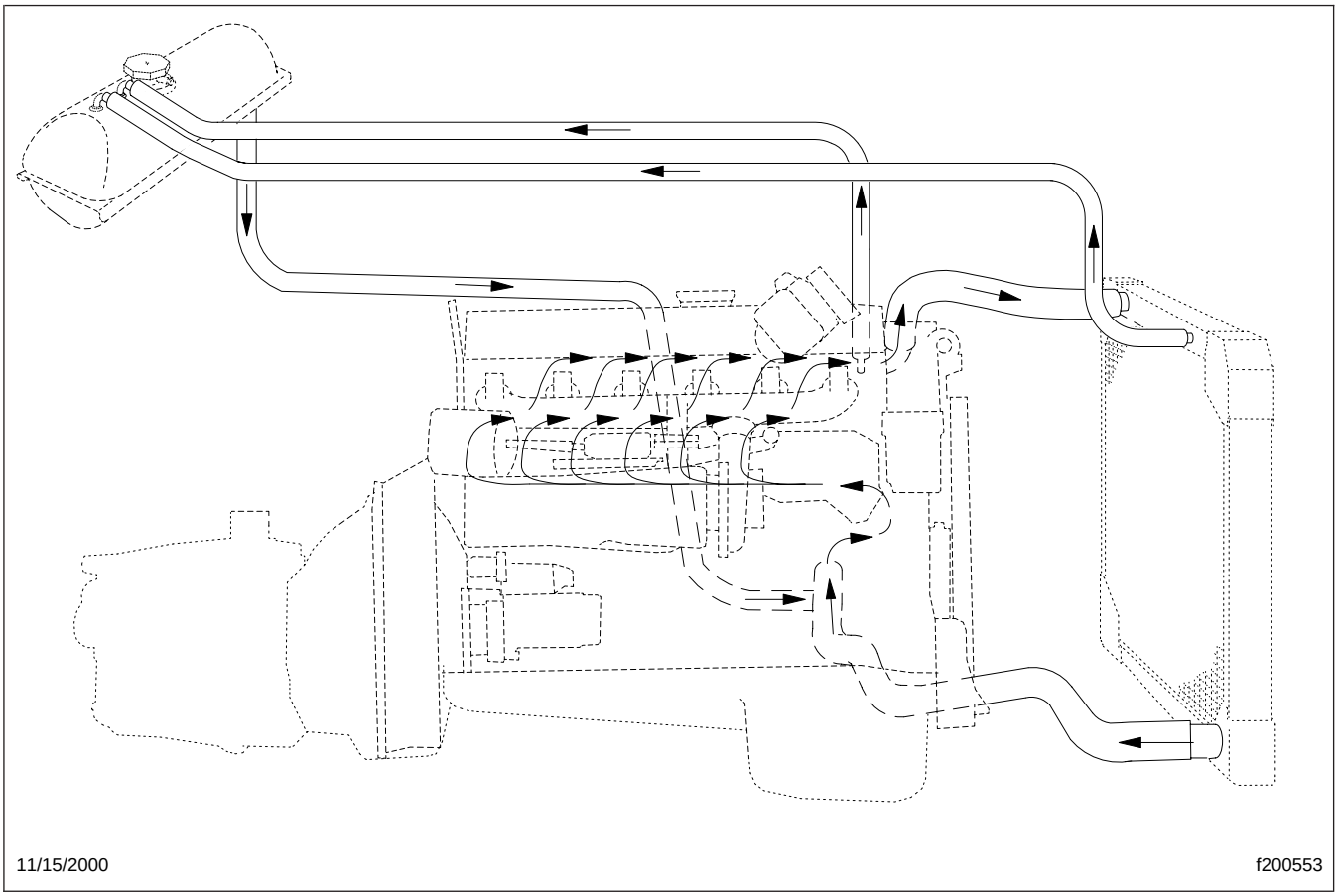


Fig. 2, Coolant Plumbing for a Mercedes-Benz Engine

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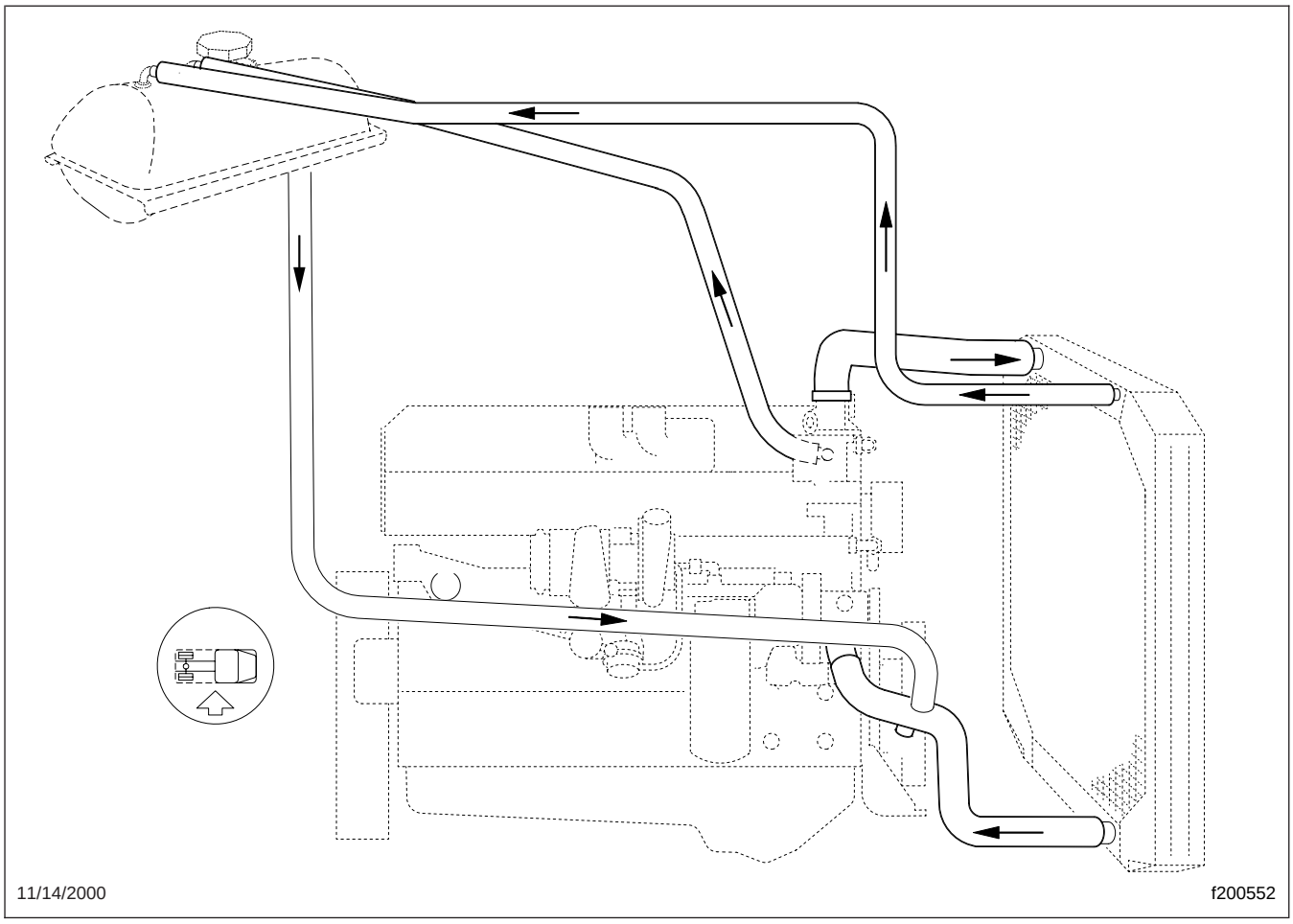


Fig. 3, Coolant Plumbing for a Caterpillar 3126B Series Engine

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Troubleshooting

Possible causes of abnormally high or low coolant temperatures are listed below. For repairs, see other sections of this manual or the engine and component manufacturer's service publications.

Problem—Coolant Temperature Above Normal

Problem—Coolant Temperature Above Normal	
Possible Cause	**Remedy**
Coolant leakage (see possible sources below) is causing a low coolant level. External Leakage: hoses and hose connections radiator seams, core, petcock and cap block core and drain plugs water pump thermostat housing surge tank heater hoses and core temperature sending unit(s) cylinder head(s) mating (gasket) surfaces coolant filter oil cooler Internal Leakage: cylinder head gasket warped head or block surfaces cracked cylinder head or block cylinder head capscrews loose, missing, or tightened unevenly oil cooler aftercooler	Do the repairs necessary to stop the leaks. Fill to the surge tank sight glass with the correct mixture of antifreeze and water. See Group 20 in the *Acterra Maintenance Manual* for coolant specifications.
Inoperative temperature gauge	Check the gauge wiring, circuit breaker, and sending unit. If the gauge circuit is okay, replace the temperature gauge. If the gauge circuit is broken, repair it and then check the temperature gauge operation.
Clogged radiator, aftercooler, or condenser fins	Clean the outside of the core and the condenser with compressed air directed from the fan side, or with water and a mild laundry soap. Straighten bent fins.
Collapsed or plugged radiator hose	Replace the hose(s).
Loose fan belt or water pump belt	Adjust belt tension.
Damaged cooling fan shroud	Repair or replace the shroud.
Incorrect or malfunctioning radiator cap	Make sure the correct radiator cap is installed. If the cap does not hold the correct pressure, replace it.
Viscous fan drive not operating to specifications	Check for unobstructed airflow through the radiator core, aftercooler, and condenser to the fan clutch sensor. Check that the radiator core is getting hot in front of the fan clutch (core is not internally clogged in that area) so that the sensor is getting a correct reading. If no radiator problems exist, refer to the viscous fan clutch section in this group for fan clutch inspection procedures and operation tests.
Incorrect engine oil level	Fill to the high (H) mark on the dipstick.
Too much antifreeze in system	Clean and flush the cooling system. Refill the system with the correct mixture of antifreeze and water.
Incorrect or inoperative thermostat	Make sure the correct thermostat is installed in the temperature regulator housing. Test the thermostat according to the engine manufacturer's instructions. Replace it if it does not operate correctly.
Malfunctioning water pump	Repair or replace the water pump.

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Troubleshooting

Problem—Coolant Temperature Above Normal	
Possible Cause	**Remedy**
Internally plugged or damaged radiator core	To check for blockages, warm the engine to normal operating temperature. Turn off the engine, and run your hand over the finned surface of the radiator. If there is a blockage in the radiator, it should cause an obvious temperature difference from one area of the core to another. An obvious difference between inlet and outlet temperatures is normal. If blockage is suspected, clean and flush the cooling system. Repair or replace a damaged core.
Air or combustion gases entering cooling system	Check the cylinder heads, head gaskets, cylinder liners, and aftercooler for leaks. Repair or replace parts, as necessary.
Internally plugged or damaged aftercooler	Repair or replace the aftercooler.
Internally plugged or damaged oil cooler	Repair or replace the oil cooler.
Engine receiving too much fuel	Refer to the engine manufacturer's fuel delivery system adjustment procedures.
Wrong replacement fan installed	Install the correct fan.
Exhaust blockage	Remove the blockage.
Frozen coolant in radiator due to subfreezing temperatures	Use the proper antifreeze-to-water ratio needed for winter temperatures.

Problem—Coolant Temperature Below Normal

Problem—Coolant Temperature Below Normal	
Possible Cause	**Remedy**
Inoperative temperature gauge	Check the gauge circuit wires, circuit breaker, and sending unit. If the gauge circuit is okay, replace the temperature gauge. If the gauge circuit is broken, repair it and then check the temperature gauge operation.
Viscous fan drive operates continuously	See the **Section 20.02** in this manual for fan clutch inspection procedures and operation tests. Replace the fan drive if necessary.
Incorrect or inoperative thermostat	Make sure the correct thermostat is installed. Test the thermostat according to the engine manufacturer's instructions. Replace it if it does not operate correctly.

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General Information

The main function of a cooling system is to keep the engine at its optimum operating temperature. This results in the most efficient use of fuel and allows the engine oil to provide a good lubricating film.

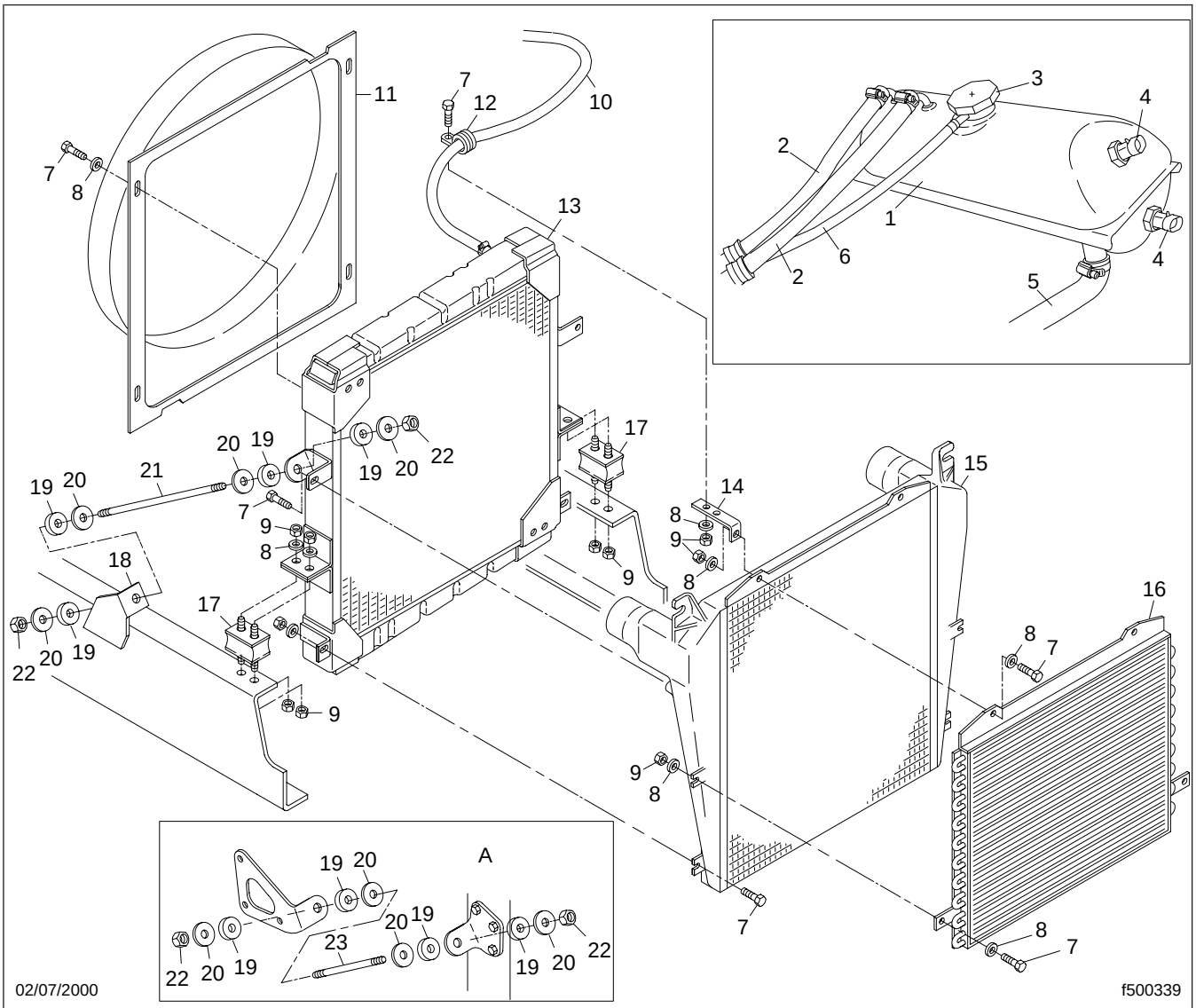
The central component of the cooling system, the radiator assembly, includes the surge tank (remote-mounted on the frontwall), the radiator, and the surge tank cap. See **Fig. 1**.

The Acterra uses full-flow (or high-flow) radiators. With full-flow radiators, the coolant flows into the radiator at the left of the top tank and flows out of the radiator at the right of the bottom tank. Most of the engine coolant is routed through the radiator, and it moves relatively quickly in a single pass.

The core of the radiator is soldered to brass top and bottom tanks, and the tanks and radiator core are held in steel side channels that mount on the frame rails. See **Fig. 2**.

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General Information



A. Right-side strut installation (Caterpillar engines).

1. Surge Tank
2. Inlet Hose
3. Surge Tank Cap
4. Sensor
5. Outlet Hose
6. Overflow Tube
7. Bolt
8. Washer
9. Nut
10. Radiator Vent Hose
11. Fan Shroud
12. Hose Cushion Clamp
13. Radiator
14. Stand-Off Bracket
15. Charge Air Cooler
16. Condenser
17. Radiator Mounting Stud
18. Radiator Strut Bracket
19. Radiator Strut Isolator
20. Hardened Washer
21. Radiator Strut
22. Radiator Strut Nut
23. Shortened Right-Side Strut, Used with Caterpillar Engines

Fig. 1, Radiator Installation for Caterpillar, Cummins ISB and ISC, and Mercedes-Benz Engines

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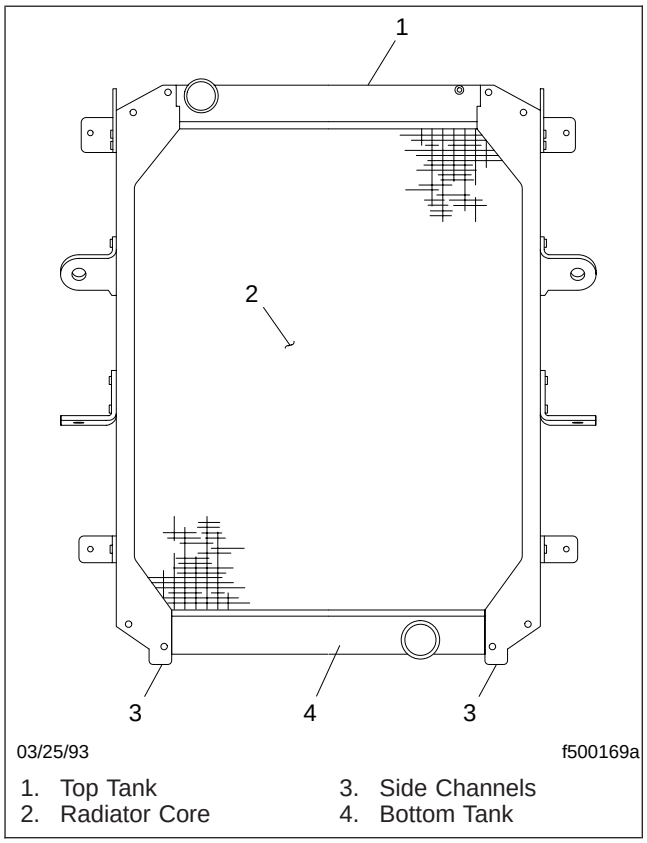


Fig. 2, Radiator Components

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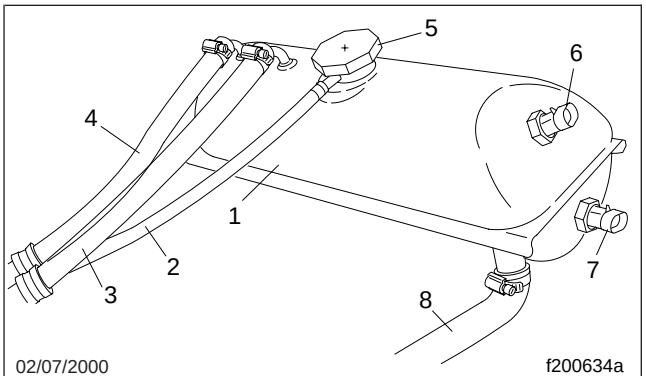
Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.

⚠ WARNING

Drain the coolant only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

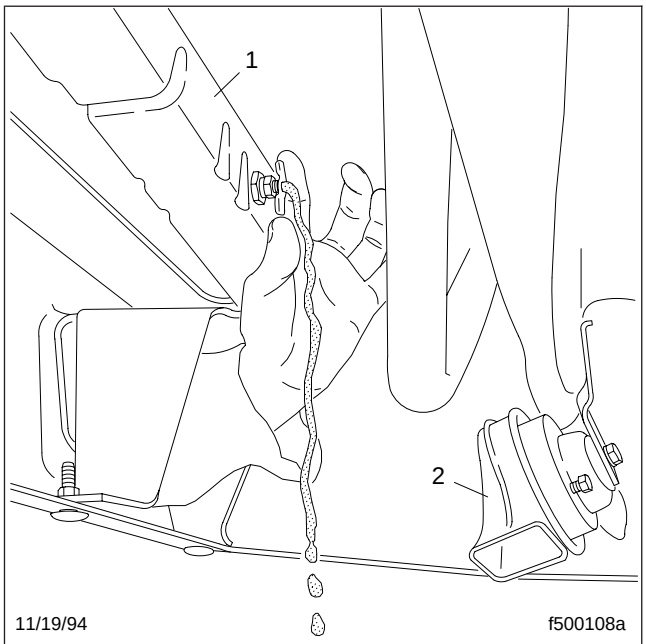
3. Drain the radiator.
   - 3.1 Remove the radiator surge tank cap. See **Fig. 1**.



1. Surge Tank
2. Overflow Tube
3. Inlet Hose
4. Inlet Hose
5. Cap
6. Engine Warning Sensor
7. Engine Shutdown Sensor
8. Outlet Hose

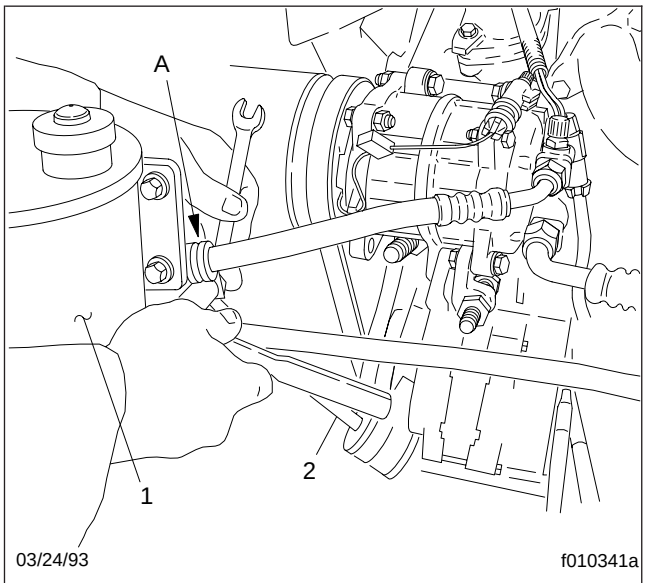
Fig. 1, Surge Tank

   - 3.2 Open the plug at the bottom of the radiator to drain the engine coolant. See **Fig. 2**.
4. Remove the hood. For instructions, see **Group 88**.
5. Move the condenser aside.
   - 5.1 Remove the clamps securing the refrigerant lines to the left radiator support strut. See **Fig. 3**.
   - 5.2 Remove the air recirculation shield from the left mounting tab of the charge air cooler. See **Fig. 4**.



1. Radiator
2. Horn

Fig. 2, Drain the Radiator



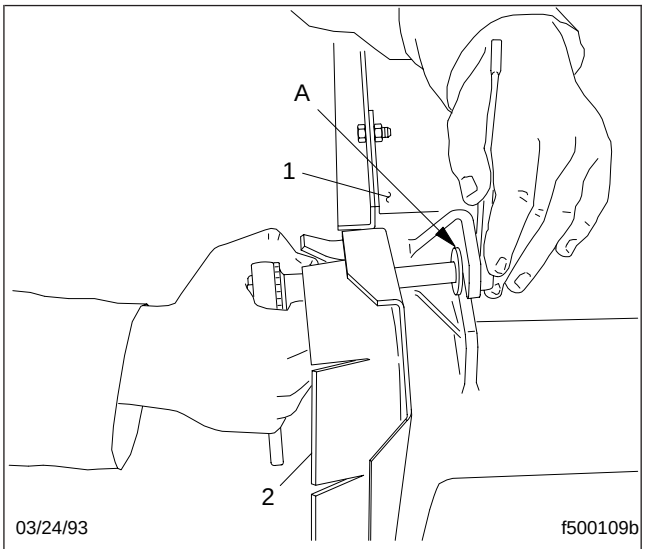
A. Remove the hose clamp from the strut.

1. Power Steering Fluid Reservoir
2. Left Radiator Strut

Fig. 3, Hose Clamp Location

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Removal and Installation

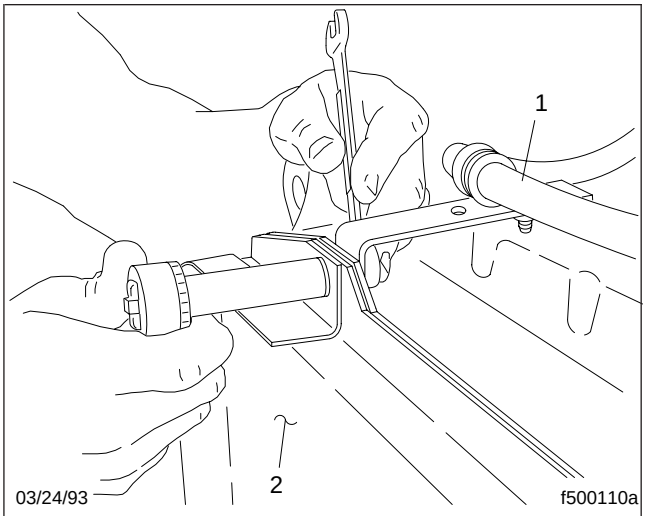


A. Remove the air recirculation shield from the mounting tab.

1. Charge Air Cooler
2. Air Recirculation Shield

Fig. 4, Shield Mounting Tab

5.3 Remove the four bolts securing the condenser and the radiator vent hose bracket. See **Fig. 5** and **Fig. 6**.



1. Radiator Vent Hose
2. Condenser

Fig. 5, Vent Hose Bracket

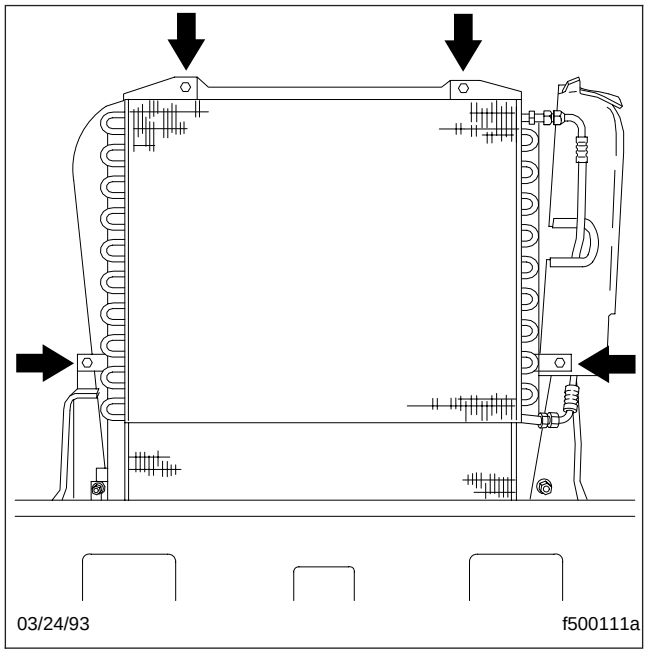


Fig. 6, Condenser Mounting Bolts

6. Remove the condenser, wrap it in a protective blanket, and secure it out of the way. See **Fig. 7**.
7. Remove the radiator and charge air cooler assembly.
   - 7.1 Remove the air hoses from the charge air cooler. See **Fig. 8**.
   - 7.2 Remove the radiator vent hose and coolant inlet hose from the radiator. See **Fig. 8**.
   - 7.3 Remove the coolant outlet hose from the bottom of the radiator.
   - 7.4 Using lifting chains, secure the radiator and charge air cooler assembly to a crane.
   - 7.5 Remove the radiator mount nuts and washers. See **Fig. 9**.
   - 7.6 Remove the radiator strut nuts, washers, and rubber isolators. See **Fig. 9**.
   - 7.7 Using a crane, lift the radiator and charge air cooler assembly from the vehicle. See **Fig. 10**. Place the assembly on a work bench.

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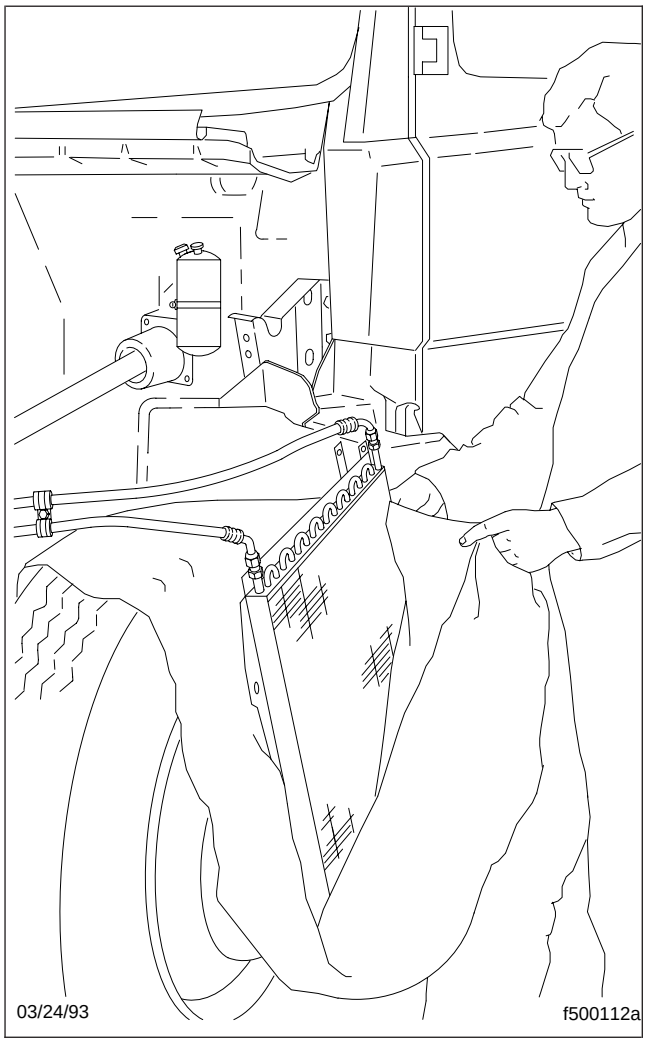


Fig. 7, Condenser Moved Aside

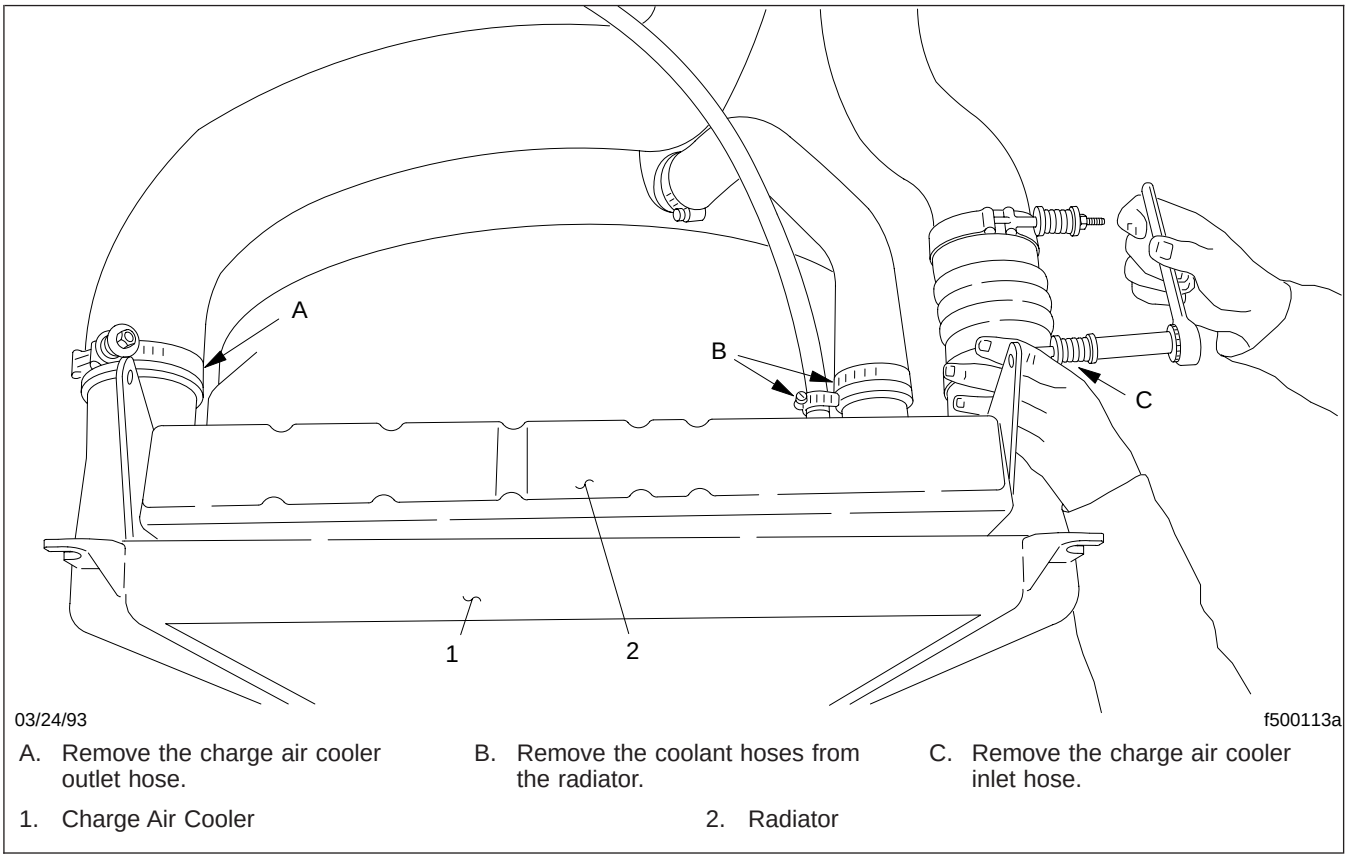
8. Disassemble the radiator and charge air cooler assembly.
   - 8.1 Remove the four sheet metal bolts that secure the fan shroud to the radiator. See **Fig. 11**. Remove the fan shroud.
   - 8.2 Remove the four bolts holding the radiator to the charge air cooler. See **Fig. 12**.
   - 8.3 Remove the hood cable brackets from the radiator. See **Fig. 13**.
   - 8.4 Remove the radiator from the charge air cooler. See **Fig. 14**.

Installation

1. Assemble the radiator and charge air cooler assembly.
   - 1.1 On a work bench, place the radiator on the charge air cooler and secure it with four bolts and washers. See **Fig. 14**. Tighten the bolts 15 lbf·ft (20 N·m). See **Fig. 12**.
   - 1.2 Install the hood cable brackets on the radiator and tighten the bracket bolts 48 lbf·in (540 N·cm).
   - 1.3 Install the fan shroud with the four sheet metal bolts and washers. Do not tighten the bolts.
2. Install the radiator and charge air cooler assembly.
   - 2.1 Secure a lifting chain to the charge air cooler and lift the assembly with a crane.
   - 2.2 Position the radiator and charge air cooler assembly on the radiator mounting studs. Secure the assembly to the mounts with nuts and washers, and tighten the nuts 30 lbf·ft (40 N·m). See **Fig. 9**.
   - 2.3 Secure the radiator support struts with rubber isolators, washers, and nuts, and tighten the nuts 35 lbf·ft (47 N·m). See **Fig. 9**.
   - 2.4 Remove the lifting chain from the radiator assembly.
   - 2.5 Connect the coolant outlet hose at the bottom of the radiator.
   - 2.6 Connect the radiator vent hose and coolant inlet hose to the radiator. See **Fig. 8**.
   - 2.7 Remove the seals from the coolant hose ends, connect the hoses to the radiator, and tighten the hose clamps. See **Table 1** for proper torque values.

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Removal and Installation



A. Remove the charge air cooler outlet hose.
B. Remove the coolant hoses from the radiator.
C. Remove the charge air cooler inlet hose.
1. Charge Air Cooler
2. Radiator

Fig. 8, Radiator and Charge Air Cooler Hoses

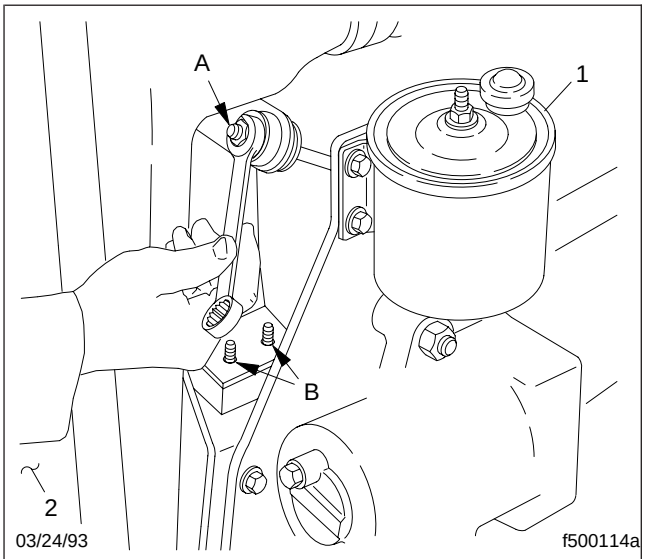
Hose Clamp Torque Values		
Clamp Type	**Size**	**Torque: lbf·in (N·cm)**
T-Bolt	All	55 (620)
Breeze Constant-Torque	5/16-inch tightening screw hex	90 (1020)
	3/8-inch tightening screw hex	90 (1020)
ABA	1.26-inch Diameter	31 (360)
	1.50-inch Diameter	35 (400)
	1.73-inch Diameter	35 (400)
	1.97-inch Diameter	35 (400)
	2.28-inch Diameter	35 (400)
	2.68-inch Diameter	40 (460)
	3.03-inch Diameter	40 (460)

Table 1, Hose Clamp Torque Values

All standard hose clamps will lose torque after installation due to "compression set." However, correctly installed Breeze Constant-Torque clamps automatically adjust during vehicle operation, and keep a constant sealing pressure. During vehicle warm-up and cool-down, the Breeze Constant-Torque adjusting screw tip may move in and out of the housing. It does this as it automatically adjusts to temperature and pressure changes, to maintain constant pressure on the hose. The torque may need to be adjusted for individual applications.

ABA hose clamp torque typically decreases by 30 percent shortly after being tightened to the recommended torque value. This characteristic is normal, and is how the clamps are designed to work. If they are properly

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A. Remove radiator strut nuts.
B. Remove radiator mount nuts.

1. Power Steering Fluid Reservoir
2. Charge Air Cooler

Fig. 9, Radiator Mounts (left side)

torqued when installed, ABA hose clamps do not need retorquing.

2.8 Connect the air hoses to the charge air cooler. Tighten the constant torque hose clamps 60 lbf·in (680 N·cm). See **Fig. 8**.

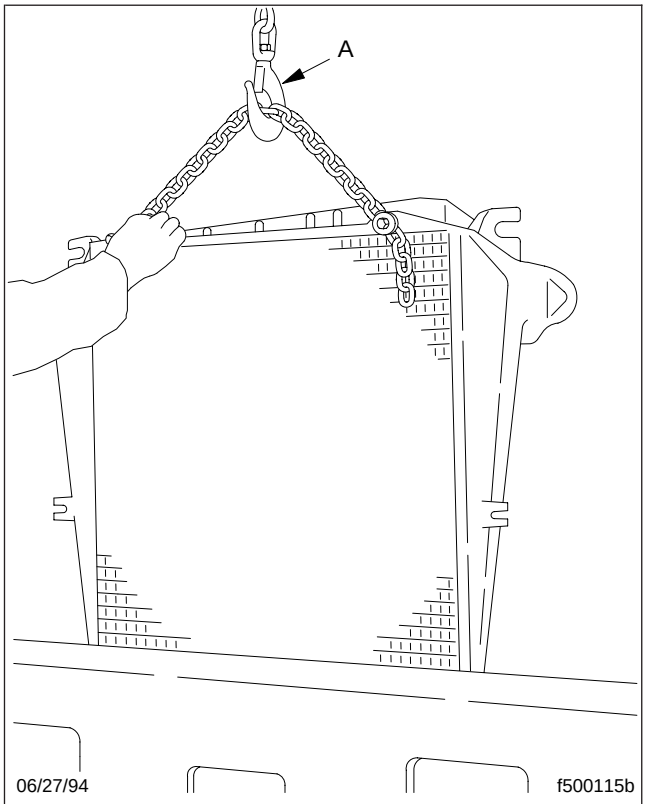
3. Secure the fan shroud.

3.1 Adjust the vertical clearance between the top of the fan blade and the fan shroud opening. It should be equal within 1/8 inch (3 mm) to the clearance between the bottom of the blade and the shroud opening.

3.2 Tighten the screws 108 lbf·in (1220 N·cm).

4. Install the condenser.

4.1 Install the condenser on the charge air cooler, and secure it with the four mounting bolts. Install the radiator vent hose bracket with the top, right mounting bolt. See **Fig. 5** and **Fig. 6**. Tighten the bolts 15 lbf·ft (20 N·m).



A. Use a crane to lift the radiator and charge air cooler.

Fig. 10, Lifting the Radiator

4.2 Install the air recirculation shield on the charge air cooler left mounting tab. See **Fig. 4**. Tighten the bolt 15 lbf·ft (20 N·m).

4.3 Clamp the refrigerant lines to the left radiator support strut. See **Fig. 3**.

5. Install the hood. For instructions, see **Group 88**.

6. Fill the coolant system and install the surge tank cap.

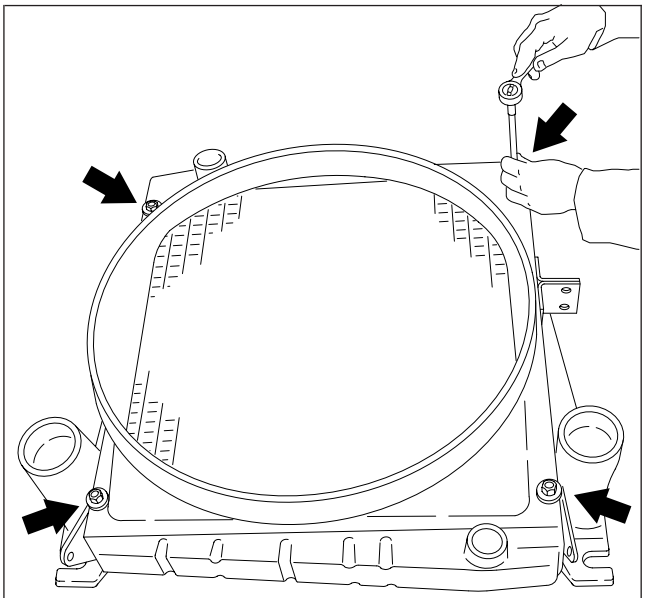
7. Start the engine and check for coolant leaks. Repair any leaks. After idling the engine for 15 to 20 minutes, add more coolant if necessary.

8. Close the hood.

9. Remove the chocks from the tires.

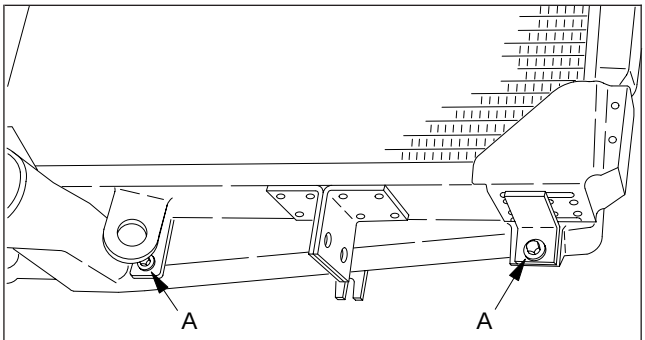
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Removal and Installation



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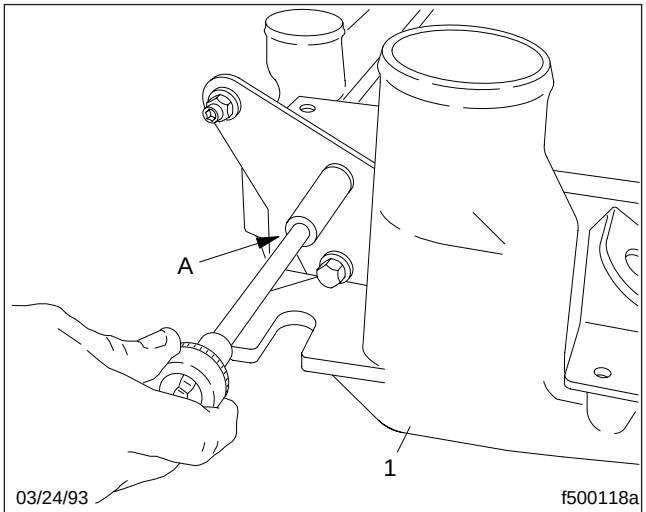
Fig. 11, Removing the Fan Shroud



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A. Remove the bolts securing the charge air cooler to the radiator.

Fig. 12, Removing the Charge Air Cooler

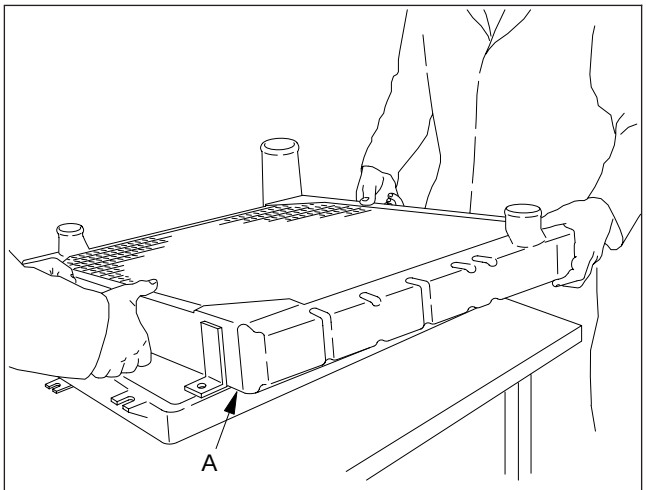


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A. Remove the hood cable brackets.

1. Charge Air Cooler

Fig. 13, Hood Cable Brackets



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A. Remove the radiator from the charge air cooler.

Fig. 14, Radiator Loose from Charge Air Cooler

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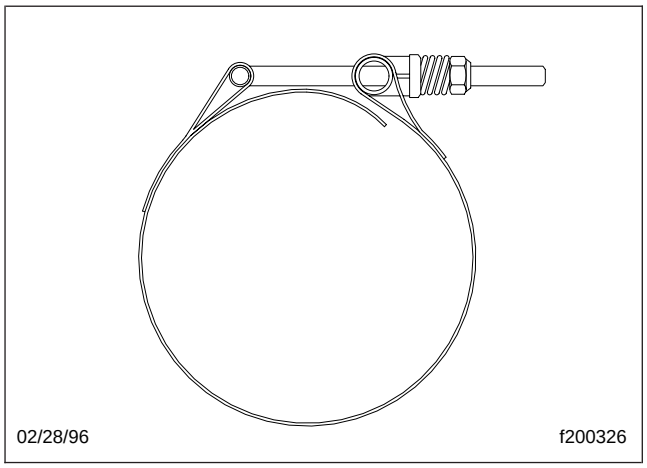
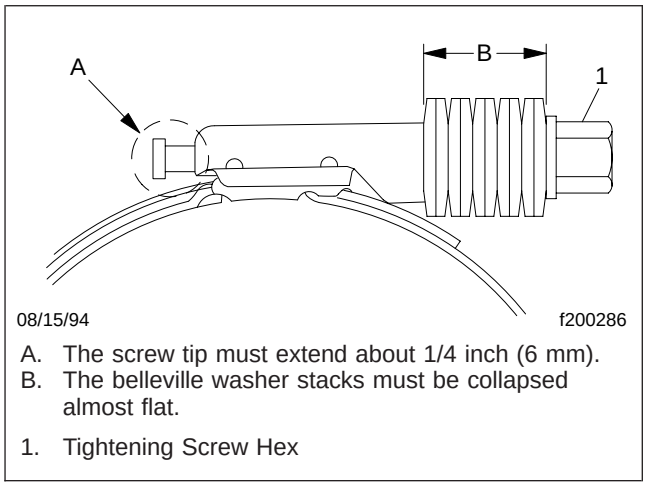


Fig. 15, T-Bolt Type Hose Clamp



A. The screw tip must extend about 1/4 inch (6 mm).
B. The belleville washer stacks must be collapsed almost flat.

1. Tightening Screw Hex

Fig. 16, Breeze Constant-Torque Hose Clamp Installation

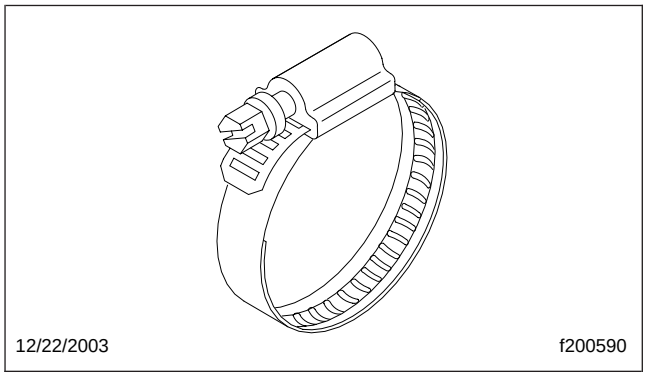


Fig. 17, ABA Radial-Worm-Drive Hose Clamp (typical)

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IMPORTANT: Disassembling and assembling nylon top- and bottom-tank radiators requires the special tools listed in **Table 1**.

Special Tools	
Description	**Quantity**
Plastech II® Tanking Machine With Five 2-Inch Cylinders	1
T-Bar	1
Hooked-End Bar	1
Wave Form Bar	1

Table 1, Special Tools

Order these tools from:

RAD PAL
2381 17 St.
Detroit, MI 48216
(313) 963-3194

Disassembly

IMPORTANT: Before disassembling the radiator, pressure flush it and check the surge tank, following the instructions in the radiator group of the vehicle maintenance manual. Clean and check the exterior of the radiator, following the instructions in Group 20 of the *Acterra Maintenance Manual*.

1. Remove the radiator from the vehicle. For instructions, see **Subject 100**.

⚠ CAUTION

Use care when handling or supporting the nylon top and bottom tanks. Failure to do so could damage the tanks.

2. Remove the side channels from the radiator assembly.

   2.1 Remove the eight spring clips that hold the side channel mounting pins in position. See **Fig. 1**. Insert a screwdriver blade in the open end of each clip, and pry the clip open until it clears the edge of the mounting pin. Slip the clip off the pin.

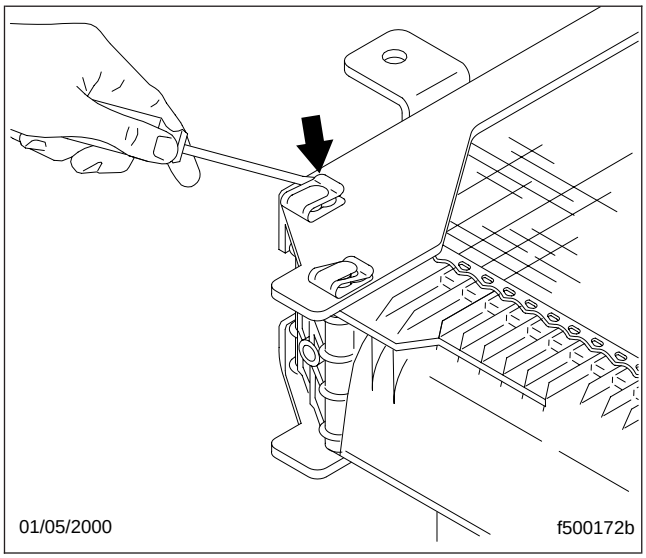


Fig. 1, Spring Clip Removal

   2.2 Use a rubber mallet and a punch to tap out the eight mounting pins. See **Fig. 2**.

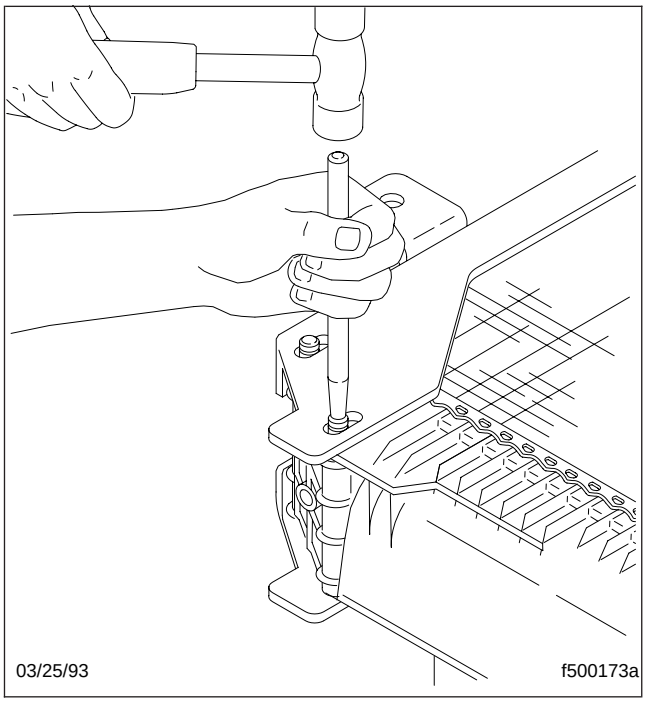
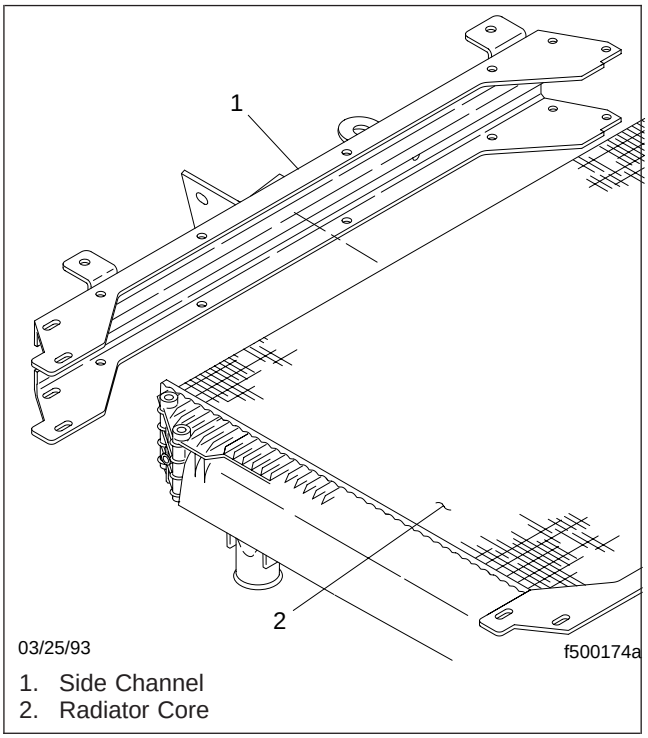


Fig. 2, Mounting Pin Removal

   2.3 Slip the side channels off the radiator core and tank assembly. See **Fig. 3**.

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Disassembly and Assembly



1. Side Channel
2. Radiator Core

Fig. 3, Side Channel from Radiator Core

3. Leak test the radiator core and tank assembly.

   3.1 Securely plug all tank ports.

⚠ CAUTION

Do not apply a higher amount of pressure than specified below; too much pressure will damage the radiator core.

   3.2 At one tank port, install a pressure regulator and gauge. Using a hand pump, apply 20 psi (138 kPa) air pressure through the port.

   3.3 Submerge the radiator in a tank of water and check it for leaks. Mark any leaks for repair. If a leak is between the radiator core header and a tank, remove the tank and inspect the tank flange, the header sealing surface, and the sealing gasket. If the leak is in the core, but within 3 inches (7.5 cm) of the tank, remove the tank before repairing the leak. If the leak is in the tank, replace the tank.

4. Remove the top and bottom tanks.

   4.1 Place the radiator core and tank assembly in the disassembly/assembly fixture. Clamp the assembly securely in place. See **Fig. 4**.

   4.2 Position the tank clamping cylinders evenly across the top of the tank. Make sure the cylinders' rubber plungers will not press against breakable fittings, such as vent tube ports.

⚠ CAUTION

Apply only enough pressure to compress the sealing gasket. Too much pressure will crack the nylon tank.

   4.3 Apply pressure evenly across the top of the tank until the tank-to-core sealing gasket is compressed enough to show a small gap between the bottom of the dimple wave lock crimp and the tank sealing flange.

⚠ CAUTION

In some places, especially around the tank ports, the wave lock crimps may have to be unlocked with a screwdriver. When using a screwdriver, use care not to crack or gouge the nylon tank.

   4.4 Place the T-bar into the T-bar groove in the disassembly/assembly fixture. See **Fig. 5**.

   4.5 Slide the hooked-end bar over the T-bar. Place the hook over the top of the wave crimp and pull the T-bar back to unlock the crimp. See **Fig. 5**.

   4.6 Slide the hooked-end bar and the T-bar down the T-bar groove to the next wave crimp. Repeat the previous step until all the wave crimps are unlocked.

5. Once the wave crimps are unlocked, remove the tank.

   5.1 Release the pressure from the tank. Move the clamping cylinders off the radiator core and tank assembly.

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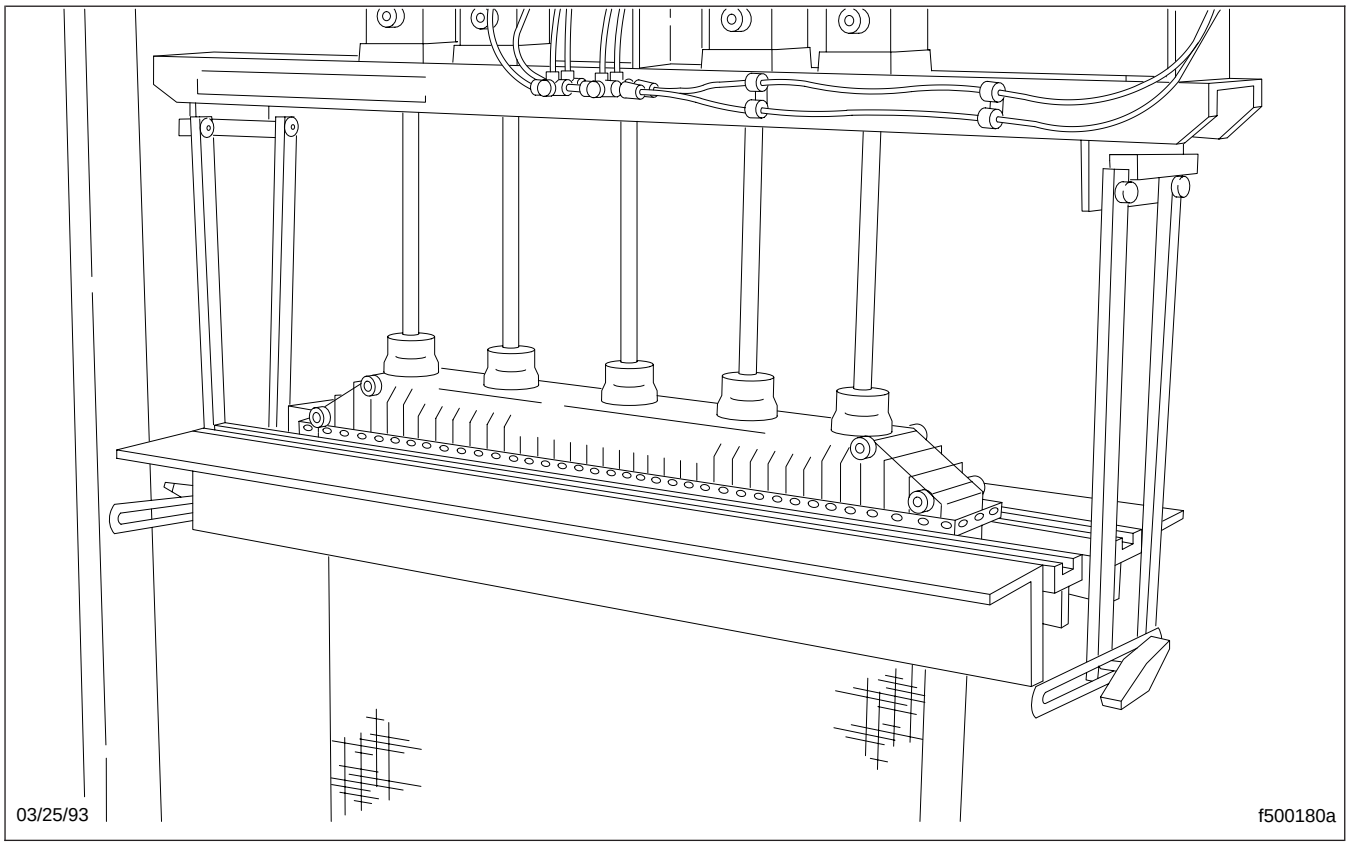


Fig. 4, Radiator Core and Tank Assembly

CAUTION

If needed, use a rubber mallet or the heel of your hand and tap the side of the tank to loosen it. Do not use a screwdriver against the tank sealing flange. A screwdriver blade may damage the flange and prevent a good seal after the tank is installed.

5.2 Lift the tank from the forward side, the side opposite the tank ports. Remove the nylon tank from the radiator core. See **Fig. 6**.

5.3 Remove the sealing gasket from the sealing surface of the radiator core header. See **Fig. 7**.

5.4 Clean the sealing surface of the radiator core header.

5.5 Repair any leaks marked during leak testing.

5.6 Remove the opposite tank.

IMPORTANT: Check the tubes of the radiator core for scale deposits. If the radiator has been pressure-flushed, and the tubes are still clogged, the radiator should be rodded or boiled out with acid by an experienced radiator shop. Otherwise, replace the core.

Assembly

1. Install the nylon top and bottom tanks on the radiator core.

1.1 With the radiator securely clamped in the disassembly/assembly fixture, header sealing surface up, make sure the bottom of the radiator core and tank assembly is completely supported, and that the

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Disassembly and Assembly

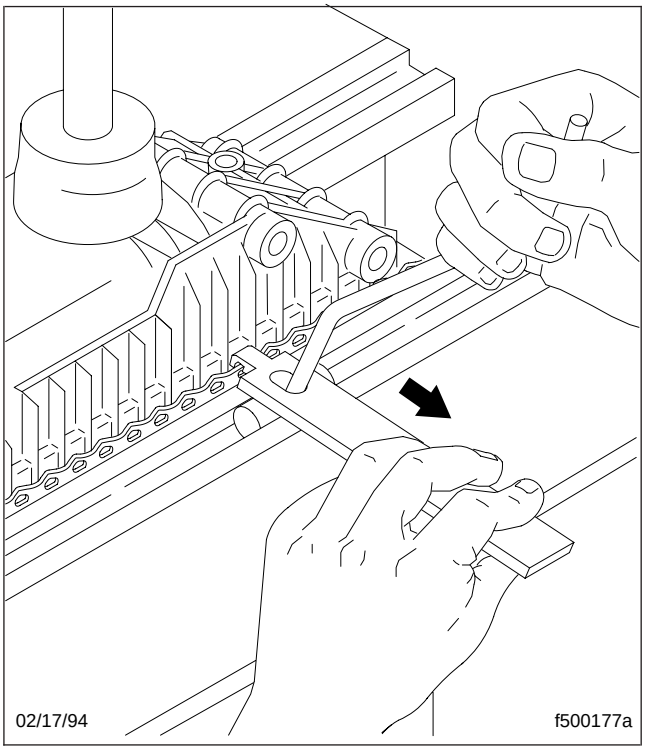
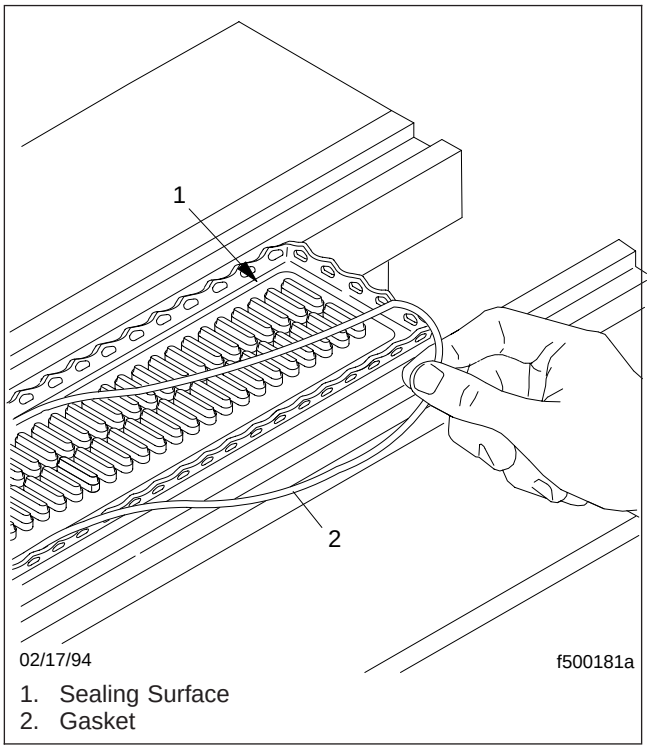


Fig. 5, Unlocking the Crimp



1. Sealing Surface
2. Gasket

Fig. 7, Sealing Gasket

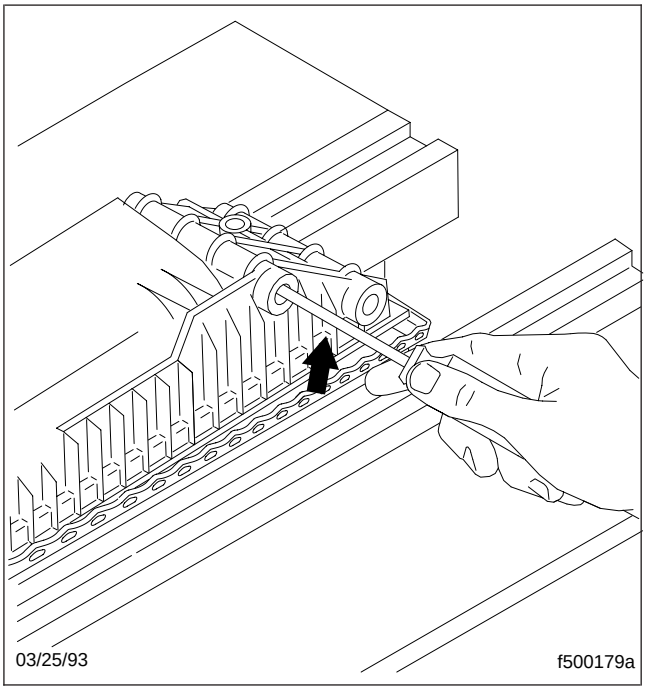


Fig. 6, Removal of Nylon Tank

header sealing surface is free of any dents, tool marks, or foreign particles.

1.2 Lubricate a new sealing gasket with a soap and water solution, and position the gasket on the header sealing surface. See **Fig. 7**. To make sure the gasket is not twisted, run a finger along the gasket as it lies on the sealing surface. The mold lines of the gasket should be on the outside and inside diameters of the gasket; if you can feel a mold line cross over the top of the gasket, the gasket is twisted.

1.3 Inspect the tank sealing flange. The flange must be clean and free of defects. If the sealing flange is damaged, replace the tank.

1.4 Place the tank on the gasket, and tap the tank with a rubber mallet or the heel of your hand to seat the tank. Make sure the tank ports are facing the correct direction.

1.5 Position the tank clamping cylinders evenly across the top of the tank. Make sure the cylinders' rubber plungers will

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not press against breakable fittings, such as vent tube ports. See **Fig. 4**.

CAUTION

Apply only enough pressure to compress the sealing gasket. Too much pressure will crack the nylon tank.

1.6 Apply pressure evenly across the top of the tank until the tank-to-core sealing gasket is compressed enough to show a small gap between the bottom of the dimple wave lock crimp and the tank sealing flange.

1.7 Place the T-bar into the T-bar groove in the disassembly/assembly fixture.

1.8 Slide the wave form bar over the T-bar, and center the bar in front of the wave crimp slot.

CAUTION

Do not push the wave crimp until it touches the side of the nylon tank, or the tank may crack.

1.9 Push the T-bar forward to crimp the header's edge until it almost touches the tank's side. See **Fig. 8**.

1.10 Slide the tools down the T-bar groove to the next wave crimp slot. Repeat until all the wave crimps are crimped.

CAUTION

In some places, especially around the tank ports, the wave crimps may have to be crimped with a screwdriver. When using a screwdriver, use care not to crack or gouge the nylon tank.

1.11 Release the pressure from the tank, and move the clamping cylinders off the radiator core and tank assembly.

1.12 Install the opposite tank.

2. Leak test the radiator core and tank assembly. For instructions, see "Disassembly" in this subject.

3. Install the radiator side channels.

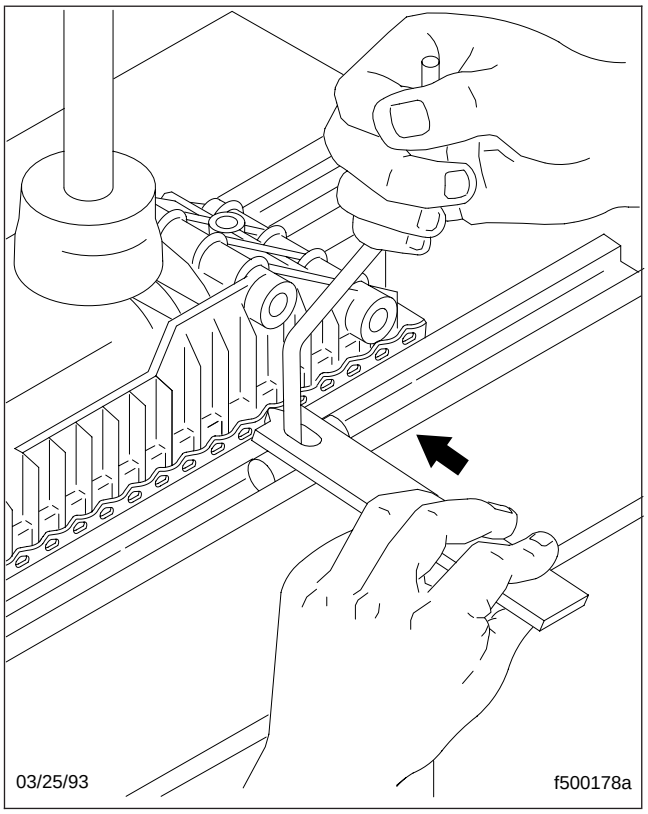


Fig. 8, Crimping the Header Edge

3.1 Slide the side channels onto the radiator core and tank assembly.

3.2 Using a rubber mallet and a punch, install the eight mounting pins through the side channel holes and tank bosses. See **Fig. 9**.

3.3 Install the eight spring clips to secure the mounting pins in position. See **Fig. 10**. To install each clip, place the clip over the end of the mounting pin, and slide the clip until it engages the groove in the pin and the open end of the clips snaps over the edge of the pin. If necessary, use a clamp to compress the side channel while installing the clips.

4. Install the radiator in the vehicle. For instructions, see **Subject 100**.

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Disassembly and Assembly

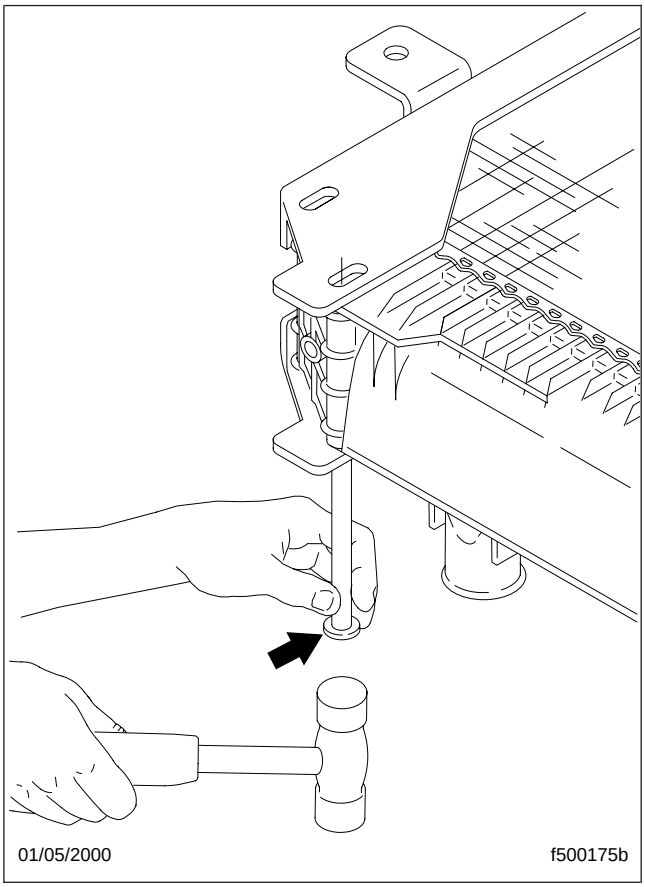


Fig. 9, Mounting Pin Installation

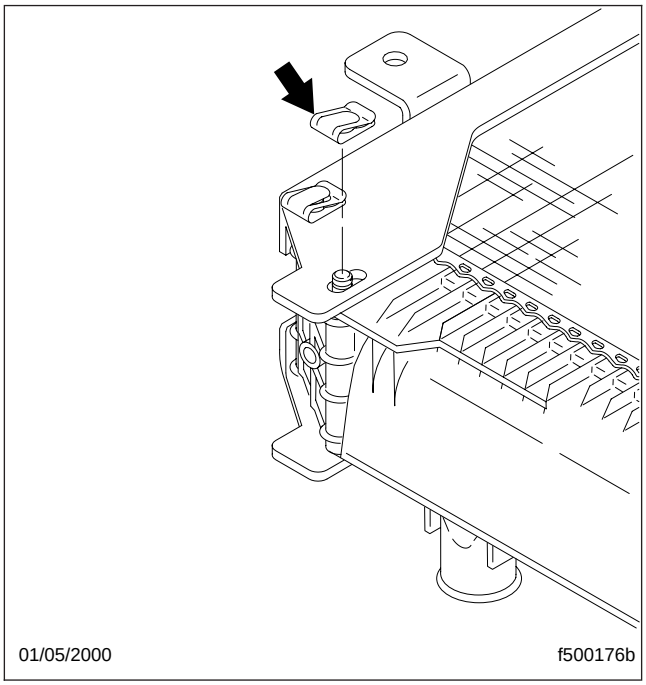


Fig. 10, Spring Clip Installation

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Pressure Testing

1. Remove the radiator. For instructions, see **Subject 100**.
2. Pressure test the radiator as follows:
   - 2.1 Leaving the coolant inlet port open, plug the outlet, and all other ports on the radiator.
   - 2.2 Using the necessary adaptor, connect a pressure regulator and a gauge on the coolant inlet port. Use a hand pump to apply 20 psi (138 kPa) air pressure through the inlet port.

⚠ CAUTION

Do not apply a higher amount of air pressure; too much pressure will damage the radiator core.

   - 2.3 Submerge the radiator in a tank of water and check it for leaks. Remove the radiator from the water.
   - 2.4 Remove the plugs and testing gauge. Repair the radiator, if necessary.
3. Install the radiator. For instructions, see **Subject 100**.

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Troubleshooting

NOTE: For additional troubleshooting information, see **Section 20.00**.

VISUAL CHECK

It is a sound service practice to give the cooling system a quick visual check whenever you tilt the hood. Look for signs of visible leaks (or the stains they leave), especially on the engine block. A final check is to look at the inside of the oil breather cap for signs of a milky substance; which means coolant is leaking into the oil.

AIR CONDITIONER CONDENSER AND CHARGE AIR COOLER

Since the condenser and charge air cooler are right in front of the radiator, air must pass through them to get to the radiator. For the heat transfer process to take place, the fins of the radiator, the condenser, and the charge air cooler must be free of blockages and deposits such as dirt or bugs. Clean the surfaces with compressed air or water and a mild laundry soap.

Also remember that because the three heat-transfer parts are so close to each other, heat will pass between them. A blocked condenser will transfer its heat to the charge air cooler and a hot charge air cooler will transfer its heat to the radiator.

RADIATOR CAP

The radiator cap is the most often ignored part in the cooling system. If it is suspect, replace it. An inspection means checking the cap with a pressure tester. A radiator cap in good condition will not open below 9 psi (62 kPa). A visual check is also in order: look for signs of deterioration on the inner gasket. Also look for cracks or breaks in the spring retainer in the cap and for corrosion or deposits on the spring itself. If the spring is not in perfect condition, it has probably lost tension; replace it.

ENGINE COOLANT

Check the level of the coolant at the surge tank. It should be up to the sight glass.

If the engine coolant is dirty or its color is beginning to fade, change it. It should also be replaced if it has a bad odor.

Be sure that the mixture is correct. See Group 20 in the *Acterra Maintenance Manual* for specifications.

RADIATOR

Radiator problems are limited to external leaks, which can be spotted visually, and internal blockages, assuming that there is good airflow and that the radiator is large enough to do the job.

To check for blockages, warm the engine to normal operating temperature. Shut down the engine, and pass your hand in front of the finned surface of the radiator. If there is a blockage in the radiator it should cause an obvious temperature difference from one area of the core to another. An obvious difference between inlet and outlet temperatures is to be expected.

FAN

See the applicable section in this group for fan and fan clutch checks.

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Specifications

Fastener Torques				
Description	Grade	Size	Torque	
			lbf·ft (N·m)	lbf·in (N·cm)
Charge Air Cooler-to-Radiator Mounting Bolts	5	5/16 inch	15 (20)	—
Hood Cable Bracket Bolts	8.8	10 mm	—	48 (540)
Fan Shroud Mounting Bolts	8	1/4 inch	—	108 (1220)
Radiator Mount Nuts	5	3/8–16	30 (40)	—
Radiator Strut Nuts	2	1/2–13	35 (47)	—
Charge Air Cooler Hose Clamps	5	6.3 mm	—	60 (680)
Condenser Mounting Bolts	5	5/16 inch	15 (20)	—
Air Recirculation Shield Bolts	5	5/16 inch	15 (20)	—
Radiator Isolator Bolt Locknut	8	3/4 inch	241 (327)	—
Radiator Brace Rod Locknuts	8	1/2 inch	68 (92)	—

Table 1, Fastener Torques

Hose Clamp Torque Values		
Clamp Type	Size	Torque: lbf·in (N·cm)
T-Bolt	All	55 (620)
Breeze Constant-Torque	5/16-inch tightening screw hex	90 (1020)
	3/8-inch tightening screw hex	90 (1020)
ABA	1.26-inch Diameter	31 (360)
	1.50-inch Diameter	35 (400)
	1.73-inch Diameter	35 (400)
	1.97-inch Diameter	35 (400)
	2.28-inch Diameter	35 (400)
	2.68-inch Diameter	40 (460)
	3.03-inch Diameter	40 (460)

Table 2, Hose Clamp Torque Values

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General Information (See Fig. 1)

The fan drive senses the air temperature behind the radiator core, and engages or disengages the fan depending on that temperature. An increase or decrease in the amount of heat from the radiator coolant causes a change in the air temperature behind the radiator core. A coiled metal heat sensor on the fan drive detects the temperature change; it engages the fan clutch when more cooling (airflow) is needed, and disengages it when the engine is sufficiently cooled.

The fan clutch consists of two basic parts: the input plate and shaft, and the output plate. The input shaft is mounted to the fan hub so it and the input plate are constantly turning as the engine runs. The output plate carries the fan blades but engages with the input plate only when extra engine cooling is needed.

When the fan is disengaged, a single bearing allows the output plate and fan to free-wheel in relation to the input shaft and plate. Both the output and input plates are lined with concentric grooves which intermesh with very close tolerance.

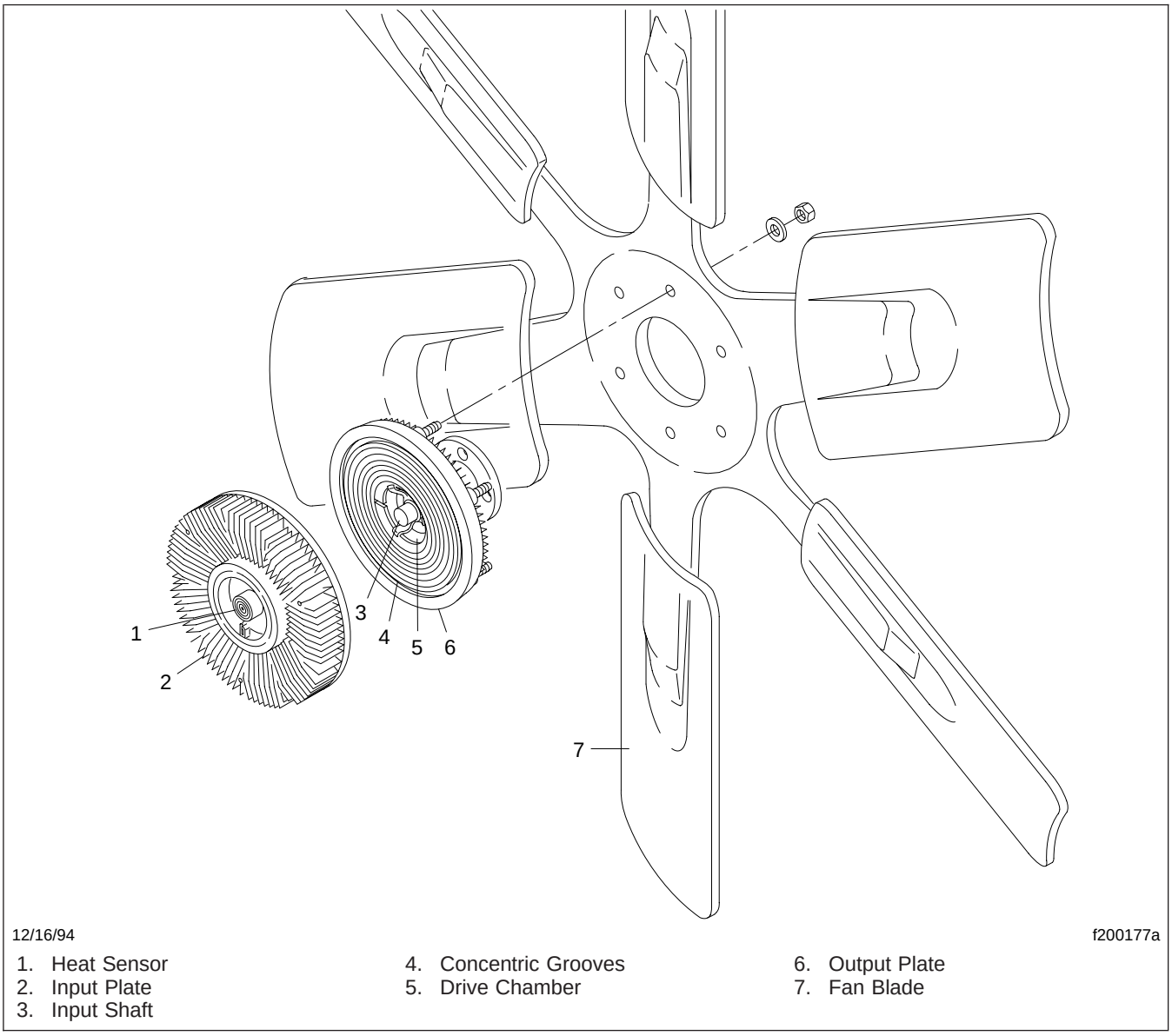
To engage the fan, the heat sensor on the front of the clutch opens a valve in the clutch's drive chamber. The centrifugal force of the turning input plate forces the viscous (thick) silicone fluid stored in the drive chamber to flow out. The fluid flows between the concentric grooves of the input and output plates, creating friction between the two plates. As that friction increases, the output plate and fan begin to turn with the input plate. The fluid continues to spread out between more grooves, increasing the friction between the plates until they spin at about the same speed.

When air passing through the radiator is cool enough, the heat sensor disengages the fan clutch. It does this by closing the valve in the drive chamber, which stops the flow of silicone fluid to the input and output plates. For the fluid already between the plates, centrifugal force continues to push it outward until it's beyond the grooves. There, at the outer edge of the clutch, it returns through a passage in the input plate to the drive chamber.

Again, without the fluid to create friction between the two plates, the output plate and fan free-wheel in relation to the input plate and input shaft.

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General Information



1. Heat Sensor
2. Input Plate
3. Input Shaft
4. Concentric Grooves
5. Drive Chamber
6. Output Plate
7. Fan Blade

Fig. 1, Eaton® 660 Fan Clutch

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Inspection

⚠ CAUTION

If the fan drive assembly is damaged, promptly replace the unit. Operating a vehicle with a seized or otherwise damaged clutch reduces fuel economy, and could cause serious engine damage.

The fan drive is only one part of the cooling system and will function well only if all other parts of the system are working right. All parts of the system should be checked if there is a cooling problem. Do all the checks in the cooling system troubleshooting section in this group, and pay special attention to the fuel flow rate and exhaust temperature. Over-fueling can cause engine overheating and high exhaust temperatures.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. With the engine off, rotate the fan at least one full turn by hand. It should have a smooth, steady drag. If it does not, replace the fan clutch.
3. Check for physical damage to the fan or fan shroud.
4. Inspect the fan clutch mounting.
   - 4.1 Check the torque of the nuts holding the fan input shaft to the fan hub or mounting adapter. They should be tightened:
     - 45 lbf·ft (61 N·m) for fan clutch input shaft-to-fan hub on Cummins ISB engine;
     - 34 lbf·ft (46 N·m) for fan clutch input shaft-to-fan hub on Cummins ISC engine;
     - 45 lbf·ft (61 N·m) for fan clutch input shaft-to-adapter on Mercedes-Benz engine;
     - 19 lbf·ft (25 N·m) for fan clutch mounting adapter-to-fan hub on Mercedes-Benz engine.
   - 4.2 Check for wear of the fan clutch bearings. There should be no side-to-side or in-and-out movement of the fan clutch.
5. Remove the chocks from the tires.

Operation Check

Use the following procedure to check for correct engagement and disengagement of the fan clutch:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Coolant temperature in the radiator should be below 140°F (60°C) before the start of the test; the outside temperature should be above 50°F (10°C). Ideally, a temperature probe placed about 1/2 inch (13 mm) from the fan clutch sensor is needed to see if the fan clutch engages at the right temperature.
3. Disconnect any hydraulic pumps (such as the power steering pump) to prevent oil overheating.
4. Get a piece of cardboard that is large enough to block the entire front of the radiator. Cut a round 7-inch (18-centimeter) hole in the cardboard; locate the hole so that it lines up with the fan clutch. Do not put the cardboard in front of the radiator yet.

⚠ WARNING

Before starting the engine, make sure people's hands and all other objects are away from the fan blades. It is extremely dangerous to get too close to the fan blades when the engine is on, because the fan could start operating without warning. Do not try to restrict the fan blade rotation when the engine is on.

5. Turn off the air conditioner, if so equipped. Start the engine, and let it idle until the oil pressure is normal.
6. As soon as there is normal oil pressure, bring the engine up to high idle (about 80 percent of governed engine speed) and lock the throttle at this speed.

   If the engine has been idle for more than eight hours, the fan clutch may engage as soon as the engine is started. If this happens, the usual noise from the fan will be heard; the noise will stop after 5 minutes or less, when the fan clutch disengages.

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Inspection and Operation Check

7. After the fan clutch disengages, put the cardboard in front of the radiator.
8. Look at the temperature gauge and note at what point the engine thermostat opens. As the engine warms up, the coolant temperature will rise steadily and then seem to level off after the thermostat opens. It will then start rising again, before the fan clutch engages.
9. Keep watching the coolant temperature and, if possible, the temperature of the air in front of the fan clutch, until the clutch engages. Note the temperature(s) at which the clutch engages. The fan should be fully engaged when the air at the fan clutch sensor rises to about 155 to 165°F (68 to 74°C).

   With the clutch engaged, the coolant temperature will keep rising, at a slower rate, as long as the radiator is blocked with cardboard.
10. Remove the cardboard from in front of the radiator. Keep watching the coolant temperature while the clutch is engaged; you should notice a decrease after the cardboard is removed.
11. The fan should disengage when the air temperature at the fan clutch sensor drops to about 120 to 130°F (49 to 54°C).

    If the coolant temperature keeps rising, even though the fan is engaged and the cardboard has been removed, the fan clutch may be working properly; the problem is probably in another part of the cooling system.

IMPORTANT: If the air temperature in front of the clutch is being tested, and it does not rise as the coolant temperature rises, the problem could be a clogged radiator or a stuck engine thermostat.

If the engine still overheats during operation, even though everything described above checks out properly, use a stroboscope to check peak fan speed. The fan speed should be at least 93 percent of the fan pulley speed when the clutch is fully engaged.

Example: 2160 = fan pulley speed x .93 = 2009 = 93 percent of fan pulley speed.

Fan speed must be at least 2009 rpm when the fan clutch is fully engaged.

12. Remove the chocks from the tires.

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Removal (See Fig. 1, Fig. 2, Fig. 3 or Fig. 4)

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries or, if the vehicle is equipped with a battery shutoff switch, turn off the switch.

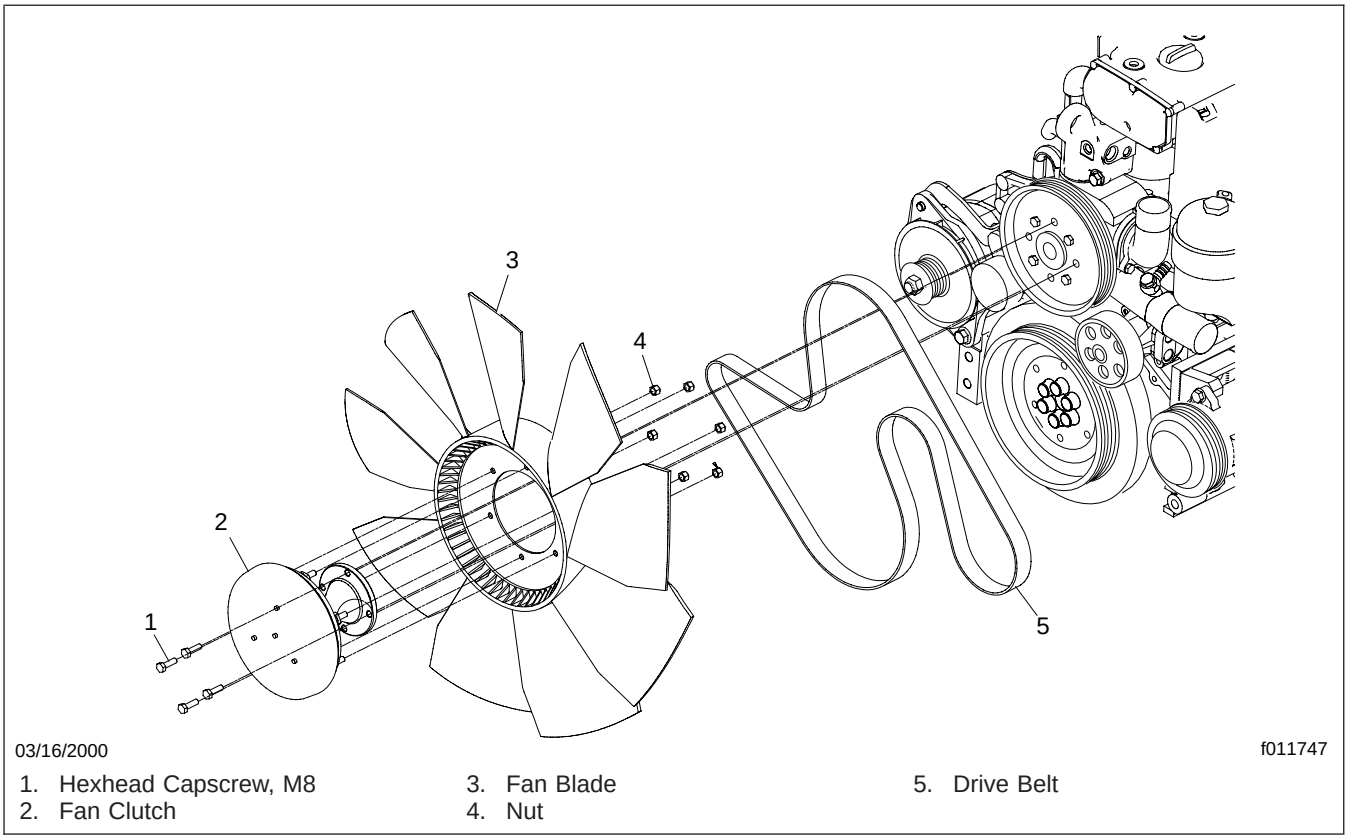
   Disconnect the battery ground cable at the vehicle frame.
3. Open the hood.
4. Remove the capscrews and lockwashers that hold the clutch to the fan hub. Remove the clutch from the engine.

   If necessary, on Mercedes-Benz engines, remove the capscrews and lockwashers that secure the fan clutch adapter to the fan hub. Remove the adapter from the fan hub.
5. Remove the nuts and lockwashers that hold the fan blade to the clutch. Remove the blade.

Installation (See Fig. 1, Fig. 2, Fig. 3 or Fig. 4)

1. Install the fan blade on the fan clutch. Tighten the fan mounting locknuts as follows:
   - Model 610: 40 lbf·ft (54 N·m);
   - Model 660: 22 lbf·ft (30 N·m);
   - Model 575: 15 to 20 lbf·ft (20 to 27 N·m).

NOTE: Use only approved fans, as specified in the *Sterling Parts Technical Information Manual*. Never go over the maximum input speeds, and

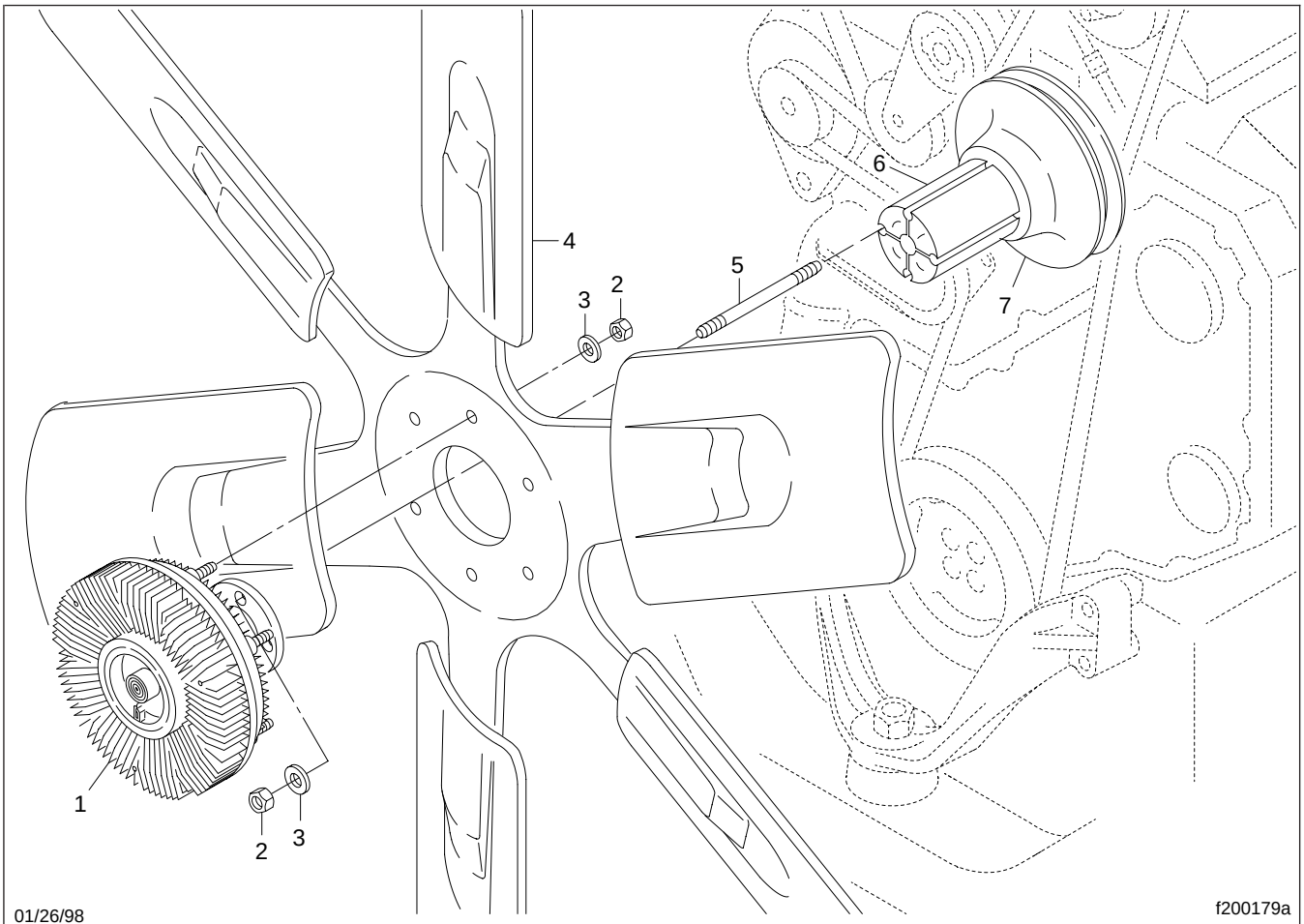


1. Hexhead Capscrew, M8
2. Fan Clutch
3. Fan Blade
4. Nut
5. Drive Belt

Fig. 1, Fan Clutch Mounting, Mercedes-Benz MBE900 Engine

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Removal and Installation



NOTE: The Eaton® 660 viscous fan clutch is shown here.

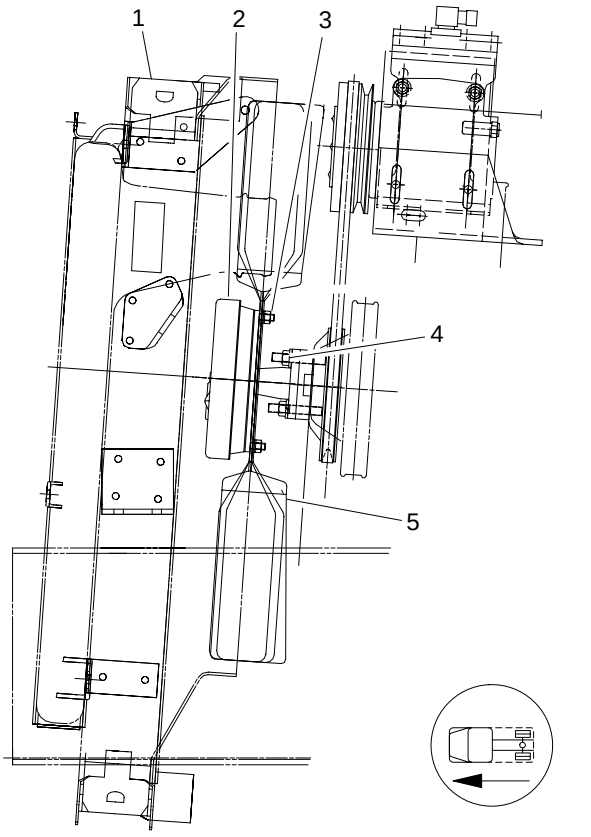
1. Fan Clutch Assembly
2. Locknut
3. Lockwasher
4. Fan Blade
5. Stud
6. Spacer
7. Fan Hub

Fig. 2, Fan Clutch Mounting, Cummins ISB Engine

do not make changes to the engine that will raise the operating speed of the fan.

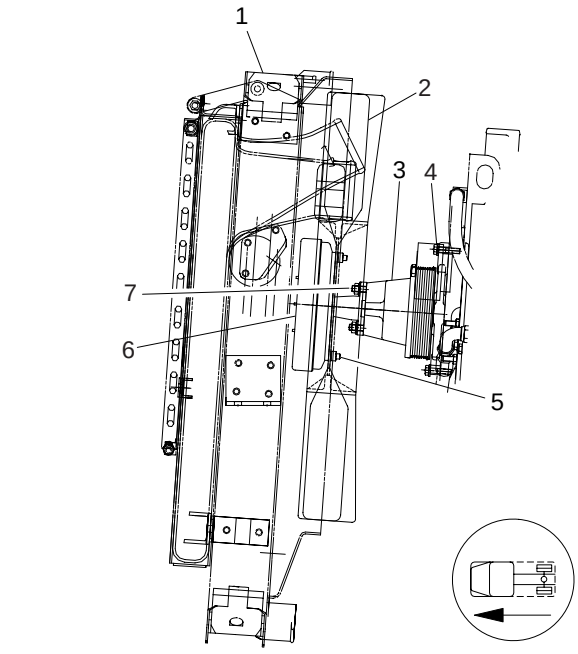
2. On Mercedes-Benz engines, if the fan clutch adapter was removed, mount it on the fan hub. Tighten the mounting capscrews 19 lbf·ft (25 N·m).
3. Install the fan clutch assembly. Tighten the fasteners as follows:
   - 45 lbf·ft (61 N·m) for Mercedes-Benz engines;
   - 45 lbf·ft (61 N·m) for Cummins ISB engines;
   - 34 lbf·ft (46 N·m) for Cummins ISC engines.
4. Lower the hood and connect the batteries.
5. Remove the chocks from the tires.

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1. Radiator
2. Fan Clutch Assembly
3. Locknut
4. Hexnut
5. Fan

Fig. 3, Fan Clutch Mounting, Cummins ISC Engine



1. Radiator
2. Fan
3. Fan Hub
4. Bolt
5. Locknut
6. Fan Clutch Assembly
7. Hexnut

Fig. 4, Fan Clutch Mounting, Caterpillar™ 3126B Engine

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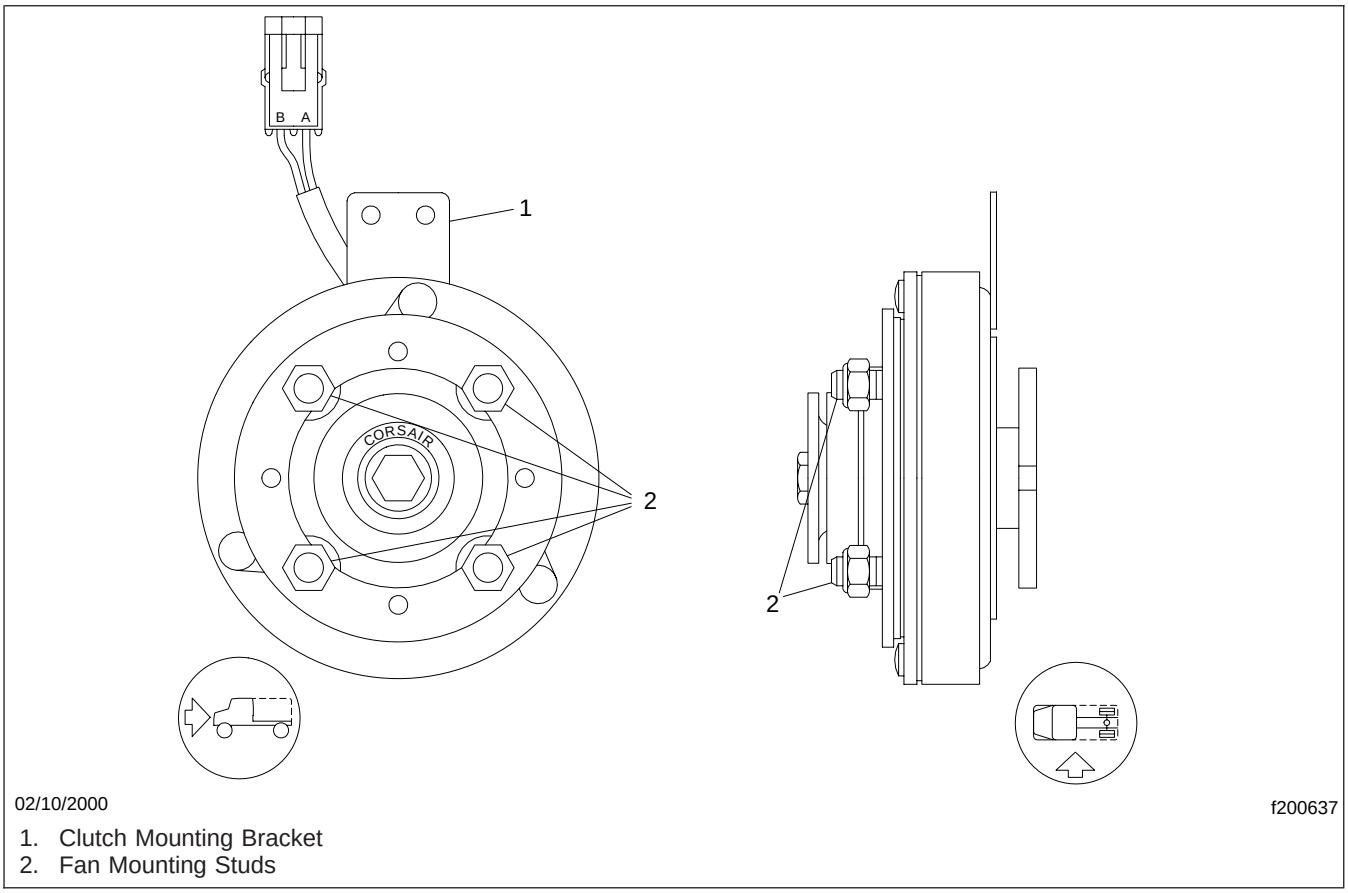
Specifications

Fastener Torques			
Description	**Grade**	**Size**	**Torque: lbf·ft (N·m)**
Fan Mounting Locknuts: Model 610 Clutch	8	3/8	40 (54)
Fan Mounting Locknuts: Model 660 Clutch	8	5/16	22 (30)
Fan Mounting Locknuts: Model 575 Clutch	—	—	15–20 (20–27)
Fan Clutch Input Shaft to Fan Hub Locknut: Cummins ISB Engine	10.9	M10	45 (61)
Fan Clutch Input Shaft to Fan Hub Locknut: Cummins ISC Engine	10	M10	34 (46)
Fan Clutch Input Shaft to Adapter Capscrew: Mercedes-Benz Engine	10.9	M10	45 (61)
Fan Clutch Mounting Adapter to Fan Hub Capscrew: Mercedes-Benz Engine	10.9	M8	19 (25)

Table 1, Fastener Torques

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General Information (See Fig. 1)



1. Clutch Mounting Bracket
2. Fan Mounting Studs

Fig. 1, Horton EC450 Electromagnetic Fan Clutch

The Horton EC450 fan clutch (previously marketed as the Corsair fan clutch) is an electromagnetic on/off-style engine cooling fan clutch. The fan clutch is electrically operated, and is not connected to the vehicle's air system.

When vehicle motion (ram air effect) provides enough airflow through the radiator to keep engine coolant temperature within operating limits, the fan is disengaged by de-energizing the fan clutch. Disengaging the fan saves fuel, lowers power consumption and engine noise, and, for cold starts, allows the engine and the cab to warm up faster.

When the vehicle is stationary, or whenever extra air flow through the radiator is necessary, the fan clutch is engaged to connect the fan with the fan drive pulley and provide extra engine cooling. On most vehicles, this extra cooling is seldom needed; the clutch is deactivated and the fan is not turning 90 to 95 percent of the time.

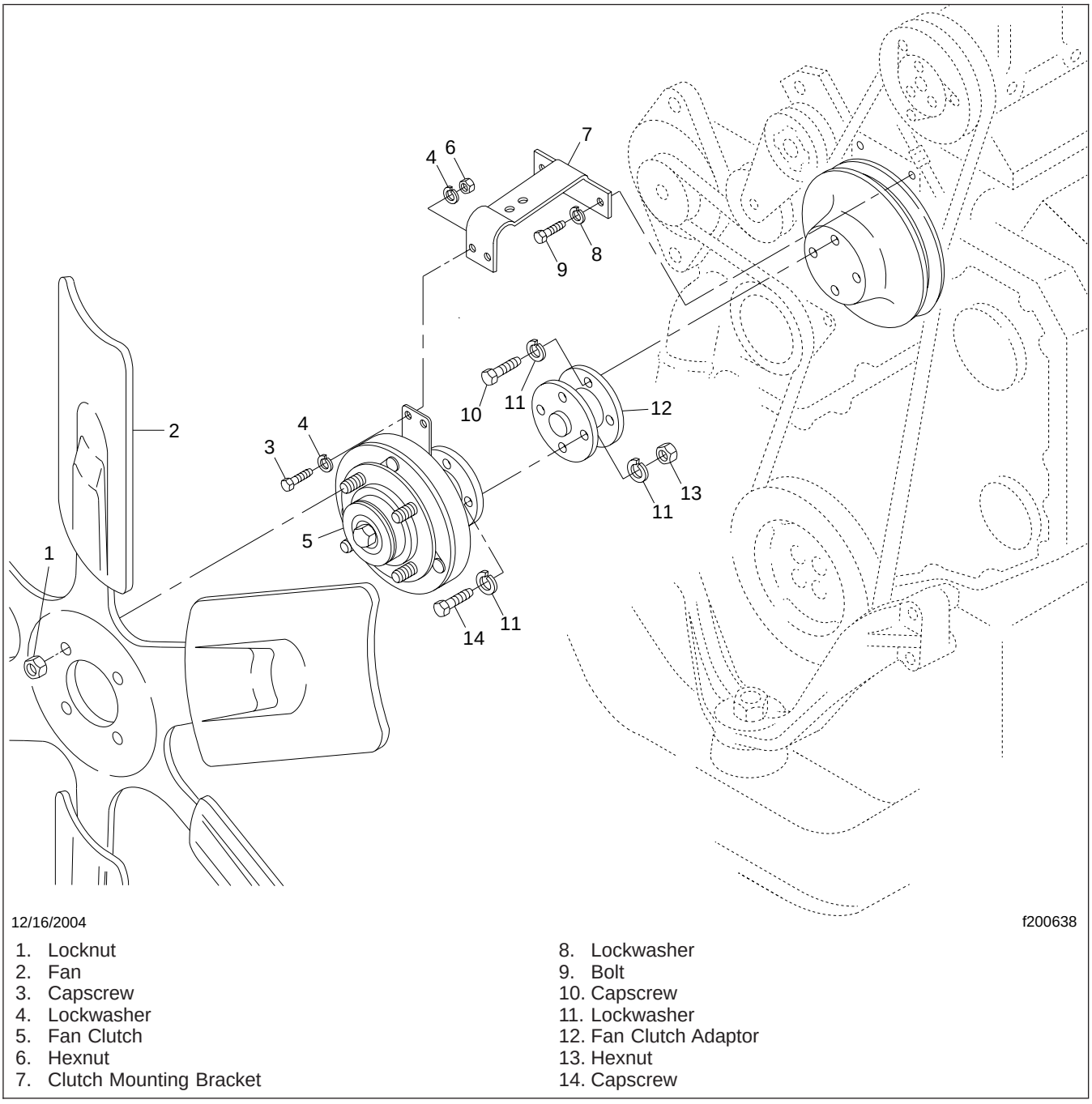
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Replacement (See Fig.1, Fig.2 or Fig.3)

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the battery ground cable at the vehicle frame, or if the vehicle is equipped with a battery shutoff switch, turn off the switch.
3. Open the hood.
4. Remove the fan clutch.
   - 4.1 Disconnect the fan clutch field coil connector.
   - 4.2 Remove the locknuts from the fan clutch studs.
   - 4.3 Remove the fan from the fan clutch.
   - 4.4 Remove the two capscrews, lockwashers, and hexnuts that hold the clutch-side clutch mounting bracket to the fan clutch.
   - 4.5 Remove the four capscrews that hold the fan clutch to the fan clutch adaptor or the fan hub.
   - 4.6 Remove the fan clutch from the vehicle.
5. Install the new fan clutch.
   - 5.1 Position the fan clutch on the fan clutch adaptor or the fan hub.
   - 5.2 Secure the fan clutch with four capscrews. For Cummins ISB engines, use new split lockwashers. Tighten the capscrews 34 lbf·ft (46 N·m).
   - 5.3 Secure the clutch-side clutch mounting bracket to the fan clutch with two capscrews. Use new split lockwashers, and tighten the capscrews 62 lbf·in (700 N·cm).
   - 5.4 Position the fan on the fan clutch, and secure it with new locknuts. Tighten the locknuts 16 lbf·ft (22 N·m).
   - 5.5 Connect the fan clutch field coil wiring to the engine wiring harness.
6. Test the fan clutch operation by running the engine until the coolant temperature is above 200°F (93°C). The fan clutch should engage.
7. Close and latch the hood.
8. Remove the chocks from the rear tires.

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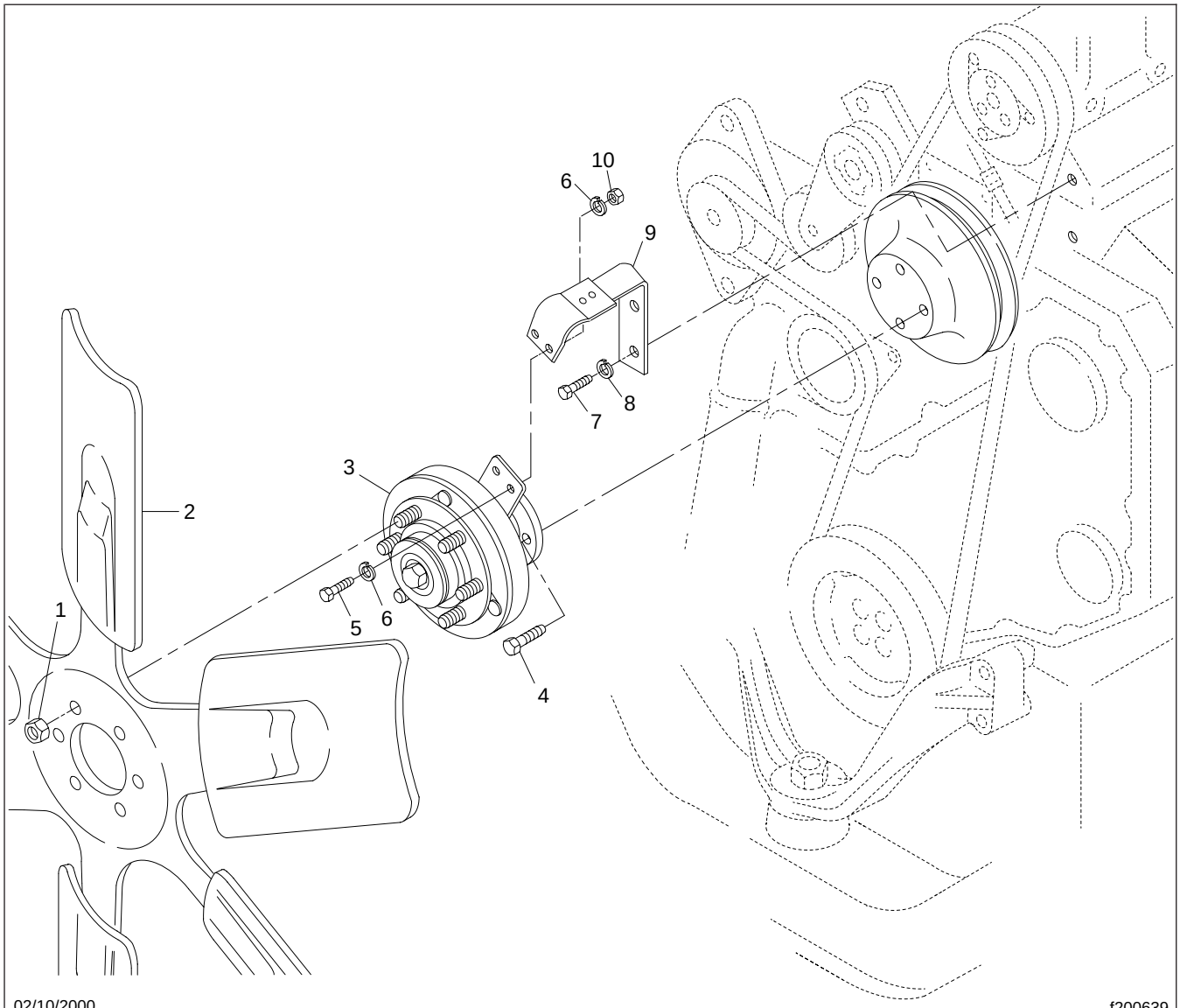
Fan Clutch Replacement



1. Locknut
2. Fan
3. Capscrew
4. Lockwasher
5. Fan Clutch
6. Hexnut
7. Clutch Mounting Bracket
8. Lockwasher
9. Bolt
10. Capscrew
11. Lockwasher
12. Fan Clutch Adaptor
13. Hexnut
14. Capscrew

Fig. 1, Fan Clutch Mounting, Cummins ISB Engine

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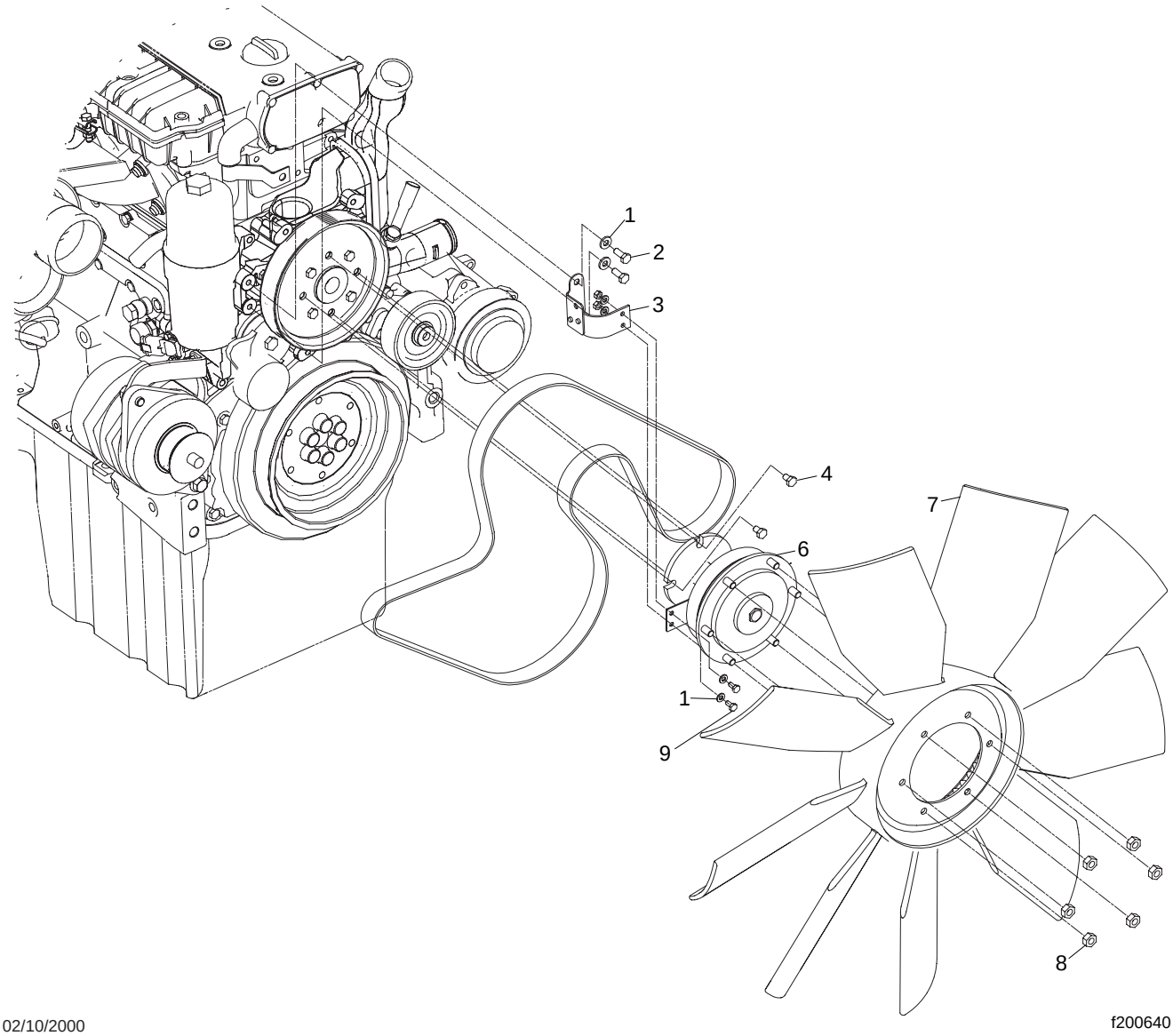


1. Locknut
2. Fan
3. Fan Clutch
4. Capscrew
5. Capscrew
6. Lockwasher
11. Capscrew
12. Lockwasher
13. Clutch Mounting Bracket
14. Hexnut

Fig. 2, Fan Clutch Mounting, Cummins ISC Engine

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Fan Clutch Replacement



1. Washer
2. Bolt
3. Bracket
4. Belt
5. Capscrew
6. Fan Clutch
7. Fan
8. Locknut
9. Capscrew

Fig. 3, Fan Clutch Mounting, Mercedes-Benz MBE900 Engine

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Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood and locate the temperature switch/sensor. See **Fig. 1** or **Fig. 2**.

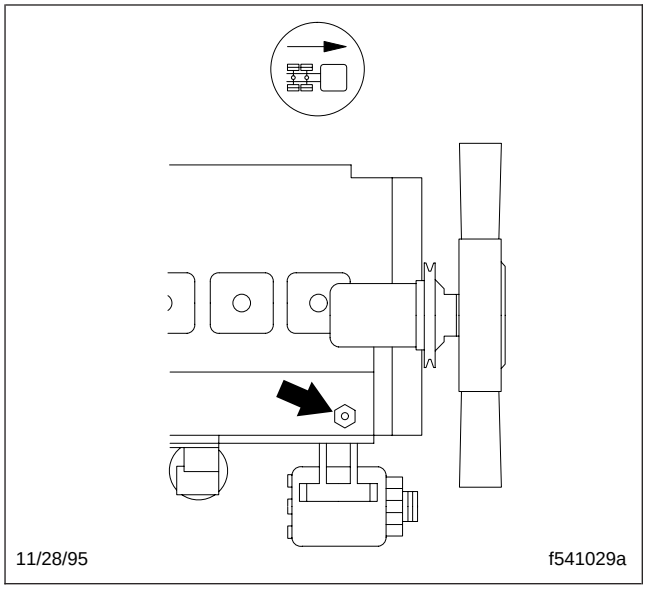


Fig. 1, Temperature Switch/Sensor Location, Cummins ISB Engine

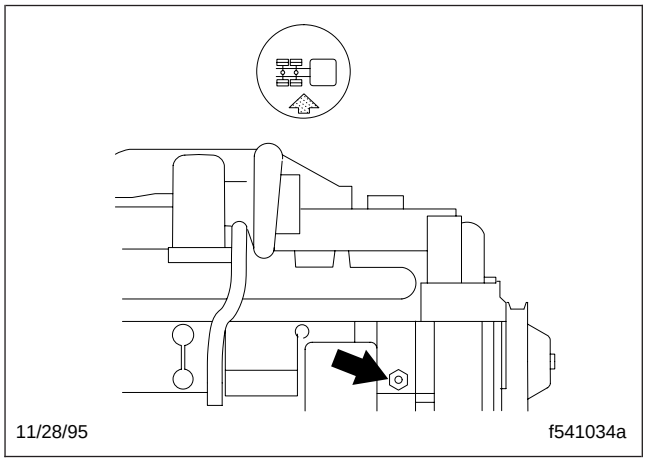


Fig. 2, Temperature Switch/Sensor Location, Cummins ISC Engine

⚠ WARNING

Do not drain the cooling system while the engine is hot. To avoid personal injury from scalding coolant, wait until the engine has cooled down before draining the system.

3. Drain coolant from the system until the coolant level drops below the temperature switch/sensor location.
   - 3.1 With the engine cool, loosen the radiator cap to release pressure from the radiator. Tighten the cap.
   - 3.2 Place a clean drain pan under the drain plug or petcock located at the bottom of the radiator left end-tank. See **Fig. 3**. Remove the drain plug or open the petcock. If necessary, use a deflector to channel coolant away from the front springs and into the drain pan.

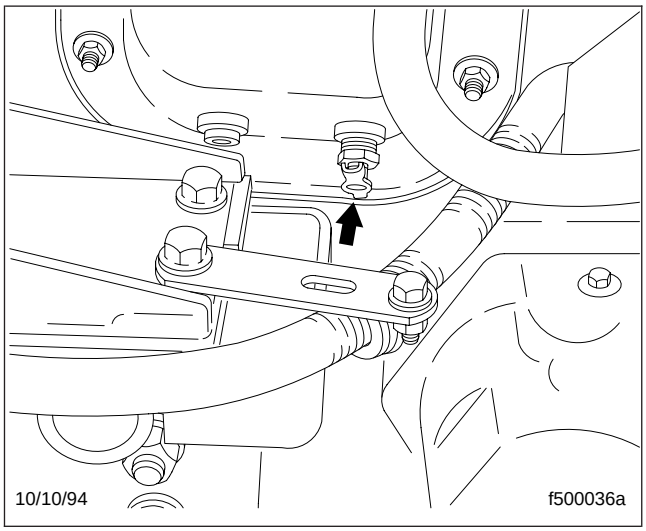


Fig. 3, Radiator Drain Location, Typical

   - 3.3 Install the drain plug or tighten the petcock.
4. Disconnect the wires from the temperature switch (or unplug the wiring harness connector from the temperature sensor), and unscrew the switch/sensor from the engine.
5. Clean old sealant residue from the threads of the switch/sensor port in the engine.

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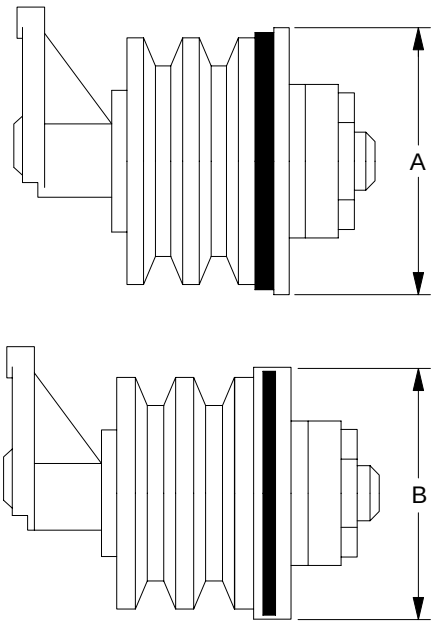
Temperature Switch/Sensor Replacement

6. Apply pipe thread sealant to the threads of the new switch/sensor, and install it in the engine port. Tighten the switch/sensor until it is snug.
7. Connect the vehicle wiring harness to the temperature switch/sensor.
8. Fill the cooling system.
9. Start the engine, check for leaks, and check that the fan clutch and coolant temperature gauge are operating properly.
10. Close and latch the hood.
11. Remove the chocks from the rear tires.

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General Information

The fan drive is a temperature-controlled, air-operated clutch for the engine cooling fan. It controls engine temperature by engaging or disengaging the fan. Internal spring pressure disengages the fan clutch when the coolant temperature is below the specified temperature range; internal air pressure engages the fan clutch when the coolant temperature rises above that range. Sterling uses two Horton fan clutch models: the S and the HT/S. See **Fig. 1**.



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A. The S model fan clutch has a 7.5 inch (187.5 mm) wide piston friction disc.
B. The HT/S model fan clutch has a 9.5 inch (237.5 mm) wide piston friction disc.

Fig. 1, Horton Fan Clutches

Air pressure to the fan clutch is controlled by a solenoid valve; the solenoid valve is controlled by a temperature switch that is installed in the thermostat housing. See **Fig. 2** and **Fig. 3**.

When you start a cold engine, the solenoid valve restricts air pressure to the cylinder and the fan clutch remains disengaged.

When the coolant temperature rises to the temperature switch setting, the switch provides power to the solenoid valve and the valve releases compressed air to engage the fan clutch.

When the coolant temperature drops to the temperature switch cutoff setting, the solenoid stops the compressed air and the clutch disengages.

On vehicles with air conditioning, the fan clutch solenoid valve is connected to a fan cycling switch at the accumulator. If the refrigerant pressure exceeds the setting of the fan cycling switch, the switch supplies power to the solenoid valve, which supplies air to engage the fan clutch.

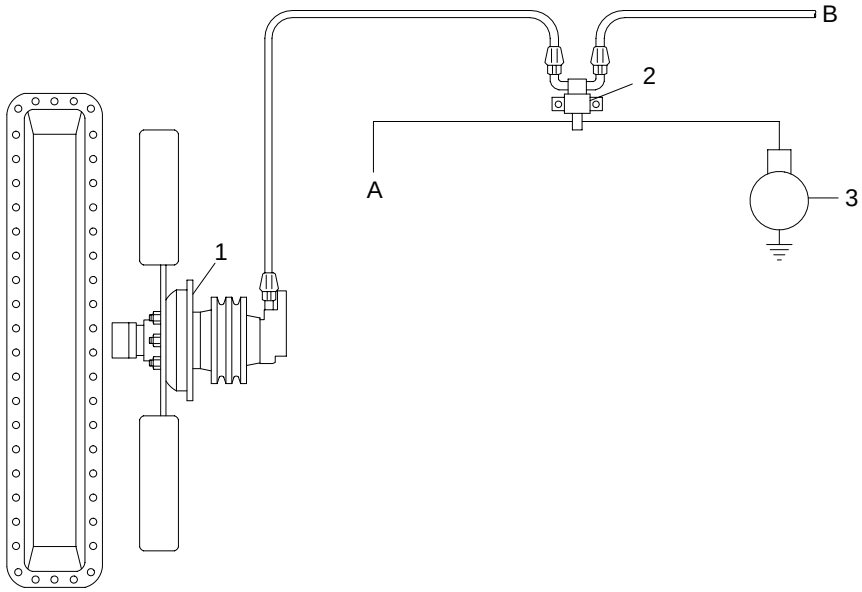
Some Horton S and HT/S fan clutch models include System Sentry™ fuses that protect the fan clutch from overheating. See **Fig. 4**. The System Sentry fuse is a brass fitting in the piston friction disc; the fitting uses lead alloy solder to hold a brass plug. If anything causes the fan clutch to slip excessively, heat from the slippage will melt the solder and release the plug. Air pressure inside the clutch will escape, and the clutch will release before heat build-up can damage the clutch bearings. The fuse is balanced by two counterweights.

If the fan clutch includes the System Sentry fuse, and the clutch will not engage, check to see if the fuse is melted, and check to see what might be making the fan clutch slip excessively.

For the fan clutch model number and serial number, see the side of the air chamber. See **Fig. 5**.

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General Information

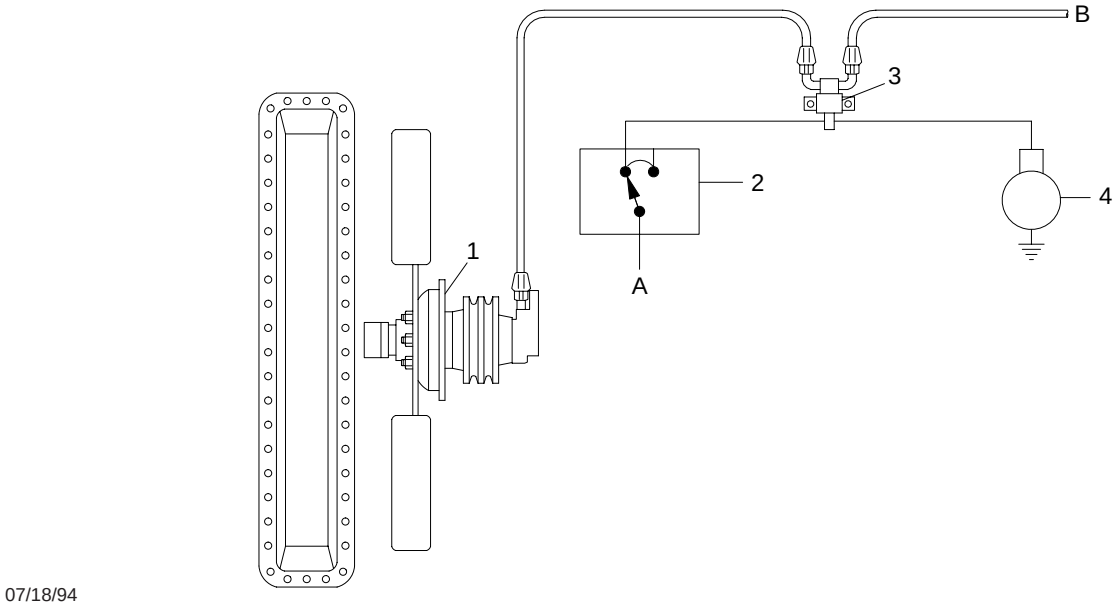


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A. To the circuit breaker.
B. From the secondary air tank.
1. Fan Clutch
2. Solenoid Valve
3. Temperature Switch

Fig. 2, Fan Clutch Piping and Wiring on Vehicle Without Air Conditioning

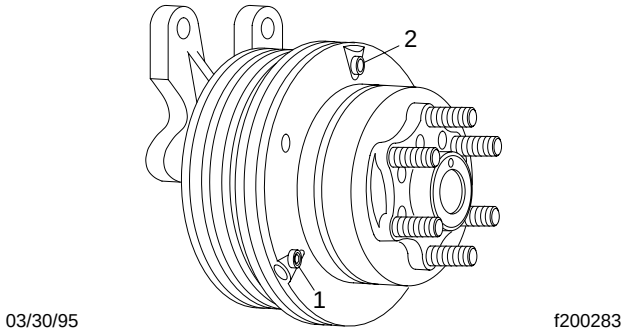
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A. To the circuit breaker.
B. From the secondary air tank.
1. Fan Clutch
2. Fan Cycling Switch at the Accumulator
3. Solenoid Valve
4. Temperature Switch

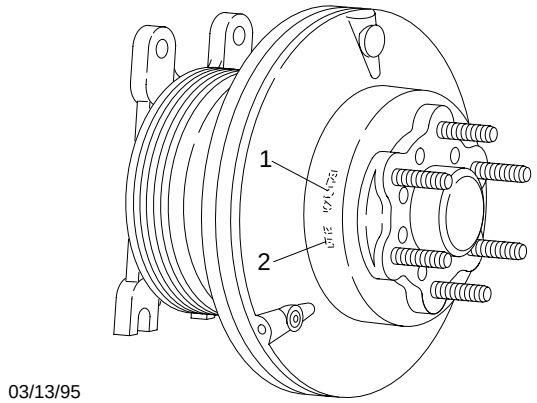
Fig. 3, Fan Clutch Piping and Wiring on Vehicle With Air Conditioning



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1. System Sentry Fuse
2. Counterweight

Fig. 4, Horton Fan Clutch With System Sentry Fuse



03/13/95 f200300

1. Model Number
2. Serial Number

Fig. 5, Fan Clutch Information, Model HT/S 981144

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Removal (See Fig. 1)

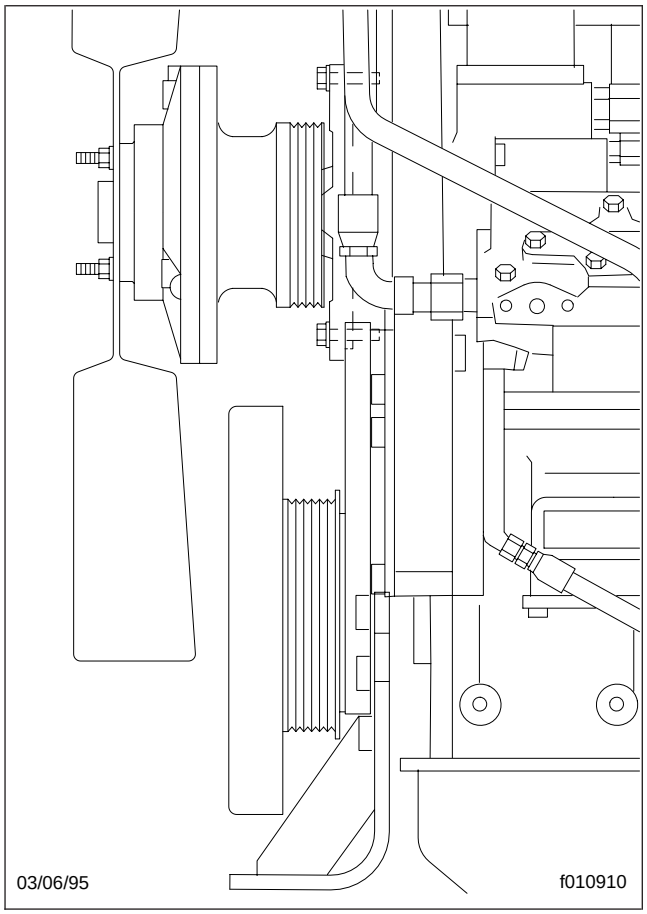


Fig. 1, Fan Clutch

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.

⚠ WARNING

Drain the coolant only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

2. Remove the drain plug from the right side of the radiator bottom tank, and drain about 2 gallons (7 liters) of coolant. Install the drain plug and tighten it firmly.
3. Disconnect the radiator inlet hose and the radiator vent hose from the radiator. Move both hoses away from the radiator and fan shroud.
4. Disconnect the air intake hoses from the aftercooler. Move both hoses away from the aftercooler and fan shroud.
5. Remove the six 3/8-inch capscrews that hold the fan shroud to the radiator.
6. Loosen the fan belt. For instructions, see **Group 01**.

⚠ WARNING

Use care when loosening the air line fitting. The line could be under pressure and may have dirt or sludge in the air stream. If quickly disconnected, the line may whip, possibly causing eye injury or other bodily injury.

7. Find the air line that runs between the fan clutch and the clutch solenoid, and disconnect the line from the solenoid. Cut any tie straps that secure the line to the engine.

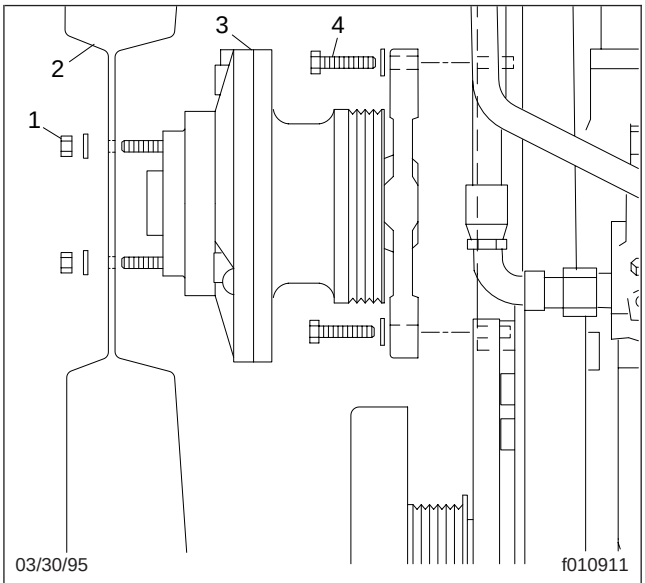
⚠ WARNING

The fan clutch is heavy and lifting it from the center of a crowded engine compartment can be awkward. To avoid injury, two people should work together to lift the fan clutch from the engine.

8. Remove the fan and fan clutch from the engine. See **Fig. 2**.
   - 8.1 Remove the four capscrews that hold the fan clutch to the engine.
   - 8.2 With a helper, lift the fan clutch and fan up and out of the engine compartment. Move the fan shroud as needed.
   - 8.3 Place the fan clutch on a work bench and remove the six nuts that hold the fan to the fan clutch. Remove the fan from the fan clutch.

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Removal and Installation



1. 3/8-Inch Locknut
2. Fan
3. Fan Clutch
4. Capscrew, M8 x 35 mm, Grade 8.8

Fig. 2, Fan Clutch Components

Installation

⚠ WARNING

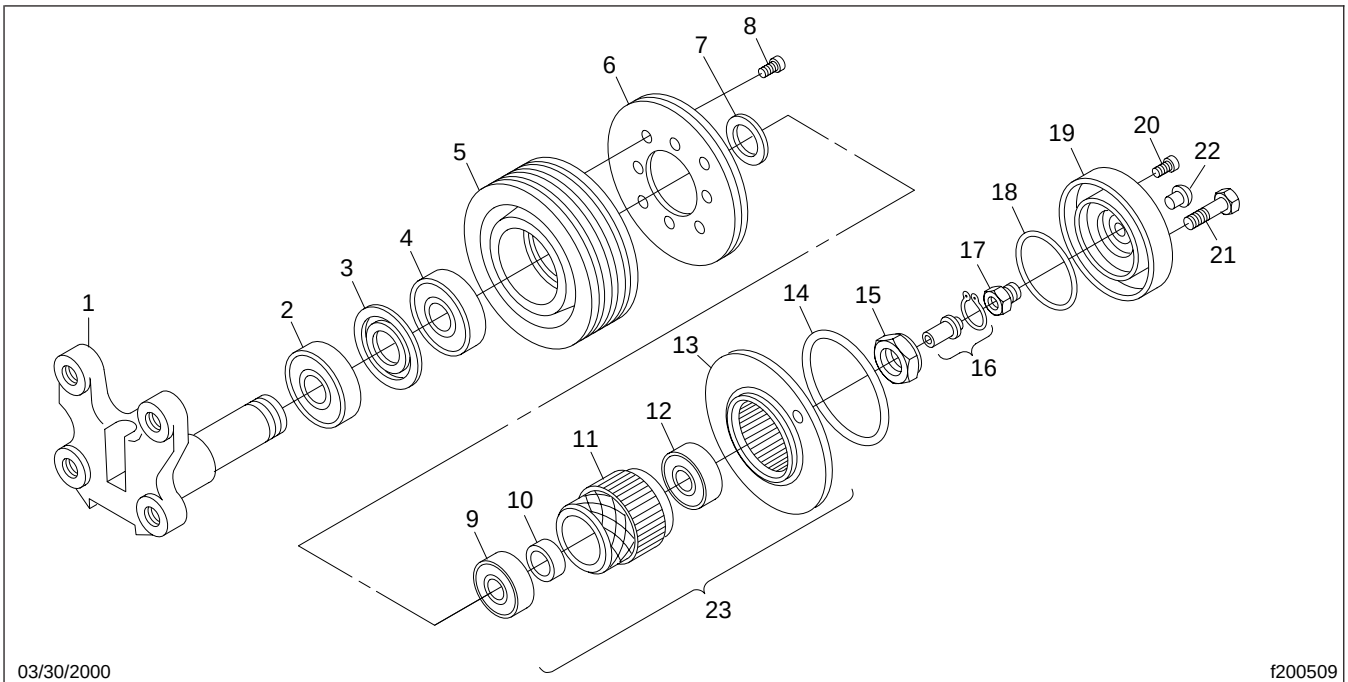
The fan clutch is heavy and placing it in the center of a crowded engine compartment can be awkward. To avoid injury, two people should work together to place the fan clutch on the engine.

1. Install the fan and fan clutch on the engine.
   - 1.1 Place the fan on the fan clutch and secure the fan with six nuts. Tighten the nuts 15 lbf·ft (20 N·m).
   - 1.2 With a helper, position the fan and fan clutch on the engine. Move the fan shroud as needed.
   - 1.3 Install the four capscrews and tighten 13 lbf·ft (18 N·m).
   - 1.4 Connect the air line to the solenoid and secure the line to the engine with tie straps.
2. Work the belt over the fan. Route and adjust the belt. For instructions, see **Group 01** in this manual.
3. Install the fan shroud on the radiator.
4. Connect the coolant hoses to the radiator and the air hoses to the aftercooler.
5. Take the coolant drained from the radiator and pour it back into the surge tank.
6. Check the fan clutch for proper operation. For instructions, see Group 20 in the *Acterra Maintenance Manual*.
7. Remove the chocks from the tires.

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Disassembly (See Fig. 1)

NOTE: This procedure involves a major rebuild of the Horton Advantage fan clutch, using parts from the manufacturer's Major or Super Kit. If you are replacing just the air cartridge, System Sentry® fuse, or the face seal, go to **Subject 120**.



1. Mounting Bracket Assembly
2. Rear Sheave Bearing
3. Inner and Outer Bearing Spacers
4. Forward Sheave Bearing
5. Sheave
6. Friction Facing
7. Journal Spacer
8. Socket-Head Capscrew
9. Rear Hub Bearing
10. Bearing Spacer
11. Splined Hub
12. Forward Hub Bearing
13. Piston Friction Disc
14. Large O-Ring
15. Locknut
16. Air Cartridge Assembly
17. Face Seal
18. Small O-Ring
19. Air Chamber
20. Socket-Head Capscrew
21. Hexbolt (some vehicles equipped with studs)
22. Rubber Umbrella Valve
23. Disc and Piston Assembly

Fig. 1, Horton Advantage Fan Clutch

1. Remove the fan and fan clutch assembly from the vehicle. For instructions, see **Subject 100**.
2. Clamp the fan clutch in a vise. See **Fig. 2**.
3. On some vehicles, the fan clutch has threaded studs on the air chamber and the fan is attached with nuts. On other vehicles, the fan is attached to the air chamber with hexbolts.

   If hexbolts were used to attach the fan, install two of the removed hexbolts in the air chamber so that a screwdriver can be used to keep the air chamber from rotating. See **Fig. 3**.

   Remove the socket-head capscrews from the air chamber.
4. If applicable, remove the two hexbolts previously installed.

⚠ WARNING

Apply air pressure slowly to the fan clutch. A sudden blast of air might blow the air chamber off the clutch, resulting in possible injury.

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Fan Clutch Major Rebuild

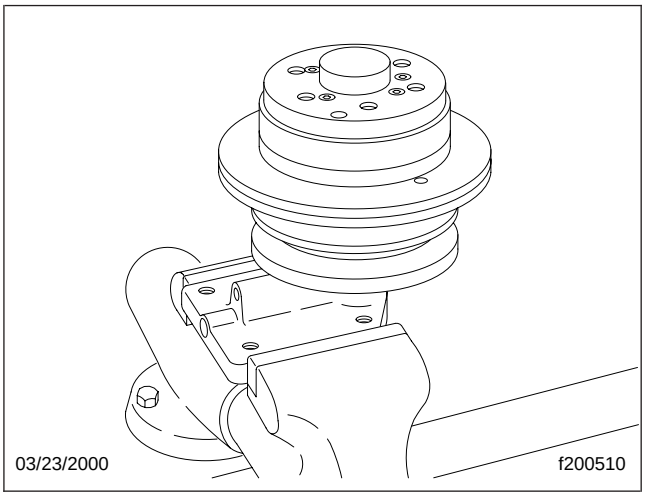


Fig. 2, Fan Clutch Placed in a Vise

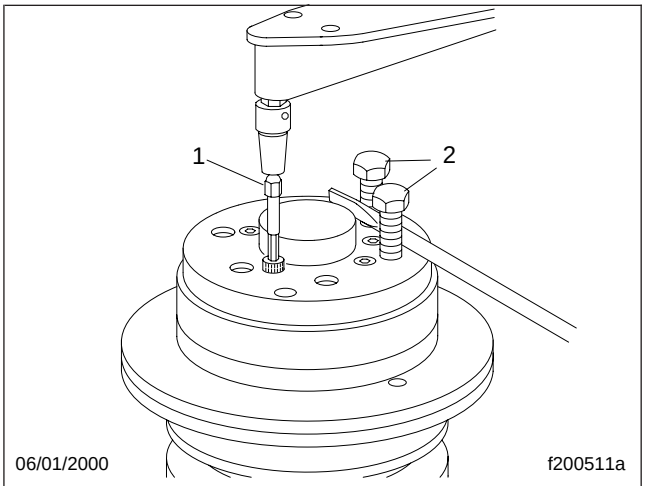


Fig. 3, Remove the Socket-Head Capscrews

5. Connect a shop air hose to the cylinder inlet. See **Fig. 4**. Slowly apply air pressure, and remove the air chamber assembly.
6. Remove and discard the O-rings from the air chamber and the piston friction disc. Clean the O-ring contact surfaces.
7. Remove the face seal from the air chamber. See **Fig. 4**.

NOTE: The System Sentry fuse has a left-hand thread.

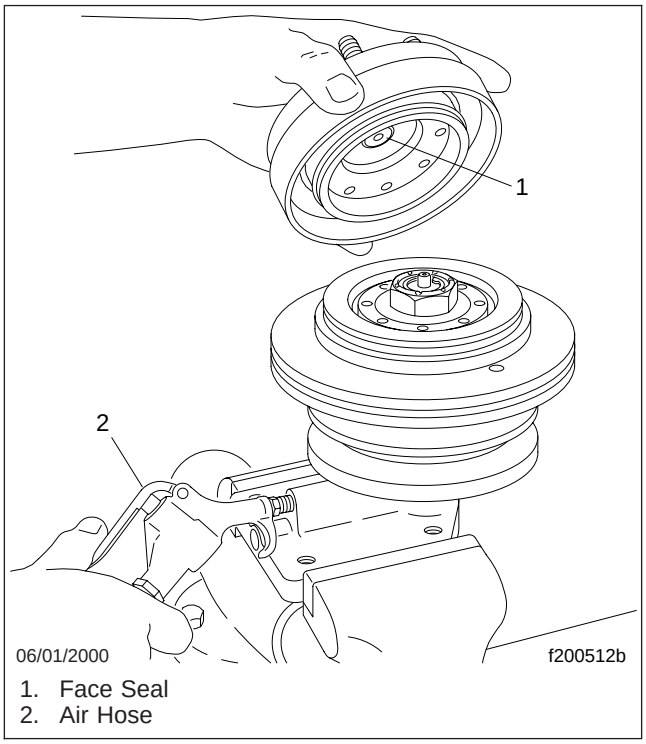


Fig. 4, Remove the Air Chamber

8. Remove the System Sentry fuse from the piston friction disc.
9. Remove the rubber umbrella valve from the air chamber.
10. Remove the adjusting nut. See **Fig. 5**.

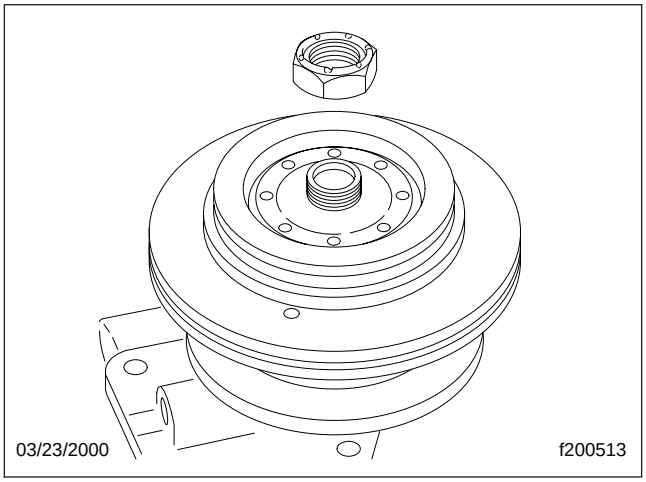


Fig. 5, Remove the Adjusting Nut

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11. Remove the disc and piston assembly, and the journal spacer. See **Fig. 6**.

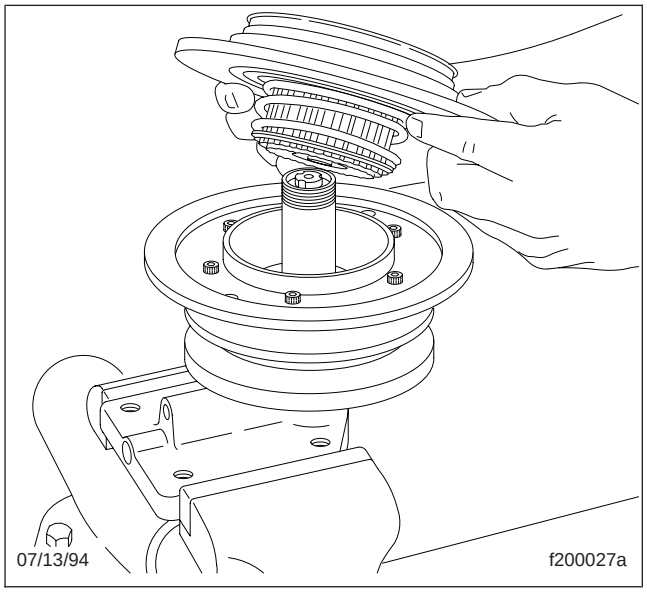


Fig. 6, Remove the Disc and Piston

12. Slide the sheave and bearings off the mounting bracket assembly. See **Fig. 7**.

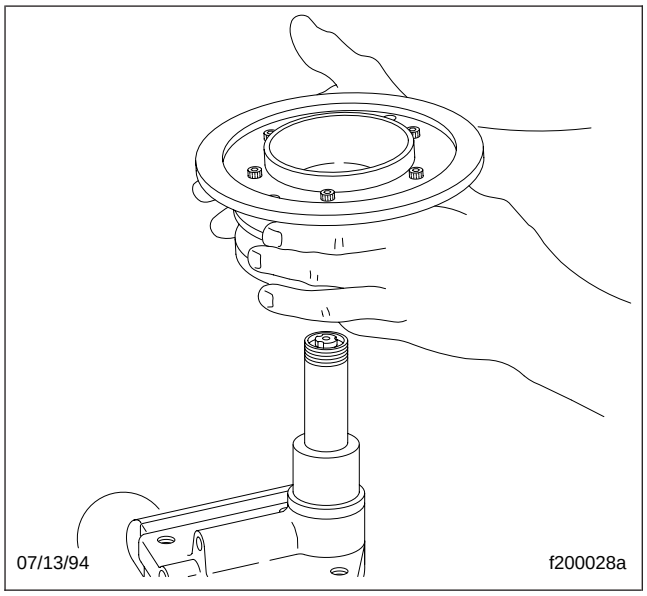


Fig. 7, Slide Off the Sheave and Bearings

13. Remove the socket-head capscrews from the friction facing. Remove the friction facing.

14. Remove the retaining ring from the air cartridge assembly. See **Fig. 8**.

    Remove the cartridge assembly from the mounting bracket assembly. See **Fig. 9**.

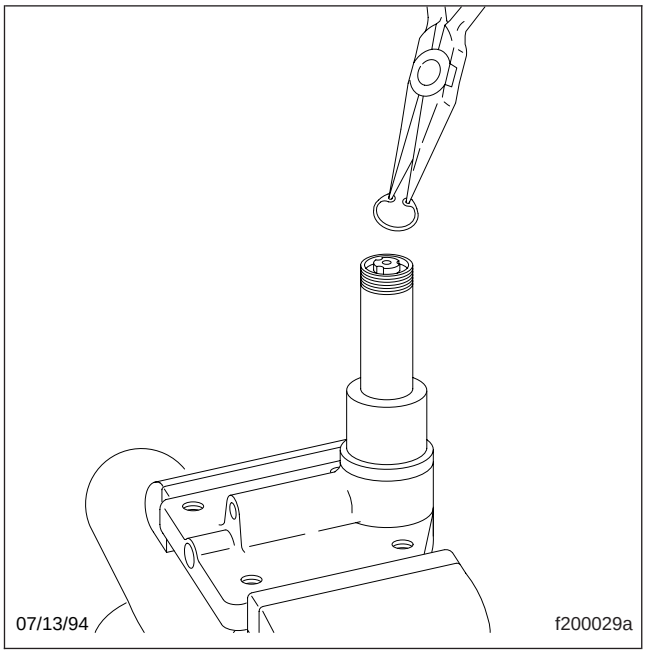


Fig. 8, Remove the Retaining Ring

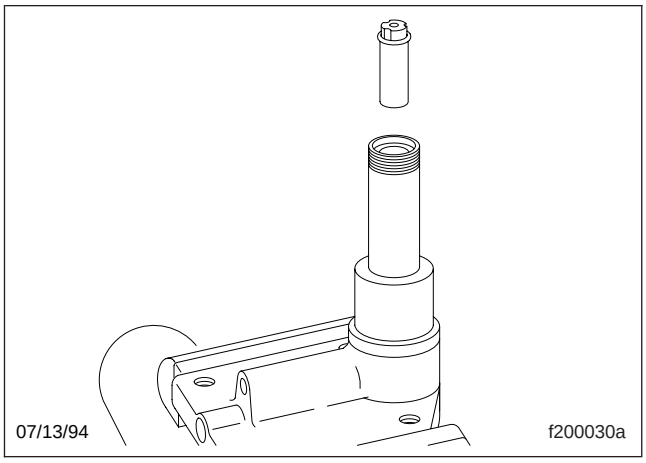


Fig. 9, Remove the Air Cartridge Assembly

15. Support the sheave and press out the bearings.

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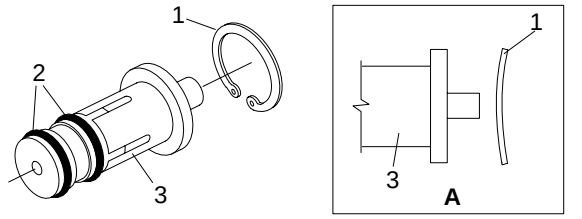
Fan Clutch Major Rebuild

Assembly

1. Coat the new sheave bearings with grease and press them into the sheave.

NOTE: Some models have a spacer between the bearings. Install the spacer if equipped.

2. Install a new air cartridge assembly in the mounting bracket assembly. Note that the retaining ring is curved. Make sure the ring is installed with the convex surface toward the air cartridge. See **Fig. 10**.



03/27/2000 f200515

A. Convex Surface of Retaining Ring Toward the Air Cartridge
1. Retaining Ring
2. O-Rings
3. Air Cartridge

Fig. 10, Air Cartridge Assembly

3. Slide the sheave and bearings onto the mounting bracket assembly.

4. Install a new friction facing onto the sheave. Following a star pattern, tighten the socket-head capscrews 60 lbf·in (680 N·cm).

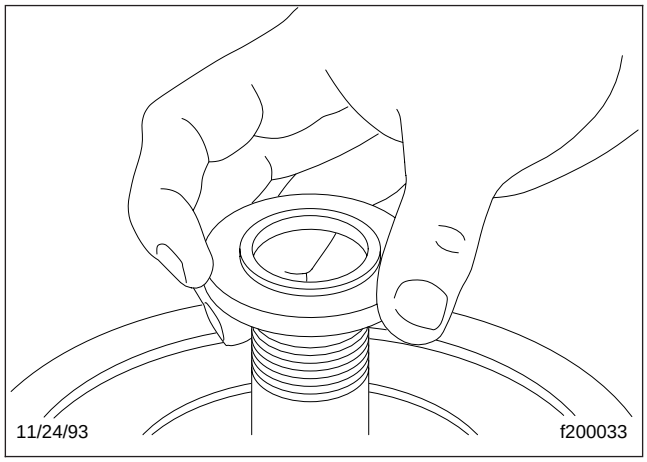
⚠ CAUTION

Never fill more than one-third of the bearing void with grease. Too much grease can cause overheating and possible bearing damage.

5. Install the journal spacer, and the disc and piston assembly. Make sure that the lip on the journal spacer is facing up. See **Fig. 11**.

6. Install the adjusting nut. Tighten 150 lbf·ft (203 N·m).

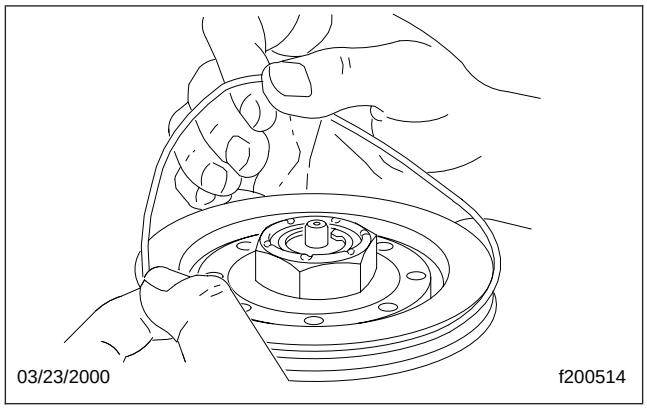
7. Remove any dust and debris from the air chamber.



11/24/93 f200033

Fig. 11, Check the Journal Lip

8. Coat the new O-rings with an approved lubricant and install them. See **Fig. 12**.



03/23/2000 f200514

Fig. 12, Install New O-Rings

9. Install the new face seal in the air chamber. Tighten 50 lbf·in (565 N·cm).

10. Install the new rubber umbrella valve in the air chamber.

NOTE: The System Sentry fuse has a left-hand thread.

11. Install the new System Sentry fuse in the piston friction disc.

12. Slide the air chamber assembly onto the clutch. If applicable, install two of the hexbolts that hold the fan in place.

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13. Using a screwdriver to keep the air chamber from rotating, install the socket-head capscrews. Following a star pattern, tighten 15 lbf·ft (20 N·m).
14. If applicable, remove the two hexbolts previously installed.
15. Install the fan and fan clutch assembly on the engine. For instructions, see **Subject 100**.

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Disassembly

NOTE: This procedure involves replacing only the air cartridge, System Sentry® fuse, the face seal, and the O-rings, using parts from the manufacturer's Seal Kit. If doing a major rebuild, go to **Subject 110**.

1. Remove the fan and fan clutch assembly from the vehicle. For instructions, see **Subject 100**.
2. Clamp the fan clutch in a vise. See **Fig. 1**.

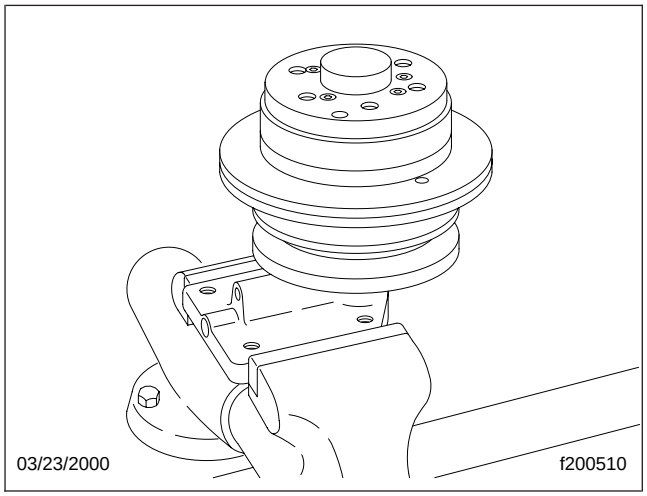


Fig. 1, Fan Clutch Placed in a Vise

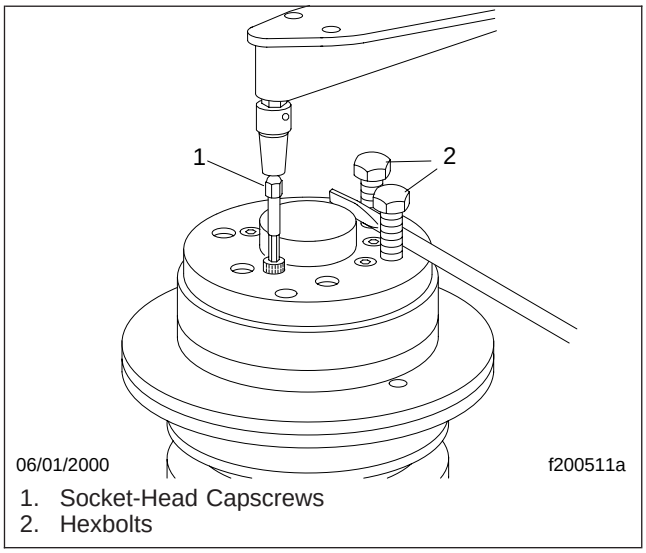
3. On some vehicles, the fan clutch has threaded studs on the air chamber and the fan is attached with nuts. On other vehicles, the fan is attached with hexbolts.

   If hexbolts were used to attach the fan, install two of the removed hexbolts in the air chamber so a screwdriver can be used to keep the air chamber from rotating. See **Fig. 2**.

   Remove the socket-head capscrews from the air chamber.
4. If applicable, remove the two hexbolts previously installed.

⚠ WARNING

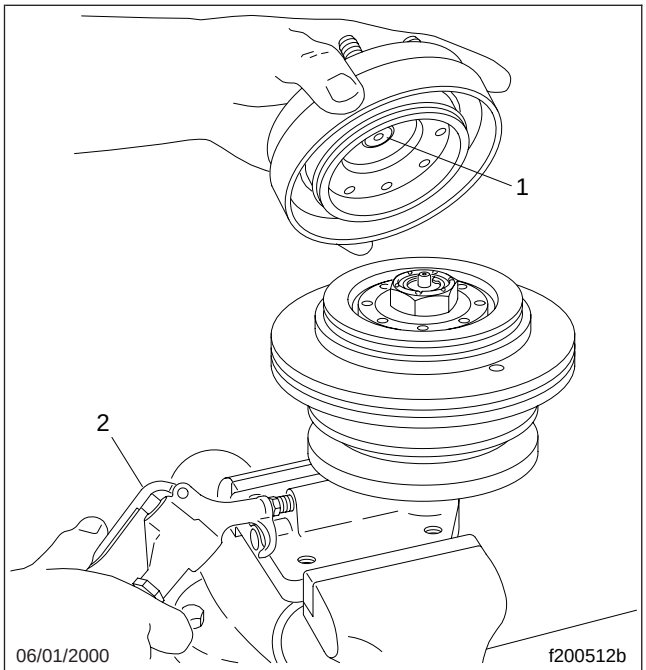
Apply air pressure slowly to the fan clutch. A sudden blast of air might blow the air chamber off the clutch, resulting in possible injury.



1. Socket-Head Capscrews
2. Hexbolts

Fig. 2, Remove the Socket-Head Capscrews

5. Connect a shop air hose to the cylinder inlet. See **Fig. 3**. Slowly apply air pressure, and remove the air chamber assembly.



1. Face Seal
2. Air Hose

Fig. 3, Remove the Air Chamber

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Fan Clutch Minor Rebuild

6. Remove and discard the O-rings from the air chamber and the piston friction disc. Clean the O-ring contact surfaces.
7. Remove the face seal from the air chamber. See **Fig. 3**.

NOTE: The System Sentry fuse has a left-hand thread.

8. Remove the System Sentry fuse from the piston friction disc.
9. Remove the rubber umbrella valve from the air chamber.
10. Remove the adjusting nut. See **Fig. 4**.

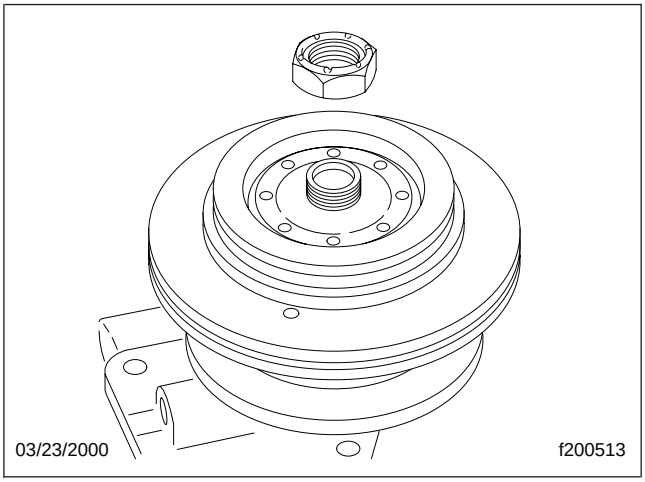


Fig. 4, Remove the Adjusting Nut

11. Remove the retaining ring from the air cartridge assembly. See **Fig. 5**.

    Remove the cartridge assembly from the mounting bracket assembly. See **Fig. 6**.

Assembly

1. Install a new air cartridge assembly in the mounting bracket assembly. Note that the retaining ring is curved. Make sure the ring is installed with the convex surface toward the air cartridge. See **Fig. 7**.
2. Install the adjusting nut. Tighten 150 lbf·ft (203 N·m).
3. Remove any dust and debris from the air chamber.

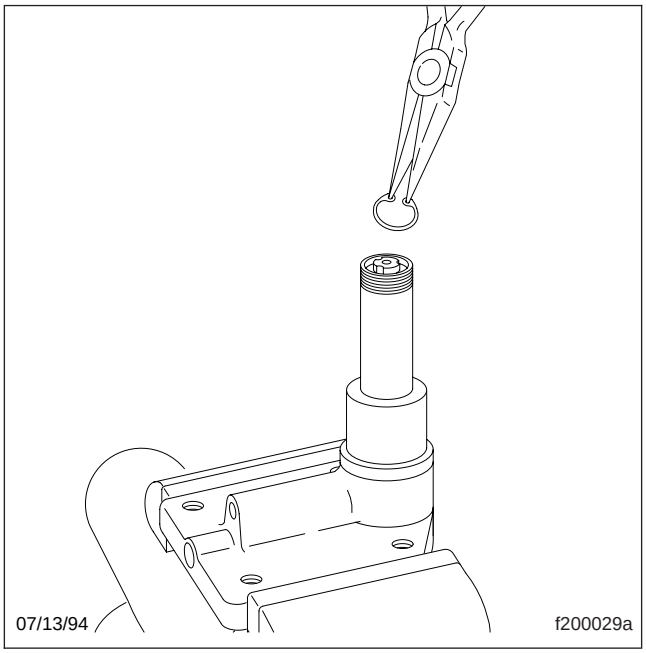


Fig. 5, Remove the Retaining Ring

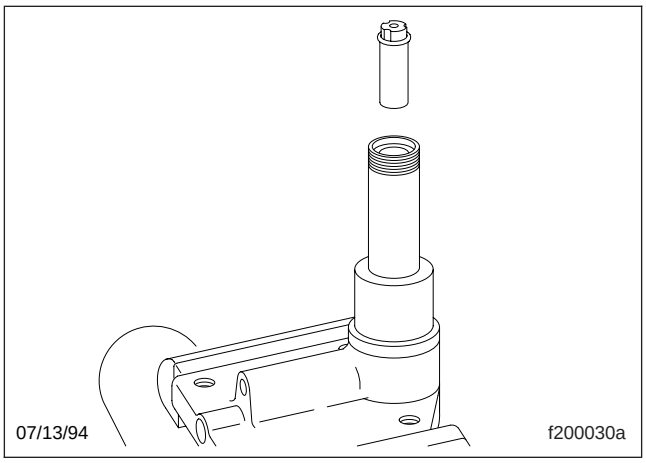
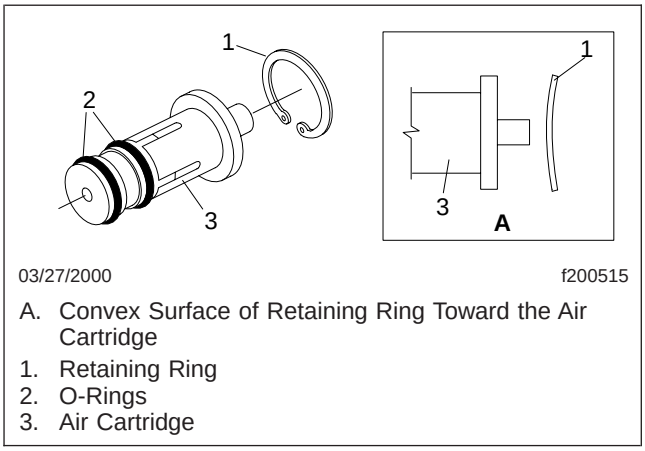


Fig. 6, Remove the Air Cartridge Assembly

4. Coat the new O-rings with an approved lubricant and install them. See **Fig. 8**.
5. Install the new face seal in the air chamber. Tighten 50 lbf·in (565 N·cm).
6. Install the new rubber umbrella valve in the air chamber.

NOTE: The System Sentry fuse has a left-hand thread.

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A. Convex Surface of Retaining Ring Toward the Air Cartridge
1. Retaining Ring
2. O-Rings
3. Air Cartridge

Fig. 7, Air Cartridge Assembly

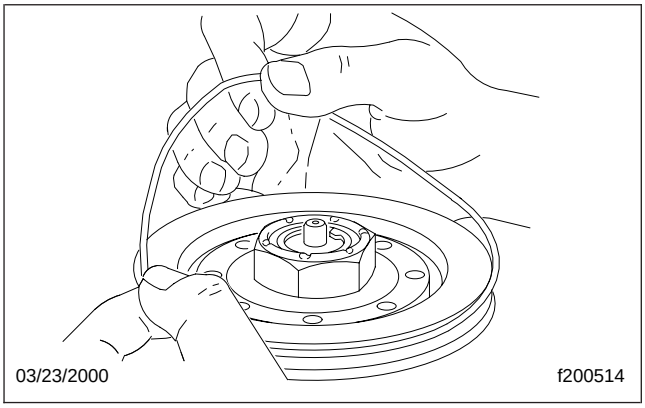


Fig. 8, Install New O-Rings

7. Install the new System Sentry fuse in the piston friction disc.
8. Slide the air chamber assembly onto the clutch. If applicable, install two of the hexbolts that held the fan in place.
9. Using a screwdriver to keep the air chamber from rotating, install the socket-head capscrews. Following a star pattern, tighten 15 lbf·ft (20 N·m).
10. If applicable, remove the two hexbolts previously installed.
11. Install the fan and fan clutch assembly on the engine. For instructions, see **Subject 100**.

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See **Fig. 1** for the fan clutch wiring diagram.

Torque Values		
Fastener	Torque	
	lbf·ft (N·m)	lbf·in (N·cm)
Fan Nut	15 (20)	—
Adjusting Nut	150 (203)	—
Air Chamber Capscrew	15 (20)	—
Friction Facing Capscrew	—	60 (680)
Fan Clutch Mounting Capscrews	13 (18)	—

Table 1, Torque Values

Approved Greases and Lubricants	
Approved Greases	Approved Lubricants
Amoco Rykon Premium No. 2 EP	Parker O-Ring Lube
Chevron SRI-2	Horton O-Ring Lube No. 13220
Texaco Premium RB No. 2	
Exxon Unirex No. 2	
Shell Dolium Grease No. 2	

Table 2, Approved Greases and Lubricants

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Specifications

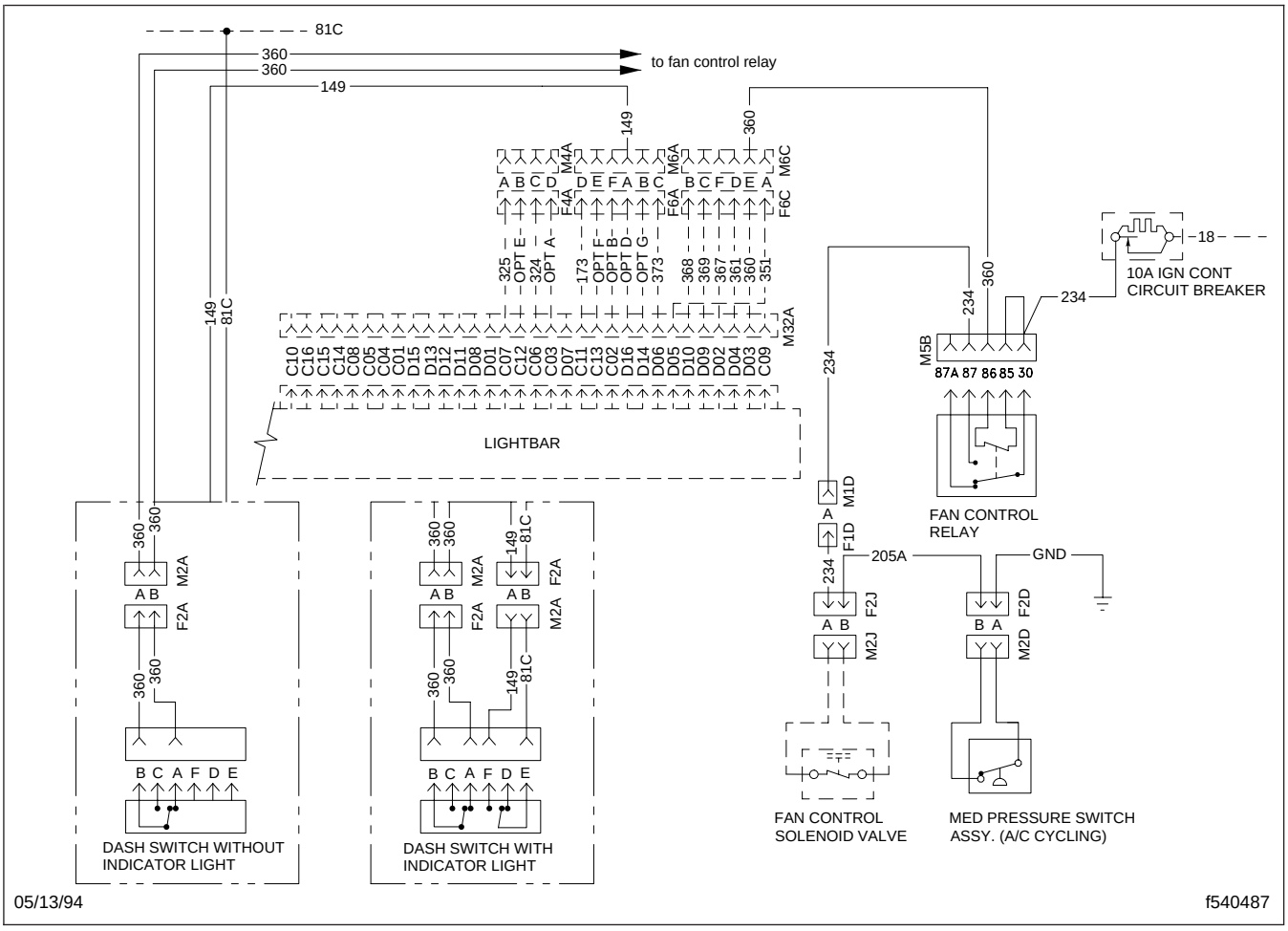


Fig. 1, Fan Clutch Wiring Diagram

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General Information

The K22RA fan drive unit is an air-operated, temperature-controlled clutch for the engine cooling fan. Its purpose is to maintain engine temperature by engaging or disengaging the fan. The fan clutch is disengaged when the coolant temperature is at or below the specified temperature range. The fan clutch engages when the coolant temperature rises above the range.

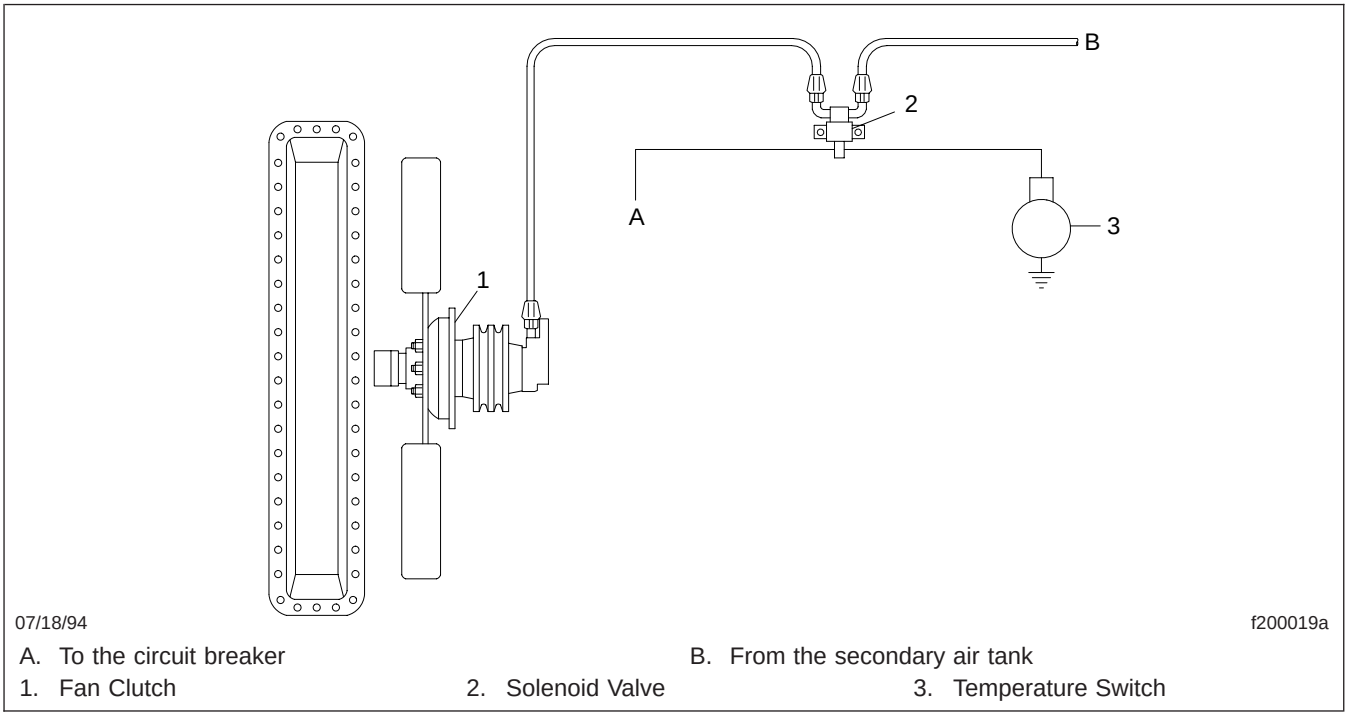
Air pressure to the fan clutch is controlled by a solenoid valve; the solenoid valve is controlled by a temperature switch that is installed in the thermostat housing. See **Fig. 1**.

lenoid is controlled by a temperature switch that is immersed in the engine coolant.

When a cold engine is started, the temperature switch is open, which activates the solenoid. The solenoid valve allows compressed air to enter the cylinder, and the fan clutch remains disengaged. The fan does not turn.

When the coolant temperature rises to the temperature switch setting, the switch closes. The solenoid valve releases the compressed air from the cylinder. The fan clutch spring engages the clutch and the fan turns.

When the coolant temperature drops to the tempera-



A. To the circuit breaker
B. From the secondary air tank
1. Fan Clutch
2. Solenoid Valve
3. Temperature Switch

Fig. 1, Fan Clutch Piping and Wiring, Vehicle Without Air Conditioning

On vehicles with air conditioning, the fan clutch solenoid valve is connected to a fan cycling switch at the receiver-drier. If the refrigerant pressure exceeds the setting of the fan cycling switch, the switch supplies power to the solenoid valve. See **Fig. 2**.

The fan clutch is spring-loaded in the engaged position. It is disengaged when air pressure is applied to the cylinder on the front of the unit. Air pressure to the cylinder is controlled by a solenoid valve: the solenoid is controlled by a temperature switch that is immersed in the engine coolant.

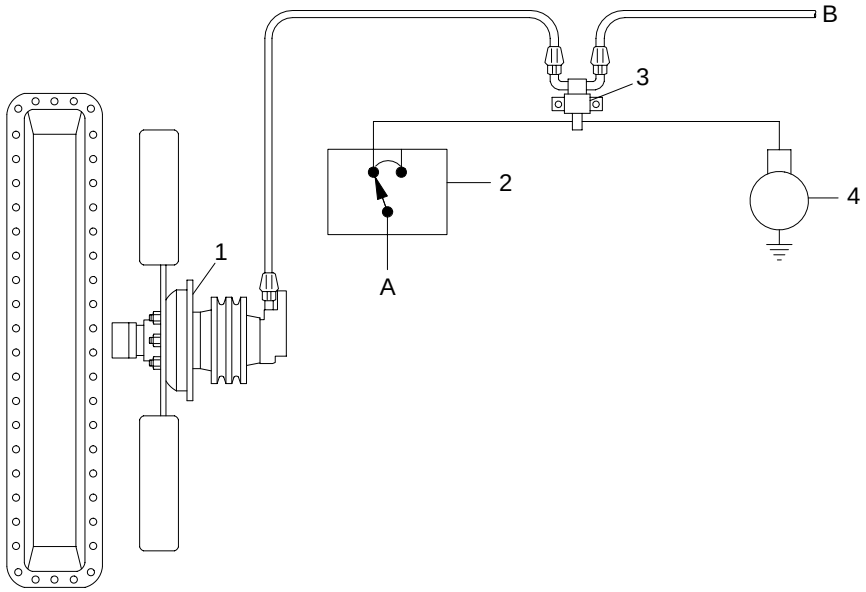
When a cold engine is started, the temperature switch is open, which activates the solenoid. Compressed air passes to the cylinder disengaging the clutch.

When the coolant temperature rises to the temperature switch cutoff setting, the switch opens, activating the solenoid. Compressed air passes to the cylinder disengaging the clutch.

On vehicles with air conditioning, the fan clutch solenoid valve is connected to a fan cycling switch at the receiver-drier. If the refrigerant pressure exceeds the setting of the fan cycling switch, the switch supplies power to the solenoid valve, which stops air flow and allows the internal spring to engage the fan clutch.

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General Information



A. To the circuit breaker
B. From the secondary air tank
1. Fan Clutch
2. Fan Cycling Switch at the Receiver-Drier
3. Solenoid Valve
4. Temperature Switch

Fig. 2, Fan Clutch Piping and Wiring, Vehicle With Air Conditioning

NOTE: When disengaged, it is normal for the housing and fan to spin at about 300 rpm. When the compressed air is released and the clutch engages, the bearing housing and fan move forward approximately 1/10-inch (2.5 mm).

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Removal (See Fig. 1)

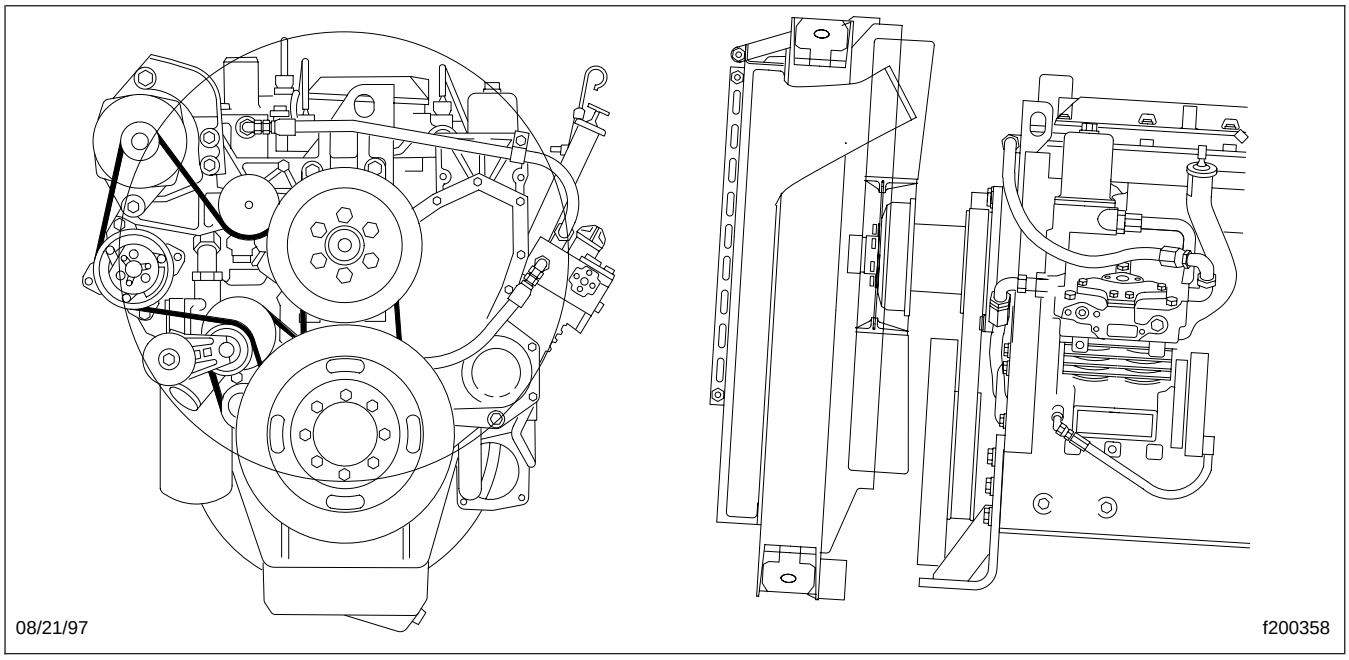


Fig. 1, Kysor Fan Clutch Installation

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.

⚠ WARNING

Use care when loosening the air line fitting. The line could be under pressure and may have dirt or sludge in the air stream. If quickly disconnected, the line may whip, possibly causing eye injury or other bodily harm.

3. Disconnect the air line from the fan clutch.

NOTE: It may be possible to unbolt the fan, carefully place it against the radiator, and have access to the fan clutch without disconnecting the radiator hoses, mounts, or fan shroud.

4. Remove the fan shroud from the radiator and move the shroud back against the engine.

⚠ WARNING

Drain the coolant only when the coolant and engine are cool. Draining the coolant when the coolant and engine are hot could cause severe personal injury due to scalding.

5. Remove the drain plug from the right side of the radiator bottom tank and drain about two gallons (seven liters) of coolant. Install the drain plug and tighten it firmly.
6. Disconnect the radiator from all hoses and mounts. For instructions, see **Section 20.00**. With one person holding each side of the radiator, tilt the top of the radiator forward.
7. With the radiator tilted forward, remove the fan.
8. Remove the fan belts. For instructions, see **Section 01.02**.

⚠ WARNING

To keep the clutch disengaged, you must supply the fan clutch with between 90 and 120 psi (620 and 827 kPa) of air pressure throughout this pro-

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Removal and Installation

cedure. If the fan clutch engages, it may cause personal injury.

9. Align the allen-head screws holding the fan clutch to the fan hub.
   - 9.1 Disengage the fan clutch and keep it disengaged throughout this procedure. To do this, apply between 90 and 120 psi (620 and 827 kPa) of air pressure to the fan clutch to disengage the clutch.
   - 9.2 Line up the access holes in the fan clutch with the 5/16-inch allen-head screws on the fan hub. See **Fig. 2**.

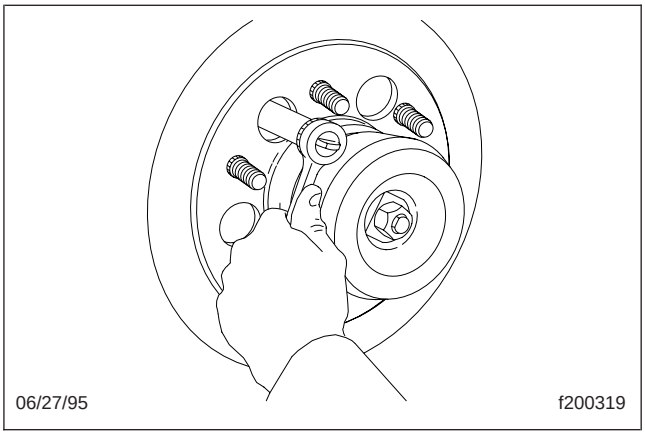


Fig. 2, Line Up the Access Holes

10. Remove the air pressure from the fan clutch and allow the fan to engage.
11. Remove the allen screws.
12. Remove the fan clutch from the fan clutch hub. It may be necessary to gently pry the clutch from the hub.

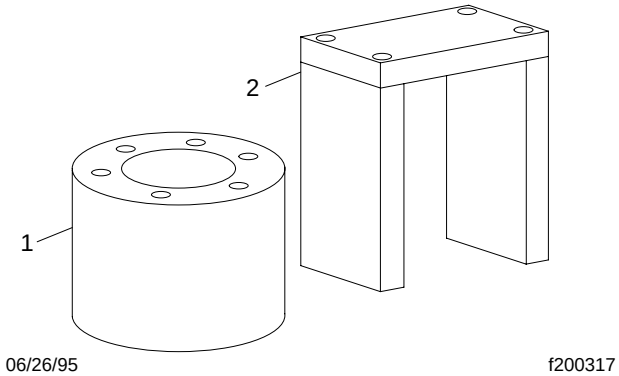
Installation

1. Position the fan clutch on the fan clutch hub and line up the access holes in the clutch with the holes for the allen screws in the clutch hub.
2. Install the allen screws and tighten them 44 lbf·ft (60 N·m).
3. Install the fan belts. For instructions, see **Section 01.02**.
4. Install the fan.
5. Install the radiator on the radiator mounts and connect all radiator hoses. For instructions, see **Section 20.00**.
6. Take the coolant drained from the radiator and pour it back into the surge tank.
7. Install the fan shroud.
8. Connect the air line to the fan clutch.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

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Special Tools

IMPORTANT: Use of the special tool set shown in **Fig. 1** is recommended, but not required for this procedure. The support and compressor, Part No. 1090-00000-02, can be ordered from: Wright Brothers Enterprises, 8171 Hibma, Marion, MI, 49665, 1-231-825-2939.



1. Support
2. Compressor

Fig. 1, Special Tools

Rebuild

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Remove the fan clutch from the vehicle. For instructions, see **Subject 100**.

⚠ CAUTION

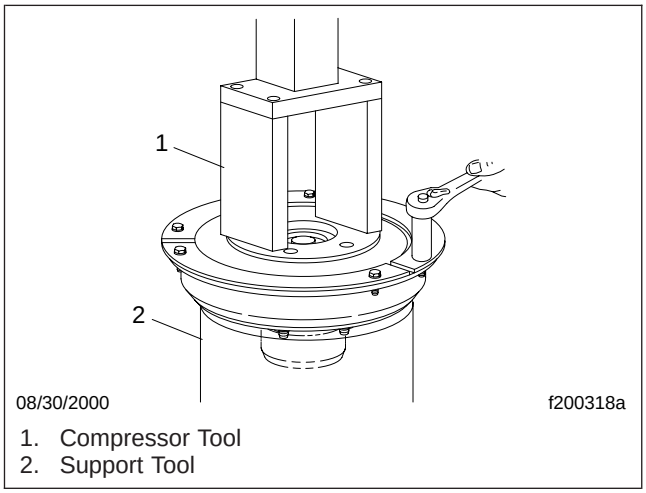
When caging and compressing the engagement spring of the fan clutch, depress the clutch shaft only enough to relieve the pressure on the retaining plates (about 1/16 inch [1.5 mm]). Applying additional force after the clutch shaft bottoms in the housing will damage the housing and make it unusable.

NOTE: There are two methods of caging the engagement spring. One uses the special tools and a press. The other uses carriage bolts, washers, and wingnuts. Either method is effective.

3. Cage the engagement spring.

   If using the special support and compressor tools, place the fan clutch in a press to cage the engagement spring. See **Fig. 2**.

   If using the optional method of caging the engagement spring, do the following:



1. Compressor Tool
2. Support Tool

Fig. 2, Caging the Engagement Spring and Removing the Lining Retaining Plates

   3.1 With the access holes in the housing assembly aligned with those in the shaft assembly, install two 3-1/2-inch (89-mm) long carriage bolts and suitable washers on opposite sides of the clutch assembly.

   3.2 On the shaft assembly side, install about a 1/2-inch (13-mm) thickness of washers onto each carriage bolt.

   3.3 Install a wingnut on the end of each carriage bolt and tighten the wingnuts evenly until the engagement spring is caged.

4. Remove the lining retaining plates and the lining. See **Fig. 2** and **Fig. 3**.

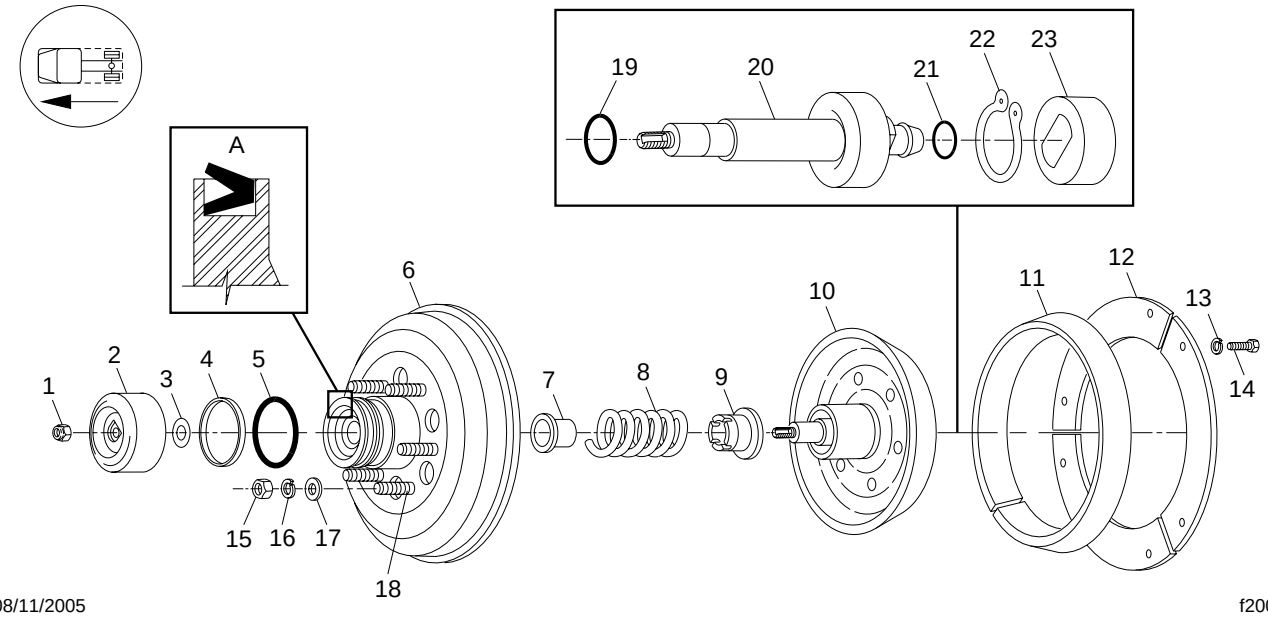
⚠ CAUTION

Do not press on the cylinder during this step, as damage to the cylinder will occur. Use a 5/8-inch wrench as shown in Fig. 4 on the piston rod flats.

5. If applicable, turn the clutch over in the press, and use the special compressor tool to cage the

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Fan Clutch Minor Rebuild



A. If a lip seal is used, install it so that it faces away from the fan studs.

1. Cylinder Nut
2. Cylinder Assembly
3. Piston Rod Seal Washer
4. Lip Seal (may be O-Ring)
5. Dust Seal
6. Housing Assembly
7. Engagement Spring End Cap
8. Engagement Spring
9. Engagement Spring Carrier
10. Shaft Assembly
11. Lining
12. Lining Retaining Plates
13. Lockwasher
14. Screw
15. Fan Nut
16. Lockwasher
17. Flatwasher
18. Fan Stud
19. O-Ring
20. Piston Rod Assembly
21. O-Ring
22. Snap Ring
23. Coupling

Fig. 3, Kysor K22RA Fan Clutch (exploded view)

engagement spring while removing the cylinder nut and cylinder. See **Fig. 4**.

6. Inspect the fan clutch. See **Fig. 3**.
   - 6.1 Inspect the two surfaces where the lining rides.
   - 6.2 Inspect the needle bearing race on the shaft.
   - 6.3 Inspect the needle bearings inside the clutch housing.
   - 6.4 Inspect the piston bearing by rotating the piston.

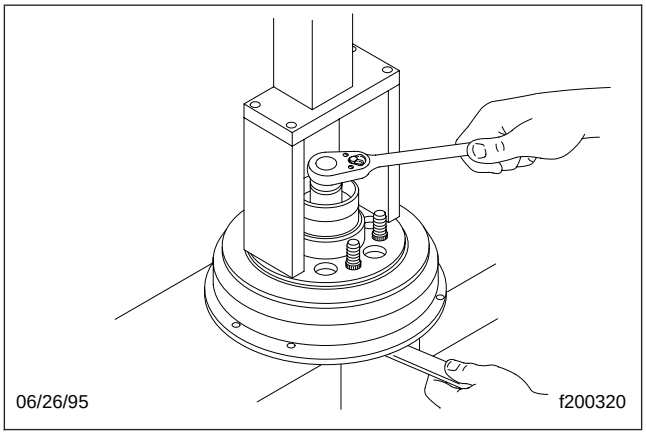


Fig. 4, Removing the Cylinder Nut and Cylinder

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7. If you find cracking or scoring on any surface, or if the bearings are rough, loose, or missing, replace the fan clutch.

NOTE: If you find metal particles in the existing grease, replace the fan clutch or contact Kysor for the training needed to perform a major fan clutch rebuild. Kysor will not provide parts for a major rebuild until the technician has completed rebuild training provided by Kysor.

IMPORTANT: Do not wash the clutch parts in solvent.

8. Using **Fig. 3** as a reference, and the lubricant supplied with the rebuild kit (if the lubricant is unavailable, use one of the approved lubricants listed in **Specifications, 400**), lubricate:
    - The piston seal (pack the seal groove also);
    - The dust seal (pack the seal groove also);
    - The needle bearings inside the housing;
    - The inside of the engagement spring;
    - The outside of the piston rod assembly;
    - The inside of the piston rod assembly;
    - The inside of the cylinder assembly;
    - And pack the lip of the grease seal.

⚠ CAUTION

When caging the engagement spring, make sure the bottom edges of the housing assembly and the shaft assembly are flush and aligned all the way around. Failure to do so will cause the engagement spring pressure to affect the torque of the cylinder nut. This could result in the cylinder nut not being tight enough to effectively compress the piston seal washer, which could cause leakage and eventual fan clutch failure.

IMPORTANT: When caging the engagement spring, compress the clutch shaft 1/16 inch (1.5 mm).

9. Assemble the fan clutch parts according to **Fig. 3**. Using either the special tools and a press, or carriage bolts, washers, and wingnuts, cage the engagement spring when installing the cylinder and lining. Be careful to depress the clutch shaft 1/16 inch (1.5 mm).

    The piston rod seal washer is the last item to install before the cylinder goes on. See **Fig. 5**.

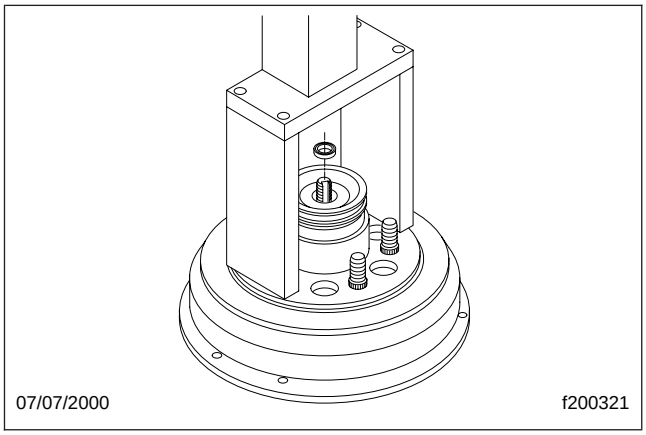


Fig. 5, Installing the Piston Rod Seal Washer

10. Tighten the cylinder nut 84 lbf·in (940 N·cm).
11. Tighten the lining screws 30 lbf·in (340 N·cm).
12. As applicable, remove the fan clutch from the press or remove the carriage bolts, washers, and wing nuts.
13. Check the front-to-rear travel of the fan clutch. For instructions, see Group 20 in the *Acterra Maintenance Manual*.
14. Install the fan clutch on the engine. For instructions, see **Subject 100**.
15. Close the hood.
16. Remove the chocks from the tires.

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Relining

IMPORTANT: Premature wearing of the fan clutch lining is due to either insufficient air pressure necessary to fully disengage the clutch (allowing the clutch to remain partially engaged, thus increasing wear), or a problem in the control circuit for the fan. Before putting the fan clutch back in service, check the fan control and air supply systems and make any necessary repairs.

1. Park the vehicle on a level surface, apply the parking brake, and shut down the engine. Chock the tires.

⚠ WARNING

If the fan clutch engages during the next step, it could cause personal injury. Keep the fan clutch disengaged throughout this procedure by maintaining between 90 and 120 psi (620 and 827 kPa) of air pressure.

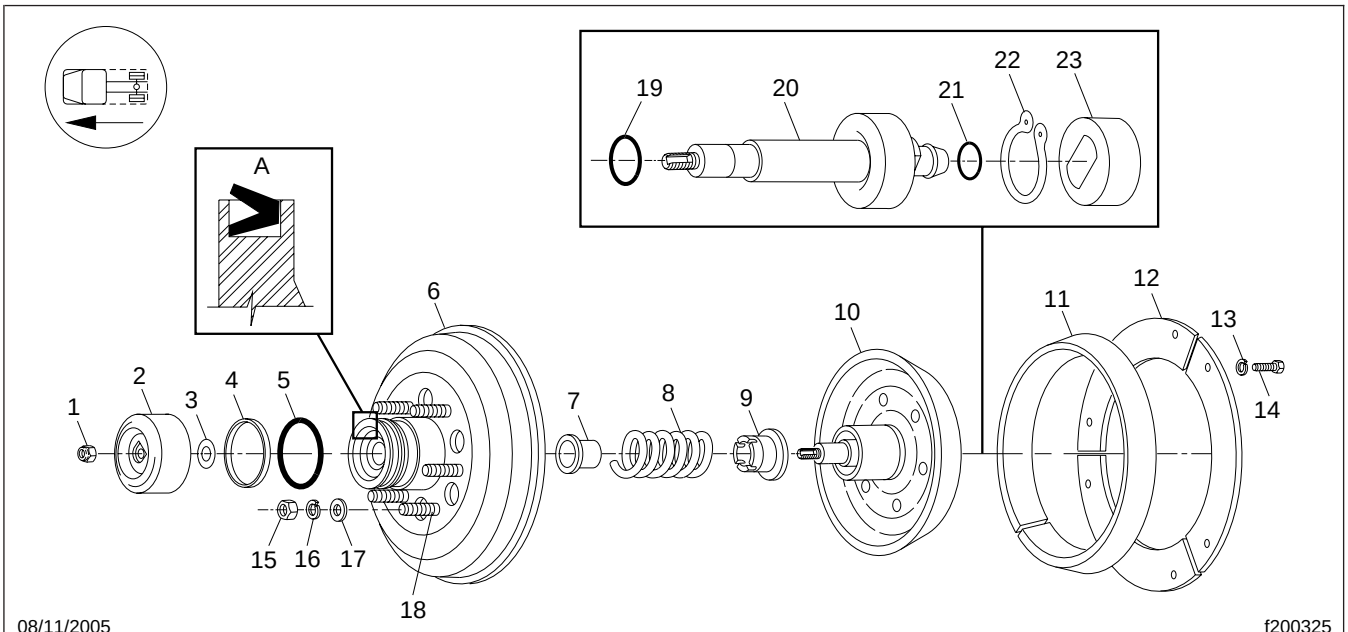
2. Bleed all the air from the primary and secondary tanks.
3. Disconnect the air line from the fan drive, and apply 90 to 110 psi (620 to 760 kPa) shop air pressure to the fan drive.
4. Remove the six lining plate screws, and remove the three lining plates. See **Fig. 1**.
5. Remove the old lining. If the lining sticks, use a hammer and a screwdriver to free it by tapping on the dividing cut in the lining.
6. Inspect the clutch shaft. If lining residue is present, or if the surface appears glazed over (non-metallic), temporarily release the air pressure from the clutch to allow shaft to protrude, and use a ScotchBrite to break the glaze.

NOTE: Some applications may be too tight to spread the lining and slip it over the pulley. If necessary, the lining can be cut in half with a hacksaw for installation.

7. Apply air pressure to the clutch again, and install the new lining. See **Fig. 2**.
8. Install the new lining plates. Tighten the screws 30 lbf·in (340 N·cm).
9. Remove the air pressure from the fan clutch, and allow the fan to engage.
10. Disconnect the shop air, and connect the air line to the fan drive.

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Fan Clutch Relining



A. If a lip seal is used, install it so that it faces away from the fan studs.

1. Cylinder Nut
2. Cylinder Assembly
3. Piston Rod Seal Washer
4. Lip Seal (may be O-Ring)
5. Dust Seal
6. Housing Assembly
7. Engagement Spring End Cap
8. Engagement Spring
9. Engagement Spring Carrier
10. Shaft Assembly
11. Lining
12. Lining Retaining Plates
13. Lockwasher
14. Screw
15. Fan Nut
16. Lockwasher
17. Flatwasher
18. Fan Stud
19. O-Ring
20. Piston Rod Assembly
21. O-Ring
22. Snap Ring
23. Coupling

Fig. 1, Kysor K22RA Fan Clutch (exploded view)

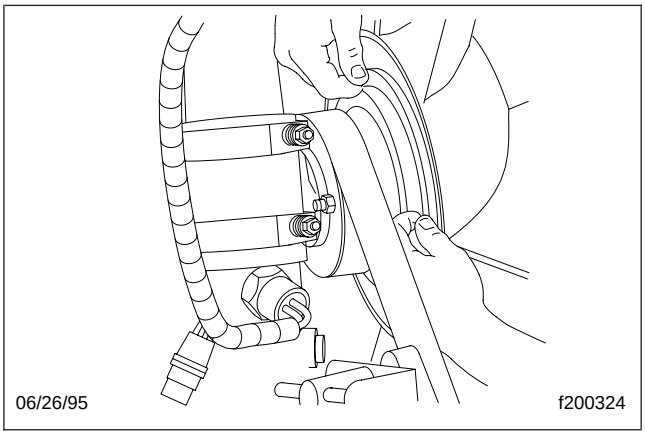


Fig. 2, Removing the Lining Plates

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Troubleshooting Tables

Problem—Fan Clutch Fails to Engage

Problem—Fan Clutch Fails to Engage	
Possible Cause	**Remedy**
No power to fan clutch control circuit	Check all electrical connections, and repair or replace wiring as needed.
Damaged engine temperature switch or incorrect sensor installed	Make sure the switch is normally-closed, not normally-open. Replace the switch if it is damaged or if the switch is the wrong type.
Malfunctioning solenoid valve	Replace the solenoid valve.
Air not venting from clutch due to restricted air line	Make sure the air lines are not pinched or plugged. Repair the air lines as needed.
Solenoid not exhausting	Make sure the solenoid exhaust port is not plugged.

Problem—Fan Clutch Does Not Disengage

Problem—Fan Clutch Does Not Disengage	
Possible Cause	**Remedy**
Damaged engine temperature switch or incorrect sensor installed	Make sure the switch is normally-closed, not normally-open. Replace the switch if it is damaged or if the switch is the wrong type.
Malfunctioning solenoid valve	Replace the solenoid valve.
Leaking fan clutch	Install a new seal kit.
Restricted air supply to the fan clutch	Make sure the fan clutch air lines are not leaking or pinched. Repair the lines as needed.

Problem—Fan Clutch Cycles Frequently

Problem—Fan Clutch Cycles Frequently	
Possible Cause	**Remedy**
Poorly grounded fan clutch control circuit or loose connection	Check all wiring connections and repair the circuit as needed.
Incorrect temperature control settings	Check the fan clutch control setting of the temperature switch according to the engine installed in the vehicle. Repair or replace the temperature switch as needed.
Fan cycling switch at receiver-drier set too low	Check the switch at the receiver-drier and, if needed, replace the switch with a switch with a higher setting.
Air restriction in front of fan clutch	Check for incorrect radiator shutter operation, winterfronts, or any other air restrictions.
Malfunctioning temperature switch	Replace the temperature switch.

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Troubleshooting

Problem—Fan Clutch Engages, But the Engine Still Overheats

Problem—Fan Clutch Engages, But the Engine Still Overheats	
Possible Cause	**Remedy**
Air restriction in front of fan clutch	Check for incorrect radiator shutter operation, winterfronts, or any other air restrictions.
Problem somewhere else in cooling system	See **Section 20.00**.

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If the lubricant that comes with the rebuild kit for the Kysor K22RA fan clutch is unavailable, use one of the following approved lubricants:

- Aeroshell 5
- Shell Alvania R3
- Chevron SR12
- Amoco Rykon Premium #2EP
- Texaco RB Premium

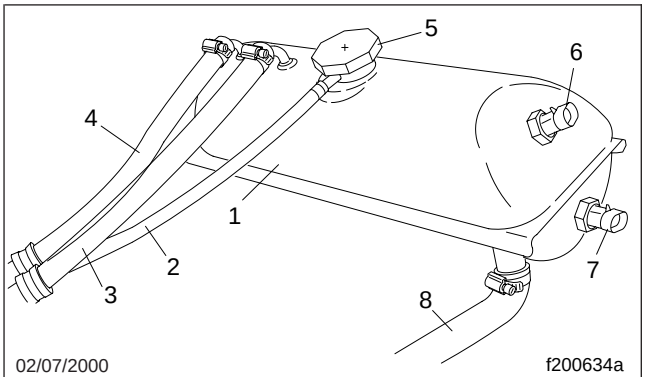
Kysor K22RA Fan Clutch Torques		
Description	Torque	
	lbf·ft (N·m)	lbf·in (N·cm)
Clutch-to-Hub Fasteners	45 (61)	—
Fan-to-Clutch Fasteners	26 (35)	—
Front Piston Nut	—	84 (950)
Lining Plate Screws	—	30 (340)

Table 1, Kysor K22RA Fan Clutch Torques

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General Information

The surge tank provides the radiator with extra reserve coolant, expansion space for heated coolant and deaeration space. See **Fig. 1**. When coolant in the radiator runs low, reserve coolant stored in the surge tank flows from the tank, through the fill hose, to the water pump. As the coolant heats and expands beyond radiator capacity, excess coolant travels back through the fill hose from the water pump to the extra space in the surge tank. Any air trapped in the engine block or radiator rises to the top of the engine or radiator and escapes through the vent hoses to the surge tank.



1. Surge Tank
2. Overflow Tube
3. Inlet Hose
4. Inlet Hose
5. Cap
6. Engine Warning Sensor
7. Engine Shutdown Sensor
8. Outlet Hose

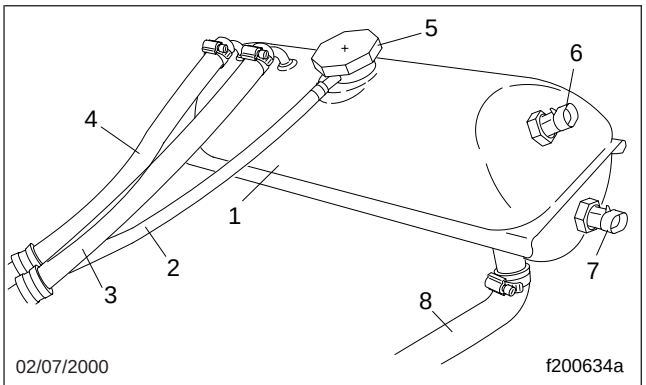
Fig. 1, Surge Tank

The surge tank cap limits system pressure to about 9 psi (62 kPa), which raises the boiling point of the coolant. If the cooling system overheats, excess coolant is released through the overflow tube.

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Surge Tank Removal and Installation

Removal (See Fig. 1)



1. Surge Tank
2. Overflow Tube
3. Inlet Hose
4. Inlet Hose
5. Cap
6. Engine Warning Sensor
7. Engine Shutdown Sensor
8. Outlet Hose

Fig. 1, Surge Tank

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.

⚠ WARNING

Drain the coolant only when the coolant and engine are cool. Draining it when they are hot could cause severe personal injury due to scalding.

3. Drain the radiator.
   - 3.1 Remove the surge tank cap.
   - 3.2 Remove the drain plug on the bottom of the radiator to drain the engine coolant. Drain only enough coolant to empty the surge tank.
4. Remove the surge tank.

   NOTE: Cap all the disconnected hoses to prevent the remaining coolant from spilling.
   - 4.1 Disconnect the overflow tube.
   - 4.2 Disconnect the outlet hose from the bottom of the surge tank.
   - 4.3 Disconnect the inlet hoses from the top of the surge tank.
   - 4.4 Disconnect the sensor.
   - 4.5 Remove the four nuts and lockwashers holding the surge tank to the cab front panel. Be sure to support the tank when removing the fasteners.
   - 4.6 Remove the surge tank.

Installation

1. Install the surge tank.
   - 1.1 Position the surge tank.
   - 1.2 Install the four nuts and lockwashers holding the surge tank to the cab front panel.
2. Connect the sensor.
3. Connect the inlet hoses to the top of the surge tank.
4. Connect the outlet hose to the bottom of the surge tank.
5. Connect the overflow tube.
6. Fill the coolant system and install the surge tank cap.
7. Start the engine and check for coolant leaks. Repair any leaks.
8. Close and latch the hood.
9. Remove the chocks from the rear tires.

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Specifications

Fastener Torques			
Description	**Grade**	**Size**	**Torque lbf·ft (N·m)**
Surge Tank Strut Nuts	5	10 mm	30 (40)

Table 1, Fastener Torques

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General Information

The Horton DriveMaster® fan clutch is a temperature-controlled, air-operated clutch for the engine cooling fan. It is spring engaged, and controls the engine temperature by engaging or disengaging the fan.

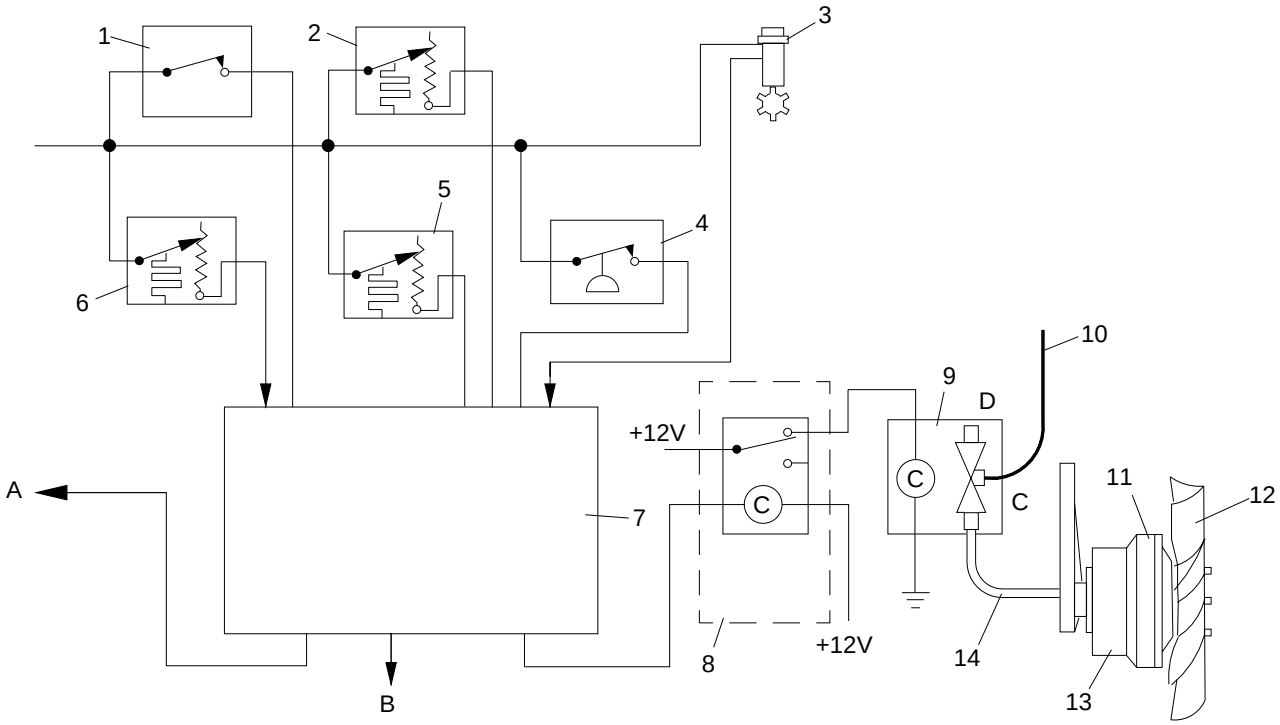
When the coolant temperature is below a specified range, air pressure keeps the fan disengaged to save engine power. When the coolant temperature rises above the specified range, air pressure to the fan clutch is cut off and internal spring pressure engages the fan.

Air pressure to the fan clutch is controlled by a solenoid valve; the solenoid valve is controlled by a temperature switch installed in the thermostat housing. The temperature switch is connected to the engine ECM, which controls the solenoid valve. See **Fig. 1**. When you start a cold engine, the solenoid valve allows air pressure to the fan clutch and the clutch remains disengaged. When the coolant temperature rises to the temperature switch setting, the switch provides power to the solenoid valve and the valve cuts off compressed air to engage the fan.

On vehicles with air conditioning, the fan clutch solenoid valve is connected to a fan cycling switch at the receiver-dryer. If the refrigerant pressure exceeds the setting of the fan cycling switch, the switch supplies power to the solenoid valve, which cuts off air to the fan clutch, engaging the fan.

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General Information



A. To Indicators and Gauges
B. To Electronic Injectors and Other Actuators
C. Normally Closed
D. Normally Open

1. Fan Override Switch
2. Air Temperature Sensor
3. Engine Speed Sensor
4. A/C Pressure Switch
5. Coolant Temperature Sensor
6. Foot Throttle
7. Engine ECM
8. Fan Relay (not present in all systems)
9. Solenoid Valve
10. Air Supply from Reservoir
11. Fan Clutch
12. Air Supply to Fan Clutch

Fig. 1, Fan Clutch Schematic (engine ECM controlled)

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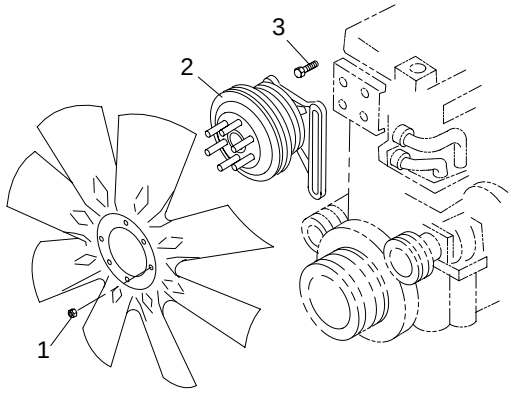
Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the tires.

⚠ WARNING

Wear safety goggles when draining the air system or disconnecting an air line because dirt and sludge could fly out at high speeds. Don't direct the airstreams at anyone. Don't disconnected pressurized air lines, as they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

2. Drain the air tanks.
3. Tilt the hood.
4. Disconnect the left-side hose from the charge air cooler.
5. Remove the drive belts from the engine.
6. Disconnect the air line from the fan hub.
7. Remove the fan.
8. Remove the fan clutch assembly from the engine. See **Fig. 1**.



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1. Hexnut
2. Fan Clutch Assembly
3. Hexbolt

Fig. 1, Fan Clutch Removal (typical)

8.1 If equipped with a metal fan ring, remove the two top fasteners holding the upper mounting bracket for the fan ring.

8.2 Remove the fasteners holding the fan clutch mounting bracket to the front of the engine.

⚠ WARNING

The fan clutch assembly may weigh up to 55 lbs. (25 kg). Be careful when lifting it. Use a helper or a hoist, if necessary. Failure to use care when lifting the fan clutch could cause the assembly to fall, which could result in injury or component damage.

8.3 Remove the fan clutch assembly from the vehicle. If equipped with a metal fan ring, carefully push the ring forward to allow removal of the fan clutch assembly.

Installation

1. Using either a helper or a hoist, position the fan clutch assembly in place on the front of the engine, aligning the holes in the mounting bracket with those in the front of the engine.
2. Install the fasteners.

   If equipped with a metal fan ring, don't tighten the upper fan clutch fasteners completely.
3. Install the drive belts.
4. Connect the air line to the fan clutch.
5. Install the fan. Tighten the fan mounting nuts firmly.
6. Tighten the M8 fan-clutch mounting fasteners 15 lbf·ft (20 N·m).
7. Connect the left-side hose to the charge air cooler.
8. Lower the hood.
9. Remove the chocks from the tires.

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Disassembly

NOTE: This procedure involves a major rebuild of the Horton DriveMaster® fan clutch, using parts from the manufacturer's Super Kit. If you are replacing just the seals or the air cartridge, see **Subject 120** for the minor rebuild procedure.

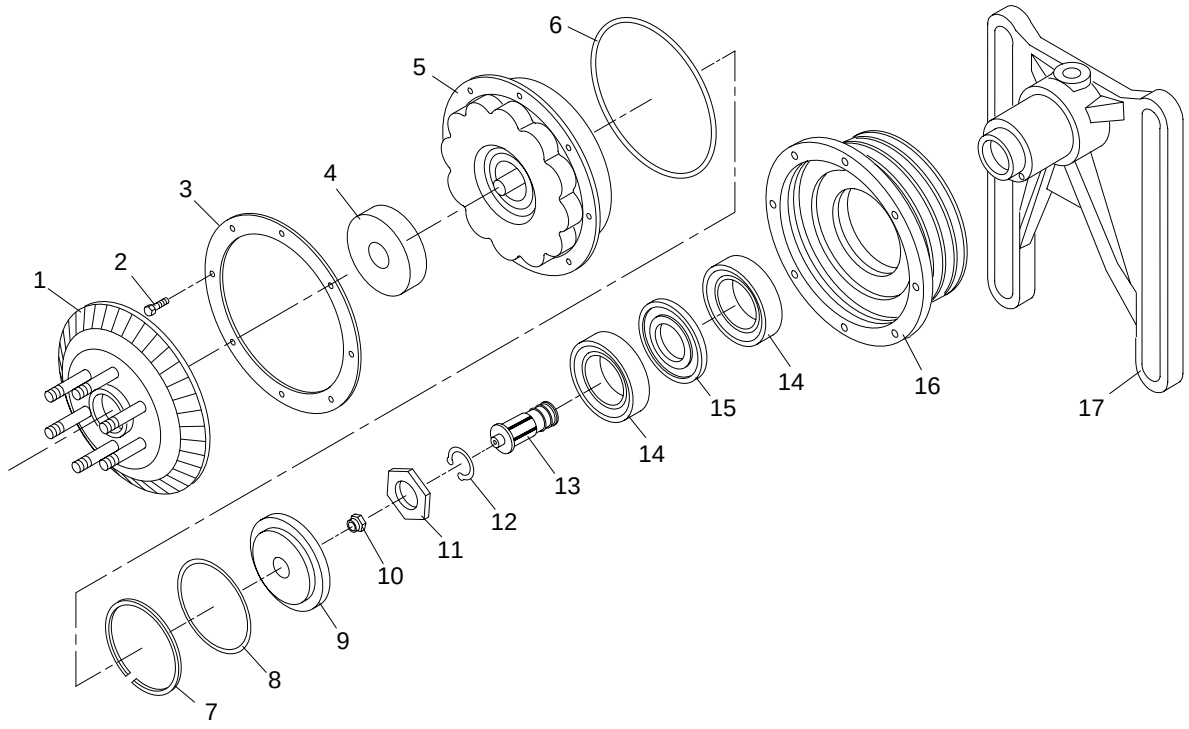
Refer to **Fig. 1** for this procedure.

1. Remove the fan clutch assembly from the vehicle. For instructions, see **Subject 100**.
2. Put the fan clutch assembly in a vise.
3. Connect a shop air hose to the fan clutch air inlet.
4. Apply 80 to 120 psi (552 to 827 kPa) to the fan clutch to lift the fan mounting disc off the spring housing/piston assembly.

⚠ CAUTION

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so may cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

5. Using a pry bar, wrench, and a T55 Torx® bit, loosen the jack bolt (left-hand thread) by turning it counterclockwise. See **Fig. 2**.
6. Unscrew the fan mounting disc from the jack bolt. See **Fig. 3**.



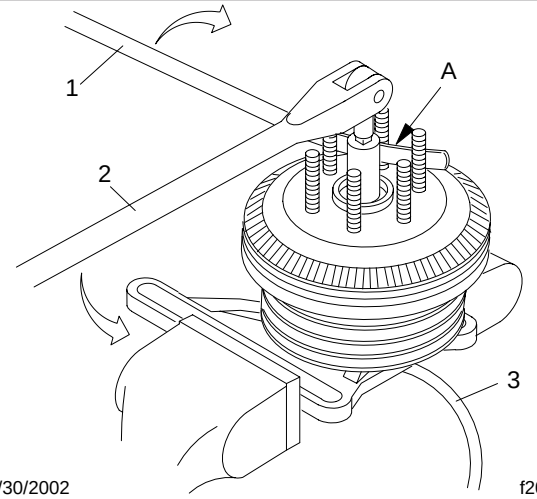
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1. Fan Mounting Disc
2. Torx®-Head Screw (8 qty.)
3. Friction Lining
4. Cage Nut (supplied with repair kit)
5. Spring Housing/Piston Assembly
6. Air Chamber Seal
7. Air Chamber Cap Retaining Ring
8. O-Ring
9. Air Chamber Cap
10. Face Seal
11. Bearing Nut
12. Air Cartridge Retaining Ring
13. Air Cartridge Assembly
14. Sheave Bearings
15. Bearing Spacer
16. Sheave
17. Journal Bracket

Fig. 1, Horton DriveMaster Fan Clutch

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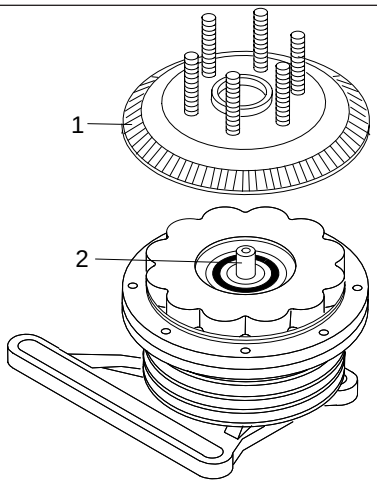
Fan Clutch Major Rebuild



A. Place the pry bar here.

1. Pry Bar (push clockwise)
2. Torx Bit and Wrench (turn counterclockwise)
3. Shop Air Hose (connected to the inlet port)

Fig. 2, Loosening the Jack Bolt



1. Fan Mounting Disc
2. Jack Bolt (left-hand thread)

Fig. 3, Fan Mounting Disc Removal and Installation

7. Inspect the fan mounting disc for wear or damage.

⚠ WARNING

Do not disassemble the spring housing from the piston. The interior springs are very strong, and if released could eject the housing with considerable force, possibly resulting in serious injury. Always use the cage nut to hold the spring housing and the piston together.

8. Using a wrench and a T55 Torx bit to hold the jack bolt, install the cage nut from the kit onto the jack bolt (left-hand thread). Hand tighten it onto the spring housing.

   The cage nut will keep the spring housing and piston together as an assembly. It will also maintain pressure on the internal springs after the Torx-head screws holding the friction lining in place are removed.

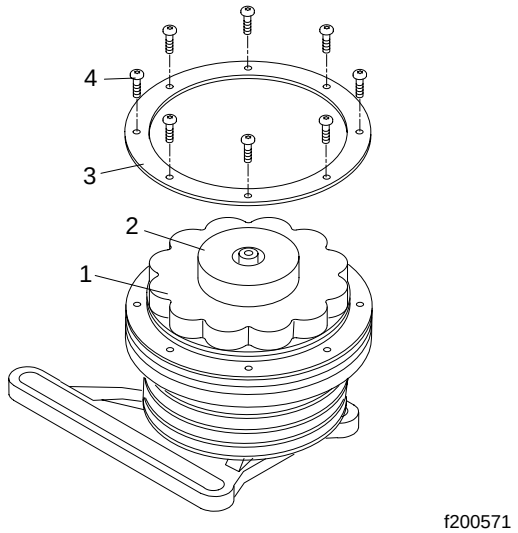
9. Release the air pressure from the fan clutch.

⚠ WARNING

Release the air pressure from the fan clutch before removing the friction lining Torx-head screws. Failure to release the air pressure could result in the spring housing/piston assembly being ejected with force, which could result in personal injury.

10. Using a T27 Torx bit, remove the eight Torx-head screws holding the friction lining in place.
11. Remove the friction lining. See **Fig. 4**.
12. *Keeping the cage nut installed and tightened,* remove the spring housing/piston assembly. See **Fig. 5**.
13. Remove the air chamber seal. See **Fig. 6**.
14. Examine the inside of the air chamber for signs of moisture and/or contaminants.
15. Remove the air chamber cap retaining ring. See **Fig. 6**.
16. Using two small screwdrivers placed 180 degrees apart, gently and evenly pry the air chamber cap out of the sheave.
17. Remove the O-ring seal from the air chamber cap. See **Fig. 6**.
18. Remove the face seal. See **Fig. 6**.
19. Inspect the face seal for signs of wear. Wear indicates that dirt may exist in the air system.

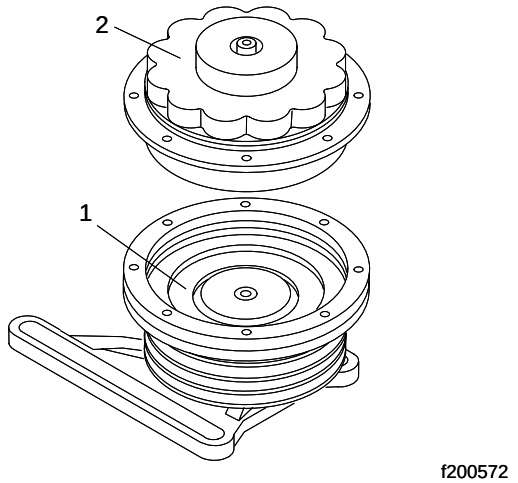
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1. Spring Housing/Piston Assembly
2. Cage Nut
3. Friction Lining
4. Torx-Head Screws

Fig. 4, Friction Lining Removal and Installation

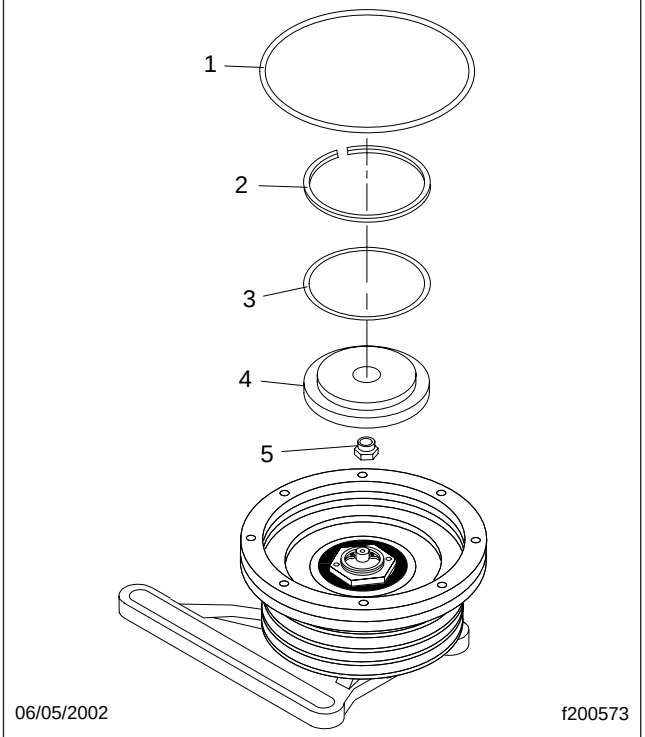


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1. Air Chamber
2. Spring Housing/Piston Assembly (with cage nut installed)

Fig. 5, Spring Housing/Piston Assembly Removal and Installation

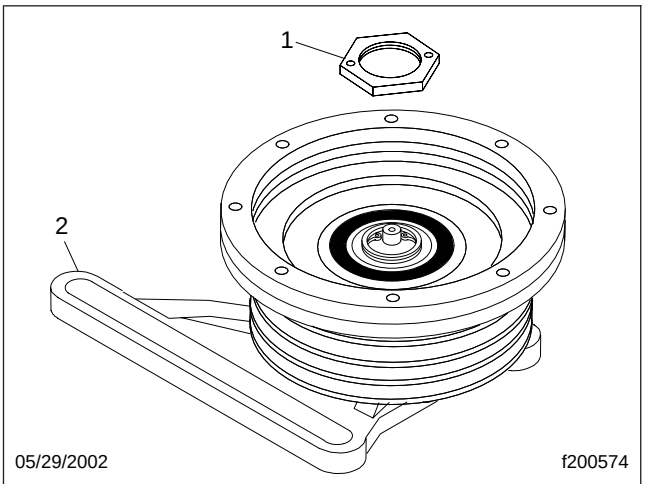
20. Remove the bearing nut from the mounting bracket. See **Fig. 7**.



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1. Air Chamber Seal
2. Retaining Ring
3. O-Ring Seal
4. Air Chamber Cap
5. Face Seal

Fig. 6, Air Chamber Seal Removal and Installation



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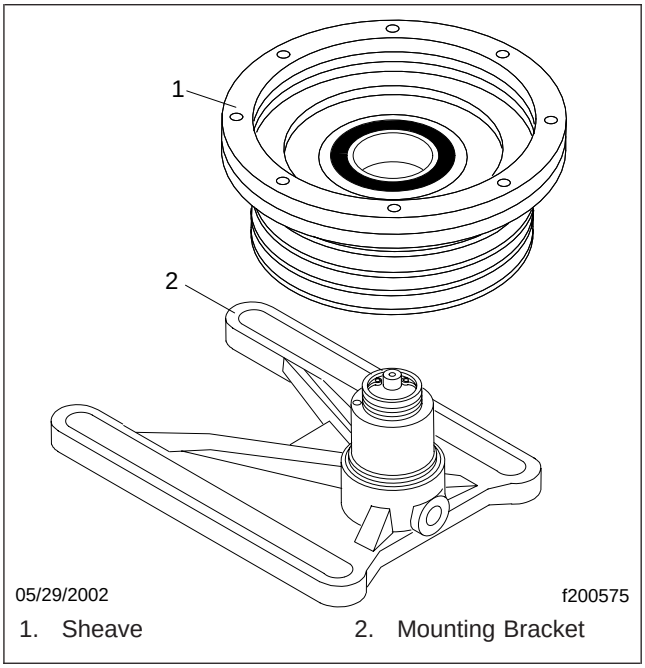
1. Bearing Nut
2. Mounting Bracket

Fig. 7, Bearing Nut Removal and Installation

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Fan Clutch Major Rebuild

21. Remove the sheave from the mounting bracket. See **Fig. 8**.



1. Sheave 2. Mounting Bracket

Fig. 8, Removing the Sheave

22. If replacing the bearings, support the sheave and press them out.
23. Clean and remove any dirt, debris, or corrosion that may be present.
24. Remove the air cartridge.
    - 24.1 Remove the retaining ring. See **Fig. 9**.
    - 24.2 Remove the air cartridge assembly. See **Fig. 10**.

Assembly

1. If necessary, clean the air cartridge bore in the mounting bracket.

NOTE: The sheave bearings do not require lubrication.

2. If replacing the sheave bearings, do the following:
    - 2.1 If equipped with two bearings, assemble the bearings so the markings on their edges line up to form an arrow. See **Fig. 11**. It doesn't matter which way the arrow faces when the bearings are installed.

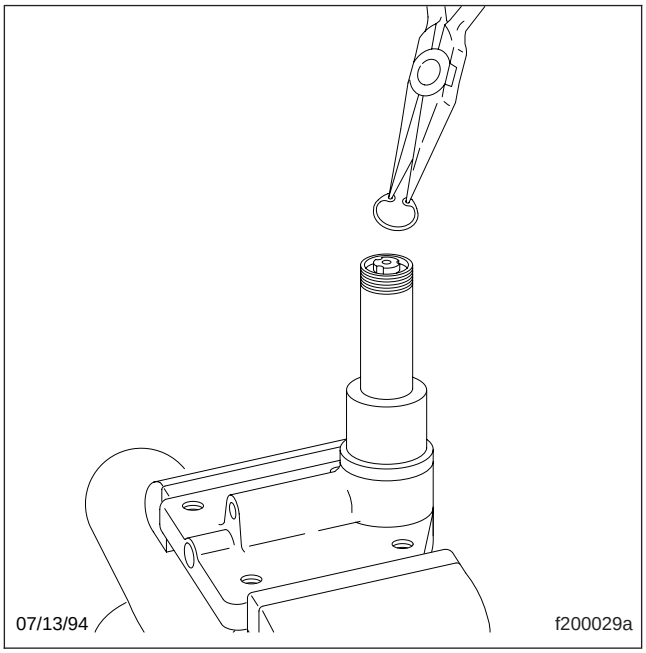
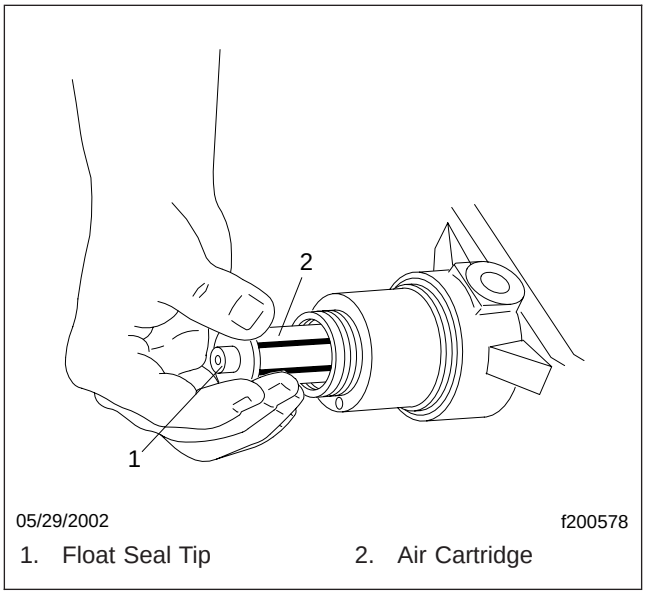


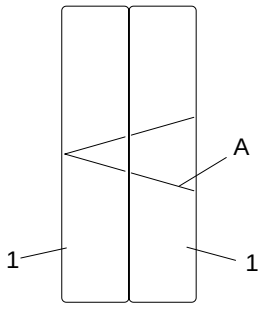
Fig. 9, Retaining Ring Removal and Installation



1. Float Seal Tip 2. Air Cartridge

Fig. 10, Removing the Air Cartridge

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A. Align the markings to form an arrow.

1. Sheave Bearing

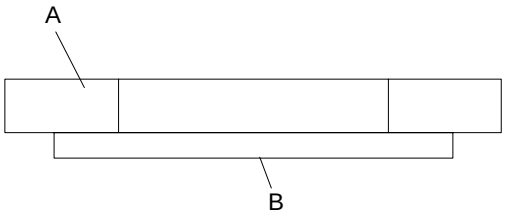
Fig. 11, Aligning the Bearings

IMPORTANT: If the fan clutch uses spacers, be sure to install them between the bearings.

2.2 Supporting the sheave, press the new sheave bearings — and spacers, if applicable — into place. Note the position of the lip inside the sheave.

2.3 Slide the sheave onto the mounting bracket. See **Fig. 8**.

2.4 Making sure that the bearing nut hex is facing up, install the bearing nut. See **Fig. 12**. Tighten 130 lbf·ft (170 N·m). See **Fig. 7**.



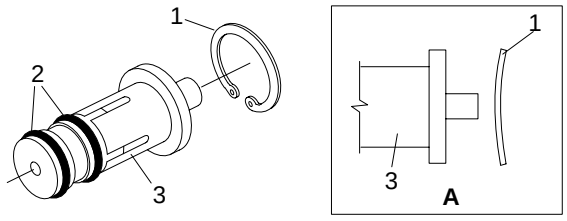
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A. Hex faces up.

B Relief faces toward mounting bracket and bearings.

Fig. 12, Correct Bearing Nut Orientation

3. Apply O-ring lubricant from the kit to the outside O-rings of the new air cartridge assembly. See **Fig. 13**.



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A. Convex surface of the retaining ring goes toward the air cartridge.

1. Retaining Ring
2. O-Rings
3. Air Cartridge

Fig. 13, Installing the Air Cartridge Retaining Ring

4. Install the new air cartridge assembly into the mounting bracket.
5. Install the retaining ring, making sure the convex surface of the ring is toward the air cartridge. See **Fig. 13**.
6. Using a clean, dry cloth, clean both the float seal tip of the air cartridge and the face seal of the air chamber cap.
7. Assemble the air chamber cap and face seal. See **Fig. 6**.

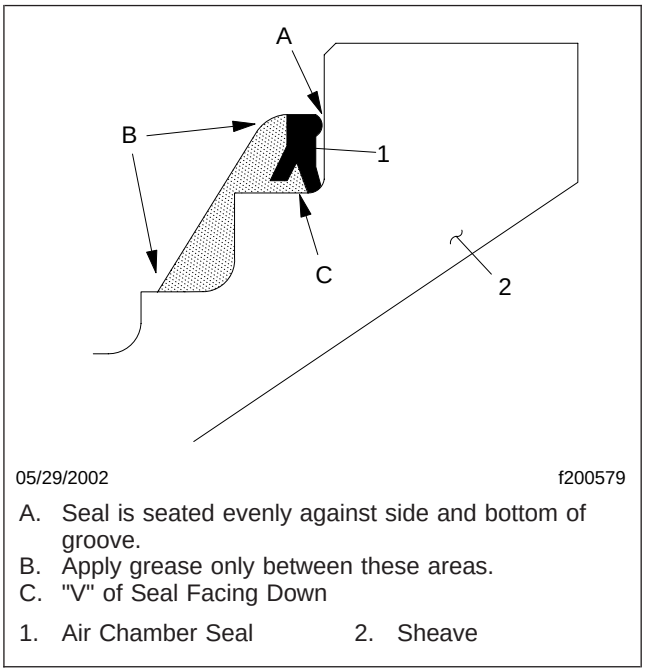
   Tighten the face seal 75 to 100 lbf·in (85 to 115 N·cm).
8. Lubricate the O-ring seal with the fresh lubricant from the kit.
9. Install the O-ring seal on the air chamber cap. See **Fig. 6**.
10. Carefully set the air chamber cap into the sheave. See **Fig. 6**.
11. Install the retaining ring. See **Fig. 6**.
12. Install the air chamber seal into the sheave. Be sure the seal is evenly seated against the side and bottom of the groove surfaces, and the "V" of the seal is facing down. See **Fig. 14**.
13. Lubricate contact surfaces with the fresh lubricant from the kit.

⚠ WARNING

The new spring housing/piston assembly from the kit has a cage nut installed on it. Do not remove the cage nut. This will cause the spring

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Fan Clutch Major Rebuild



A. Seal is seated evenly against side and bottom of groove.
B. Apply grease only between these areas.
C. "V" of Seal Facing Down

1. Air Chamber Seal
2. Sheave

Fig. 14, Correct Installation of Air Chamber Seal (cross-section view)

housing to be forcibly ejected from the piston assembly, which could result in serious injury.

14. Carefully set the new spring housing/piston assembly into position. See **Fig. 6**. Note that the new assembly has a cage nut installed on it.
15. Rotate the new spring housing/piston assembly to align the mounting holes with those of the sheave.

IMPORTANT: Handle the new friction liner by the edges to avoid contamination.

16. Set the new friction liner from the kit into place, being careful to touch only the edges.
17. Using a T27 Torx bit, install the eight Torx-head screws. See **Fig. 4**. Tighten alternately 80 lbf·in (9 N·m).
18. Apply a minimum of 80 psi (552 kPa) of clean air to the air inlet.
19. Remove the cage nut from the spring housing/piston assembly.
20. Install the new fan mounting disc from kit.

⚠ CAUTION

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so may cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

21. Using a suitable wrench, a T55 Torx bit, and a pry bar, tighten the jack bolt (left-hand thread) 100 lbf·ft (136 N·m). Turn the wrench clockwise and push the pry bar counterclockwise.
22. Using shop air, actuate the fan clutch and check for correct engagement and disengagement of the fan mounting disc. If there is a problem, it must be corrected before installing the fan clutch onto the engine.
23. Check for air leaks at the bleed hole and around the spring housing/piston assembly.
24. Install the fan clutch assembly onto the engine. See **Subject 100** for instructions.

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Disassembly

NOTE: This procedure involves a minor rebuild of the Horton DriveMaster® fan clutch, using parts from the manufacturer's Seal Kit. If a major rebuild of the fan clutch is needed, see **Subject 110**.

1. Remove the fan clutch assembly from the vehicle. For instructions, see **Subject 100**.
2. Put the fan clutch assembly in a vise.
3. Connect a shop air hose to the fan clutch air inlet.
4. Apply 80 to 120 psi (552 to 827 kPa) to the fan clutch to lift the fan mounting disc off the spring housing/piston assembly.

⚠ CAUTION

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so may cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

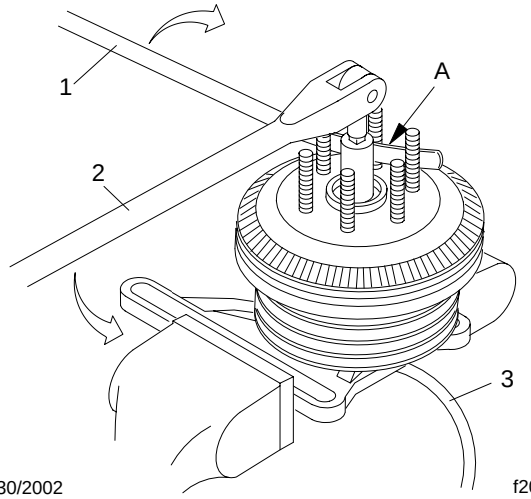
5. Using a pry bar, wrench, and a T55 Torx® bit, loosen the jack bolt (left-hand thread) by turning it counterclockwise. See **Fig. 1**.
6. Unscrew the fan mounting disc from the jack bolt. See **Fig. 2**.
7. Inspect the fan mounting disc for wear or damage.

⚠ WARNING

Do not disassemble the spring housing from the piston. The interior springs are very strong, and if released could eject the housing with considerable force, possibly resulting in serious injury. Always use the cage nut to hold the spring housing and the piston together.

8. Using a wrench and T55 Torx bit to hold the jack bolt, install the cage nut from the kit onto the jack bolt (left-hand thread). Hand tighten it onto the spring housing.

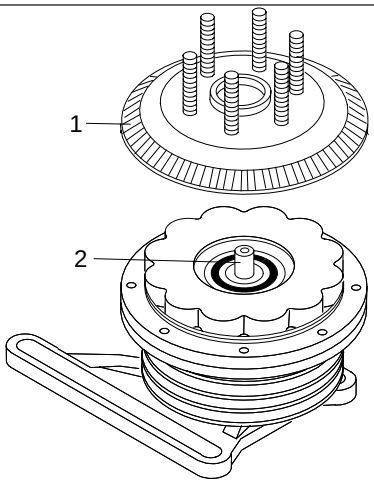
   The cage nut will keep the spring housing and piston together as an assembly. It will also maintain pressure on the internal springs after the Torx-head screws holding the friction lining in place are removed.



A. Place the pry bar here.

1. Pry Bar (push clockwise)
2. Torx Bit and Wrench (turn counterclockwise)
3. Shop Air Hose (connected to the inlet port)

Fig. 1, Loosening the Jack Bolt



1. Fan Mounting Disc
2. Jack Bolt (left-hand thread)

Fig. 2, Fan Mounting Disc Removal and Installation

9. Release the air pressure from the fan clutch.

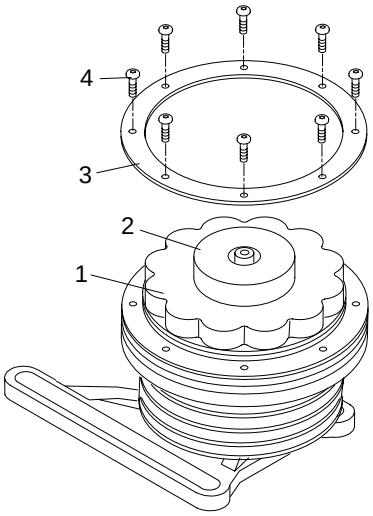
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Fan Clutch Minor Rebuild

WARNING

Release the air pressure from the fan clutch before removing the friction lining Torx-head screws. Failure to release the air pressure could result in the spring housing/piston assembly being ejected with force, which could result in personal injury.

10. Using a T27 Torx bit, remove the eight Torx-head screws holding the friction lining in place.
11. Remove the friction lining. See **Fig. 3**.

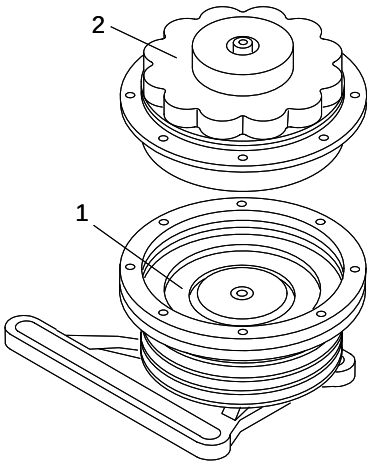


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1. Spring Housing/Piston Assembly
2. Cage Nut
3. Friction Lining
4. Torx-Head Screws

Fig. 3, Friction Lining Removal and Installation

12. *Keeping the cage nut installed and tightened,* remove the spring housing/piston assembly. See **Fig. 4**.
13. Remove the air chamber seal. See **Fig. 5**.
14. Examine the inside of the air chamber for signs of moisture and/or contaminants.
15. Remove the air chamber cap retaining ring. See **Fig. 5**.
16. Using two small screwdrivers placed 180 degrees apart, gently and evenly pry the air chamber cap out of the sheave.



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1. Air Chamber
2. Spring Housing/Piston Assembly (with cage nut installed)

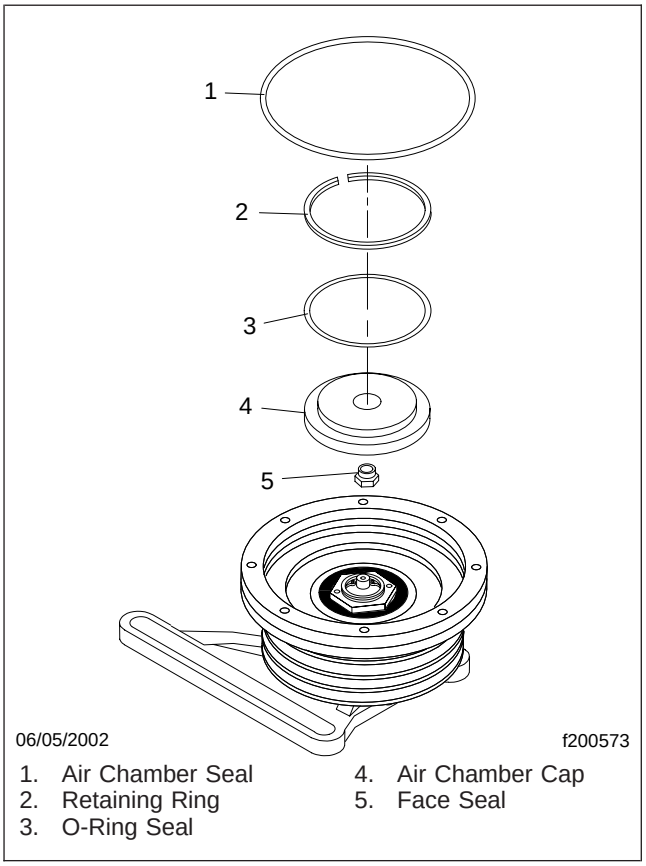
Fig. 4, Spring Housing/Piston Assembly Removal and Installation

17. Remove the O-ring seal from the air chamber cap. See **Fig. 5**.
18. Remove the face seal. See **Fig. 5**.
19. Inspect the face seal for signs of wear. Wear indicates that dirt may exist in the air system.
20. Remove the air cartridge.
    - 20.1 Remove the retaining ring. See **Fig. 6**.
    - 20.2 Remove the air cartridge assembly. See **Fig. 7**.

Assembly

1. Clean the mounting bracket bore if necessary.
2. Apply O-ring lubricant from the kit to the outside O-rings of the new air cartridge assembly. See **Fig. 8**.
3. Install the new air cartridge assembly into the mounting bracket.
4. Install the retaining ring, making sure the convex surface of the ring is toward the air cartridge. See **Fig. 8**.
5. Using a clean, dry cloth, clean both the float seal tip of the air cartridge and the face seal of the air chamber cap.

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1. Air Chamber Seal
2. Retaining Ring
3. O-Ring Seal
4. Air Chamber Cap
5. Face Seal

Fig. 5, Air Chamber Seal Removal and Installation

6. Assemble the air chamber cap and face seal. See **Fig. 5**.

   Tighten the face seal 75 to 100 lbf·in (85 to 115 N·cm).

7. Lubricate the O-ring seal with the fresh lubricant from the kit.
8. Install the O-ring seal on the air chamber cap. See **Fig. 5**.
9. Carefully set the air chamber cap into the sheave. See **Fig. 5**.
10. Install the retaining ring. See **Fig. 5**.
11. Install the air chamber seal into the sheave. Be sure the seal is evenly seated against the side and bottom of the groove surfaces, and the "V" of the seal is facing down. See **Fig. 9**.
12. Lubricate contact surfaces with the fresh lubricant from the kit.

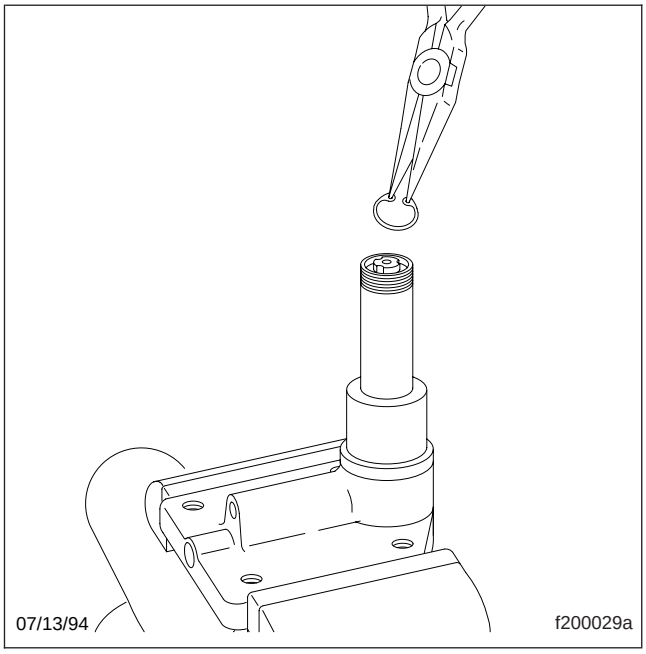
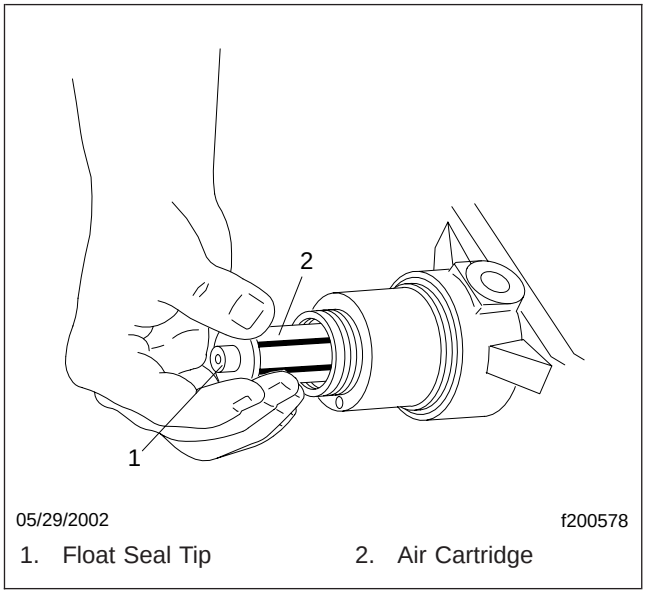


Fig. 6, Retaining Ring Removal and Installation (sheave not shown)



1. Float Seal Tip
2. Air Cartridge

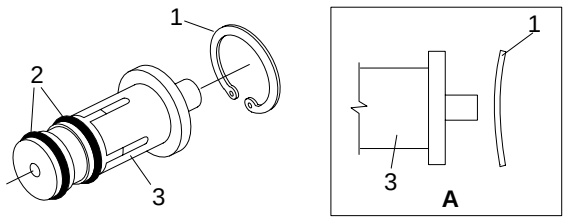
Fig. 7, Removing the Air Cartridge (sheave not shown)

WARNING

The new spring housing/piston assembly from the kit has a cage nut installed on it. Do not remove the cage nut. This will cause the spring

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Fan Clutch Minor Rebuild

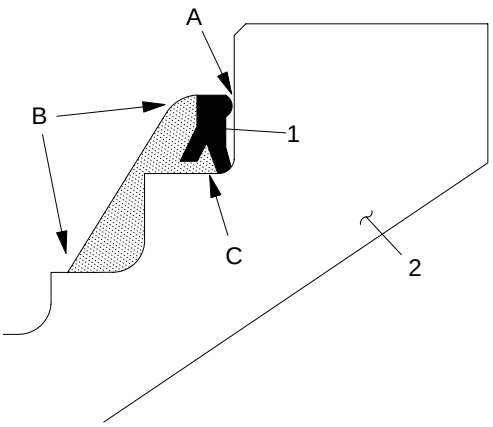


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A. Convex surface of the retaining ring goes toward the air cartridge.

1. Retaining Ring
2. O-Rings
3. Air Cartridge

Fig. 8, Installing the Air Cartridge Retaining Ring



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A. Seal is seated evenly against side and bottom of groove.
B. Apply grease only between these areas.
C. "V" of Seal Facing Down

1. Air Chamber Seal
2. Sheave

Fig. 9, Correct Installation of Air Chamber Seal (cross-section view)

housing to be forcibly ejected from the piston assembly, which could result in serious injury.

13. Carefully set the new spring housing/piston assembly into position. See **Fig. 4**. Note that the new assembly has a cage nut installed on it.
14. Rotate the new spring housing/piston assembly to align the mounting holes with those of the sheave.
15. Set the friction liner from the kit into place, being careful to touch only the edges.
16. Using a T27 Torx bit, install the eight Torx-head screws. See **Fig. 3**. Tighten alternately 80 lbf·in (9 N·m).
17. Apply a minimum of 80 psi (552 kPa) of clean air to the air inlet.
18. Remove the cage nut from the spring housing/piston assembly.

CAUTION

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so may cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

19. Using a suitable wrench, a T55 Torx bit, and a pry bar, tighten the jack bolt (left-hand thread) 100 lbf·ft (136 N·m). Turn the wrench clockwise and the pry bar counterclockwise.
20. Using shop air, actuate the fan clutch and check for correct engagement and disengagement of the fan mounting disc. If there is a problem, it must be corrected before installing the fan clutch onto the engine.
21. Check for air leaks at the bleed hole and around the spring housing/piston assembly.
22. Install the fan clutch assembly onto the engine. See **Subject 100** for instructions.

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Troubleshooting Tables

Problem—Air Is Leaking from the Fan Clutch

Problem—Air Is Leaking from the Fan Clutch	
Possible Cause	**Remedy**
The face seal or air cartridge is damaged or worn.	Install a new seal kit.
The O-ring seals are damaged or worn.	Install a new seal kit.

Problem—The Fan Clutch Fails to Engage

Problem—The Fan Clutch Fails to Engage	
Possible Cause	**Remedy**
There's no power to the fan clutch control circuit.	Check all electrical connections, and repair or replace wiring as needed. Check the circuit breaker for the engine fan and repair or replace as needed.
The engine temperature switch is damaged or an incorrect sensor has been installed.	Make sure the switch is normally open, not normally closed. Replace the switch if it is damaged or if the switch is the wrong type.
The solenoid valve is malfunctioning.	Replace the solenoid valve.
The solenoid is not exhausting.	Make sure the solenoid exhaust port is not plugged.

Problem—The Fan Clutch Does Not Disengage

Problem—The Fan Clutch Does Not Disengage	
Possible Cause	**Remedy**
The engine temperature switch is damaged or an incorrect sensor has been installed.	Make sure the switch is normally open, not normally closed. Replace the switch if it is damaged or if the switch is the wrong type.
A restricted air line doesn't allow air supply to the clutch.	Make sure the air lines are not pinched or plugged. Repair the air lines as needed.
The fan clutch is leaking.	Install a new seal kit.
The air supply to the fan clutch is restricted.	Make sure the fan clutch air lines are not leaking or pinched. Repair the lines as needed.
The piston is seized due to contamination or dry seals.	Clean the air supply. Do a major rebuild.

Problem—The Fan Clutch Cycles Frequently

Problem—The Fan Clutch Cycles Frequently	
Possible Cause	**Remedy**
The fan clutch control circuit has a loose connection or is poorly grounded.	Check all wiring connections, and repair the circuit as needed. Check the circuit breaker for the engine fan and repair or replace as needed.
The temperature control settings are incorrect.	Check the fan clutch control setting of the temperature switch, according to the engine installed in the vehicle. Repair or replace the temperature switch as needed.

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Troubleshooting

Problem—The Fan Clutch Cycles Frequently	
Possible Cause	**Remedy**
The fan cycling switch at the receiver-dryer is set too low.	Check the switch at the receiver-dryer, and if needed, replace the switch with a switch with a higher setting. Check the ACPU switch and unit.
There is an air restriction in front of the fan clutch.	Check for incorrect radiator shutter operation, winterfronts, or any other air restrictions.
The engine temperature is too high.	Check the programmable engine control parameters, and reprogram as needed.
The temperature switch is malfunctioning.	Replace the temperature switch.

Problem—The Fan Clutch Engages, But the Engine Still Overheats

Problem—The Fan Clutch Engages, But the Engine Still Overheats	
Possible Cause	**Remedy**
There is an air restriction in front of the fan clutch.	Check for incorrect radiator shutter operation, winterfronts, or any other air restrictions.
There is a problem somewhere else in the cooling system.	Refer to the cooling system troubleshooting section, **Section 20.00**.

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Specifications

Horton DriveMaster® Repair Kits		
Kit Description *	**Part Number**	**When Used**
Super Kit	HOR994347	Fan Clutch Major Rebuild
Seal Kit	HOR994346	Replacing Seals and Air Cartridge
Friction Disc Kit	HOR994348	Replacing Fan Mounting Disc and Friction Lining
Friction Liner Kit	HOR994349	Replacing Friction Lining Only

* All kits are available from the PDCs.

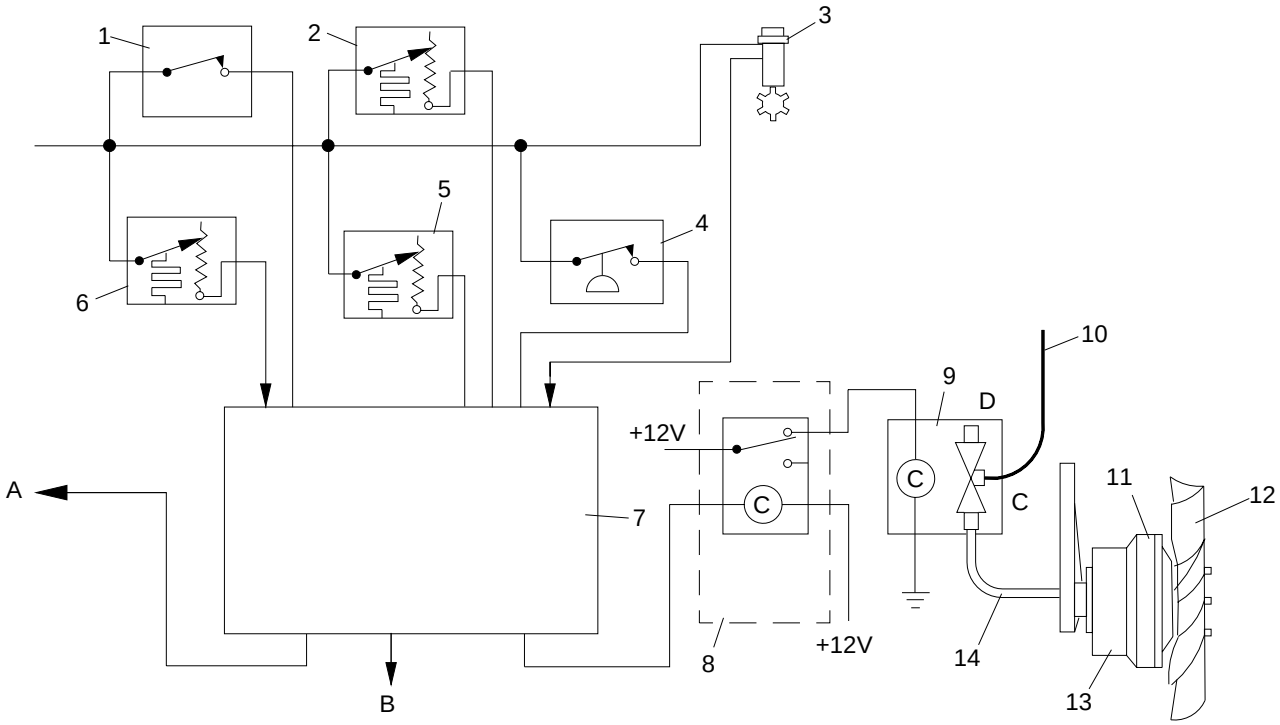
Table 1, Horton DriveMaster Repair Kits

Description	Torque	
	lbf·in (N·cm)	**lbf·ft (N·m)**
Friction Lining Screws	80 (90)	—
Face Seal	75 to 100 (85 to 115)	—
Bearing Nut	—	130 (136)
Jack Bolt	—	100 (136)

Table 2, Torque Values

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Specifications



A. To Indicators and Gauges
B. To Electronic Injectors and Other Actuators
C. Normally Closed
D. Normally Open

1. Fan Override Switch
2. Air Temperature Sensor
3. Engine Speed Sensor
4. A/C Pressure Switch
5. Coolant Temperature Sensor
6. Foot Throttle
7. Engine ECM
8. Fan Relay (not present in all systems)
9. Solenoid Valve
10. Air Supply from Reservoir
11. Fan Clutch
12. Air Supply to Fan Clutch

Fig. 1, Fan Clutch Schematic (engine ECM controlled)

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General Information

The clutch linkage transfers the motion of the clutch pedal to the clutch release bearing.

Free-play in the clutch pedal is required to ensure that the fingers of the release bearing do not run against the release bearing. There should not be any play or looseness in the connections and joints of the clutch linkage.

On pull-type clutches, depressing the clutch pedal pulls the release bearing away from the pressure plate, disengaging the clutch. As the clutch pedal is released, the pressure plate is forced toward the engine flywheel until the driving and driven discs turn at the same speeds, engaging the clutch.

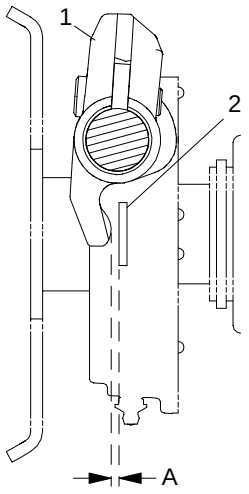
IMPORTANT: On pull-type clutches, release bearing and release fork clearance are internal clutch adjustments and *can not be adjusted* by adjusting the clutch linkage. For internal clutch adjustments, see either the applicable clutch section in this group, or the clutch manufacturer's service literature.

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Adjustment

1. Park the vehicle, shut down the engine, set the parking brake, and chock all the tires.
2. Observe the following points before beginning clutch linkage adjustment:
   - Be sure internal clutch adjustments are correct before making adjustments to the clutch linkage.
   - Adjust the clutch linkage only after repair or replacement of the clutch or clutch linkage components.
   - If the cab is equipped with an air suspension, be sure the air springs are properly inflated. If the air springs are not inflated, the clutch linkage can't be adjusted correctly.
3. Open the hood.
4. Remove the clutch inspection cover from the bottom of the bell housing.
5. Measure the distance between the release yoke and the release bearing.

   If this measurement is 0.105 to 0.145 inch (2.7 to 3.6 mm), no further work is needed. See **Fig. 1**. If the measurement is incorrect, do all of the remaining steps.
6. Disconnect the clutch linkage. See **Fig. 2**.
   - 6.1 Disconnect the clutch rod end, near the cab, from the relay lever.
   - 6.2 Loosen the jam nut on the clutch rod.
7. Adjust the clutch linkage.
   - 7.1 Hold the clutch rod in the same position. Adjust the rod length in or out, as needed. Shorten the rod to decrease the clearance. Lengthen the rod to increase the clearance.
   - 7.2 Attach the rod end to the relay lever.
   - 7.3 Tighten the jam nut on the clutch rod 14 lbf·ft (19 N·m).
8. Measure the distance between the release yoke and the release bearing. If this measurement is 0.105 to 0.145 inch (2.7 to 3.6 mm), go to the next step. If the measurement is not within these limits, go back to the "Disconnect the clutch linkage" step and adjust the linkage until it is correct.
9. Install the clutch inspection cover on the bottom of the bell housing.
10. Close the hood.
11. Remove the chocks from all the tires.

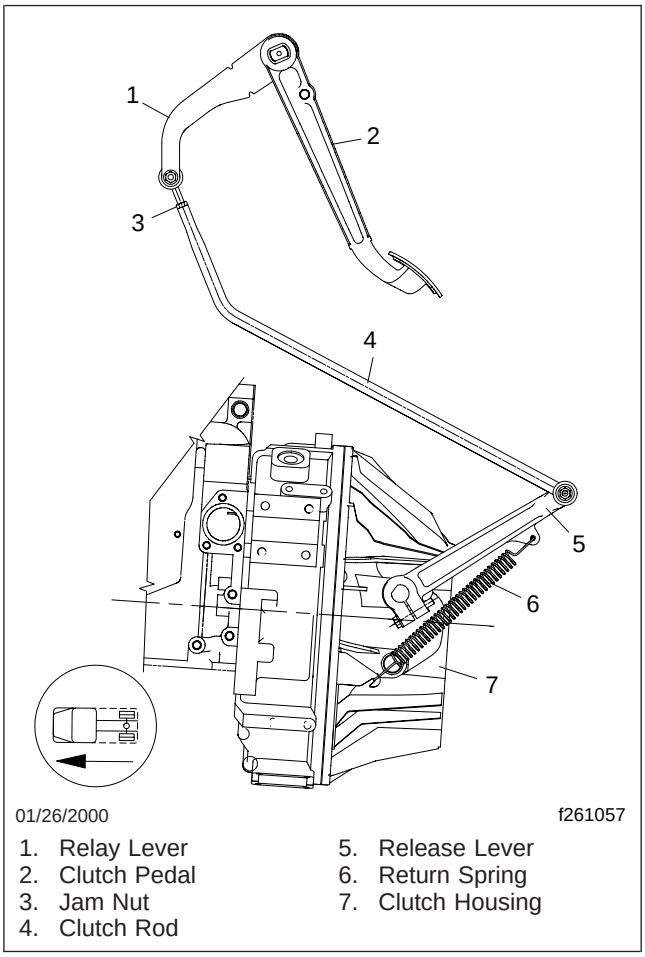


A. Clearance Between Release Yoke and Release Bearing: 0.105 inch (2.7 mm) minimum
1. Release Yoke
2. Clutch Release Bearing Wear Pads

Fig. 1, Clutch Adjustments

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Clutch Linkage Adjustment



1. Relay Lever
2. Clutch Pedal
3. Jam Nut
4. Clutch Rod
5. Release Lever
6. Return Spring
7. Clutch Housing

Fig. 2, Linkage for Pull-Type Clutch

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Specifications

Torque Values, Clutch Adjustment	
Description	**Torque lbf·ft (N·m)**
Clutch Rod Nut	30 to 40 (41 to 54)
Jam Nut	12 to 15 (16 to 20)

Table 1, Torque Values, Clutch Adjustment

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Clutch Pedal Removal and Installation

Removal

See **Fig. 1** for a complete exploded view of the clutch- and brake-pedal assembly.

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the tires.
2. Inside the cab, remove the five screws from the under steering panel and remove the panel. See **Fig. 2**.
3. Remove the ABS check-switch bracket by removing the screw from the lower left dash panel. Move the bracket out of the way to allow better access to the clutch pedal.
4. Remove the clutch pedal. See **Fig. 3**.
   - 4.1 Remove the capscrews and belleville washers from the wedge at the end of the clutch cross-shaft.
   - 4.2 Pry the wedge out from the end of the pedal.
   - 4.3 Remove the pedal. Discard the wedge, washers, and capscrew.

Installation

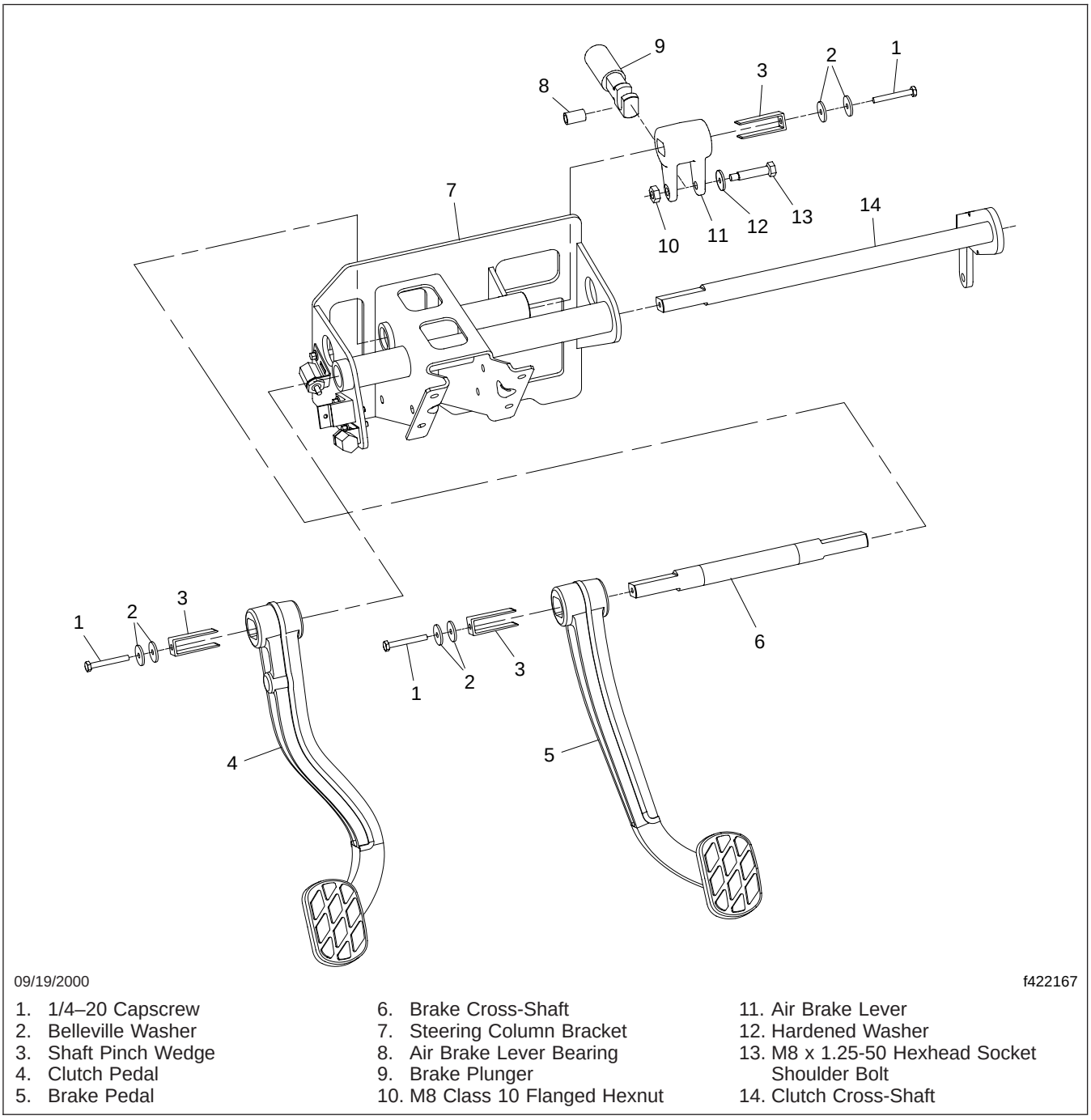
1. Slide the pedal on to the end of the clutch cross-shaft.

IMPORTANT: The wedge, belleville washers and capscrews must be replaced after they are removed for any reason. For part numbers, see **Specifications 400**.

2. Install a new wedge, belleville washers and capscrew as shown in **Fig. 3**. The belleville washers are concave and must be installed facing each other as shown.
3. Tighten the capscrew 8 lbf·ft (10.8 N·m).
4. Install the ABS check-switch bracket.
5. Install the under steering panel.
   - 5.1 Position the under steering panel.
   - 5.2 Install the spacer.
   - 5.3 Tighten the five screws. See **Fig. 2**.
6. Remove the chocks from the tires.
7. Test the drive the vehicle at a slow speed to test clutch pedal operation.

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Clutch Pedal Removal and Installation



1. 1/4–20 Capscrew
2. Belleville Washer
3. Shaft Pinch Wedge
4. Clutch Pedal
5. Brake Pedal
6. Brake Cross-Shaft
7. Steering Column Bracket
8. Air Brake Lever Bearing
9. Brake Plunger
10. M8 Class 10 Flanged Hexnut
11. Air Brake Lever
12. Hardened Washer
13. M8 x 1.25-50 Hexhead Socket Shoulder Bolt
14. Clutch Cross-Shaft

Fig. 1, Brake- and Clutch-Pedal Assembly

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Clutch Pedal Removal and Installation

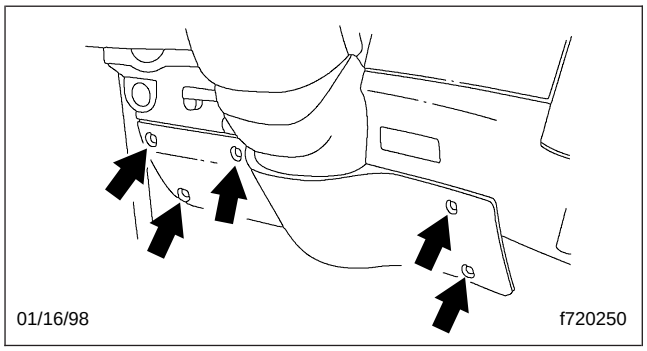
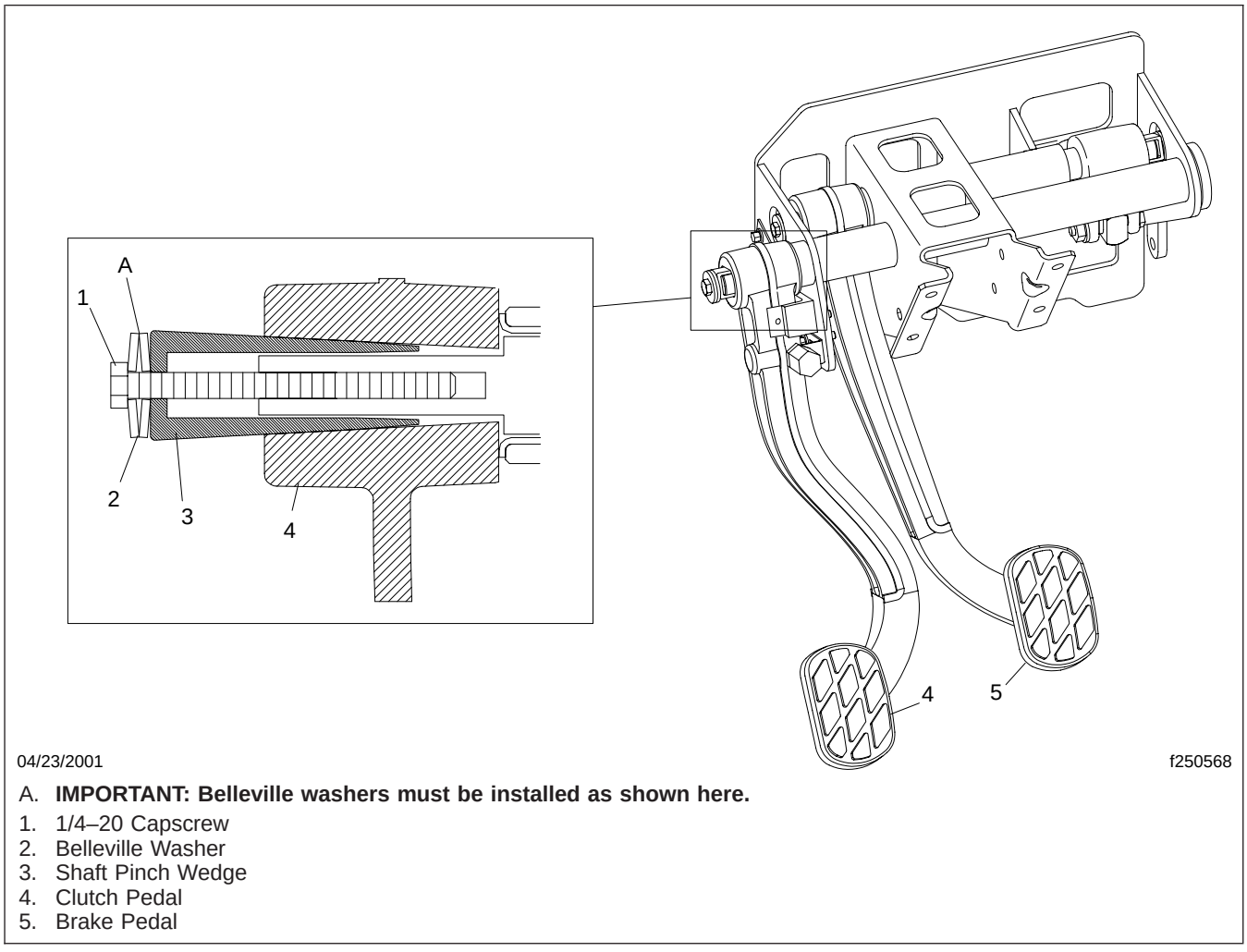


Fig. 2, Under Steering Panel Screw Location



A. **IMPORTANT: Belleville washers must be installed as shown here.**
1. 1/4–20 Capscrew
2. Belleville Washer
3. Shaft Pinch Wedge
4. Clutch Pedal
5. Brake Pedal

Fig. 3, Clutch Pedal Removal and Installation

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Specfications

Clutch Pedal Replacement Parts	
Description	**Part Number**
Shaft Pinch Wedge	12-17561-000
Belleville Washer	23-12105-000
1/4–20 Capscrew	23-12686-250

Table 1, Clutch Pedal Replacement Parts

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Removal

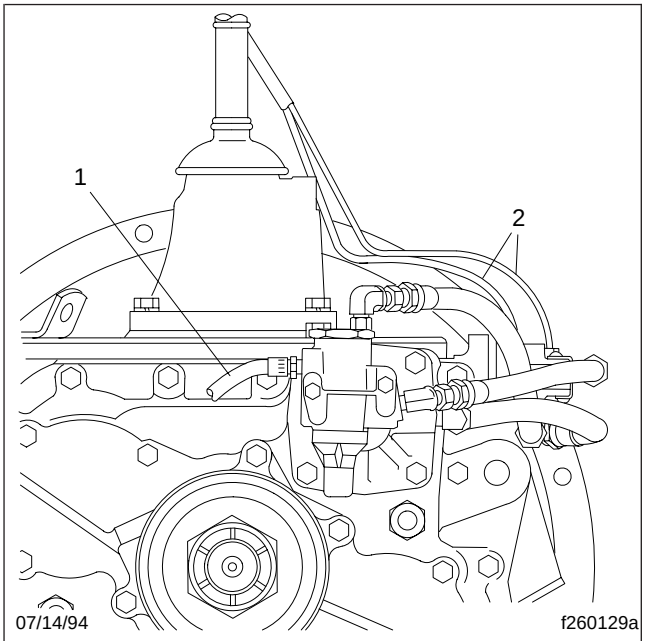
NOTE: For disassembly, repair, and assembly of the transmission, see the manufacturer's service literature.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.

⚠ WARNING

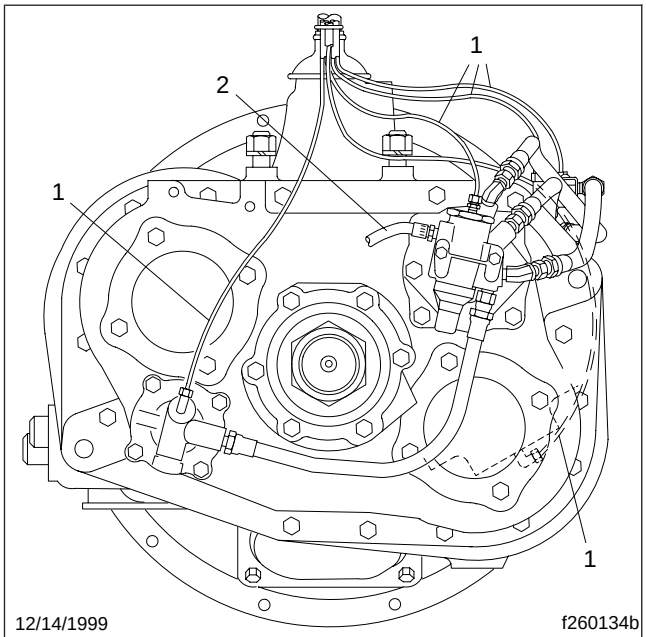
Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. Do not direct the airstreams at anyone. Do not disconnect pressurized hoses, since they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

2. If applicable, drain the vehicle system at the air reservoirs.
3. If applicable, disconnect the transmission air supply and signal lines. See **Fig. 1** or **Fig. 2**. Label the lines for reconnection.



1. Supply Line
2. Signal Lines

Fig. 1, Fuller RT/RTO-6610 Transmission



1. Signal Lines
2. Supply Lines

Fig. 2, Fuller RT/RTO-6613 Transmission

4. Remove the shift lever from the transmission.
   - 4.1 Place the transmission in high gear.
   - 4.2 Remove the four Phillips-head screws from the ring holding the shift lever boot. See **Fig. 3**. Remove the ring and the boot.
   - 4.3 Remove the four capscrews from the plate holding the shift tower to the top cover. See **Fig. 4**.
   - 4.4 Lift up on the shift lever and remove it and the air signal lines (if applicable). See **Fig. 5**.
   - 4.5 Cover the opening in the shift tower to prevent entry of dirt.
5. Disconnect the driveshaft from the transmission.
   - 5.1 If the vehicle is equipped with a driveline parking brake, remove the nuts on the brake flange. See **Fig. 6**.

     If the vehicle is not equipped with a driveline parking brake, remove the transmission yoke U-joint end caps.

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Transmission Removal and Installation

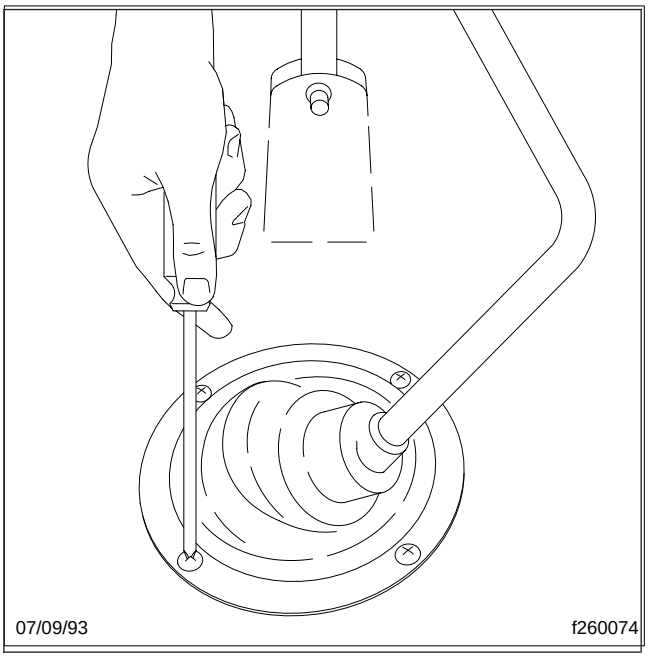


Fig. 3, Phillips-Head Screws on Shift Lever Boot Ring

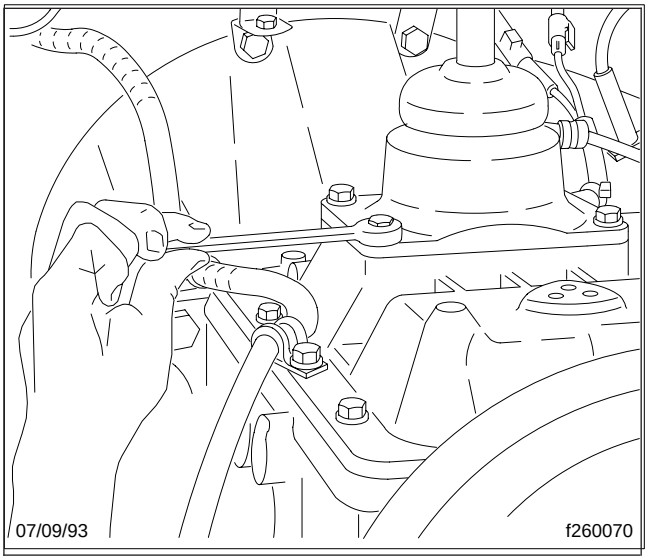


Fig. 4, Shift Tower Plate Capscrews

5.2 Loosen the bolts holding the midship bearing bracket so the driveshaft can slide to the rear. See **Fig. 7**.

5.3 Slide the front of the driveshaft off the driveline brake flange or out of the transmission output yoke.

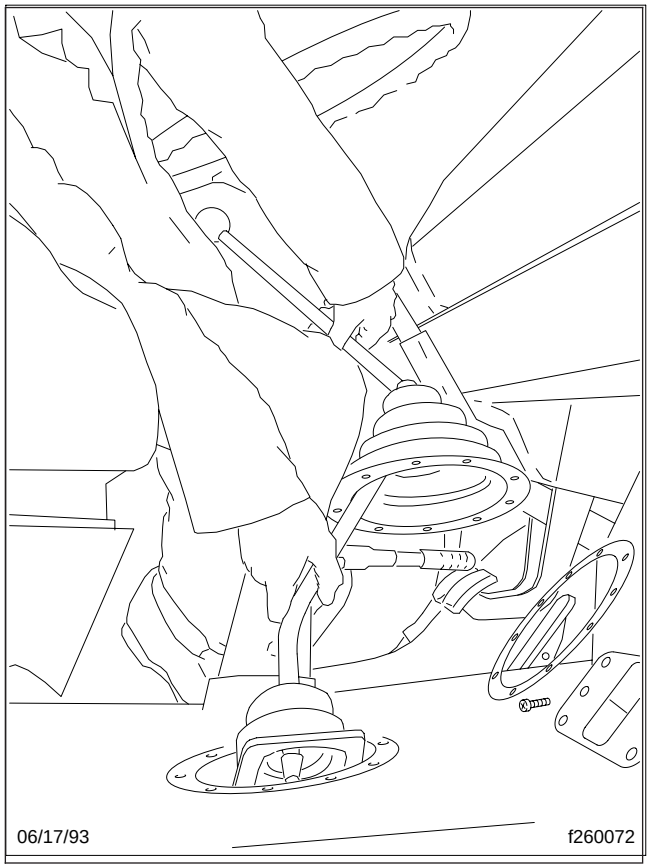


Fig. 5, Shift Lever Removal

NOTE: It may be necessary to remove the bolts from the midship bearing bracket so the driveshaft can be moved far enough back.

5.4 Support the disconnected driveshaft or tie it out of the way.

6. Remove all electrical connections from the transmission.

6.1 Disconnect the back-up light cables. See **Fig. 8**.

6.2 Disconnect the electrical cable from the speedometer sensor. See **Fig. 9**.

6.3 Loosen the capscrews holding the speedometer sensor wiring harness to the transmission. See **Fig. 10**. Move the harness out of the way.

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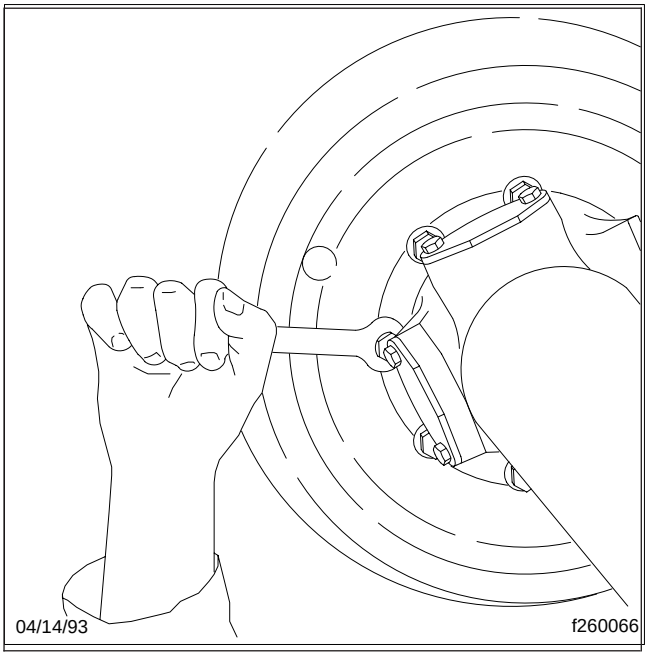


Fig. 6, Parking Brake Flange Nut Removal

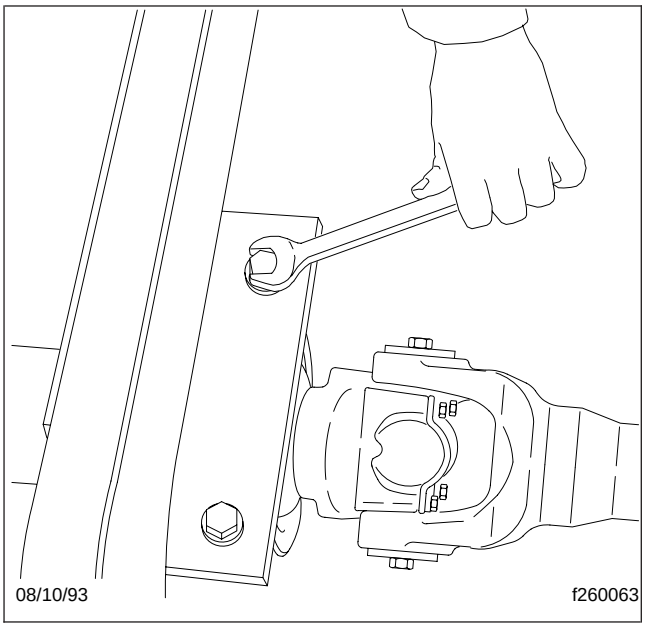


Fig. 7, Midship Bearing Bracket Bolts

7. If the vehicle is equipped with a driveline parking brake, remove the cotter pin holding the clevis to the driveline brake lever. See **Fig. 11**. Remove the two bolts holding the driveline brake cable bracket to the transmission. Remove the bracket.

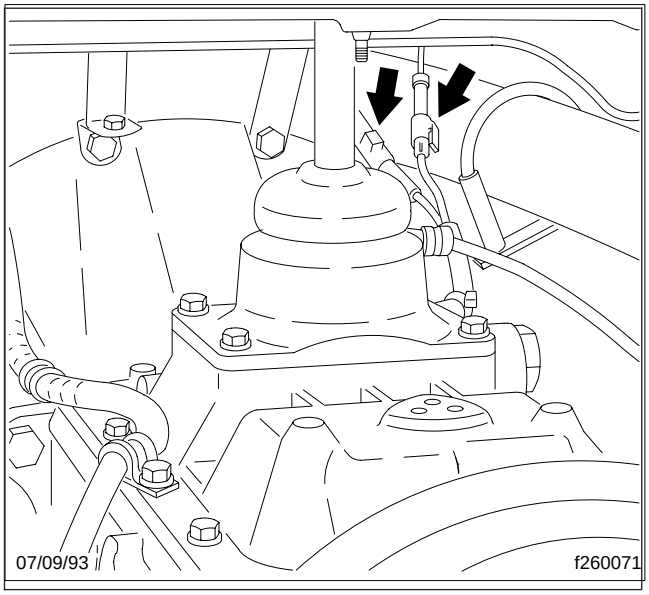


Fig. 8, Back-up Light Cables

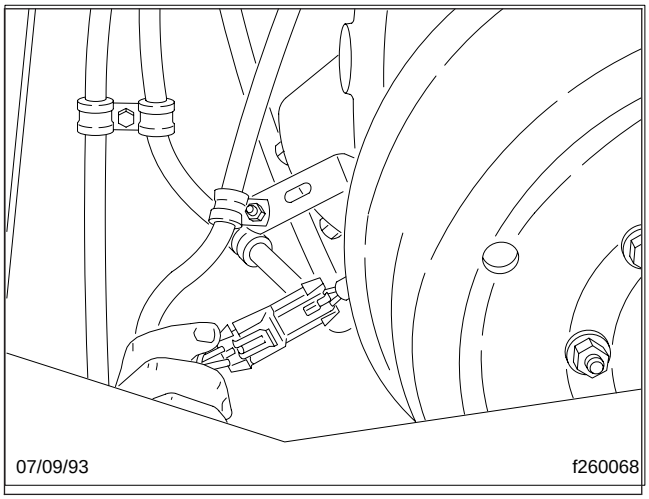


Fig. 9, Speedometer Sensor Electrical Cable

8. If the vehicle is equipped with optional dual fuel tanks, remove the fuel cross-over line and its support between the tanks.

   8.1 Remove the mounting clamps holding the fuel cross-over line to its support. See **Fig. 12**.

   8.2 Remove the support mounting bolts. See **Fig. 13**. Remove the support.

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Transmission Removal and Installation

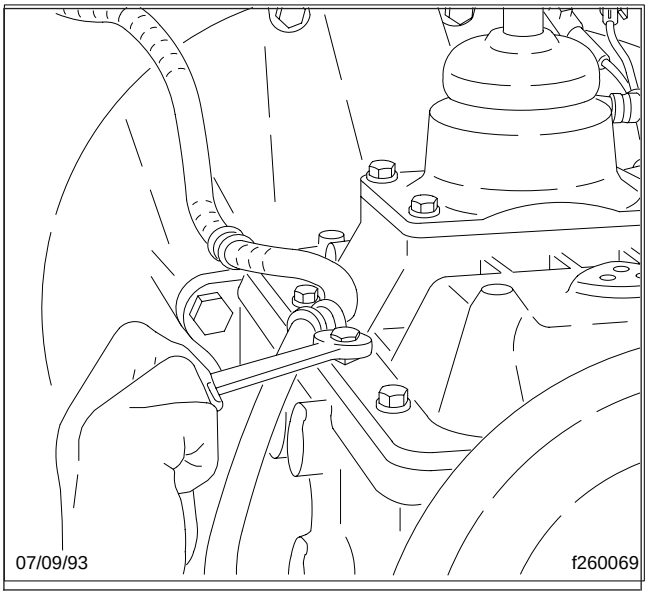


Fig. 10, Speedometer Sensor Wiring Harness Capscrews

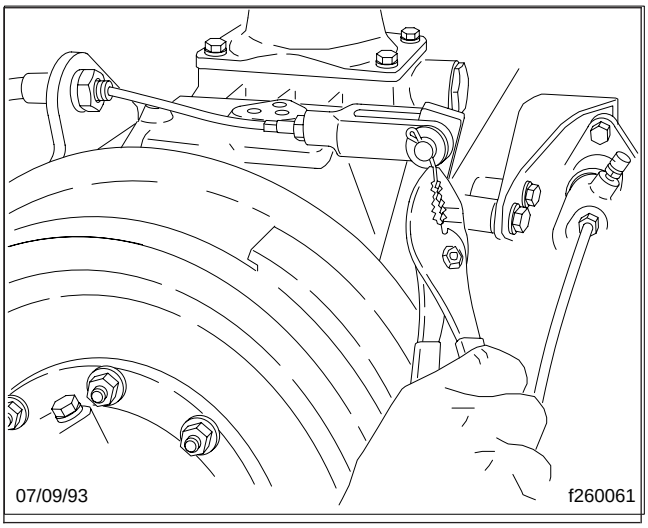


Fig. 11, Cotter Pin Removal from the Driveline Brake Lever Clevis

8.3 Close the fuel cross-over line shutoff valve at the bottom of the passenger-side fuel tank. See **Fig. 14**.

8.4 Remove the allen-head plug in the driver-side fuel tank and drain the tank. See **Fig. 15**.

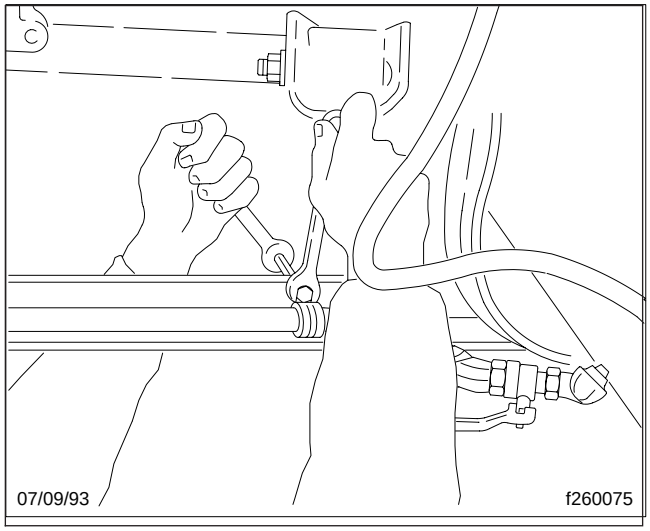


Fig. 12, Fuel Cross-Over Line Mounting Clamps

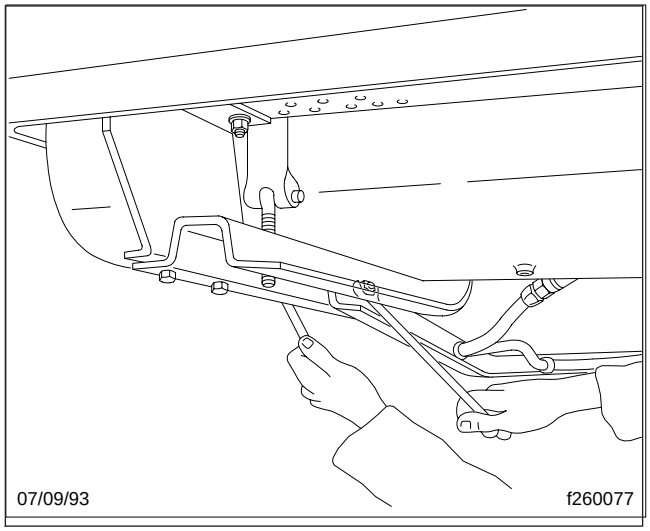


Fig. 13, Support Mounting Bolt Removal

8.5 Disconnect the fuel cross-over line from the driver-side fuel tank. See **Fig. 16**.

9. Support the transmission with a jack.

9.1 Position a transmission jack under the transmission and raise its support plates against the bottom of the transmission.

9.2 Adjust the support plates to cradle the transmission.

9.3 Using a chain, secure the transmission to the jack.

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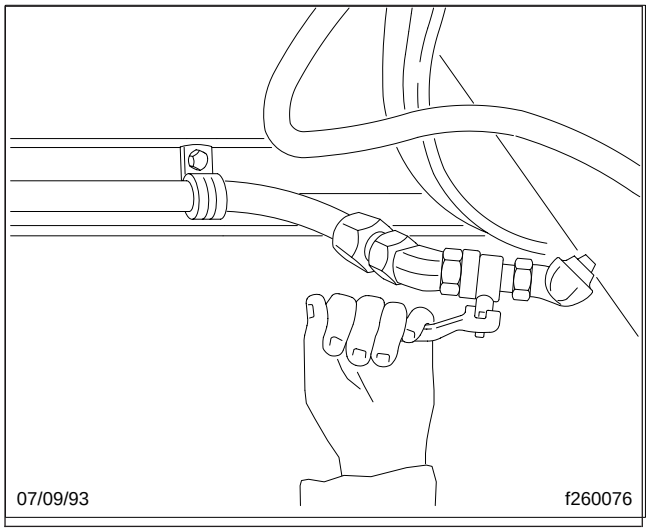


Fig. 14, Closing the Fuel Cross-Over Line Shutoff Valve

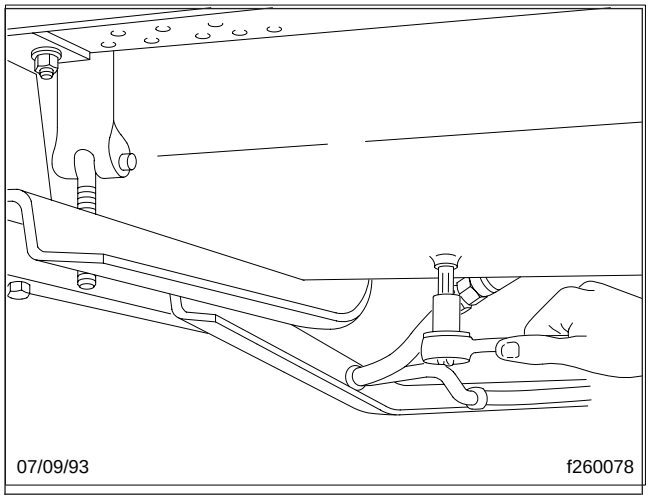


Fig. 15, Allen-Head Plug Removal

10. Remove the transmission.

    10.1 *On a single-countershaft transmission,* remove the capscrews that hold the transmission to the clutch housing. See **Fig. 17**.

    On a twin-countershaft transmission, remove the capscrews that hold the clutch housing to the flywheel housing, and remove the clutch housing with the transmission.

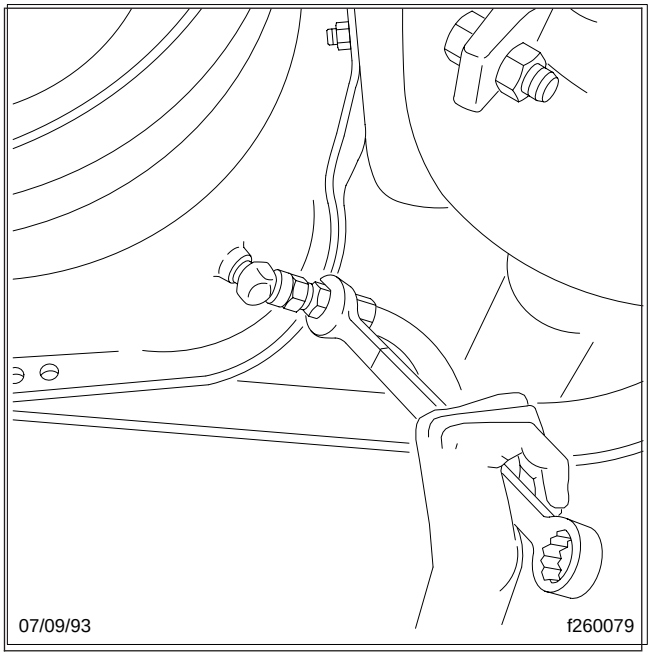


Fig. 16, Disconnecting the Fuel Cross-Over Line

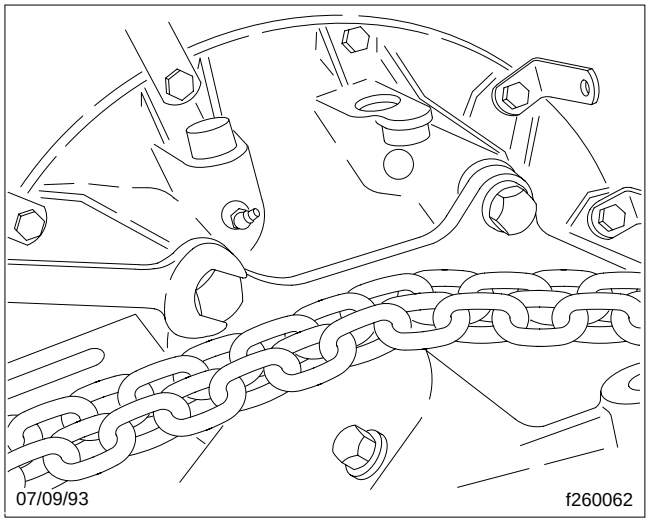


Fig. 17, Transmission Capscrews

    10.2 Pull the transmission and jack straight back, until the transmission input shaft is clear of the clutch.

    10.3 If required, lower the jack supporting the transmission. Raise the front of the truck and slide the transmission and jack out from under the truck.

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Transmission Removal and Installation

CAUTION

Do not let the rear of the transmission drop, and do not let the transmission hang unsupported in the splined hubs of the clutch disc(s). Keep the flange of the clutch housing parallel, all the way around, to the flange of the flywheel housing, until the input shaft is clear of the clutch. Taking these precautions will prevent damage to the clutch disc(s).

Installation

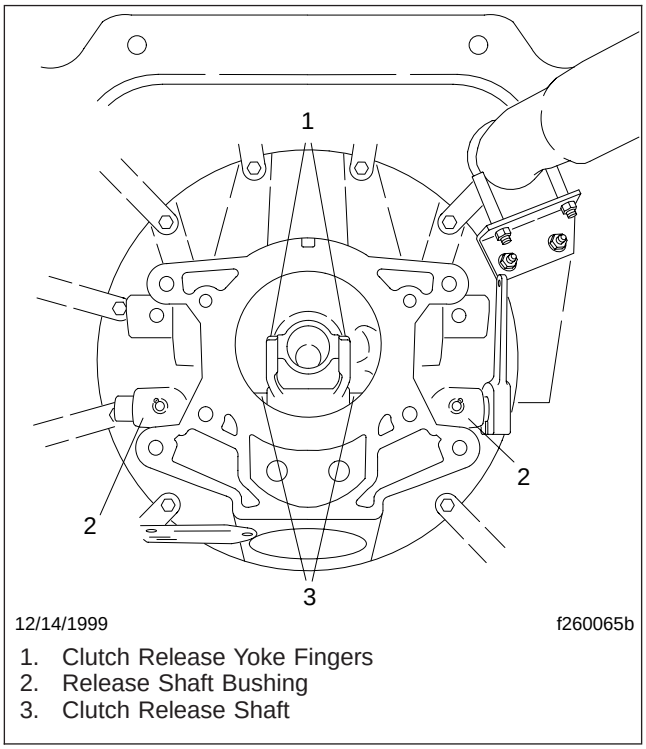
IMPORTANT: Before installing the transmission, make sure that the rear tires are chocked and that the transmission is securely chained to the transmission jack support plates.

1. If the vehicle is equipped with a clutch brake, install it on the transmission input shaft. Slide it tight against the input shaft bearing cap.

NOTE: When installing a torque-limiting clutch brake on a Fuller transmission, install the smaller face toward the transmission.

2. Check for wear on the fingers of the clutch release yoke, release shaft, and the release shaft bushings. Replace any worn parts as needed. See **Fig. 18**.
3. Install the transmission.
   - 3.1 Shift the transmission into gear, so that the transmission input shaft can be rotated during assembly to line it up with the clutch driven-disc hub splines.
   - 3.2 Align the jack and the transmission behind the engine. Raise the transmission, and adjust the angle of the jack until the bell housing and the transmission input flange (single-countershaft transmissions) or the flywheel housing flange and the clutch housing flange (twin-countershaft transmissions) are parallel.
   - 3.3 Push the transmission and jack straight forward making sure the flanges remain parallel.

   NOTE: On twin-countershaft transmissions, be sure the release-bearing yoke clears the bearing, and is rotated over the wear pads as the transmission is moved forward. See **Fig. 19**. Align the splines by turning the transmission output shaft.



1. Clutch Release Yoke Fingers
2. Release Shaft Bushing
3. Clutch Release Shaft

Fig. 18, Clutch Release and Shaft

   - 3.4 Reach through the access hole in the bottom of the bell housing and hold the throw-out bearing in place by hand. See **Fig. 20**.
   - 3.5 Slide the splined input shaft into the clutch driven disc.

CAUTION

Use care to avoid springing the driven disc(s) when the transmission is being installed. Do not force the transmission into the bell housing if it does not enter freely. Do not let the transmission drop or hang unsupported in the driven disc(s); doing so can damage the clutch assembly.

   - 3.6 *On a single-countershaft transmission,* install the capscrews holding the transmission to the clutch housing. See **Fig. 17**. Tighten them 150 lbf·ft (203 N·m).

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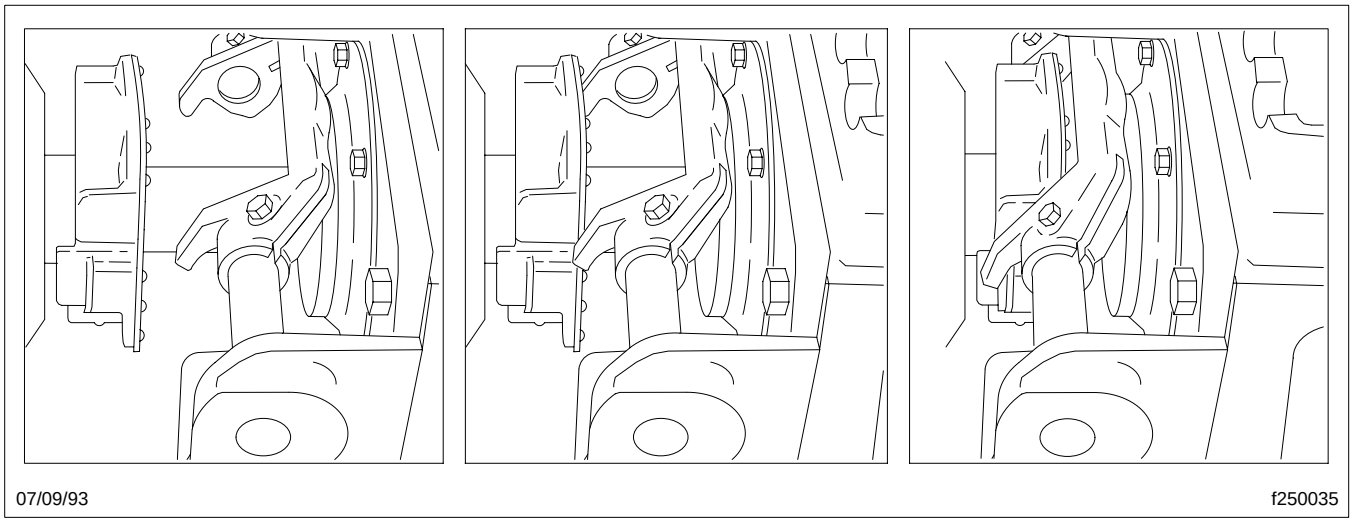


Fig. 19, Release Bearing Yoke Rotation

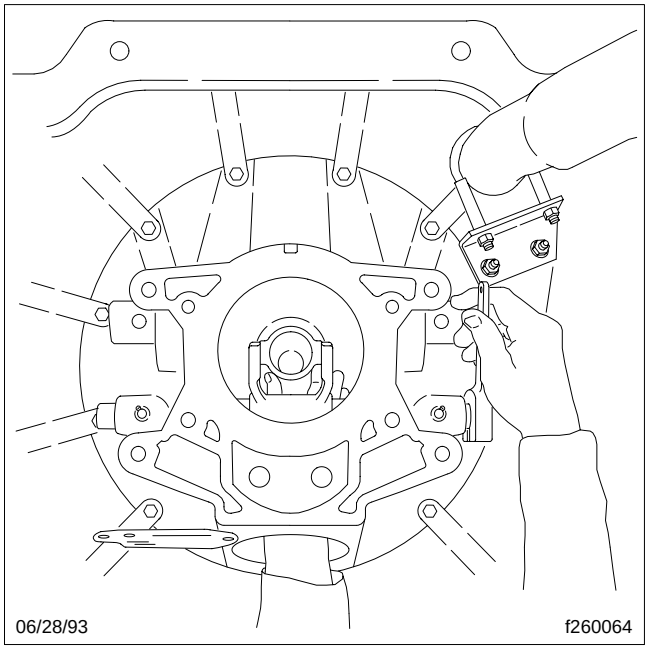


Fig. 20, Throw-Out Bearing Held Stationary

On a twin-countershaft transmission, install the capscrews holding the clutch housing to the flywheel housing. Tighten them 34 lbf·ft (46 N·m).

3.7 Remove the chain securing the transmission to the jack. Remove the jack.

4. If the vehicle is equipped with the optional dual fuel tanks, install the fuel cross-over line and its support between the tanks.

   4.1 Install the allen-head drain plug in the driver-side fuel tank. See **Fig. 15**. Finger-tighten the plug. Tighten it 1-1/2 turns more.

   4.2 Install the fuel cross-over line support and its mounting bolts. See **Fig. 13**. Tighten the bolts 95 lbf·ft (129 N·m).

   4.3 Connect the fuel cross-over line to the driver-side fuel tank. See **Fig. 16**.

   4.4 Open the fuel cross-over line shutoff valve at the bottom of the passenger-side fuel tank. See **Fig. 14**.

   4.5 Install the mounting clamps holding the fuel cross-over line onto its support. See **Fig. 12**. Tighten them 40 lbf·ft (54 N·m).

5. If the vehicle is equipped with a driveline parking brake, mount the driveline brake cable bracket to the transmission. Install the two bolts, and tighten them 100 lbf·ft (136 N·m). Attach the clevis to the brake lever. Insert and lock the cotter pin. See **Fig. 11**.

6. Connect all electrical lines to the transmission.

   6.1 Connect the back-up light cables. See **Fig. 8**.

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6.2 Connect the electrical cable to the speedometer sensor. See **Fig. 9**.

6.3 Install the speedometer sensor wiring harness. Install the capscrews fastening it to the transmission. See **Fig. 10**. Tighten them 40 lbf·ft (54 N·m).

7. Connect the driveshaft.

7.1 Slide the front of the driveshaft into the transmission output yoke or onto the driveline parking brake flange if so equipped.

7.2 On vehicles without a driveline parking brake, install the transmission yoke U-joint end caps. Tighten the bolts 45 lbf·ft (61 N·m).

On vehicles with a driveline parking brake, slide the driveshaft flange onto the studs in the parking brake.

Install the nuts, and tighten them 40 lbf·ft (54 N·m).

7.3 Install the capscrews and nuts on the midship bearing bracket. Tighten them 95 lbf·ft (129 N·m).

8. Install the shift lever.

8.1 Remove the covering from the opening in the shift tower.

8.2 Install the shift lever and plate. See **Fig. 5**.

8.3 Install the four capscrews in the plate. See **Fig. 4**. Tighten them 28 lbf·ft (38 N·m).

8.4 Install the rubber boot and the metal ring. Install the four Phillips-head screws. See **Fig. 3**.

9. If applicable, connect the air signal and supply lines to the transmission. See **Fig. 1** or **Fig. 2**.

10. Remove the chocks from the tires.

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See **Fig. 1** for a full view of the manual transmission wiring.

See **Fig. 2** for a full view of Sheet 1 for AutoShift with SmartShift wiring.

See **Fig. 3** and **Fig. 4** for partial views of Sheet 1.

See **Fig. 5** for a full view of Sheet 2 for AutoShift with SmartShift wiring.

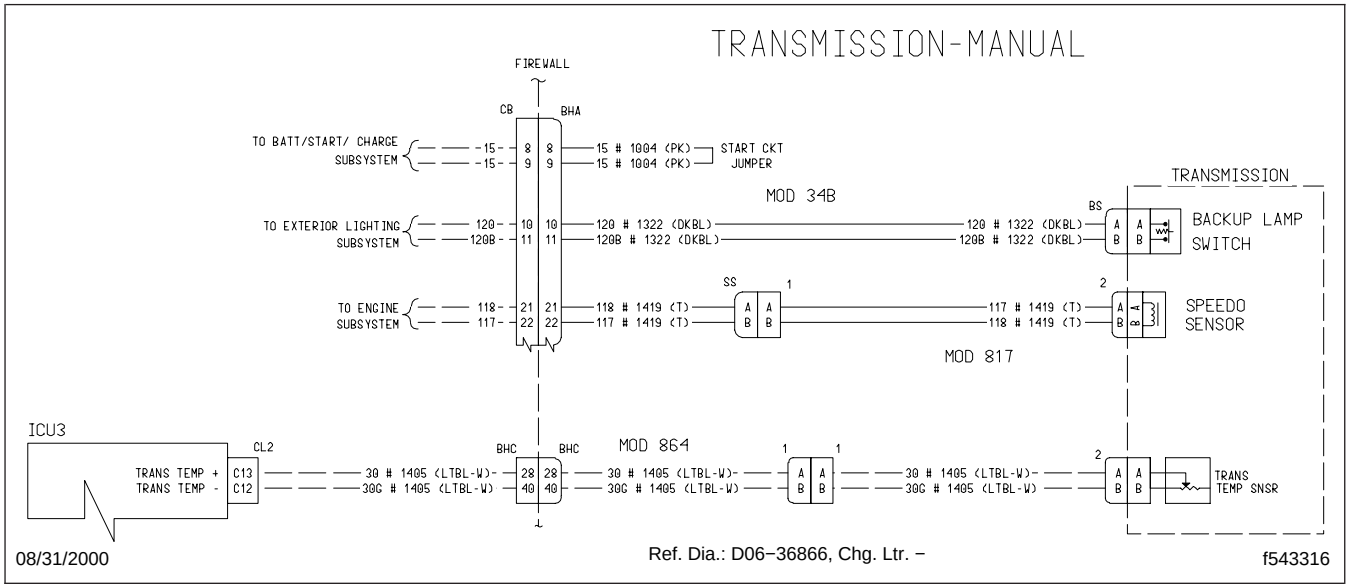


Fig. 1, Manual Transmission Wiring

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Specifications

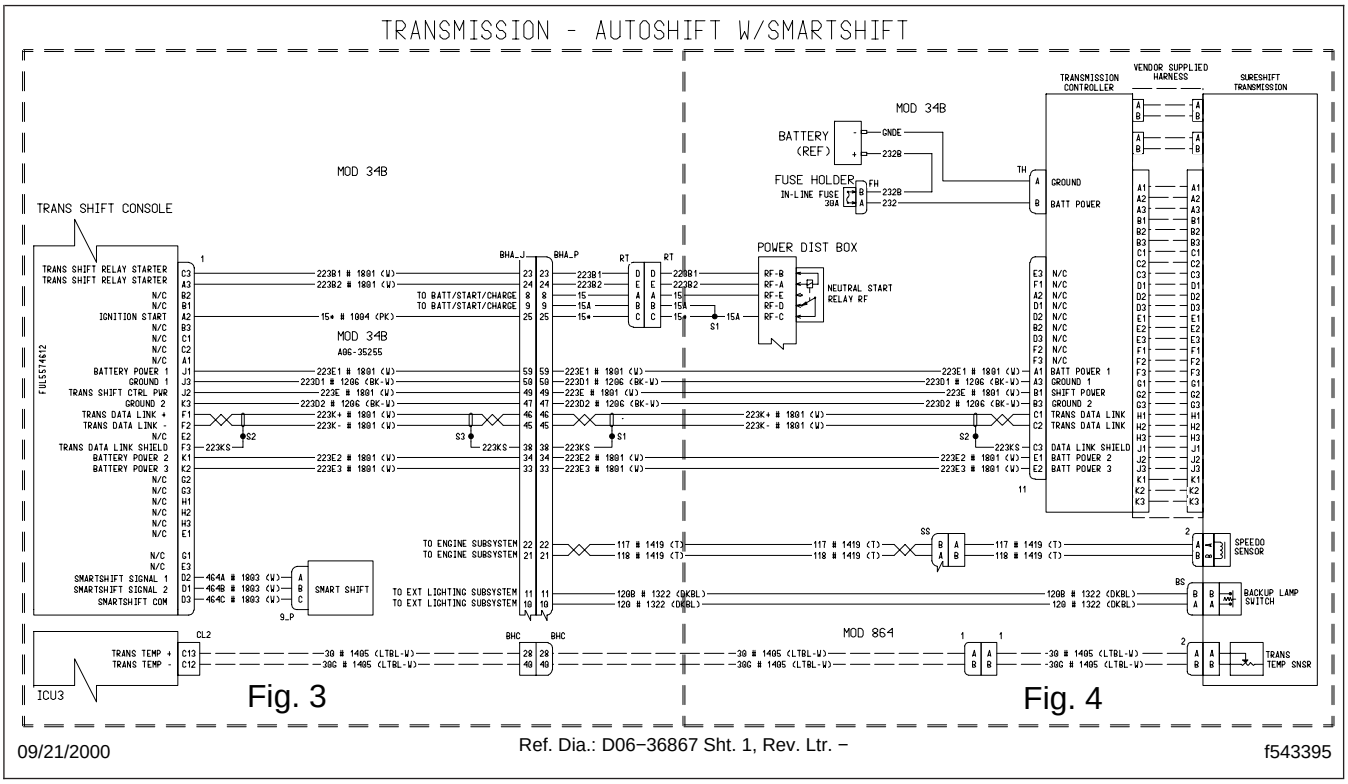


Fig. 2, AutoShift With SmartShift Wiring, Sheet 1 (full view)

Tightening Torques	
Description	**Torque lbf·ft (N·m)**
Shift Lever Plate Capscrews	28 (38)
Transmission-to-Clutch-Housing Capscrews	150 (203)
Clutch-Housing-to-Flywheel-Housing Capscrews	34 (46)
Fuel Cross-Over Line Mounting Bolts	95 (129)
Fuel Cross-Over Line Mounting Clamps	40 (54)
Fuel Tank Drain Plug	Finger-Tight + 1-1/2 turns
Driveline Parking Brake Cable Bracket Mounting Bolts	100 (136)
Speedometer Sensor Wiring Harness Clamp Mounting Capscrews (see Transmission Top Cover Capscrews)	—
Transmission Top Cover Capscrews	40 (54)
U-Joint End Cap Bolts	45 (61)
Driveline Parking Brake Stud Nuts	40 (54)
Midship Bearing Bracket Capscrews	95 (129)

Table 1, Tightening Torques

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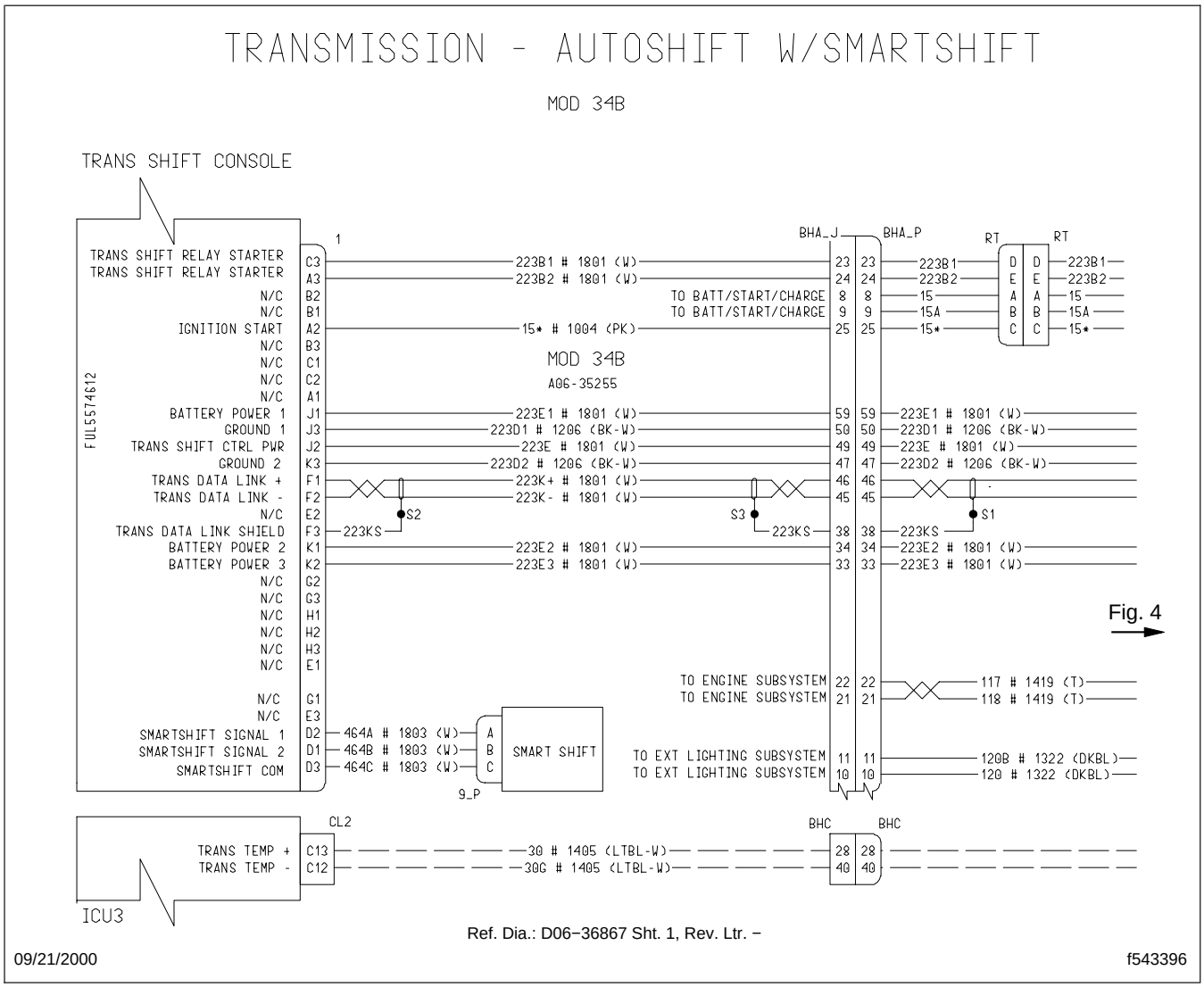


Fig. 3, AutoShift With SmartShift Wiring, Sheet 1 (partial view)

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Specifications

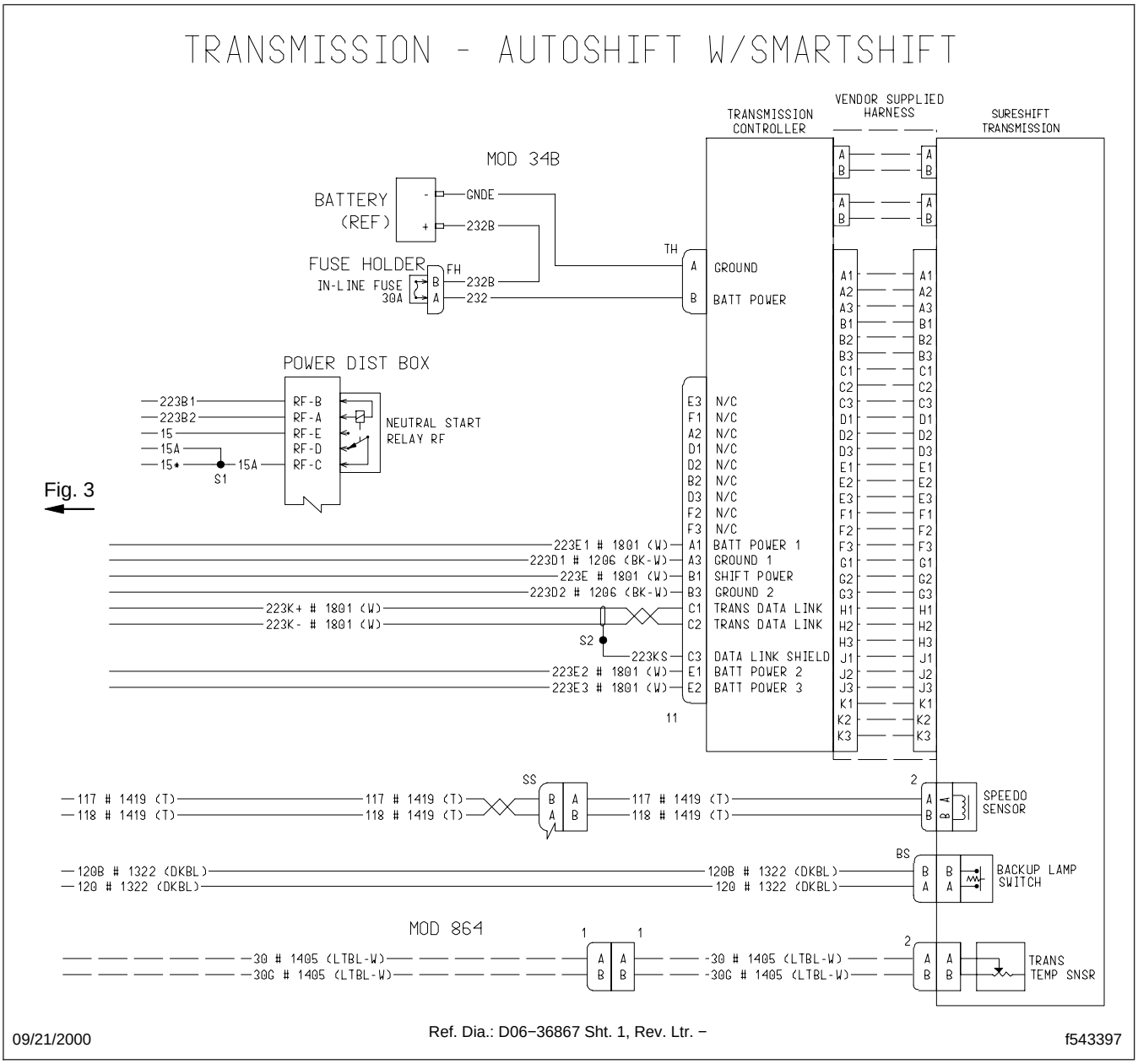


Fig. 4, AutoShift With SmartShift Wiring, Sheet 1 (partial view)

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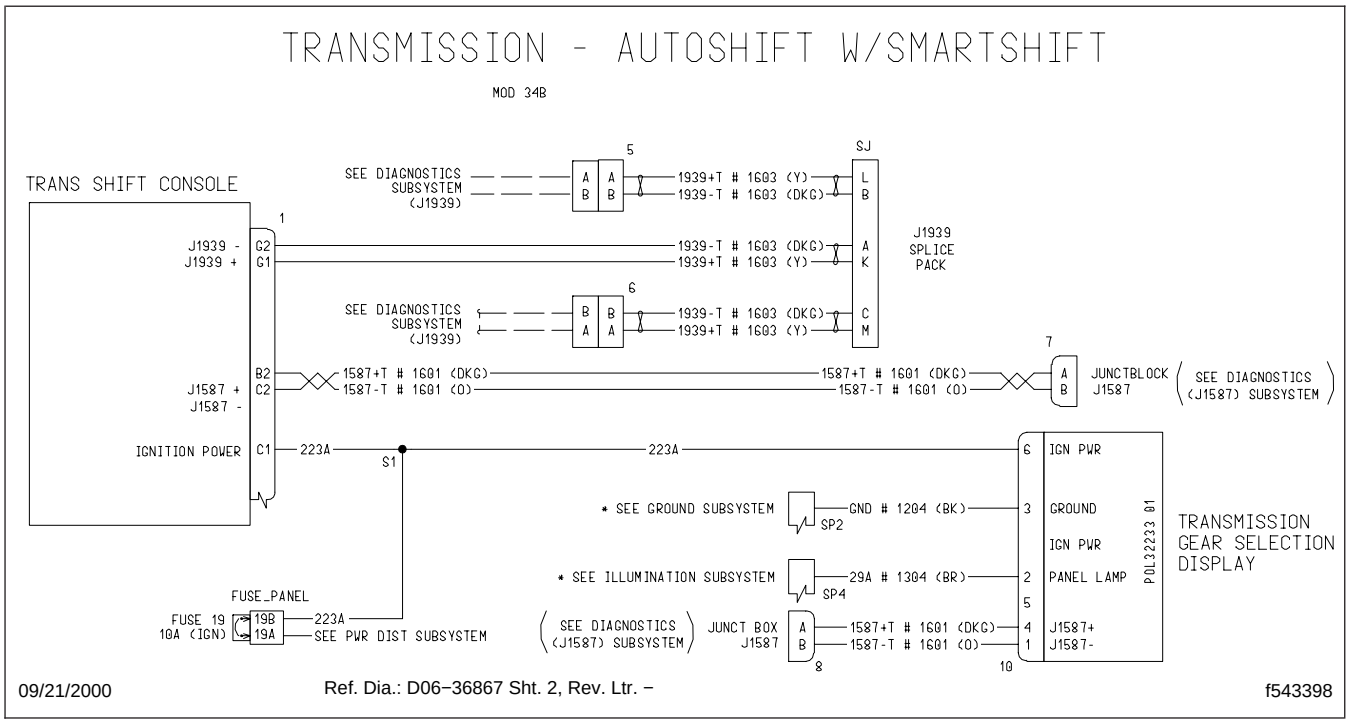


Fig. 5, AutoShift With SmartShift Wiring, Sheet 2 (full view)

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Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries.
3. Remove the transmission drain plug and drain the automatic transmission fluid (ATF). See **Fig. 1**. Install the drain plug and tighten it 18 to 24 lbf·ft (25 to 32 N·m).

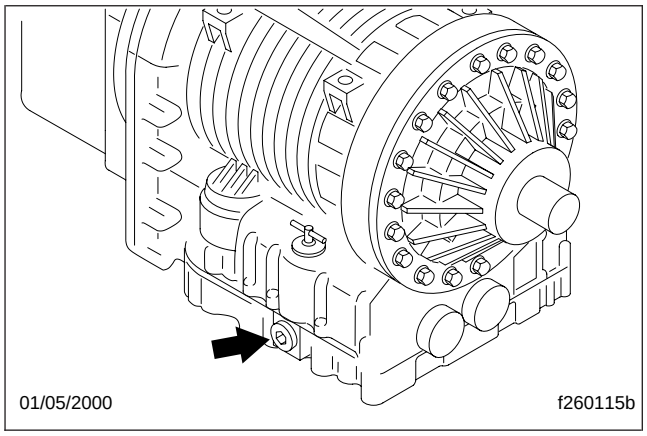


Fig. 1, Transmission Drain Plug

NOTE: The ATF drained from the transmission can be used again if it is clean and if the container into which it was drained contained no ethylene glycol.

4. Support the driveline with a jack stand between the transmission output yoke and the midship bearing.
5. Disconnect the driveline from the transmission.
   - 5.1 Loosen the bolts holding the midship bearing bracket so the driveshaft can slide to the rear. See **Fig. 2**.
   - 5.2 If the vehicle is equipped with a driveline parking brake, remove the nuts on the brake flange. See **Fig. 3**.

     If the vehicle is not equipped with a driveline parking brake, remove the transmission yoke U-joint end caps or lock straps.
   - 5.3 Slide the front of the driveshaft off the driveline brake flange or out of the transmission output yoke.

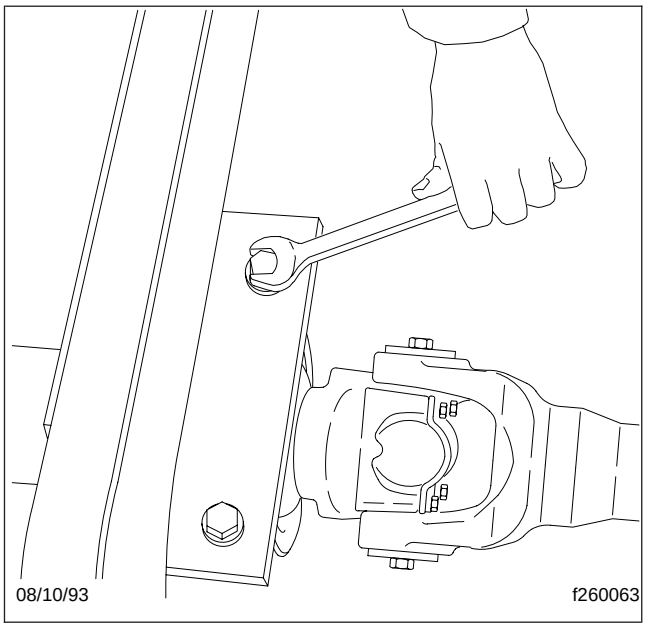


Fig. 2, Midship Bearing Bracket Bolts

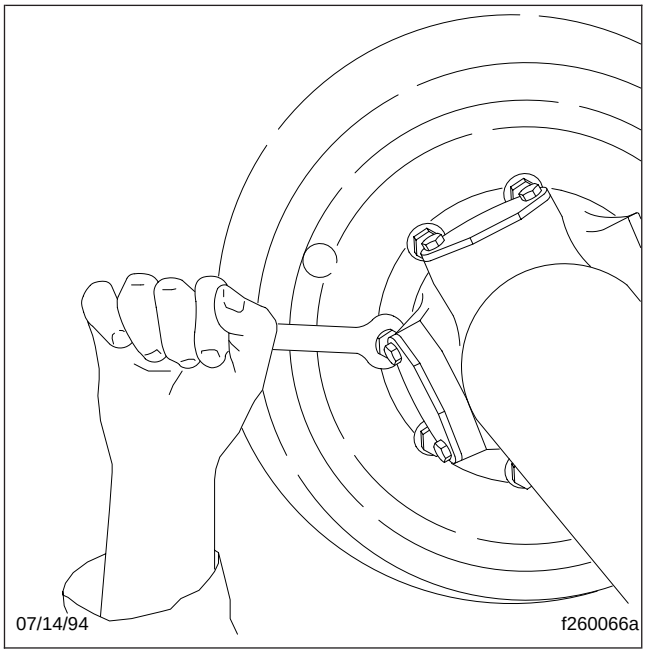


Fig. 3, Driveline Parking Brake Flange Nuts

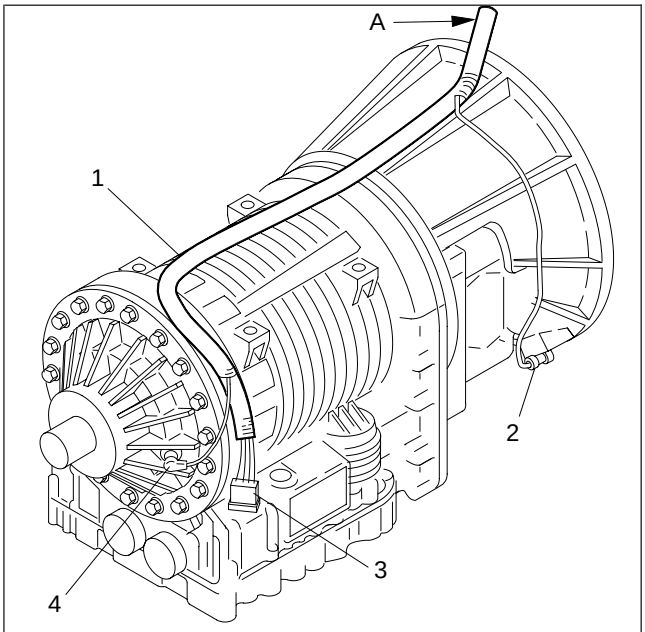
NOTE: It may be necessary to remove the mounting bolts from the midship bearing bracket so the driveshaft can be moved far enough back.

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Removal and Installation

5.4 Support the disconnected driveshaft and tie it to the frame rail.

6. Disconnect the three electrical connections to the transmission. See **Fig. 4**.



A. To bulkhead connector
1. Transmission Wiring Harness
2. Engine Speed Sensor
3. Transmission Control Connector
4. Output Speed Sensor

Fig. 4, Transmission Electrical Connections

7. If the vehicle is equipped with a driveline parking brake, release the parking brake, and remove the cotter pin holding the clevis to the driveline brake lever. See **Fig. 5**. Remove the flanged bolt and flanged nut holding the driveline brake cable bracket to the transmission. Remove the bracket.

8. Remove the ATF fill/dipstick tube. See **Fig. 6**.

8.1 Remove the U-bolt holding the fill/dipstick tube to its support bracket.

8.2 Remove the bolt and metal strap holding the fill/dipstick tube.

8.3 Pull the fill/dipstick tube out of the transmission case.

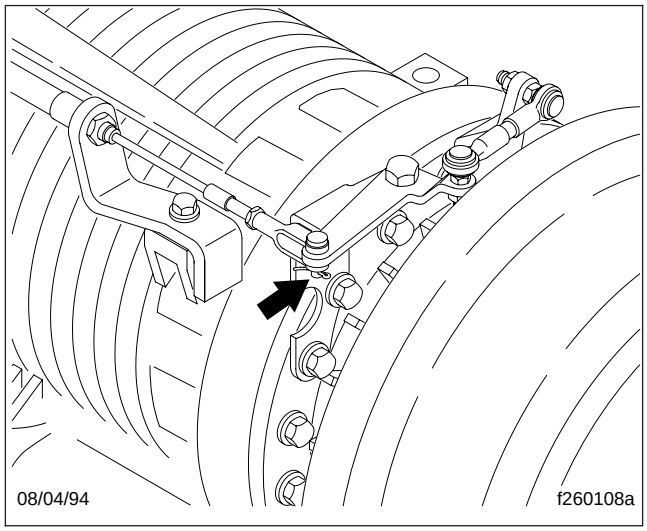


Fig. 5, Cotter Pin Holding Clevis to Driveline Brake Lever

8.4 Plug the hole with a clean rag to prevent entry of foreign material.

9. Disconnect the flexplate from the transmission.

9.1 Remove the capscrews holding the ring gear access cover. Remove the cover. See **Fig. 7**.

NOTE: For easier access on Mercedes-Benz engines, remove the three bolts holding the exhaust pipe to the turbocharger exhaust elbow. Lower the exhaust pipe.

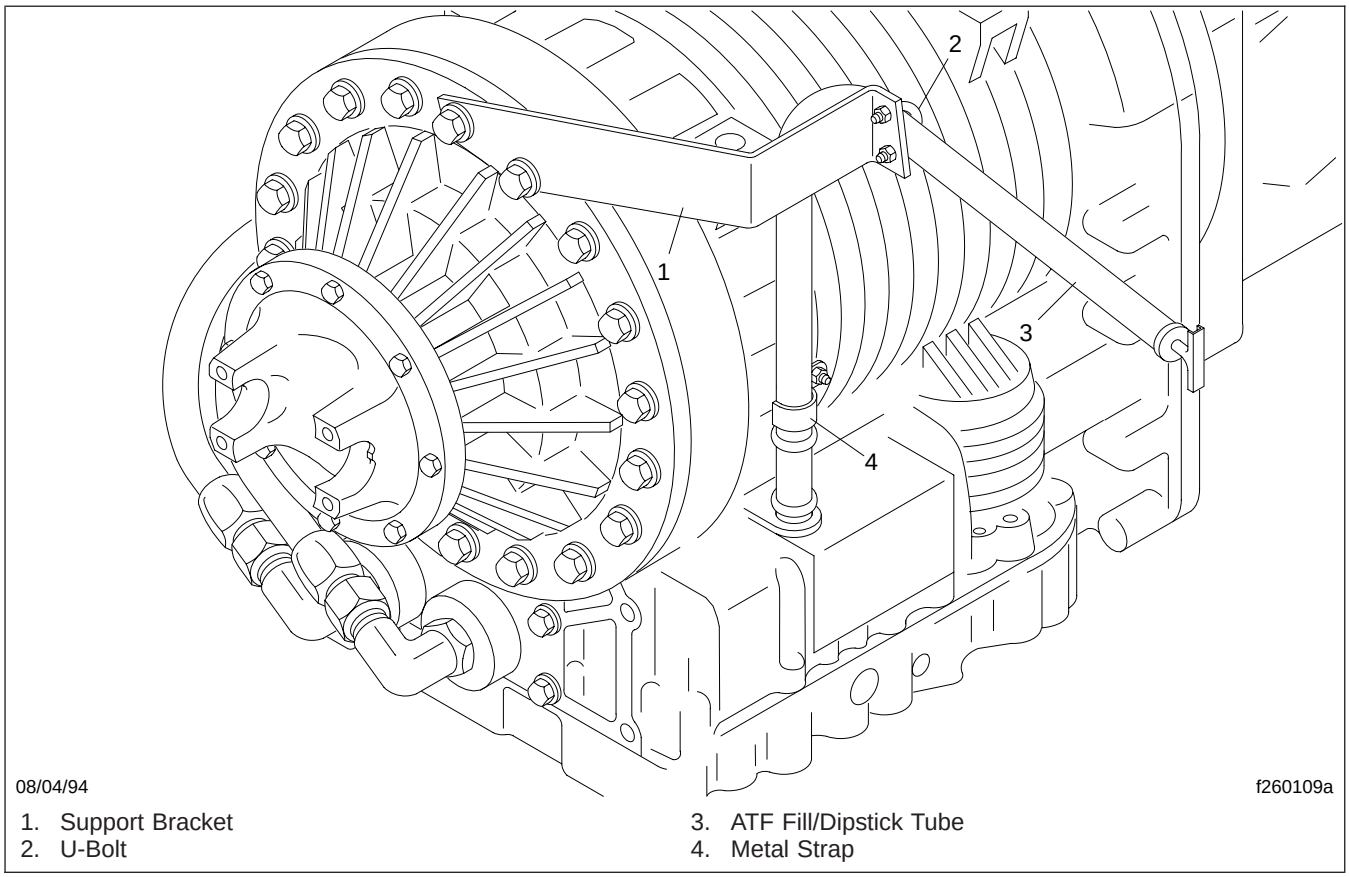
9.2 Using a screwdriver, turn the ring gear until one of the capscrews holding the flexplate adapter to the torque converter can be removed. Continue turning the ring gear and removing the capscrews through the access hole until all 12 are removed.

10. Remove the wiring harness and the air line from the standoff bracket on the right side of the transmission. See **Fig. 8**. Remove the standoff bracket.

11. Disconnect the transmission fluid cooler lines from the transmission and drain the remaining ATF. See **Fig. 9**.

12. Place a piece of plywood on a transmission jack to support the transmission.

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1. Support Bracket
2. U-Bolt
3. ATF Fill/Dipstick Tube
4. Metal Strap

Fig. 6, ATF Fill/Dipstick Tube and Supports

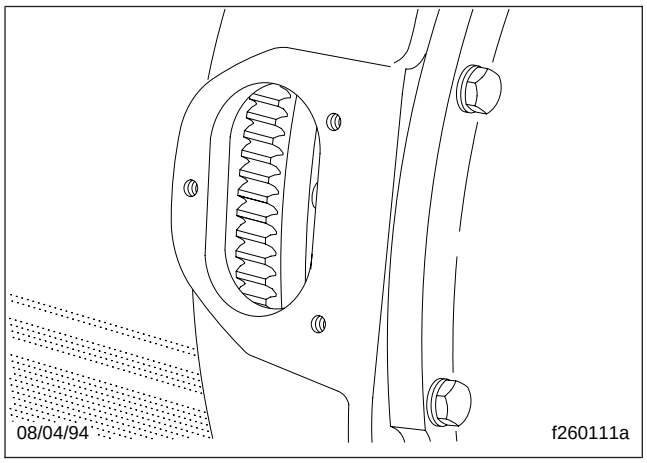
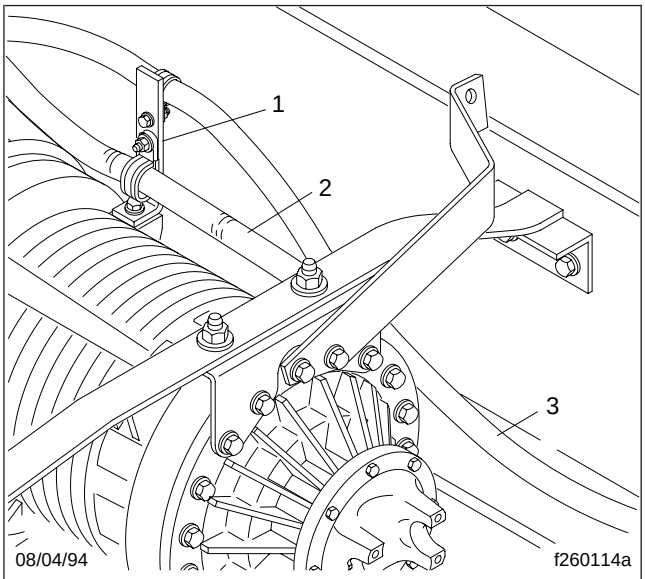


Fig. 7, Ring Gear Access Cover Capscrews

13. Slide the jack into place under the transmission. Secure the transmission with a chain. Anchor the chain with bolts at the front lifting bosses on the top of the transmission. See **Fig. 10**.
14. Remove the two bolts holding the transmission to the rear overslung transverse support spring. See **Fig. 11**.
15. Remove the 12 transmission flange bolts. See **Fig. 12**.
16. Move the transmission jack to the rear. Lower the jack and lift the front of the truck, as needed, so the transmission clears the frame rail and any attached components.
17. Place jack stands under the raised front of the vehicle.
18. Roll the transmission jack back and remove the transmission.

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Removal and Installation



1. Standoff Bracket
2. Wiring Harness
3. Air Line

Fig. 8, Wiring Harness, Air Line and Bracket

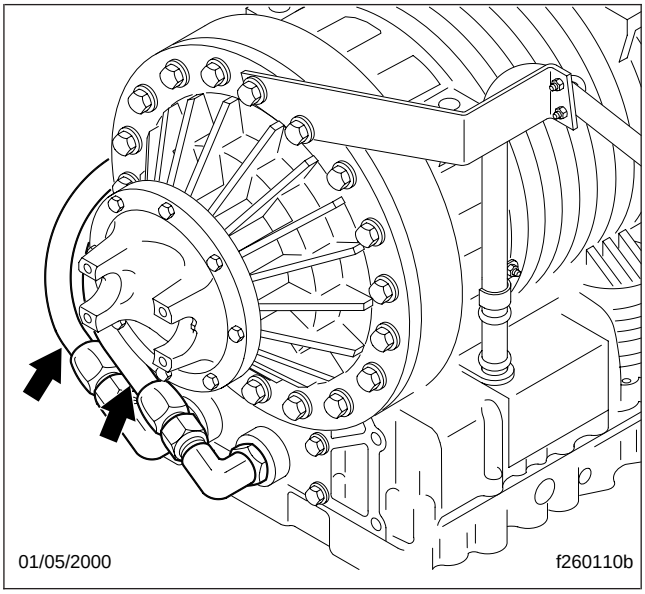


Fig. 9, ATF Cooler Hose Connections

Installation

IMPORTANT: Before installing the transmission, make sure the rear tires are chocked and the transmission is securely chained to the transmission jack.

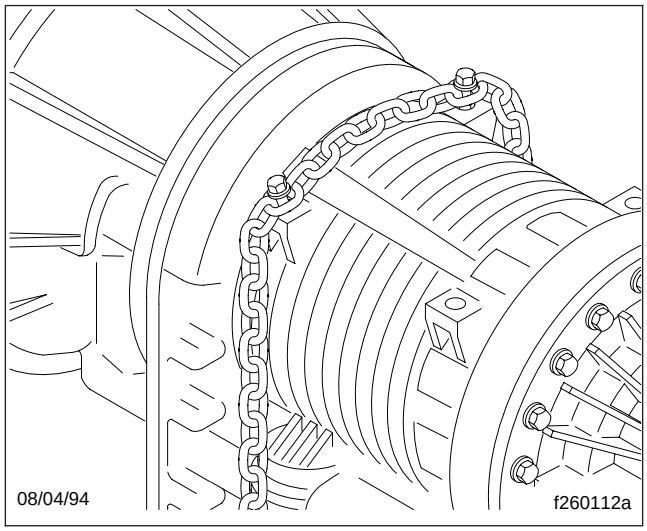


Fig. 10, Chain Around Transmission

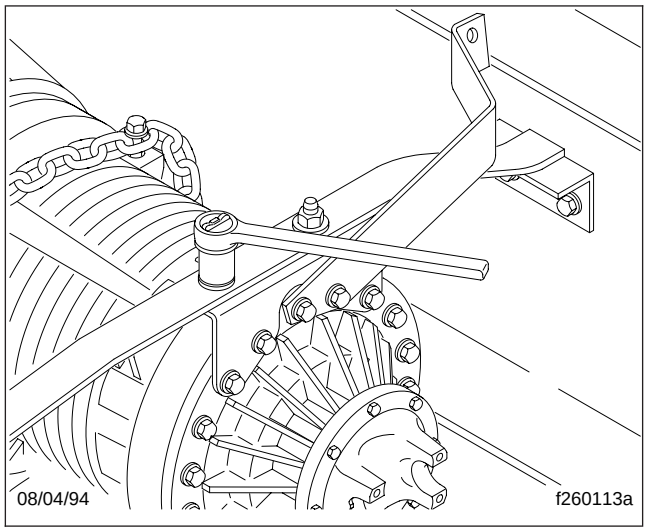


Fig. 11, Transverse Support Spring Bolts

1. Raise the front of the vehicle frame with a hydraulic jack to obtain adequate clearance for installing the transmission. Place jack stands under the front of the vehicle.
2. With the transmission on a jack, roll the transmission into place behind the flexplate. Remove the jack stands and lower the front of the vehicle frame.

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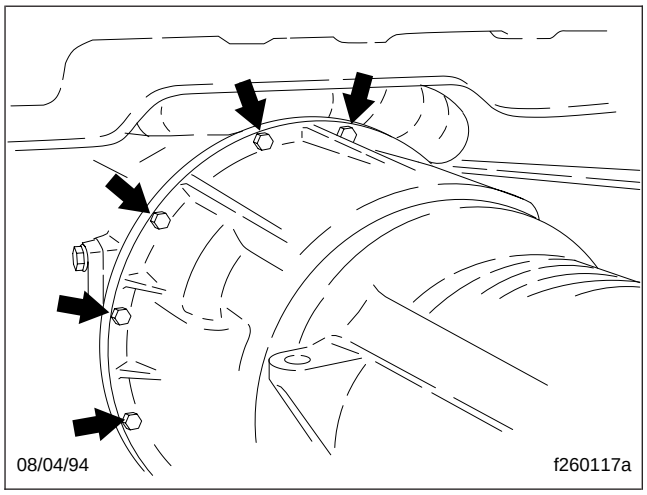


Fig. 12, Transmission Flange Bolts

3. Raise the jack until the transmission lines up with the flexplate.
4. Push the transmission toward the engine until it seats squarely against the engine flywheel housing with the bolt holes in the transmission housing aligned with those in the flywheel housing.

NOTE: No force is required. If interference is encountered, move the transmission away from the engine and correct the problem.

5. Install the transmission flange bolts finger-tight.
6. Install the transverse support spring at the rear of the transmission. Install the two bolts and washers. Tighten the bolts 136 lbf·ft (184 N·m). See **Fig. 11**.
7. Remove the chain holding the transmission to the transmission jack.
8. Lower the transmission jack and remove it.
9. Connect the transmission fluid cooler hoses to the transmission. Tighten the fittings 40 to 50 lbf·ft (54 to 68 N·m). See **Fig. 9**.
10. Install the 12 flexplate adapter capscrews.

    10.1 Turning the ring gear for access, install all the capscrews through the access hole. Do not tighten them now.

    Be careful not to drop the capscrews inside the torque converter cover. The transmission must be removed to get them out.

    IMPORTANT: Install all the capscrews before tightening any of them to prevent cocking of the flexplate adapter.

    10.2 Tighten the capscrews 18 to 21 lbf·ft (24 to 29 N·m) in a star pattern.

    10.3 Install the access cover and its capscrews. There are three capscrews on Mercedes-Benz engines, two on Cummins engines.

11. Tighten the 12 M10 transmission flange bolts 38 to 45 lbf·ft (51 to 61 N·m) in a star pattern. See **Fig. 12**.
12. If the vehicle is equipped with a driveline parking brake, mount the driveline brake cable bracket to the transmission. Install the two flanged bolts and flanged nuts, and tighten them 31 N·m (23 lbf·ft). Attach the clevis to the brake lever. Insert and lock the cotter pin. See **Fig. 5**.
13. Connect the driveshaft.

    13.1 Slide the front of the driveshaft into the transmission output yoke or onto the driveline parking brake flange, if so equipped.

    13.2 On vehicles without a driveline parking brake, install the transmission yoke U-joint end caps or lock straps.

    On vehicles with a driveline parking brake, slide the driveshaft flange onto the studs in the parking brake. Install the nuts and tighten them 40 lbf·ft (54 N·m).

    13.3 If the midship bearing bracket bolts and nuts were removed, install them. Tighten the nuts 95 lbf·ft (129 N·m).

14. On Mercedes-Benz engines, if the exhaust pipe was disconnected from the turbocharger exhaust elbow, connect the pipe and tighten the bolts 60 lbf·ft (81 N·m).
15. Install the ATF fill/dipstick tube.

    15.1 Install the fill/dipstick tube support bracket. Tighten the two capscrews 80 lbf·ft (108 N·m).

    15.2 Inspect the fill/dipstick tube seal. Replace it if damaged.

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Removal and Installation

15.3 Install the fill/dipstick tube and clamp. Tighten the capscrew 12 lbf·ft (16 N·m).

15.4 Install the U-bolt and nuts holding the fill/dipstick tube to the bracket. Tighten the U-bolt nuts 8 lbf·ft (11 N·m).

16. Install the standoff bracket on the right side of the transmission.

    Make sure the air line and the wiring harness are securely attached to the standoff bracket.

17. Fill the transmission with ATF.

18. Connect all electrical lines to the transmission.

    18.1 Connect the transmission control connector.

    18.2 Connect the electrical cable to the output speed sensor.

    18.3 Connect the cable to the engine speed sensor.

    18.4 Using tie straps, secure the cables where necessary.

19. Connect the batteries and remove the chocks from the tires.

20. Start the engine, and check for any leaks. Repair leaks as needed.

21. Check the ATF level. Add fluid as needed.

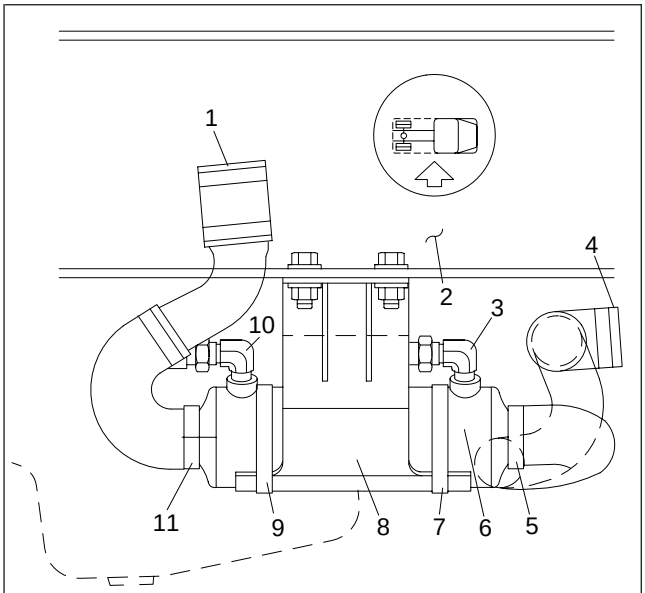
22. Remove the chocks from the tires.

23. Road test the vehicle, and check for correct transmission operation.

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Automatic Transmission Fluid (ATF) Cooler Removal and Installation

Removal (See Fig. 1 and Fig. 2)



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1. Coolant Return Hose
2. Frame Rail
3. ATF Supply Line
4. Coolant Supply Hose
5. Coolant Clamp
6. ATF Cooler
7. T-Bolt Clamp
8. ATF Cooler Mounting Bracket
9. T-Bolt Clamp
10. ATF Return Line
11. Coolant Clamp

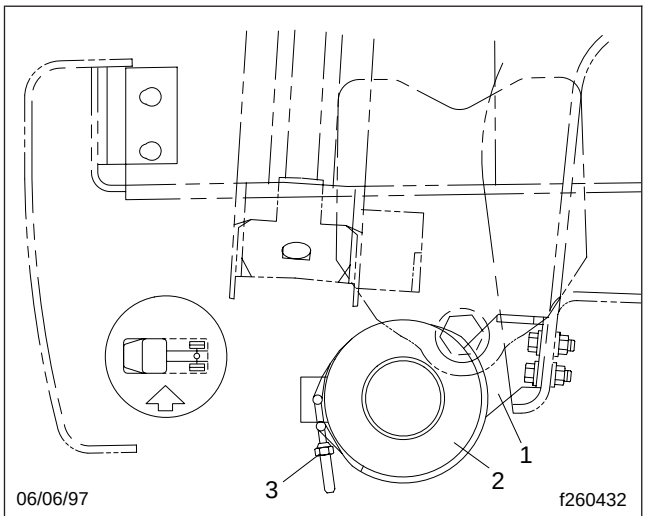
Fig. 1, ATF Cooler (frame mounted)

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.

⚠ WARNING

Drain the coolant system only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

2. With the engine cool, loosen the surge tank cap to release cooling system pressure.
3. Place a suitable container under the radiator. Open the drain petcock at the bottom of the radiator and drain the cooling system. Close the drain petcock.
4. Disconnect the coolant hoses from the fittings at both sides of the automatic transmission fluid (ATF) cooler. When the coolant stops draining, secure the ends of the hoses to prevent leakage.



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1. ATF Cooler Mounting Bracket
2. ATF Cooler
3. T-Bolt Clamp

Fig. 2, ATF Cooler (transverse mounted)

5. Disconnect the ATF hoses from the fittings at both sides of the ATF cooler. Catch the ATF by directing the disconnected end of each hose into a drain pan. When the ATF stops draining, plug the hoses and cap the fittings.
6. Remove the two hexnuts and washers that attach the ATF cooler to the T-bolt mounting bracket assembly, and remove the ATF cooler. Drain the ATF cooler into a drain pan.

Installation

1. Hold the ATF cooler in place. Install the hexnuts and washers on the T-bolt mounting bracket assembly. Tighten them 28 lbf·ft (38 N·m).
2. Attach the coolant hoses to the fittings at both sides of the ATF cooler, as removed.
3. Remove the plugs from the ATF hoses and the caps from the fittings. Attach the ATF hoses to the fittings at both sides of the ATF cooler. Tighten the fittings 40 to 50 lbf·ft (54 to 68 N·m).
4. Fill the coolant system and install the surge tank cap.

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Automatic Transmission Fluid (ATF) Cooler Removal and Installation

5. Start the engine and operate the transmission for one or two minutes, then add the correct ATF to the transmission as needed. For instructions and lubricant specifications, see Group 26 of the *Acterra Maintenance Manual*.
6. Run the engine until operating temperature is reached and check for leaks in the coolant system or ATF cooler. Repair leaks as needed.
7. Check the coolant level and add as needed.
8. Remove the chocks from the tires.

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Specifications

Fastener Torques	
Description	**Torque: lbf·ft (N·m)**
Transmission Drain Plug	18–24 (25–32)
ATF Cooler Hose Fittings	40–50 (54–68)
Flexplate Adapter Capscrews	18–21 (24–29)
Transmission Flange Bolts	38–45 (51–61)
Driveline Parking Brake Cable Bracket Mounting Nuts	23 (31)
Driveline Parking Brake Stud Nuts	40 (54)
Midship Bearing Bracket Nuts	95 (129)
Exhaust Pipe-to-Turbocharger Mounting Bolts	60 (81)
ATF Fill/Dipstick Tube Support Bracket Capscrews	80 (108)
ATF Fill/Dipstick Tube Clamp Capscrews	12 (16)
ATF Fill/Dipstick Tube-to-Bracket U-Bolt Nuts	8 (11)
ATF Cooler T-Bolt Nuts	28 (38)

Table 1, Fastener Torques

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General Information

The Mercedes-Benz transmission is offered in two 6-speed models:

- MBT520S-6D, direct drive, 520 lb·ft torque rating
- MBT660S-6O, overdrive, 660 lb·ft torque rating

The gear case holds 9.5 quarts (9.0 liters) of oil. MobilTrans SHC® DC is the approved oil.

Both models are fully synchronized for reduced shifting effort. Equipped with six forward speeds and one reverse speed, both models show a particularly large overall ratio between low and top gear. See **Specifications, 400** for gear ratios for each model.

To reduce fluid change intervals and to increase bearing life, M-B transmissions are designed with "clean" bearings. These bearings have covers on both sides. They cannot be damaged by the wear particles that accumulate in the fluid. The geometry of the gear teeth has been optimized to provide low-noise operation and extended gear life.

The bell housing has been designed around standard SAE bolt patterns. SAE2 is standard on both MBT660S-6O and MBT520S-6D models.

Other features of the M-B transmissions include:

- Light metal gear cases with integrated bell housings
- Low installation height (the shift interface is positioned laterally)
- Double synchronization from 1st gear to 4th gear
- Electronic vehicle speed sensor
- Longer oil change intervals
- Full range of PTO units available

Each model requires a hydraulic clutch system. No clutches with manual control can be installed for use on M-B transmissions. With the hydraulic system installed, the clutch linkage is self-adjusting.

The hydraulic clutch system consists of the following parts

- Hydraulic fluid reservoir
- Clutch pedal unit
- Master cylinder
- Slave cylinder
- Hydraulic lines connecting the various parts of the system

The teardown procedures included in this section also apply to the AGS automated transmission, with slight changes which are indicated at appropriate places in the procedures. If it is necessary to tear down the AGS transmission, be sure to remove the AGS assembly before proceeding. See **Section 26.03, Subject 200** for procedures.

On all transmissions, disassembly of the transmission main shaft is not recommended except when it is necessary to check for synchronizer wear. Disassembly of the countershaft is not recommended in any case.

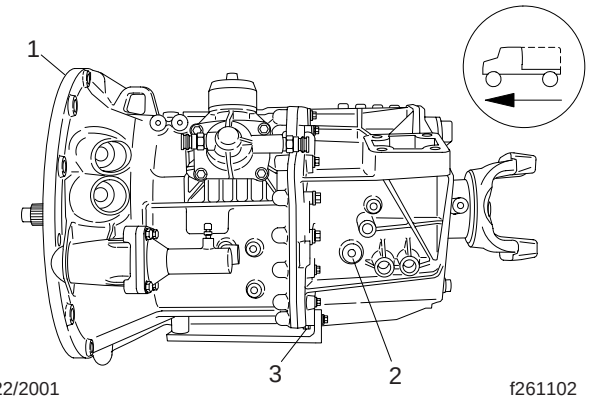
It is important to check main shaft end play if either gear case half, the main shaft bearings, or the input shaft is replaced. For detailed procedures, see **Subject 250**.

To prevent premature tool wear, use extreme pressure lubricant such as Kent-Moore J 23444-A or equivalent on tool threads and at all friction and contact points.

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Removal

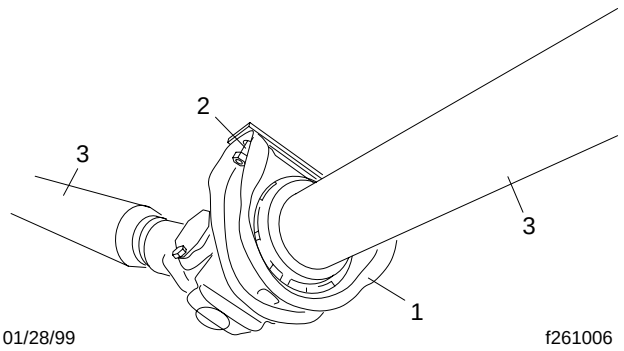
1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the rear tires.
2. Drain the transmission fluid. See **Fig. 1** for the location of the drain plug.



1. Transmission
2. Fill Plug
3. Drain Plug

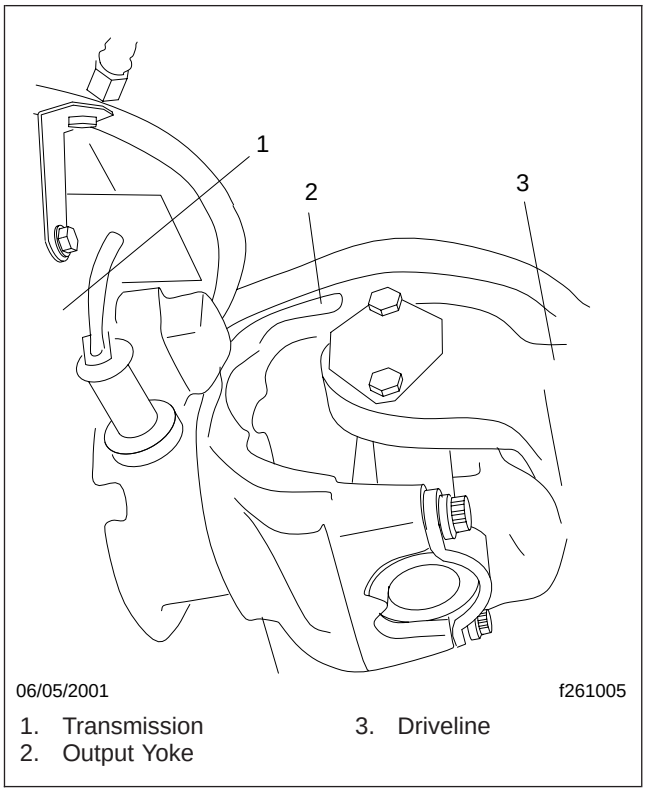
Fig. 1, Transmission Drain and Fill Plugs

3. Disconnect the driveshaft from the transmission, as follows.
   - 3.1 Support the midship bearing.
   - 3.2 Disconnect the front driveshaft from the midship bearing. See **Fig. 2**.
   - 3.3 Disconnect the midship bearing from the frame. Lower the midship bearing until it is fully supported.
   - 3.4 Remove the driveshaft from the midship bearing yoke and lower it to the ground.
   - 3.5 Remove the primary coupling shaft from the transmission output yoke. See **Fig. 3**.



1. Midship Bracket
2. Mounting Bolt
3. Driveline

Fig. 2, Midship Bearing Bracket



1. Transmission
2. Output Yoke
3. Driveline

Fig. 3, Transmission Output Yoke

4. Remove the shift lever from the transmission, as follows.
   - 4.1 Before removing the shift lever, place the transmission in high gear.
   - 4.2 Disconnect any electrical connector(s) necessary to remove the shift lever.
   - 4.3 Remove the seven screws that secure the carpet trim plate to the floor. See **Fig. 4**. Remove the trim plate and carpet.
   - 4.4 Remove the shift lever and boot from the shift linkage on the transmission. See **Fig. 5**.

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Removal and Installation

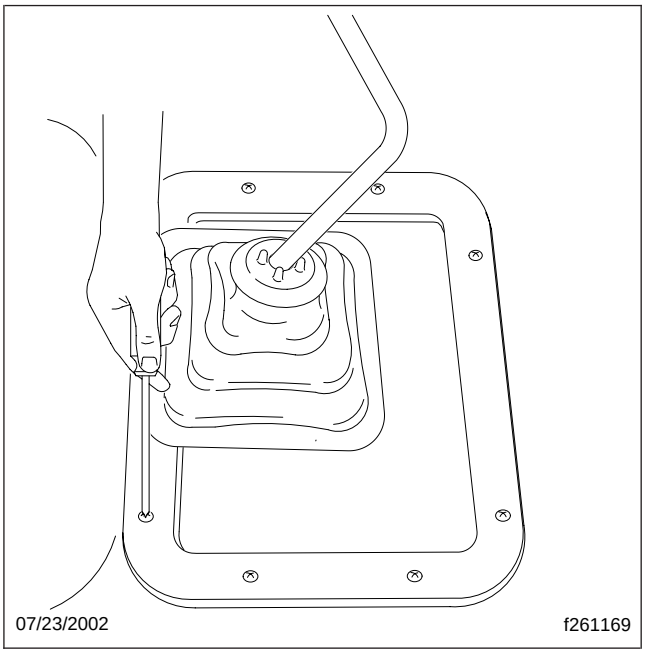
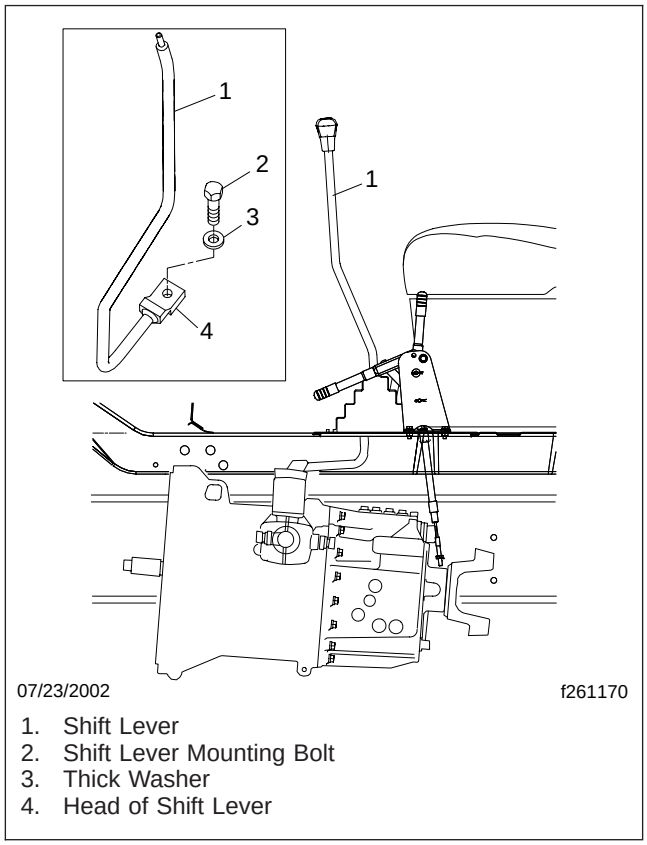


Fig. 4, Shift Lever and Boot

5. Remove the engine cover (doghouse) from the cab, as follows. See **Fig. 6**.
   - 5.1 Remove the passenger seat. See the proper section in **Group 91** for the type of seat installed.
   - 5.2 Release the two latches on the sides of the engine cover.
   - 5.3 Remove the two hold-down screws that secure the engine cover to the cab floor.
   - 5.4 Remove the engine cover and floor seal.
6. Remove the fuel lines and the fuel line standoff bracket from the transmission. See **Fig. 7**.
7. Disconnect the electrical connectors for the reverse gear switch and the optional starter lock switch (if installed). Mark with a paint pen for ease of installation.

⚠ WARNING

Do not press down on the clutch pedal after removing the slave cylinder. Hydraulic brake fluid may squirt out, causing personal injury and damage to the vehicle.

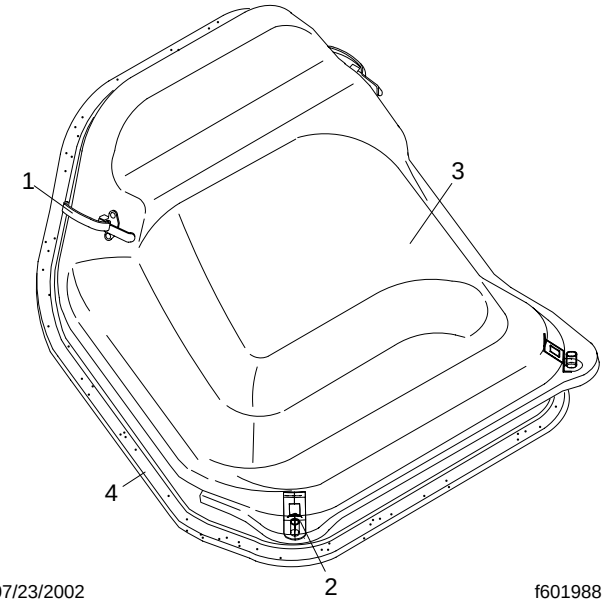


1. Shift Lever
2. Shift Lever Mounting Bolt
3. Thick Washer
4. Head of Shift Lever

Fig. 5, Shift Lever Connection

8. Remove the bolts that attach the clutch slave cylinder to the mounting flange on the gear case. Move the slave cylinder out of the way. See **Fig. 8**.
9. Bend back the nut retainers and remove the power takeoff unit (PTO), if installed. See **Fig. 9**.
10. If the vehicle is equipped with optional dual fuel tanks, remove the fuel crossover line and the compression brace between the tanks.
11. Disconnect the electrical cable from the speedometer sensor and mark it with a paint pen for ease of installation. See **Fig. 10**.
12. Remove the battery cable bracket(s) around the transmission and move the battery cables out of the way. See **Fig. 11**.
13. Remove the exhaust pipe and muffler or aftertreatment device from the vehicle. See **Group 49**. See **Fig. 12**.

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1. Latch
2. Hold-Down Screw
3. Engine Cover
4. Floor Seal

Fig. 6, Engine Cover (doghouse)

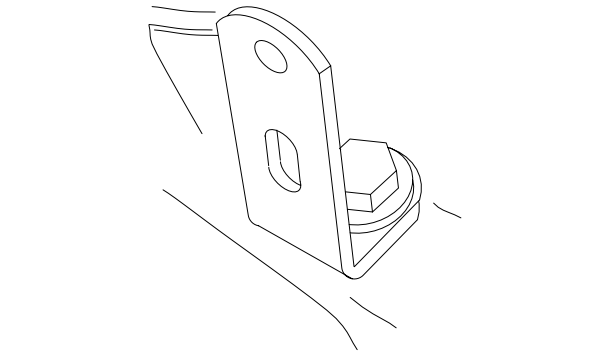
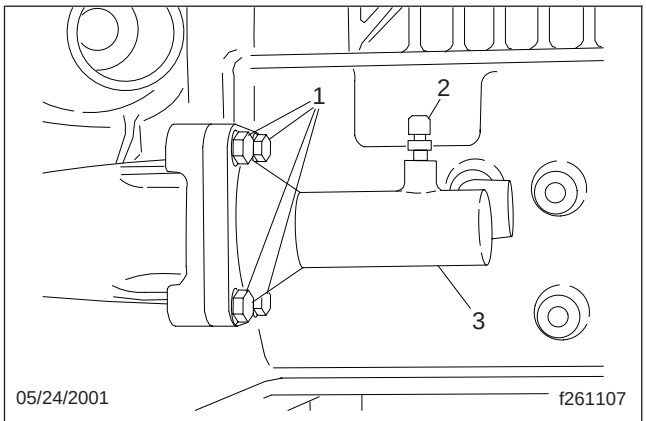


Fig. 7, Fuel Line Standoff Bracket

14. Support the transmission with a jack. See **Fig. 13**.

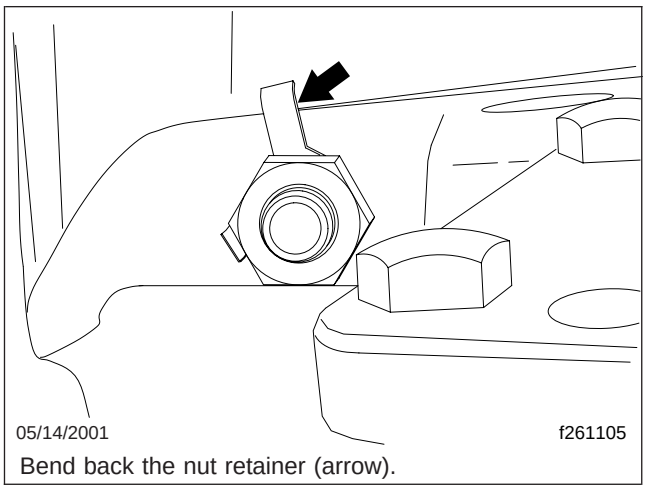
    14.1 Position a transmission jack under the transmission and raise its support plates against the base of the transmission.

    14.2 Adjust the support plates to cradle the transmission.



1. Mounting Bolts, M8
2. Bleed Valve
3. Slave Cylinder

Fig. 8, Hydraulic Clutch Slave Cylinder



Bend back the nut retainer (arrow).

Fig. 9, Power Take-Off Unit (PTO) Nut Retainers

    14.3 Using a chain, secure the transmission to the jack.

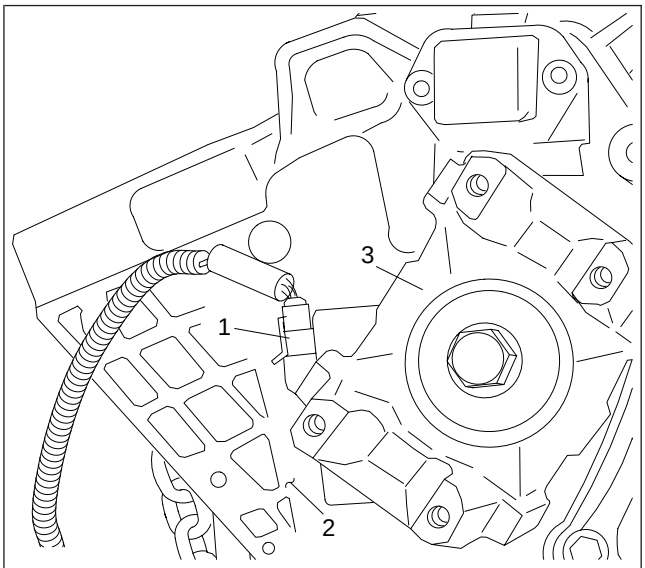
15. Remove the M10 x 1.5 capscrews that attach the timing case to the bell housing. After removing the transmission, insert the capscrews into the holes in the timing case for safekeeping. See **Fig. 14**.

⚠ CAUTION

Do not allow the rear of the transmission to drop, and do not allow the transmission to hang unsupported. Keep the flange of the bell housing parallel, all the way around, to the flange of the

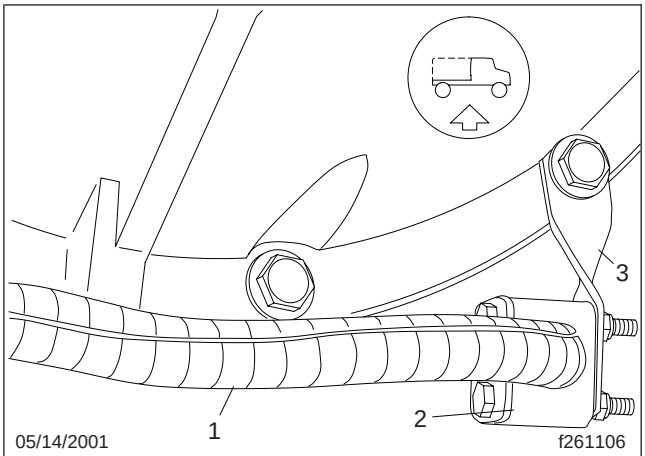
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Removal and Installation



1. Speedometer Sensor
2. Gear Case
3. Output Yoke

Fig. 10, Speedometer Sensor

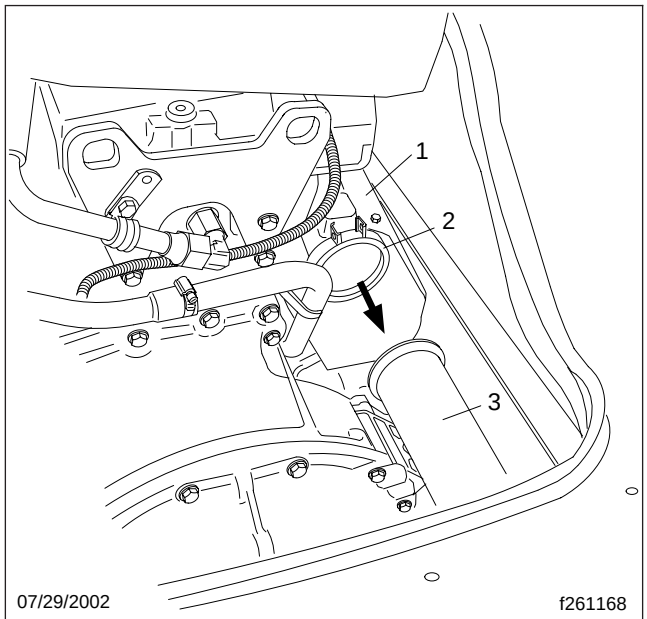


1. Battery Cable
2. Battery Cable Clamp
3. Battery Cable Bracket

Fig. 11, Battery Cable Routing

timing case, until the input shaft is clear of the flywheel. Taking these precautions will prevent damage to the input shaft, flywheel, and clutch.

16. Remove the transmission, as follows. See **Fig. 15**.



1. Heat Shield
2. Clamp
3. Exhaust Pipe

Fig. 12, Exhaust Pipe

16.1 Pull the transmission and jack straight back until the transmission input shaft is clear of the clutch.

16.2 Roll the transmission out from under the vehicle.

IMPORTANT: Watch closely the clearance between the bell housing and the leaf spring.

16.3 Pull the transmission out through the space behind the front wheel.

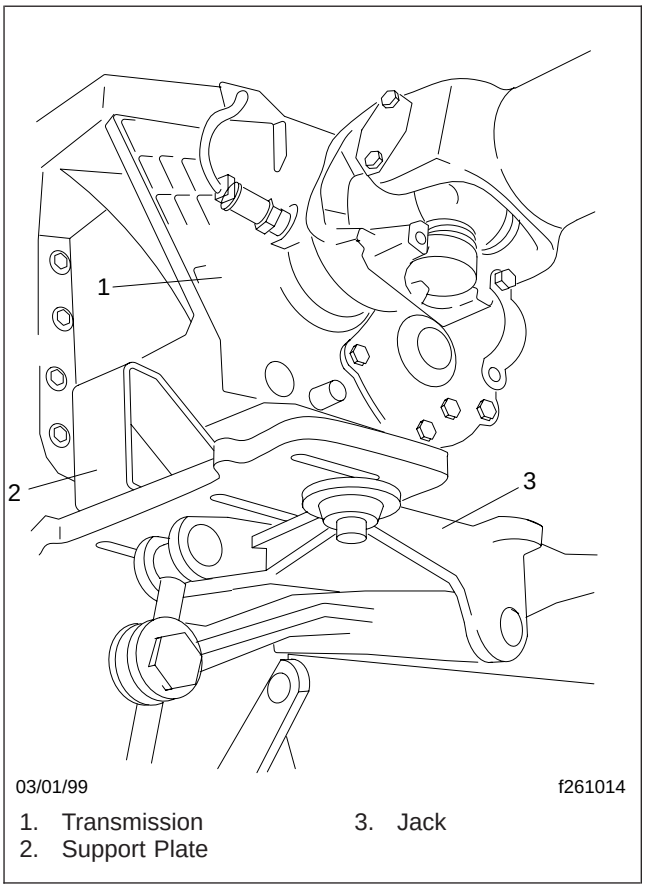
Installation

IMPORTANT: Before installing the transmission, make sure that the rear tires are chocked and that the transmission is securely chained to the support plates on the transmission jack.

1. Install the transmission, as follows.

1.1 Align the jack and the transmission behind the engine.

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1. Transmission
2. Support Plate
3. Jack

Fig. 13, Supporting the Transmission

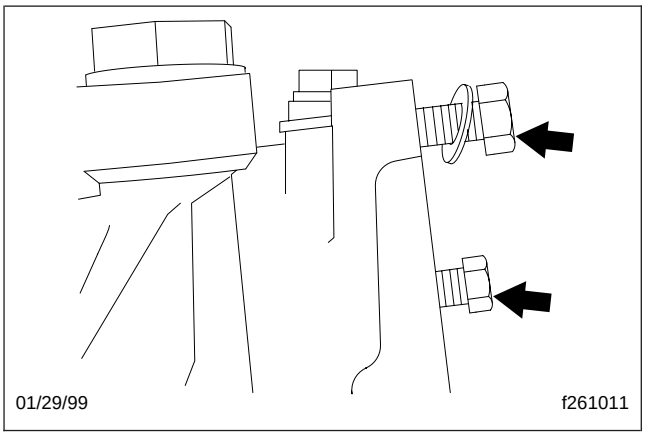


Fig. 14, Inserting the Capscrews in the Timing Case

1.2 Raise the transmission and adjust the angle of the jack until the bell housing and the timing case flange are parallel.

1.3 Push the transmission and jack straight forward, making sure the flanges remain parallel and the mating seals align with each other without overlap as shown in **Fig. 16**.

1.4 Install the eleven M10 capscrews that attach the bell housing to the timing case. Use a crossover pattern. Do a final tightening of the capscrews to 33 lbf·ft (45 N·m). While installing the bell housing-to-timing case capscrews, also install the battery cable bracket(s), as removed. See **Fig. 17**.

1.5 Remove the chain securing the transmission to the jack; then remove the jack.

2. Install the exhaust pipe and muffler or aftertreatment device, as removed.
3. If the vehicle is equipped with the optional dual fuel tanks, install the fuel crossover line and compression brace. Tighten the clamps 40 lbf·ft (54 N·m) and the mounting bolts 95 lbf·ft (129 N·m).
4. Install the PTO cover on the transmission. Tighten the M10 hardened mounting capscrews 43 lbf·ft (58 N·m). Bend back the tabs on the nut retainers.
5. Connect the driveshaft, as follows.

   5.1 Slide the front of the driveshaft into the transmission output yoke.

   5.2 Install the U-joint end caps on the output yoke. Tighten the nuts 50 lbf·ft (68 N·m) for 3/8-inch end cap bolts and 110 lbf·ft (149 N·m) for 1/2-inch end cap bolts.

   5.3 Install the bolts and nuts that attach the midship bearing bracket to the frame crossmember. Tighten the nuts 95 lbf·ft (129 N·m).

6. Install the fuel line standoff bracket and connect the fuel lines to the bracket.
7. Connect the electrical connectors. Connect the electrical cable to the speedometer sensor. Connect the electrical connector(s) to the shift lever, as removed.
8. Install the engine cover (doghouse) in the cab, as follows.

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Removal and Installation

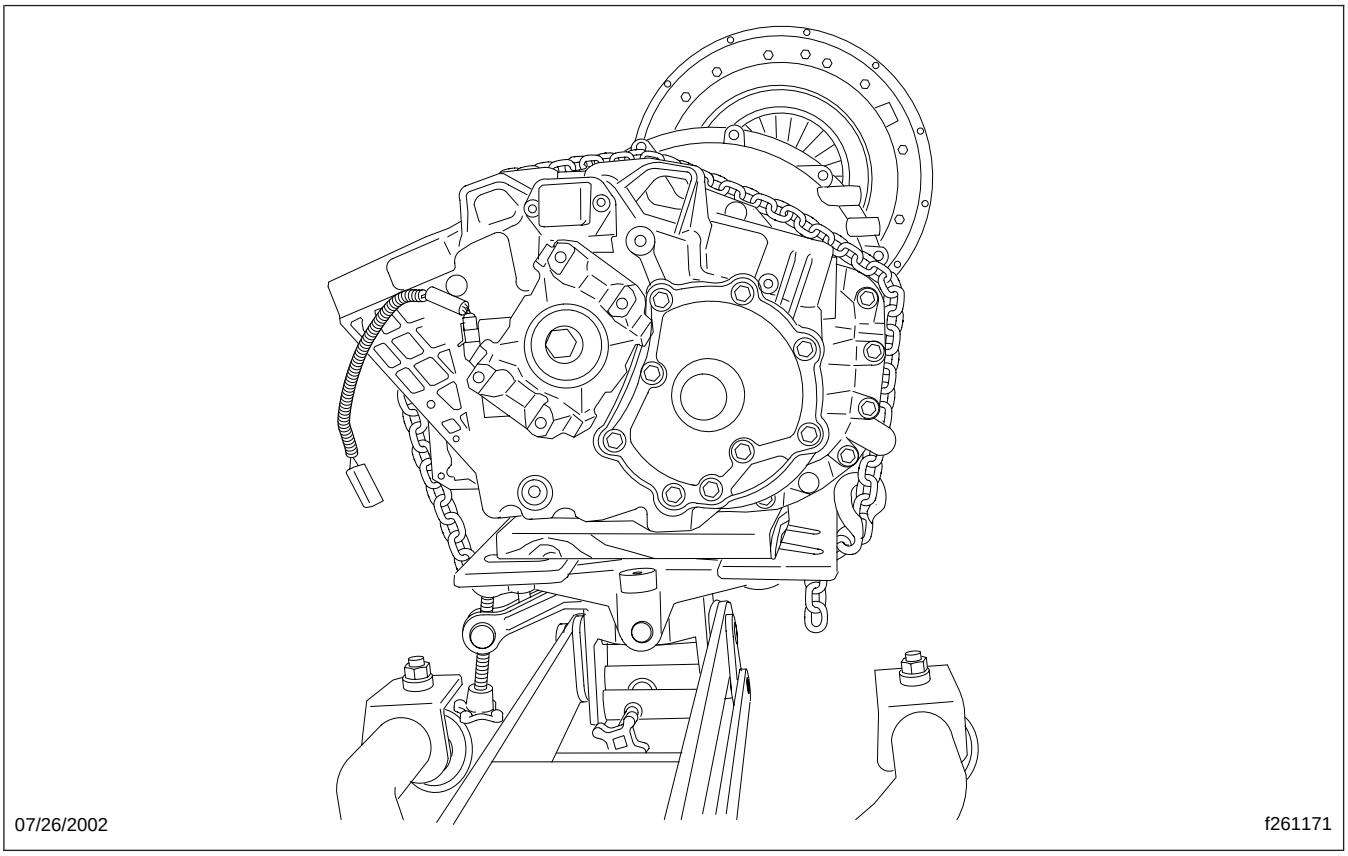


Fig. 15, Removed Transmission

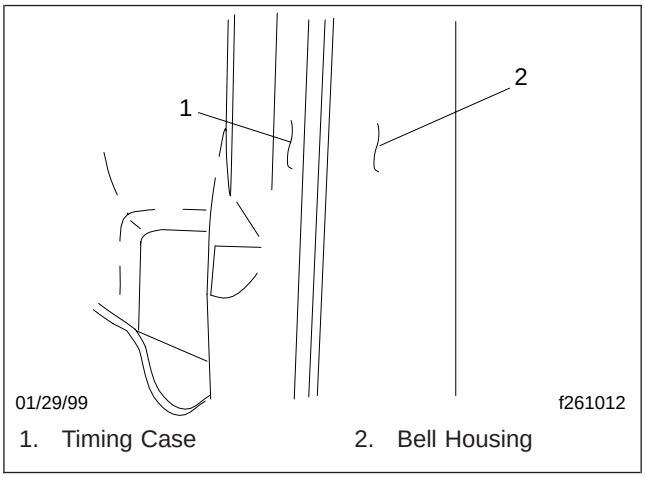


Fig. 16, Correct Seal Alignment

8.1 Position the engine cover with the floor seal in place on the cab floor, as removed.

8.2 Install the two hold-down screws that secure the engine cover to the cab floor and tighten them until firm.

8.3 Fasten the two latches on the sides of the engine cover.

8.4 Install the passenger seat. See the proper section in **Group 91** for the type of seat installed.

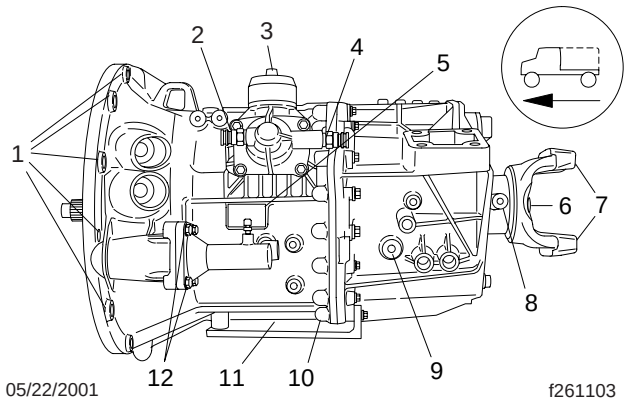
9. Install the shift lever, as follows.

9.1 Fit the shift lever over the cone of the transmission tower.

9.2 Insert the hardened M10 x 1.5 shift lever mounting bolt and a thick washer into the hole in the shift lever. See **Fig. 5**.

IMPORTANT: Don't forget to install the washer. Without the washer, the shift lever may loosen. The driver could lose control of the vehicle.

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1. Bell Housing-to-Timing Case Capscrews
2. Reverse Gear Switch
3. Shift Lever Mounting Bolt
4. Starter Lock Switch
5. Nameplate
6. Output-Yoke Pressure Plate Capscrew
7. U-Joint End Cap Bolts
8. Speedometer Sensor Lock
9. Transmission Fluid Fill Plug
10. Transmission Fluid Drain Plug
11. PTO Mounting Capscrews
12. Clutch Slave Cylinder Mounting Bolts

Fig. 17, Transmission Fasteners

9.3 Tighten the M10 bolt 50 lbf·ft (68 N·m).

9.4 Install the rubber boot, carpet, and carpet trim plate. Install the seven screws and tighten the carpet trim plate against the cab floor 28 lbf·ft (38 N·m). See **Fig. 4**.

10. Fasten the clutch slave cylinder to the mounting flange and tighten the four M8 mounting bolts 15 lbf·ft (20 N·m).
11. Bleed the hydraulic clutch system. For detailed instructions, see **Section 25.02, Subject 140**.
12. Clean the transmission drain plug and install it on the transmission, along with a new aluminum gasket. Tighten the drain plug 42 lbf·ft (57 N·m).
13. Add transmission fluid until it is level with the lower edge of the fill opening. See **Fig. 1** for the location of the fill plug and **Fig. 18** for the correct level. See **Group 26** of the *Acterra® Maintenance Manual* for approved transmission lubricants and lubricant capacities.

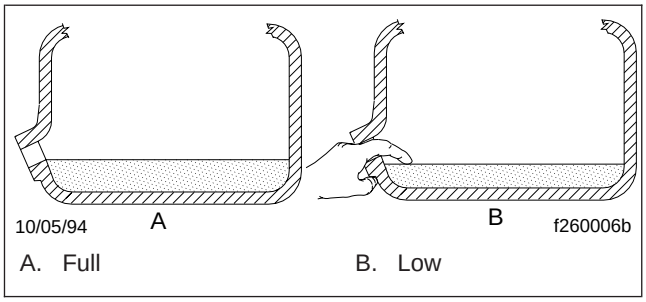


Fig. 18, Transmission Fluid Level Checking

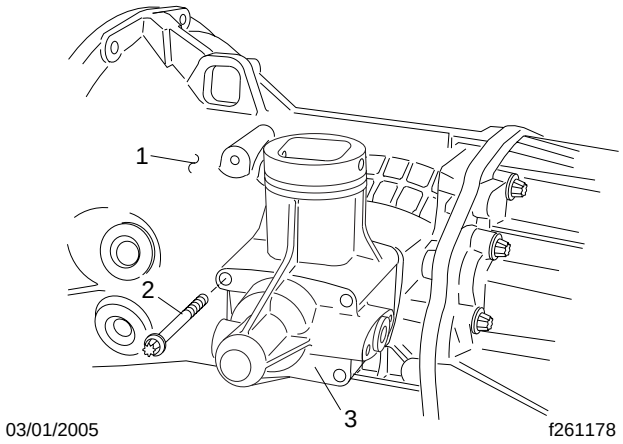
14. Clean the transmission fill plug and install it in the transmission, along with a new aluminum gasket. Tighten the fill plug 42 lbf·ft (57 N·m).
15. Remove the chocks from the rear tires.

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NOTE: These procedures are for the manual transmission with shift lever only. For the automated AGS transmission, see **Section 26.03, Subject 200**.

Removal

1. Remove the transmission; for detailed procedures, see **Subject 100**.
2. Secure the transmission on a wooden pallet, or other device to keep it from moving.
3. Make sure the transmission is in neutral.
4. Remove the four capscrews that attach the shift rod housing to the flange on the front gear case. See **Fig. 1**.



1. Front Gear Case
2. Shift Rod Housing Capscrew
3. Shift Rod Housing

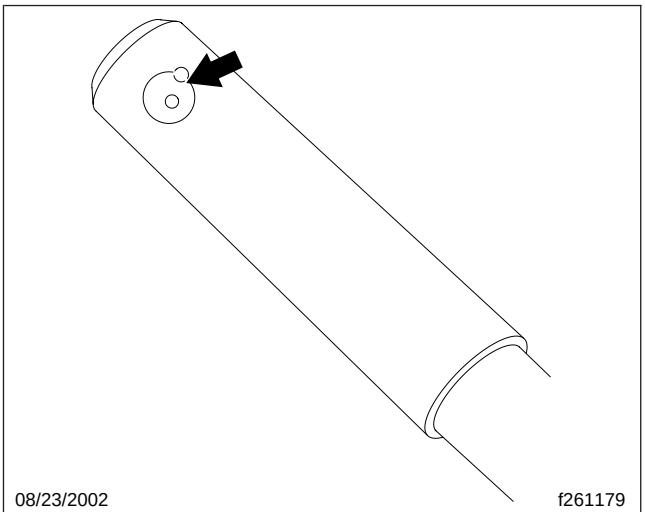
Fig. 1, Shift Mechanism

5. Remove the shift rod from the front gear case, as follows.
   - 5.1 From the right-hand side of the transmission, remove the setscrew that holds the end of the shift rod. Discard the old setscrew.
   - 5.2 Remove and discard the shift rod cover from the right-hand side of the gear case.
   - 5.3 Pull the shift rod all the way out of the gear case.

Installation

NOTE: See the installation procedure in **Section 26.03, Subject 200** for more information on the proper alignment of the shift finger in the shift rod.

1. Make sure that the indent in the shift rod end (shown by the arrow in **Fig. 2**) is facing aft for proper engagement with the setscrew.
2. Insert the shift rod into the front gear case. Then turn the shift rod until the dimple is at the 9 o'clock position.
3. Install the shift rod housing on the front gear case, as follows.
   - 3.1 Push the housing in until the indent in the rod end is showing in the setscrew hole.
   - 3.2 Coat the threads of a new setscrew with Loctite® 242 or equivalent thread-locking compound. Insert the new setscrew and tighten it 30 lbf·ft (40 N·m). See **Fig. 3**.
   - 3.3 Install a new shift rod cover in the shift cover housing.
   - 3.4 Position the shift rod housing over the flange in the front gear case. Coat the mating surfaces with a bead of Loctite 509 or equivalent sealing compound.



Indent must face aft as shift rod is installed.

Fig. 2, Shift Rod End

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Shift Mechanism Removal and Installation

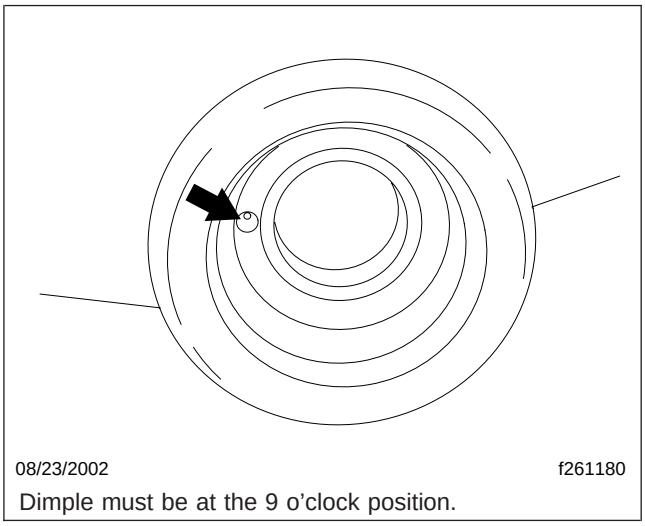


Fig. 3, Shift Mechanism Setscrew

3.5 Install the four capscrews that attach the shift rod housing to the front gear case. Coat the threads of the two lower capscrews with Loctite 242 or equivalent thread-locking compound. Tighten all four capscrews 18 lbf·ft (25 N·m).

4. Install the transmission; for detailed procedures, see **Subject 100**.

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Special Tools

A special tool is required for this procedure. See **Table 1**.

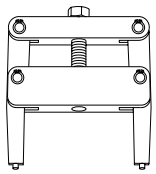
Special Tool for Input Shaft Removal			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580393	Snap Ring Removal Tool	Kent-Moore	J-46730

Table 1, Special Tool for Input Shaft Removal

Removal

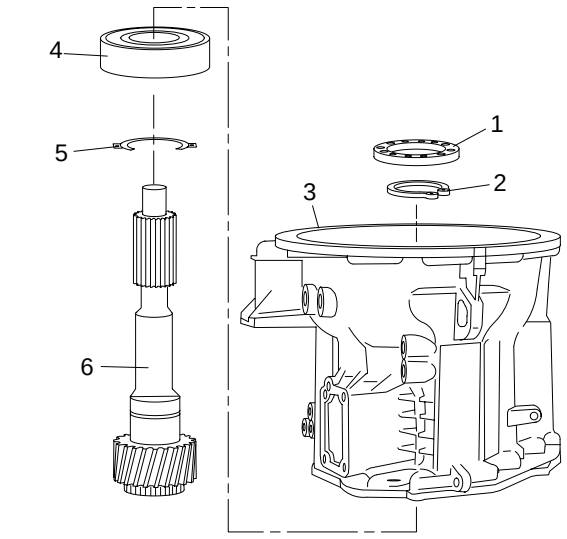
1. With the transmission removed from the vehicle and secured to keep it from moving, remove the shift mechanism. For instructions, see **Subject 110**.
2. Remove the front gear case; for instructions, see **Subject 150**.
3. Remove the input shaft radial seal; for instructions, see **Subject 130**.
4. Remove and discard the upper snap ring underneath the radial seal. See **Fig. 1**.
5. Press the input shaft out of the front gear case.
6. Using the snap ring removal tool, remove and discard the half-round snap ring under the deep-groove ball bearing. See **Table 1** for tool information and **Fig. 2** for tool use.
7. Press the deep-groove ball bearing out of the front gear case.

Installation

1. Heat the front gear case in the area of the bearing seat to 176°F (80°C).

IMPORTANT: Press only on the outer race of the deep-groove ball bearing.

2. When the gear case is properly heated, install the deep-groove ball bearing into its seat. Install a new half-round snap ring.



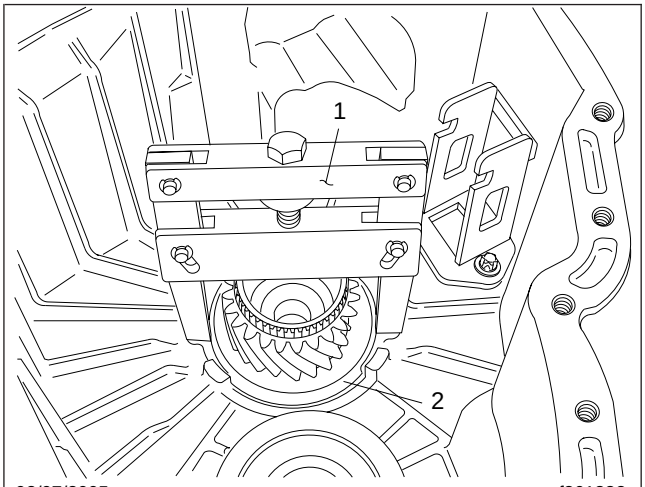
1. Input Shaft Radial Seal
2. Upper Snap Ring
3. Front Gear Case
4. Deep-Groove Ball Bearing
5. Half-Round Snap Ring
6. Input Shaft

Fig. 1, Input Shaft Assembly

3. Using a feeler gauge, measure the gap between the deep-groove ball bearing and the half-round snap ring. This measurement should not be more than 0.0003 inch (0.007 mm).
4. Heat the deep-groove ball bearing 176°F (80°C).

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Input Shaft Removal and Installation



1. Snap Ring Removal Tool
2. Half-Round Snap Ring

Fig. 2, Half-Round Snap Ring Removal

5. When the bearing is properly heated, install the input shaft into the seat in the front gear case. Install a new upper snap ring.
6. Using a feeler gauge, measure the gap between the deep-groove ball bearing and the upper snap ring. This measurement should not be more than 0.0003 inch (0.007 mm).
7. Check main shaft end play; for procedures, see **Subject 250**.
8. Install the input shaft radial seal; for instructions, see **Subject 130**.
9. Install the front gear case; for instructions, see **Subject 150**.
10. Install the shift mechanism; for instructions, see **Subject 110**.

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Input Shaft Radial Seal Replacement

Special Tools

A special tool is required for this procedure. See **Table 1**.

Special Tool for Input Shaft Radial Seal Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580401	Input Shaft Seal Installer	Kent-Moore	J-47901

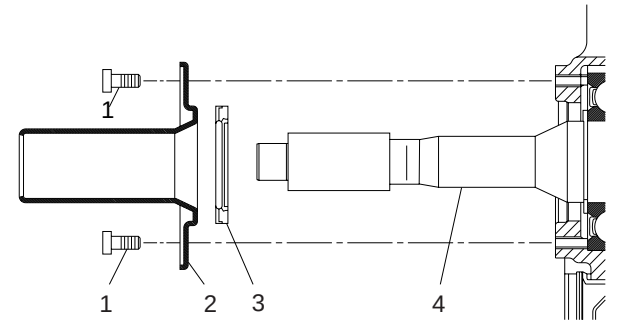
Table 1, Special Tool for Input Shaft Radial Seal Replacement

Replacement

1. Remove the transmission; for detailed procedures, see **Subject 100**.
2. Secure the transmission on a wooden pallet, or other device to keep it from moving.
3. Remove the release fork and release bearing.

NOTE: On AGS transmissions, remove the clutch actuator. For procedures, see **Section 26.03, Subject 120**.

4. Remove the guide tube from the transmission case. Discard the mounting bolts. See **Fig. 1**.
5. Remove the radial seal from the input shaft. Discard the old radial seal.



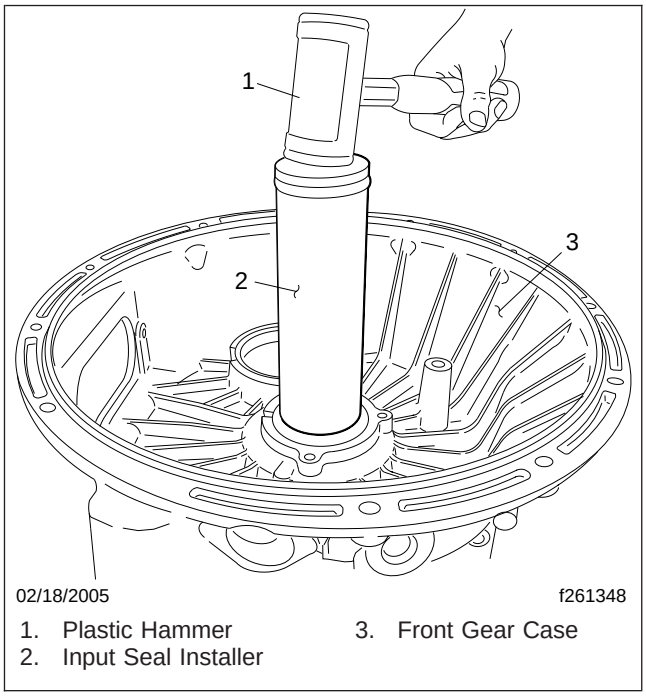
1. Guide Tube Mounting Capscrew
2. Guide Tube
3. Radial Seal
4. Input Shaft

Fig. 1, Input Shaft Radial Seal Replacement

CAUTION

To prevent damage, make sure that the new radial seal is not installed on the race of the old seal.

6. Using the input shaft seal installer, install a new radial seal on the input shaft. See **Table 1** for tool information and **Fig. 2** for tool use.



1. Plastic Hammer
2. Input Seal Installer
3. Front Gear Case

Fig. 2, Installing the Input Shaft Radial Seal

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Input Shaft Radial Seal Replacement

7. Install the guide tube on the transmission case. Use new M8 x 18 low-profile guide tube mounting capscrews. Tighten the capscrews 17 lbf·ft (23 N·m).
8. Install the release fork and release bearing. Tighten the release fork mounting capscrews 26 lbf·ft (36 N·m).
9. Install the transmission; for detailed procedures, see **Subject 100**.

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Special Tools

Special tools are required for this procedure. See **Table 1**.

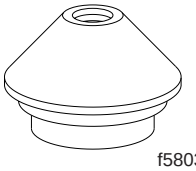
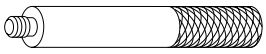
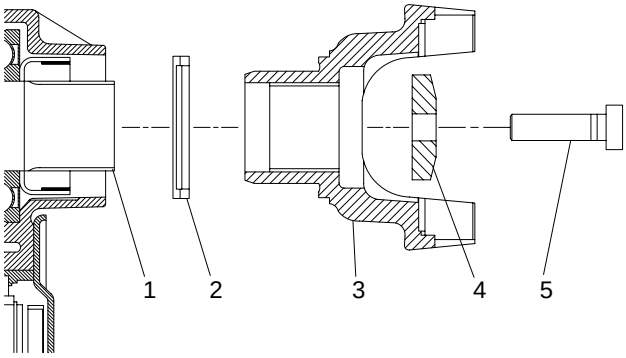
Special Tools for Output Shaft Radial Seal Installation			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580398	Output Shaft Seal Installer	Kent-Moore	J-47863
 f580400	Universal Handle	Kent-Moore	J-8901

Table 1, Special Tools for Output Shaft Radial Seal Installation

Replacement

1. Secure the output yoke so that it cannot turn the output shaft.
2. Remove the pressure plate capscrew. Remove the pressure plate. See **Fig. 1**.



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1. Output Shaft
2. Radial Seal
3. Output Yoke
4. Pressure Plate
5. Pressure Plate Capscrew

Fig. 1, Output Yoke Assembly

3. Remove the output yoke. Use a suitable extractor tool.
4. Remove and discard the output shaft radial seal.
5. Assemble the output shaft seal installer onto the threaded end of the universal handle. See **Table 1**.

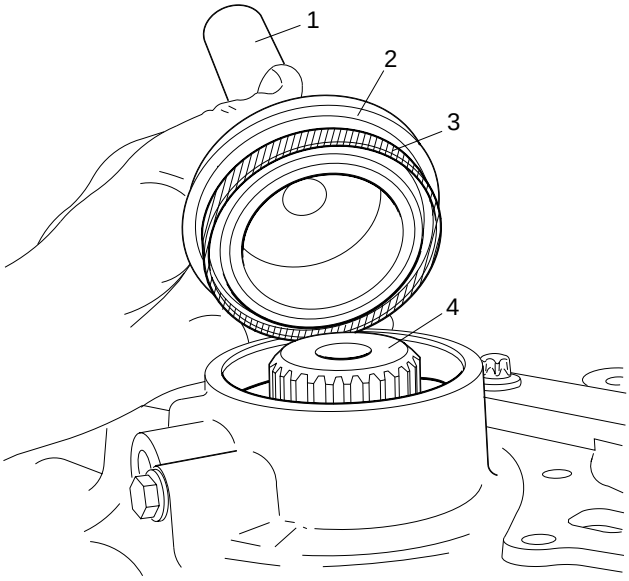
⚠ CAUTION

To prevent damage, make sure that the new radial seal is not installed on the race of the old seal.

6. Using the output shaft seal installer assembly, install a new radial seal on the output shaft. See **Fig. 2**.
7. If the output yoke cannot be pressed on cold, preheat the output yoke to 176°F (80°C) and try again.
8. Position the pressure plate on the output shaft. Secure it to the shaft using the pressure plate capscrew. Tighten the M16 capscrew 190 lbf·ft (258 N·m).

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Output Shaft Radial Seal Replacement



1. Universal Handle
2. Seal Installer
3. Radial Seal
4. Output Shaft

Fig. 2, Output Shaft Radial Seal Ready to Install

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Special Tools

Special tools are required for these procedures. See **Table 1**.

To prevent premature tool wear, use extreme pressure lubricant such as Kent-Moore J 23444-A or equivalent on tool threads and at all friction and contact points.

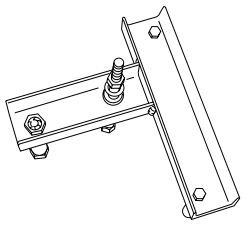
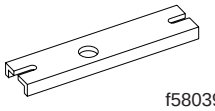
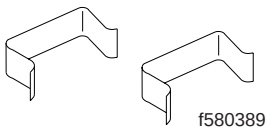
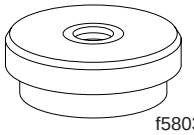
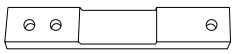
Special Tools for Front Gear Case Removal and nstallation			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580397	Rear Case Puller/Installer/Stand	Kent-Moore	J-46739
 f580390	Front Gear Case Bridge	Kent-Moore	J-46727
 f580389	Synchro Retainer Clips	Kent-Moore	J-46726
 f580399	Countershaft Seal Cover Installer	Kent-Moore	J-47901
 f580400	Universal Handle	Kent-Moore	J-8901
 f580396	Countershaft Retainer	Kent-Moore	J-46733

Table 1, Special Tools for Front Gear Case Removal and Installation

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Front Gear Case Removal and Installation

Removal

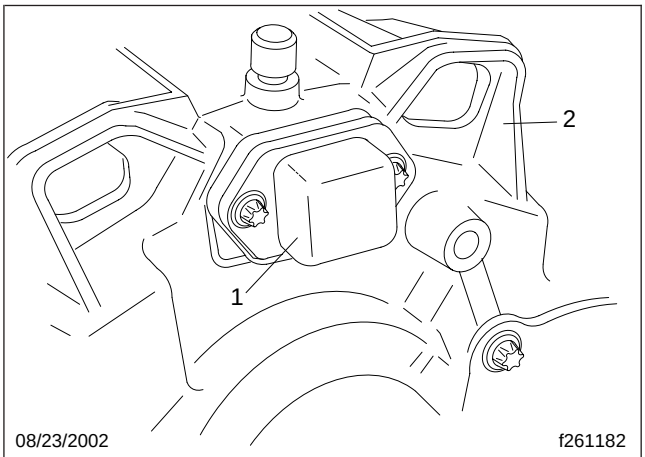
1. With the transmission removed from the vehicle and secured to keep it from moving, remove the shift mechanism. For instructions, see **Subject 110**.

NOTE: Take care that the tone wheel does not gouge the walls of the rear case where it opens to admit the output shaft.

2. Remove the output yoke and output shaft radial seal from the rear gear case.
3. Remove the rear countershaft cover from the output end of the rear gear case.
4. Remove the speed sensor from the output shaft. Remove the plug for the oil temperature sensor on the back of the rear gear case.

NOTE: On AGS transmissions, remove two speed sensors on the output shaft and one on the lower left-hand side of the rear gear case.

5. Remove the shift rail detent bolts.
6. Remove the shift rail cover from the output end of the rear gear case. See **Fig. 1**.



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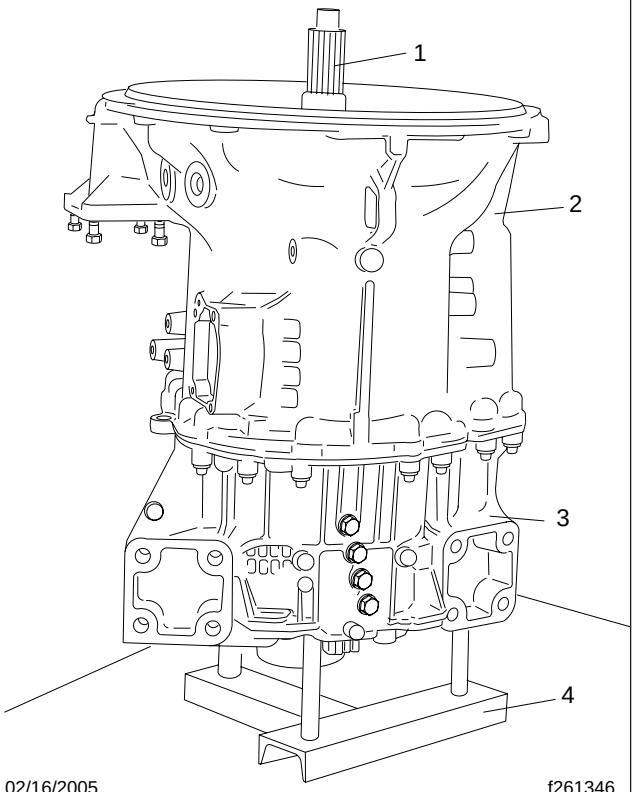
1. Shift Rail Cover
2. Rear Gear Case

Fig. 1, Shift Rail Cover

7. Attach the rear case puller/installer/stand to the output end of the rear gear case, and coat its all-thread rod with J 23444-A extreme-pressure lubricant. See **Table 1**.

NOTE: J 23444-A extreme-pressure lubricant can be ordered from SPX Kent-Moore at 1-800-345-2233.

8. Stand the transmission on the puller/installer/stand. See **Fig. 2**.



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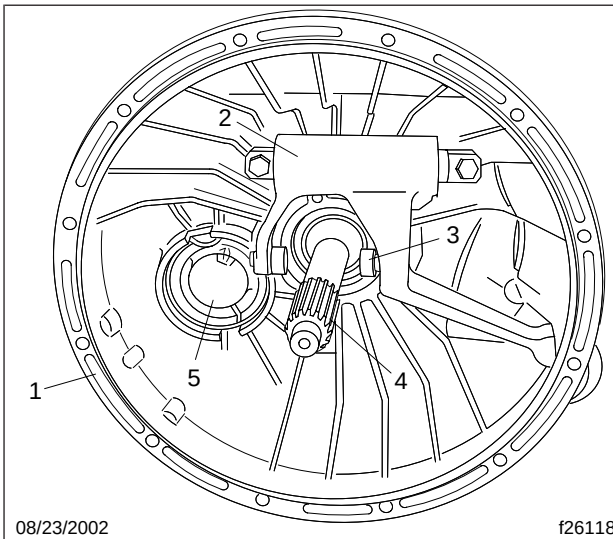
NOTE: The release bearing has been removed for clarity.

1. Input Shaft
2. Front Gear Case
3. Rear Gear Case
4. Puller/Installer/Stand

Fig. 2, Transmission on Puller/Installer/Stand

9. Remove the guide tube, the input shaft radial seal, and the inner snap ring. For instructions, including removal of the clutch release bearing and release fork, see **Subject 130**.
10. Remove the snap ring on the front countershaft seal cover. See **Fig. 3**.
11. Remove and discard the front countershaft seal cover. The seal cover may be difficult to remove. Use a pry tool and/or screwdriver as shown in **Fig. 4**.

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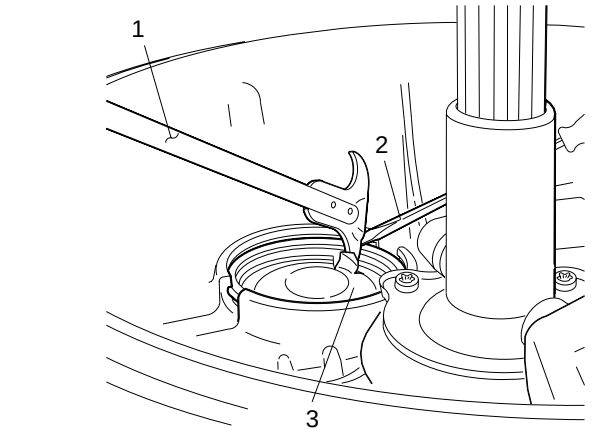


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NOTE: The release bearing has been removed for clarity.

1. Front Gear Case
2. Release Fork
3. Pressure Point
4. Input Shaft
5. Front Countershaft Seal Cover

Fig. 3, Front End of Transmission



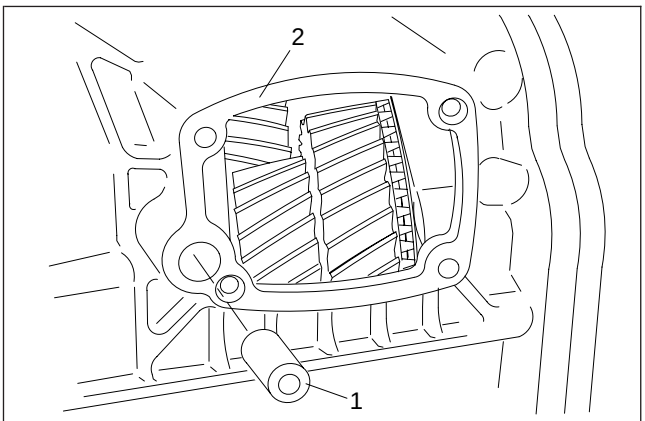
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1. Pry Tool
2. Screwdriver
3. Front Countershaft Seal Cover

Fig. 4, Prying Out the Front Countershaft Seal Cover

12. Remove the two snap rings on the countershaft ball bearing. Discard the snap rings.

13. On model 660 only, pull out the two shift fork guide pins, one located on the left-hand side in the flanged mating surface of the shift rod housing and the other on the right-hand side of the front gear case next to the shift cover (this pin has a T60 Torx® head). See **Fig. 5**.



09/26/2002 f261186

NOTE: The shift fork guide pins are installed on Model 660 only.

1. Shift Fork Guide Pin (left-hand side)
2. Flange

Fig. 5, Pulling the Left-Hand Shift Fork Guide Pin

14. Remove the gear case capscrews that attach the front gear case to the rear gear case. See **Fig. 6**.

15. After removing the capscrews, pry up on the front gear case to break the seal. Do not remove the front gear case at this time.

16. Using the front gear case bridge, remove the front gear case from the rear gear case and twin transmission shafts. See **Table 1** for more information about the special tool.

    16.1 Install the front gear case bridge so the hole is centered over the countershaft. Fasten it to the lip of the gear case with two gear case capscrews. See **Fig. 7**.

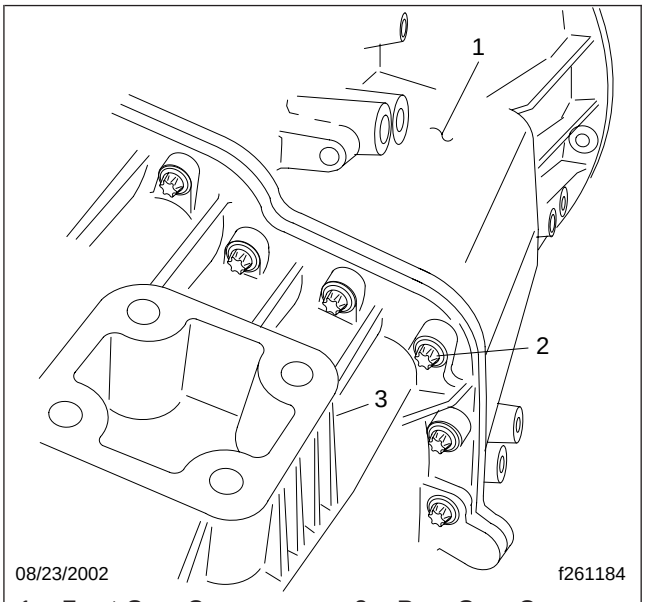
    16.2 Carefully press the front gear case off the countershaft and rear gear case. See **Fig. 8**.

17. Clean any remnants of sealant from the mating surfaces of the two gear case halves.

18. On model 660 only, remove the 5th/6th gear fork on the 5th/6th gear synchro slide and shift rail.

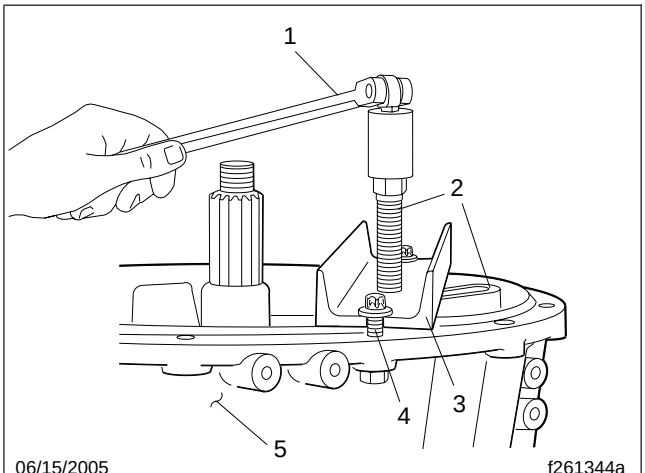
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Front Gear Case Removal and Installation



1. Front Gear Case
2. Gear Case Capscrew
3. Rear Gear Case

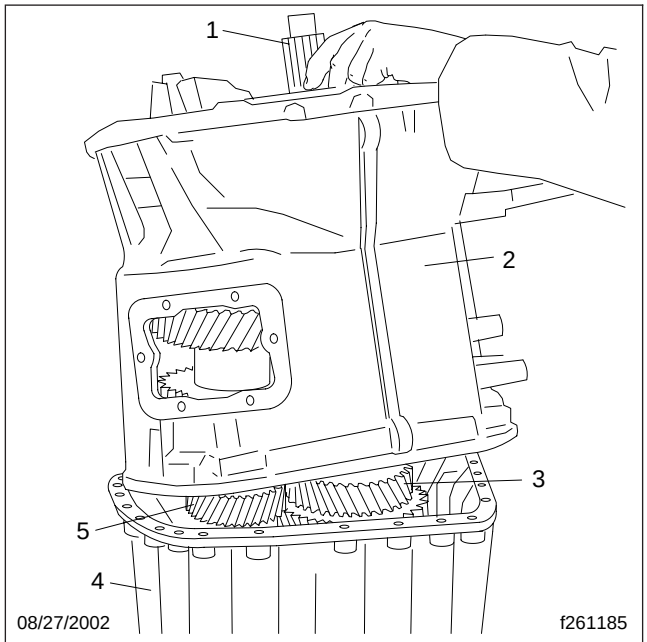
Fig. 6, Gear Case Capscrews



1. Socket Wrench
2. T-Bar Puller
3. Bridge
4. Gear Case Capscrew (used to fasten bridge)
5. Front Gear Case

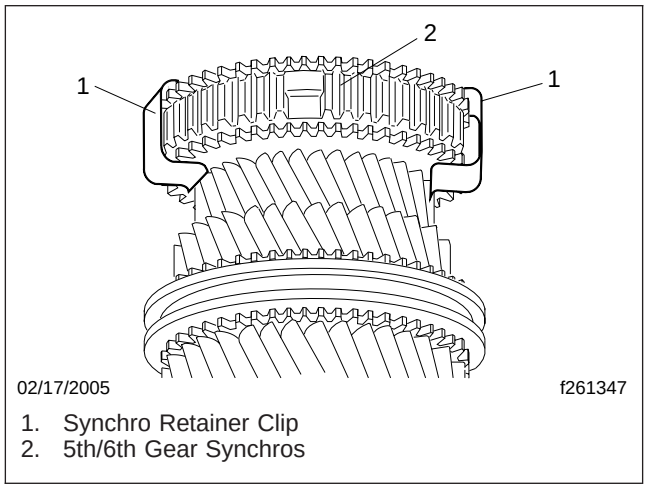
Fig. 7, Front Gear Case Bridge

19. After the case comes off, install the synchro retainer clips on the 5th/6th gear synchros. See **Fig. 9** for the installation and **Table 1** for more information about the special tool.
20. Remove the countershaft ball bearing from the front gear case.
21. Remove the pilot bearing from the main shaft.



1. Input Shaft
2. Front Gear Case
3. Main Shaft
4. Rear Gear Case
5. Countershaft

Fig. 8, Removing the Front Gear Case



1. Synchro Retainer Clip
2. 5th/6th Gear Synchros

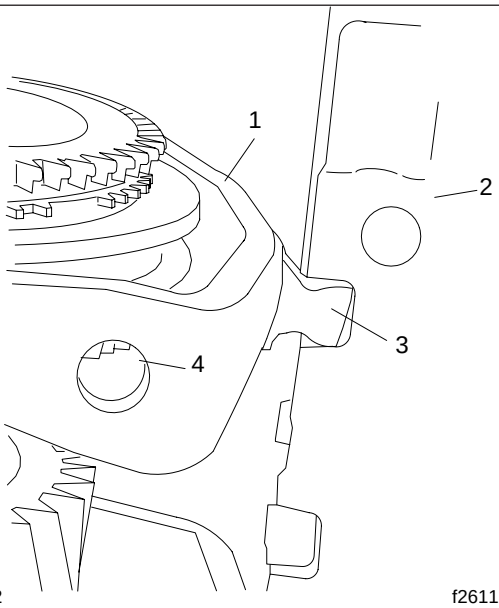
Fig. 9, Installing the Synchro Retainer Clips

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Installation

NOTE: If either gear case half, the main shaft bearings, or the input shaft was replaced, check the main shaft end play. For detailed procedures, see **Subject 250**.

1. Lubricate the pilot bearing with approved transmission oil. Install the pilot bearing on the main shaft.
2. Remove the synchro retainer clips from the 5th/6th gear synchros.
3. On model 660 only, install the 5th/6th gear fork on the 5th/6th gear synchro slide and shift rail. Make sure the shoes on the fork are properly positioned. The finger of the 5th/6th gear fork must engage the available notch in the shift rail. See **Fig. 10**.
4. Apply a bead of Loctite® 509 or equivalent sealing compound along the entire mating surface of the rear gear case, going fully around each hole and cavity.
5. Lift the front gear case onto the rear gear case. Carefully align the case over the shift rods. Install the gear case capscrews and tighten them 22 lbf·ft (30 N·m).
6. On model 660 only, check the 5th/6th gear fork through the opening for the shift rod housing to make sure the correct engagement of the finger has been maintained. See **Fig. 10**. Install the shift rail detent bolts finger-tight.
7. Install the shift fork guide pins, if removed (model 660 only), as follows. See **Fig. 11**.
   - 7.1 On the left-hand side, the pin slides in and is held in place by the shift mechanism when installed.
   - 7.2 On the right-hand side, coat the threads of the T60 Torx fastener with Loctite 242 or equivalent thread-locking compound, and tighten the fastener 88 lbf·ft (120 N·m).
8. Using a heat gun, warm the countershaft bearing seat to 176°F (80°C). Install the countershaft ball bearing on the countershaft by pressing on the inner race. Install two new snap rings.
9. Assemble the countershaft seal cover installer onto the threaded end of the universal handle. See **Table 1**.

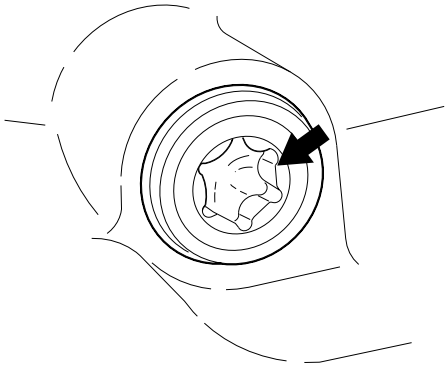


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The finger of the 5th/6th gear fork must continue to engage the available notch in the shift rail.

1. 5th/6th Gear Fork
2. Shift Rail
3. Finger
4. Hole for Insertion of Shift Fork Guide Pin (model 660 only)

Fig. 10, Correct Finger Engagement



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Install the shift fork guide pins. On the right-hand side, tighten the T60 Torx fastener (arrow).

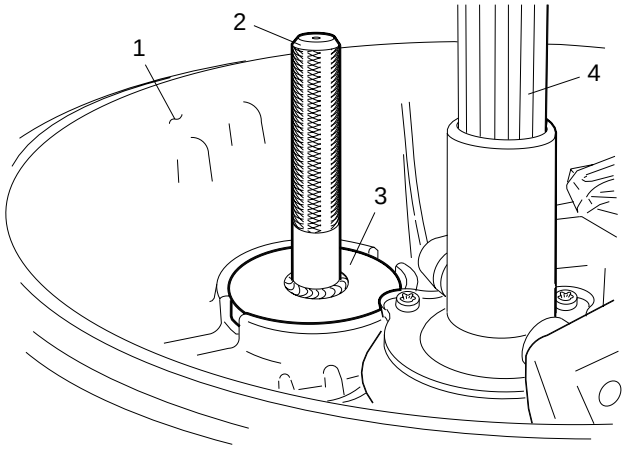
NOTE: The shift fork guide pins are installed on Model 660 only.

Fig. 11, Tightening the T60 Fastener

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Front Gear Case Removal and Installation

10. Using the countershaft seal cover installer assembly, carefully press the front countershaft seal cover onto the countershaft. See **Fig. 12**.



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1. Front Gear Case
2. Universal Handle
3. Countershaft Seal Cover Installer
4. Input Shaft

Fig. 12, Pressing the Front Countershaft Seal Cover

11. Install the snap ring on the front countershaft seal cover. Remove the countershaft retainer from the rear gear case. See **Table 1** for more information about the countershaft retainer.
12. Install the input shaft radial seal. For instructions, including installation of the clutch release bearing and release fork, see **Subject 130**.
13. Turn the transmission so the output end is exposed. Remove the puller/installer/stand.
14. Install the speed sensor on the output shaft, as removed. Install the plug for the oil temperature sensor on the back of the rear gear case.

NOTE: On AGS transmissions, install two speed sensors on the output shaft and one on the lower left-hand side of the rear gear case.

15. Coat the mating surface of the shift rail cover with Loctite 509 or equivalent sealing compound. Install the shift rail cover on the output end of the rear gear case. Tighten the shift rail cover capscrews 29 lbf·ft (39 N·m).
16. Tighten the shift rail detent bolts 22 lbf·ft (30 N·m).
17. Coat the mating surface of the rear countershaft cover with Loctite 509 or equivalent sealing compound. Install the rear countershaft cover. Tighten the rear countershaft cover capscrews 18 lbf·ft (25 N·m).
18. Install the output shaft radial seal; for procedures, see **Subject 140**. Install the output yoke on the rear gear case.
19. Install the shift mechanism; for instructions, see **Subject 110**.

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Special Tools

Special tools are required for these procedures. See **Table 1**.

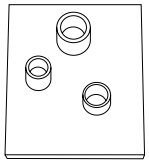
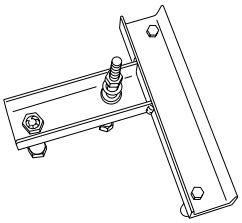
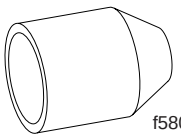
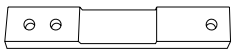
Special Tools for Rear Gear Case Removal and Installation			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580395	Main Shaft/Countershaft Stand	Kent-Moore	J-46732
 f580397	Rear Case Puller/Installer/Stand	Kent-Moore	J-46739
 f580394	Reverse Idler Shaft Puller	Kent-Moore	J-46731
 f580391	Countershaft Guide	Kent-Moore	J-46728
 f580396	Countershaft Retainer	Kent-Moore	J-46733

Table 1, Special Tools for Rear Gear Case Removal and Installation

To prevent premature tool wear, use extreme-pressure lubricant such as Kent-Moore J 23444-A or equivalent on tool threads and at all friction and contact points.

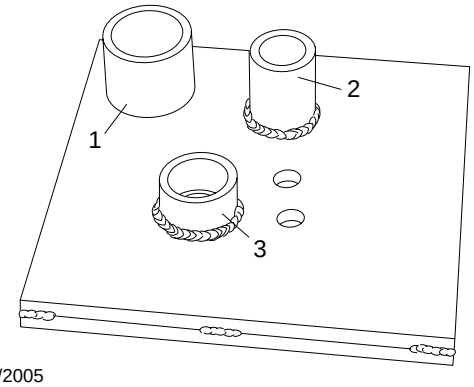
Removal

1. Secure the transmission on a wooden pallet, or other device to keep it from moving.
2. Remove the front gear case; for instructions, see **Subject 150**.

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Rear Gear Case Removal and Installation

3. Install the main shaft/countershaft stand on the exposed gear shafts. For more information about the main shaft/countershaft stand, see **Table 1** and **Fig. 1**.
4. Turn the transmission over and set it down with the rear case up. See **Table 1** for more information about the puller/installer/stand.



02/07/2005 f580403

1. Main Shaft Support (output end)
2. Main Shaft Support (input end)
3. Countershaft Support

Fig. 1, Main Shaft/Countershaft Stand

5. Stand the transmission on the main shaft/countershaft stand and secure the stand to the table with a clamp. See **Fig. 2**.
6. Using the reverse idler shaft puller, remove the reverse idler shaft, as follows. For more information about the reverse idler shaft puller, see **Table 1**.

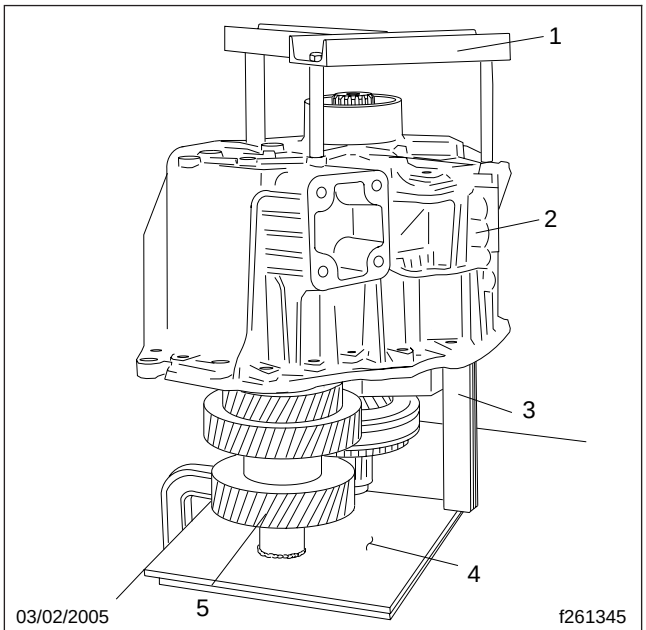
   6.1 Coat the forcing screw running through the puller body with J 23444-A extreme-pressure lubricant.

   NOTE: J 23444-A extreme-pressure lubricant can be ordered from SPX Kent-Moore at 1-800-345-2233.

   6.2 Insert the small-diameter threaded end of the forcing screw into the reverse idler shaft. Tighten the locknut on the forcing screw against the reverse idler shaft. **Figure 3** shows the reverse idler shaft puller installed.

   6.3 Attach a suitable wrench, socket or boxend, to the nut at the top end of the forcing screw, and turn the large nut clockwise until the reverse idler shaft is pulled up. **Figure 4** shows the reverse idler shaft ready for removal.

   6.4 Remove the reverse idler shaft and puller from the rear gear case. Separate the reverse idler shaft from the puller.



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1. Puller/Installer/Stand
2. Rear Gear Case
3. Shift Rails
4. Main Shaft/Countershaft Stand
5. Main Shaft

Fig. 2, Transmission with the Rear Case Up

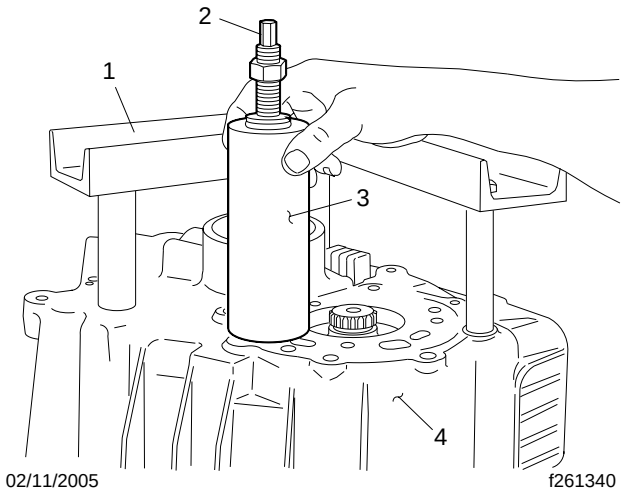
7. Make sure the speed sensor has been removed.

IMPORTANT: On AGS transmissions, there are three speed sensors on the rear gear case: the input shaft speed sensor on the lower left-hand side, and the two output shaft speed sensors on the rear output flange.

8. Pull the rear gear case from the twin gear shafts, as follows. See **Fig. 5**.

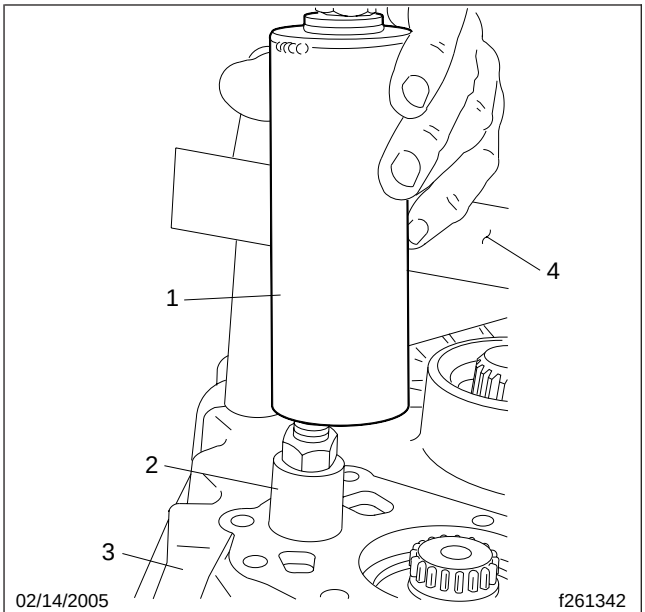
   8.1 Install the all-thread rod and two nuts through the puller/installer/stand and into the output shaft. Lubricate the rod threads with high-pressure grease. Tighten one nut against the other to create a jam nut.

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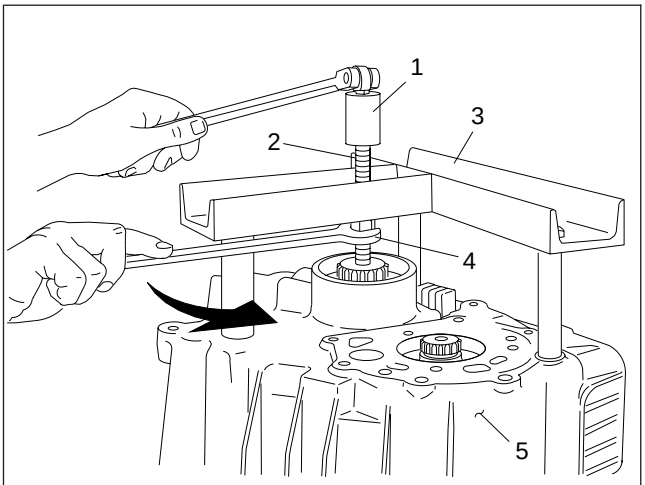
1. Puller/Installer/Stand
2. Forcing Screw
3. Reverse Idler Shaft Puller
4. Rear Gear Case

Fig. 3, Reverse Idler Shaft Puller Installed



1. Reverse Idler Shaft Puller
2. Reverse Idler Shaft (pulled up)
3. Rear Gear Case
4. Puller/Installer/Stand

Fig. 4, Reverse Idler Shaft (ready for removal)



Hold with the socket wrench and turn with the open-end wrench in the direction of the arrow.

1. Socket Wrench on Jam Nut
2. All-Thread Rod
3. Puller/Installer/Stand
4. Open-End Wrench on Working Nut
5. Rear Gear Case

Fig. 5, Raising the Rear Gear Case

8.2 Using a socket wrench, hold the jam nut at the head of the all-thread rod.

8.3 Install two washers between the puller/installer/stand and the working nut. Using an open-end wrench, turn the working nut counterclockwise.

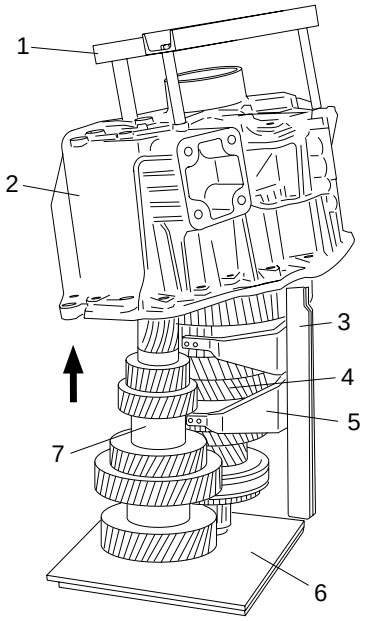
8.4 Keep turning the working nut until the rear case releases from the main shaft.

8.5 Remove the all-thread rod from the output shaft.

9. Carefully lift the rear gear case off the gear shafts. See **Fig. 6**. Leave the puller/installer/stand installed.
10. The reverse idler gear may hang up on the gear below it. Carefully remove the reverse idler gear and needle bearing. Inspect them for damage.
11. Separate the puller/installer/stand from the rear gear case.

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Rear Gear Case Removal and Installation



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Lift the rear gear case carefully.

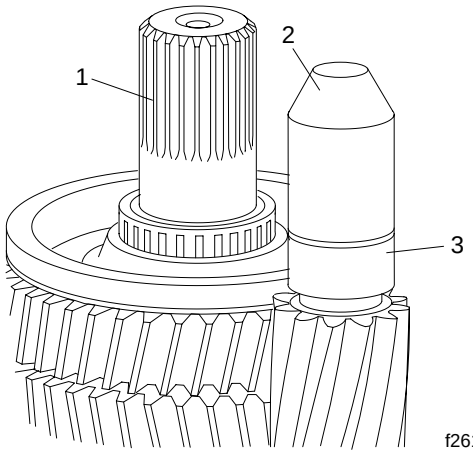
1. Puller/Installer/Stand
2. Rear Gear Case
3. Shift Rail
4. Main Shaft
5. Shift Fork
6. Main Shaft/ Countershaft Stand
7. Countershaft

Fig. 6, Removing the Rear Gear Case

Installation

NOTE: During installation, the transmission should be standing on the main shaft/ countershaft stand with the output end of the rear gear case exposed.

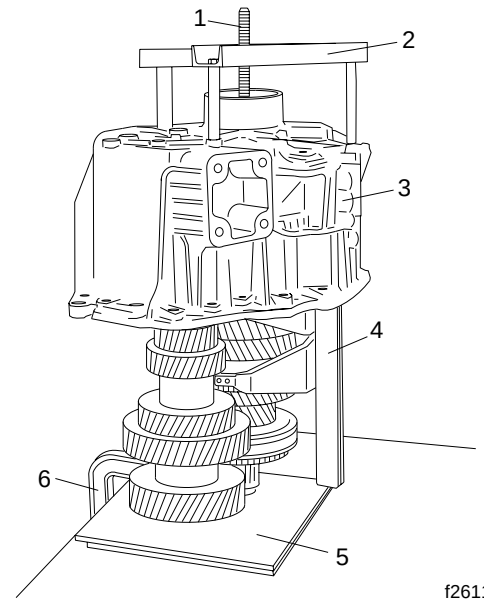
1. Place the reverse idler gear and needle bearing in the rear gear case.
2. Install the shift rails and forward shift forks on the gear shafts.
3. Install the countershaft guide. For more information about the countershaft guide, see **Table 1**. **Figure 7** shows the guide installed on the countershaft.
4. Install the rear gear case, with the puller/installer/ stand on the exposed gear shafts. See **Fig. 8**.
5. Lower the rear gear case onto the gear shafts, as follows.



09/17/2002 f261197

1. Main Shaft
2. Countershaft Guide
3. Countershaft

Fig. 7, Countershaft Guide



03/02/2005 f261194

1. All-Thread Rod
2. Puller/Installer/Stand
3. Rear Gear Case
4. Shift Rails
5. Main Shaft/Countershaft Stand
6. Clamp

Fig. 8, Installing the Rear Gear Case

5.1 Install the all-thread rod into the output shaft.

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IMPORTANT: As the rear gear case is being lowered, carefully inspect the reverse idler gear and make sure that it meshes.

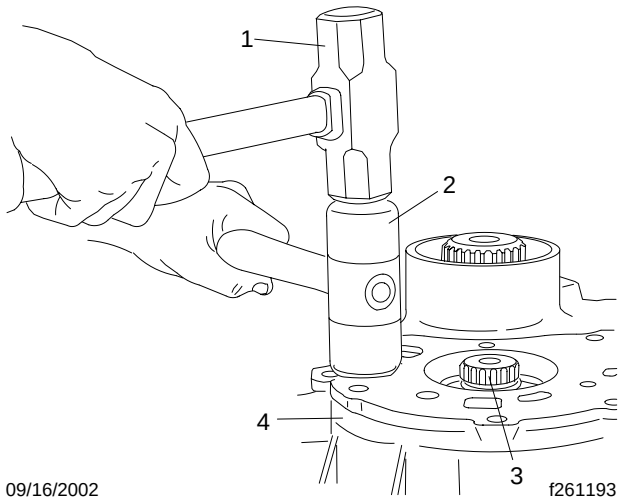
5.2 Hold a socket wrench on the bolt head.

5.3 Using an open-end wrench, turn the nut.

5.4 Continue the process of turning the nut until the rear case bottoms out.

NOTE: At the start, only a small bit of the machined surface of the idler shaft will be visible. When finished, the idler shaft must be flush with the surface of the gear case.

6. Install the reverse idler shaft in the rear gear case. Use two hammers as shown in **Fig. 9**, with the metal-faced hammer doing the striking, and the dead-blow hammer transmitting the force of the blow to the reverse idler shaft.



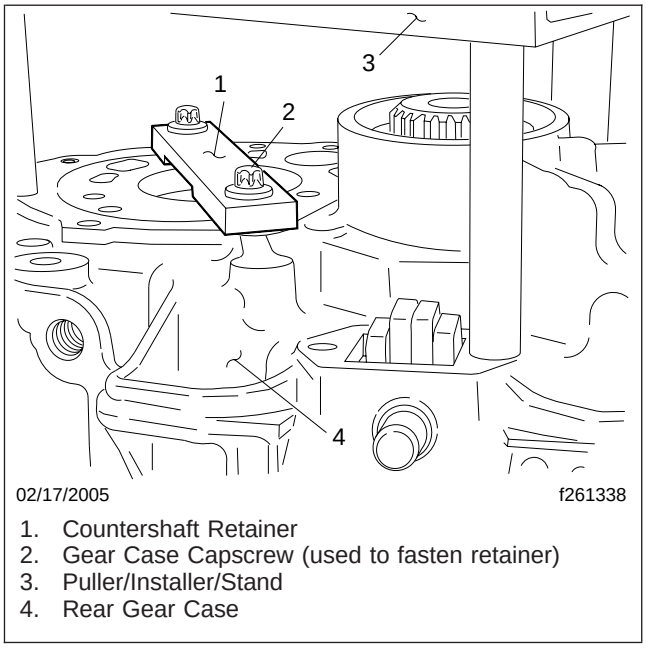
Use two hammers: a metal-faced one to strike with, and a dead-blow hammer to transmit the force of the blow.

1. Metal-Faced Hammer
2. Dead-Blow Hammer
3. Countershaft
4. Rear Gear Case

Fig. 9, Installing the Reverse Idler Shaft

7. Install the countershaft retainer on the rear gear case. **Figure 10** shows the countershaft retainer installed. See **Table 1** for more information about the countershaft retainer.

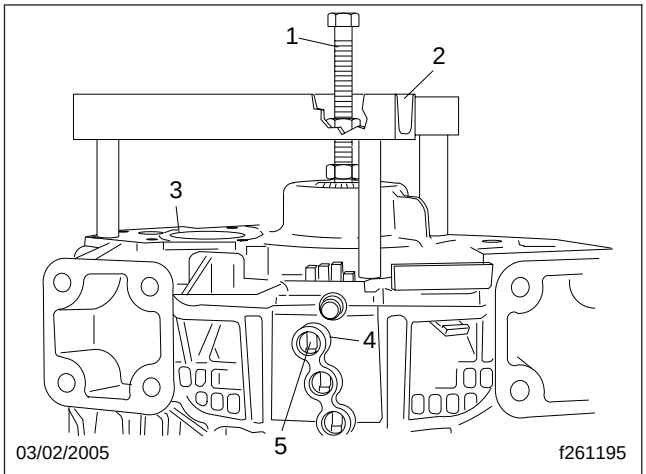
8. Remove the all-thread rod from the puller/installer/stand. Turn the transmission over and place it rear case down on the puller/installer/stand. Remove the main shaft/countershaft stand.



1. Countershaft Retainer
2. Gear Case Capscrew (used to fasten retainer)
3. Puller/Installer/Stand
4. Rear Gear Case

Fig. 10, Countershaft Retainer Installed

9. Align the detents in each shift rail with the bolt holes in the rear case. See **Fig. 11**.



1. All-Thread Rod
2. Puller/Installer/Stand
3. Rear Gear Case
4. Bolt Hole
5. Detent (in shift rail)

Fig. 11, Shift Rail Detents

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Rear Gear Case Removal and Installation

10. Check the main shaft end play; for detailed procedures, see **Subject 250**.
11. Install the front gear case; for instructions, see **Subject 150**.

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Special Tools

A special tool is required for these procedures. See **Table 1**.

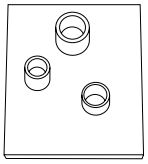
Special Tool for Reverse, First, and Second Gear Disassembly			
Tool	Description	Manufacturer	Part Number
 f580395	Main Shaft/Countershaft Stand	Kent-Moore	J-46732

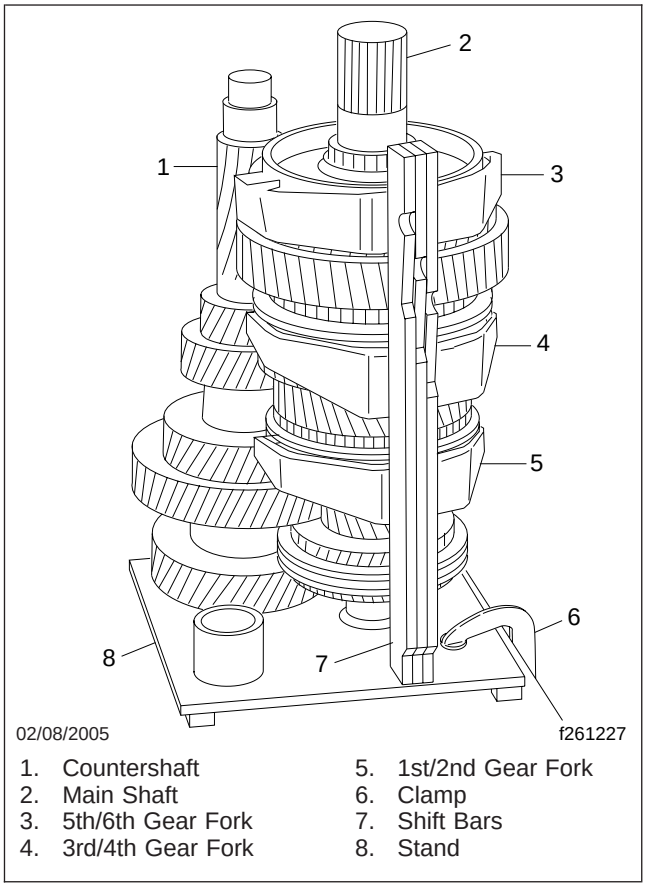
Table 1, Special Tool for Reverse, First, and Second Gear Disassembly

Reverse Gear

1. Secure the transmission on a wooden pallet, or other device to keep it from moving.
2. Remove the shift mechanism; for instructions, see **Subject 110**.
3. Remove the front gear case; for instructions, see **Subject 150**.
4. Remove the rear gear case; for instructions, see **Subject 160**.
5. Make sure the twin gear shafts are supported on the main shaft/countershaft stand. See **Table 1**.
6. Remove the shift bars and shift forks from the transmission, as follows. See **Fig. 1**.
   - 6.1 Lift the 5th/6th gear fork off the shift bars.
   - 6.2 Pull the remaining shift forks and shift bars away from the main shaft as a group.
   - 6.3 Tie the shift bars and forks together.
7. Inspect the synchro rings for compliance with the wear limits given in **Subject 240**.
8. Remove the reverse gear wheel and needle bearing from the main shaft.

First Gear

1. Using suitable snap ring pliers, remove the 1st gear snap ring from the main shaft. Measure the snap ring thickness and record it. Discard the snap ring after recording its thickness.



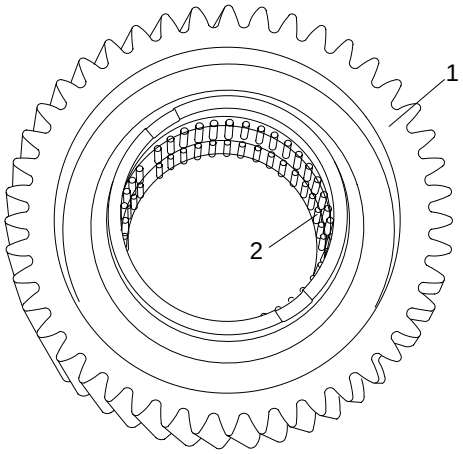
1. Countershaft
2. Main Shaft
3. 5th/6th Gear Fork
4. 3rd/4th Gear Fork
5. 1st/2nd Gear Fork
6. Clamp
7. Shift Bars
8. Stand

Fig. 1, Shift Bars and Forks

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Reverse, First, and Second Gear Disassembly

2. Remove the inner gear wheel.
3. Remove the 1st gear wheel and the needle bearing. See **Fig. 2**.



09/26/2002 f261216

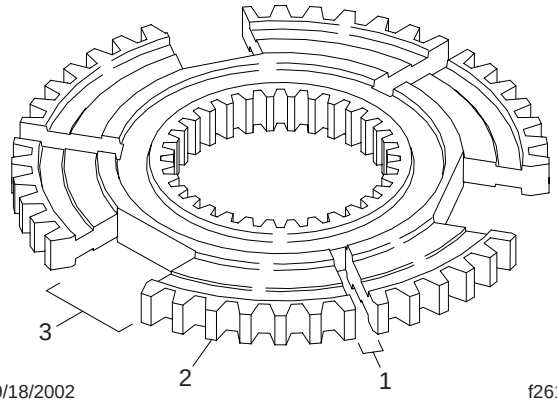
1. 1st Gear Wheel
2. Needle Bearing

Fig. 2, 1st Gear Wheel and Needle Bearing

4. Remove the 1st gear inner synchro cone.
5. Remove the 1st gear synchro ring.
6. Remove the 1st gear outer synchro cup.

Second Gear

1. Remove the 1st/2nd gear synchro slide collar carefully from the synchro body.
2. Remove the compression springs and spring holders from the synchro body. Remove the synchro body from the main shaft. See **Fig. 3**.
3. Using snap ring pliers, remove the 2nd gear snap ring from the synchro body. Measure the snap ring thickness and record it. Discard the snap ring after recording its thickness.
4. Remove the synchro body from the main shaft.
5. Remove the 2nd gear outer synchro cup.
6. Remove the 2nd gear synchro ring and inner synchro cone.
7. Remove the 2nd gear driver, wheel, and needle bearing. See **Fig. 4**.

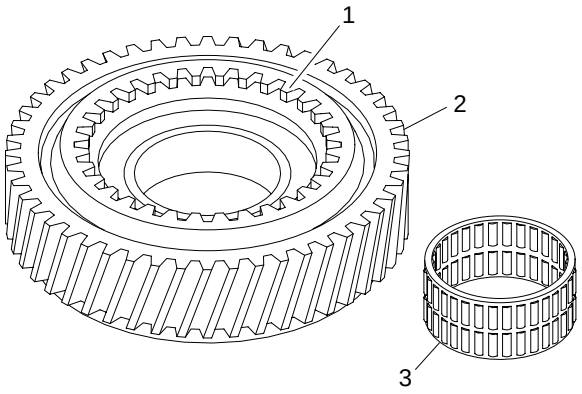


09/18/2002 f261201

NOTE: The mounts of the 2nd gear outer synchro cup must engage in the large recesses in the synchro body.

1. Slot for Compression Spring
2. Tooth Flank
3. Large Recess

Fig. 3, 1st/2nd Gear Synchro Body



09/17/2002 f261203

1. Short Teeth
2. 2nd Gear Wheel
3. Needle Bearing

Fig. 4, 2nd Gear Wheel and Needle Bearing

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Special Tools

Special tools are required for this procedure. See **Table 1**.

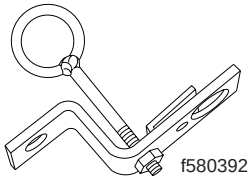
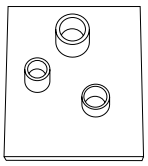
Special Tools for Countershaft Removal and Installation			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580392	Main Shaft/Countershaft Lifting Device	Kent-Moore	J-46729
 f580395	Main Shaft/Countershaft Stand	Kent-Moore	J-46732

Table 1, Special Tools for Countershaft Removal and Installation

Removal

1. Remove the front gear case; fr instructions, see **Subject 150**.
2. Remove the rear gear case; for instructions, see **Subject 160**.
3. Remove the reverse gear and the 1st gear from the main shaft; for instructions, see **Subject 170**.
4. Remove the 2nd gear from the main shaft; for instructions, see **Subject 170**.
5. Attach the main shaft/countershaft lifting device to the input ends of the main shaft and countershaft. For more information about the special tool, see **Table 1**. See **Fig. 1** for the countershaft with the tool installed.
6. Attach a hoist to the ring of the lifting device. Lift the two shafts in the air.
7. Remove the main shaft/countershaft stand.
8. Remove the bolt that's attaching the lifting device to the main shaft. Carefully separate the countershaft gears from the main-shaft gears. See **Fig. 2**.
9. Place the main shaft on the main shaft/countershaft stand, with the output end down. See **Table 1**.
10. Remove the lifting device from the countershaft.

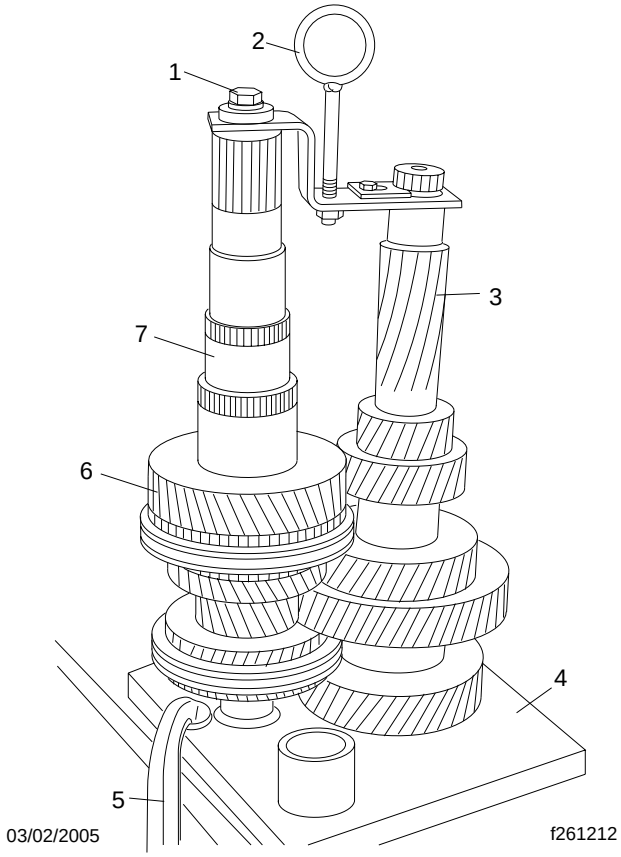
NOTE: Do not attempt to disassemble the countershaft. If there is damage, replace the entire countershaft. For further disassembly of the main shaft gears, see **Subject 190** and **Subject 200**.

Installation

1. Carefully mesh the teeth of the countershaft gears with the teeth of the main shaft gears.
2. Lay the main shaft on the bench and attach the lifting device to it. Attach a hoist to the ring of the lifting device and raise the main shaft off the stand.
3. Fasten the countershaft to the lifting device.
4. Lower the hoist and place both shafts on the stand. Remove the hoist from the lifting device.
5. Install the 2nd gear on the main shaft. For instructions, see **Subject 230**.

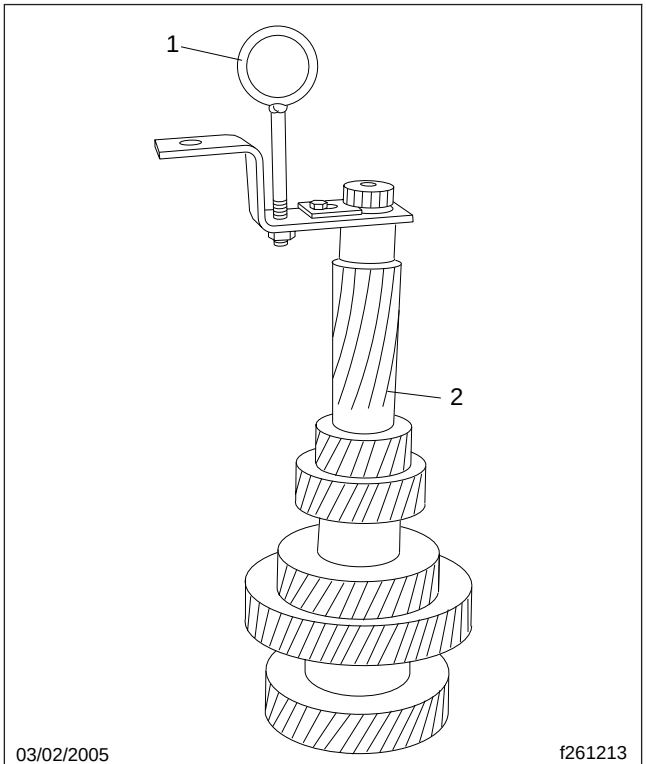
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Countershaft Removal and Installation



1. Bolt
2. Lifting Device
3. Countershaft
4. Stand
5. Clamp
6. Third Gear Wheel
7. Main Shaft (stripped area)

Fig. 1, Countershaft Ready to Remove



1. Lifting Device
2. Countershaft

Fig. 2, Countershaft Separated From Main Shaft

6. Install the reverse gear and the 1st gear on the main shaft; for instructions, see **Subject 230**.
7. Install the rear gear case; for instructions, see **Subject 160**.
8. Install the front gear case; for instructions, see **Subject 150**.

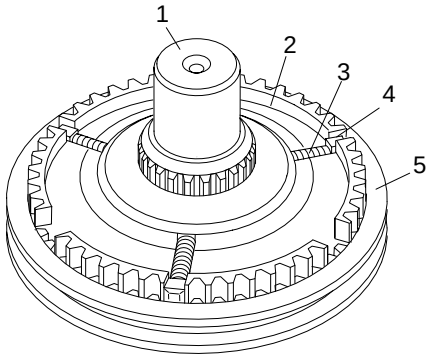
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Fifth Gear

1. Remove the front gear case; for instructions, see **Subject 150**.
2. Remove the rear gear case; for instructions, see **Subject 160**.
3. Remove the reverse gear and the 1st gear from the main shaft; for instructions, see **Subject 170**.
4. Remove the 2nd gear from the main shaft; for instructions, see **Subject 170**.
5. Separate the countershaft from the main shaft; for instructions, see **Subject 180**.
6. Remove the 5th gear synchro cone and synchro ring from the main shaft.

Sixth Gear

1. Carefully remove the 5th/6th gear synchro slide collar from the synchro body. Take care to extract the compression springs and spring holders from the synchro body. See **Fig. 1**.

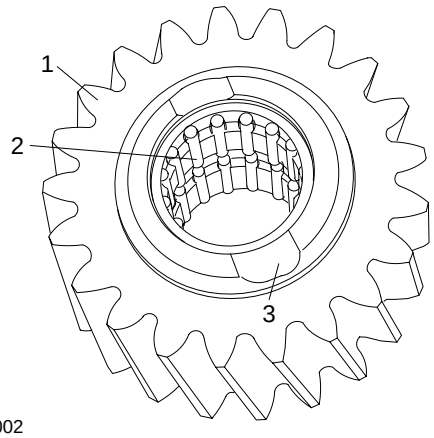


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1. Main Shaft
2. Synchro Body
3. Compression Spring
4. Spring Holder
5. Synchro Slide Collar

Fig. 1, 5th/6th Gear Synchronizers

2. Using snap ring pliers, remove the 5th/6th gear snap ring from the main shaft. Measure the snap ring thickness and record it. Discard the snap ring after recording its thickness.
3. Remove the 5th/6th gear synchro body from the main shaft.
4. Remove the 6th gear synchro ring and cone.
5. Inspect the synchro rings for compliance with the wear limits given in **Subject 240**.
6. Remove the 6th gear wheel and needle bearing. See **Fig. 2**.



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1. 6th Gear Wheel
2. Needle Bearing
3. Oil Groove

Fig. 2, 6th Gear Wheel and Needle Bearing

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Fourth Gear

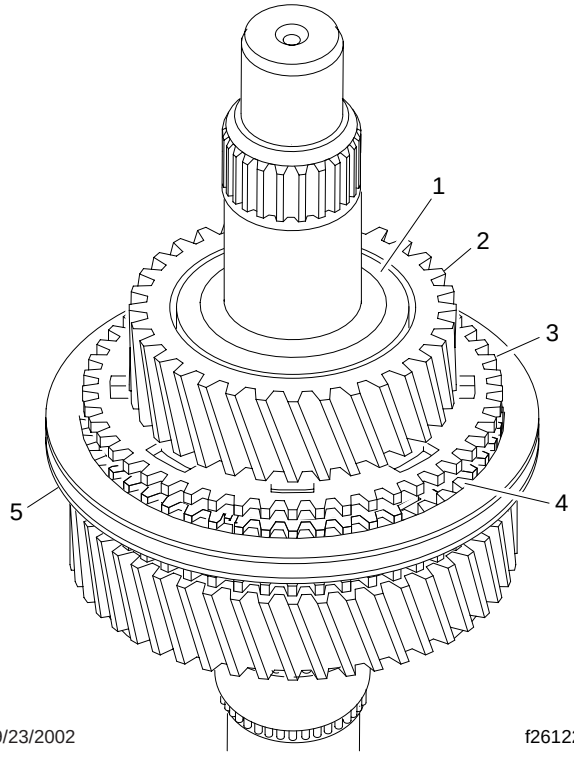
1. Remove the front gear case; for instructions, see **Subject 150**.
2. Remove the rear gear case; for instructions, see **Subject 160**.
3. Remove the reverse gear and the 1st gear from the main shaft; for instructions, see **Subject 170**.
4. Remove the 2nd gear from the main shaft; for instructions, see **Subject 170**.
5. Separate the countershaft from the main shaft; for instructions, see **Subject 180**.
6. Remove the 5th and 6th gears from the main shaft; for instructions, see **Subject 190**.
7. Using snap ring pliers, remove the 4th gear snap ring from the main shaft. Measure the snap ring thickness and record it. Discard the snap ring after recording its thickness.
8. Remove the 4th gear wheel and thrust washer from the main shaft. See **Fig. 1**.
9. Lift the driver off the main shaft.

NOTE: On some models, the driver is welded to the 4th gear wheel.

10. Remove the needle bearing.
11. Remove the 4th gear inner synchro cone, synchro ring, and outer synchro cup. See **Fig. 2**.

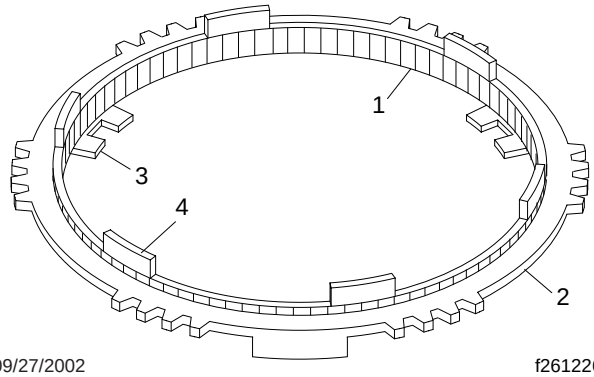
Third Gear

1. Carefully remove the 3rd/4th gear synchro slide collar from the synchro body. Take care to extract the compression springs and spring holders from the synchro body. See **Fig. 3**.
2. Using snap ring pliers, remove the 3rd gear snap ring from the synchro body. Measure the snap ring thickness and record it. Discard the snap ring after recording its thickness. See **Fig. 4**.
3. Remove the 3rd gear synchro body from the main shaft.
4. Remove the 3rd gear outer synchro cup, synchro ring, and inner synchro cone from the main shaft.
5. Lift the driver off the 3rd gear wheel.
6. Inspect the synchro rings for compliance with the wear limits given in **Subject 240**.



1. Thrust Washer
2. 4th Gear Wheel
3. Driver Teeth
4. Teeth of Slide
5. 3rd/4th Gear Synchro Slide Collar

Fig. 1, 4th Gear Synchronizers

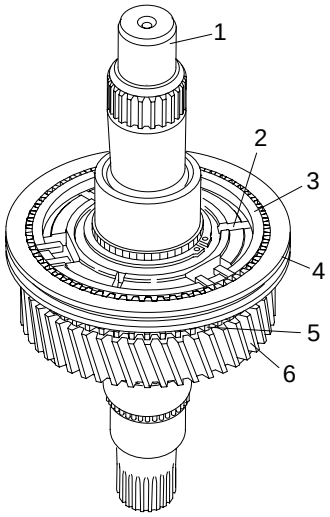


1. Synchro Ring
2. Outer Synchro Cup
3. Mount
4. Stop Lug

Fig. 2, 4th Gear Synchro Ring and Outer Cup

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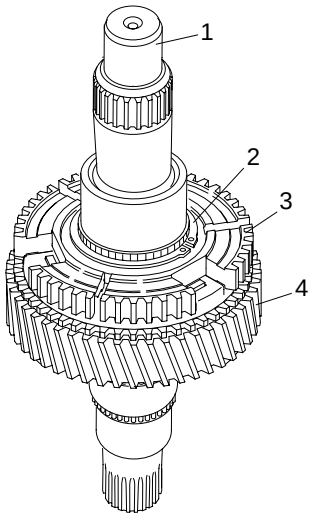
Fourth and Third Gear Disassembly



09/27/2002 f261209

1. Main Shaft
2. Synchro Body
3. Inner Cone
4. Synchro Slide Collar
5. Outer Cone
6. 3rd Gear Wheel

Fig. 3, 3rd Gear Synchronizers

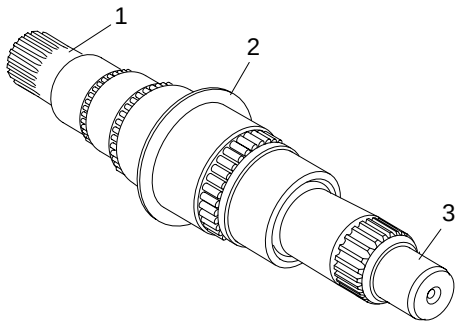


09/23/2002 f261208

1. Main Shaft
2. Snap Ring
3. Synchro Body
4. 3rd Gear Wheel

Fig. 4, 3rd Gear Snap Ring

7. Remove the 3rd gear wheel and needle bearing, leaving the main shaft stripped. See **Fig. 5**.



09/27/2002 f261207

1. Main Shaft (output end)
2. Partition
3. Main Shaft (input end)

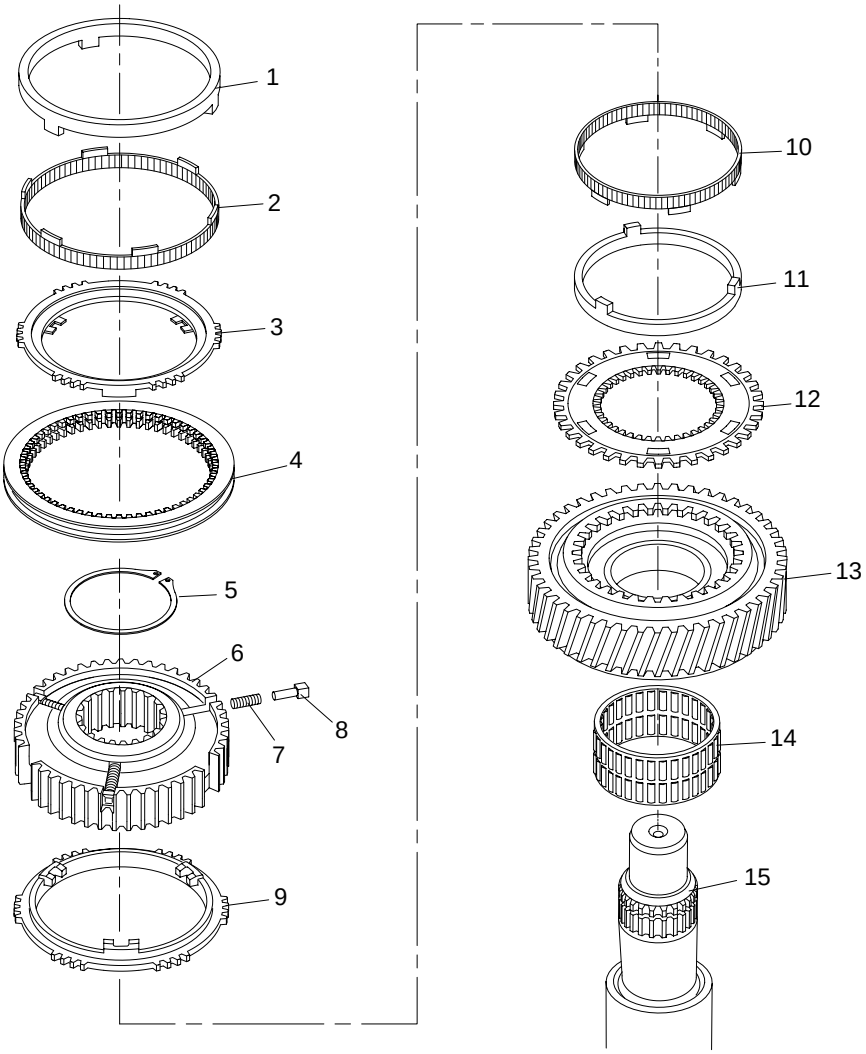
Fig. 5, Main Shaft (stripped)

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Third Gear

For an exploded view of this assembly, see **Fig. 1**.

1. Apply a coating of MobilTrans SHC® DC (the approved transmission oil) to the needle bearing.



10/11/2002 f261223

1. 4th Gear Inner Synchro Cone
2. 4th Gear Synchro Ring
3. 4th Gear Outer Synchro Cup
4. 3rd/4th Gear Synchro Slide Collar
5. 4th Gear Snap Ring
6. 3rd/4th Gear Synchro Body
7. Compression Spring
8. Spring Holder
9. 3rd Gear Outer Synchro Cup
10. 3rd Gear Synchro Ring
11. 3rd Gear Inner Synchro Cone
12. 3rd Gear Driver
13. 3rd Gear Wheel
14. 3rd Gear Needle Bearing
15. Main Shaft (input end)

Fig. 1, 3rd Gear Assembly

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Third and Fourth Gear Assembly

2. Fit the needle bearing onto the main shaft. Mount the 3rd gear wheel over the needle bearing with the short splines facing up.

IMPORTANT: When installing the gear wheel, spin it and let it drop. This helps prevent damage to the bearings.

3. Place the driver on the 3rd gear wheel with the chamfered teeth facing up.
4. Place the 3rd gear inner synchro cone on the driver with the stop lugs facing up.
5. Apply a coating of approved transmission oil to the 3rd gear synchro ring. Fit the synchro ring onto the synchro cone with the stop lugs facing down. The stop lugs must engage the slotted holes in the driver.
6. Install the 3rd gear outer synchro cup on the synchro ring. The mounts on the outer cup must engage the stop lugs of the inner cone.

NOTE: Make sure the synchro body is installed right side up, with the ridge for the snap ring exposed.

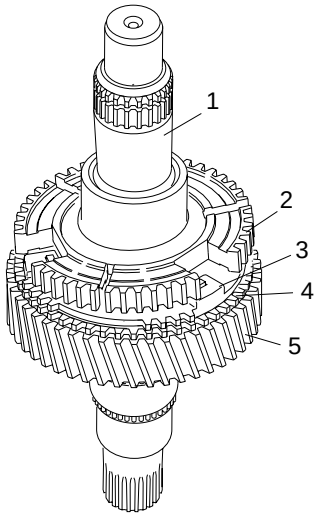
7. Fit the 3rd/4th gear synchro body onto the main shaft. If there is resistance, heat the synchro body using a heat gun. The stop lugs of the outer synchro cup must mesh with the large recesses in the synchro body. See **Fig. 2**.
8. Using snap ring pliers, install a new snap ring. Make sure the snap ring is tight when installed, with no free play.

IMPORTANT: If there is free play, remove the snap ring and replace it with a snap ring of the correct thickness to eliminate any free play.

9. Install the synchro slide collar on the synchro body as far as the stop.
10. Install the three compression springs into the slots in the synchro body. Using a short-bladed screwdriver, press them in until the spring holder engages the tooth of the synchro slide collar. See **Fig. 3**.

Fourth Gear

1. Insert the 4th gear outer synchro cup into the synchro body. The mounts of the outer cup must engage with the recesses in the synchro body.

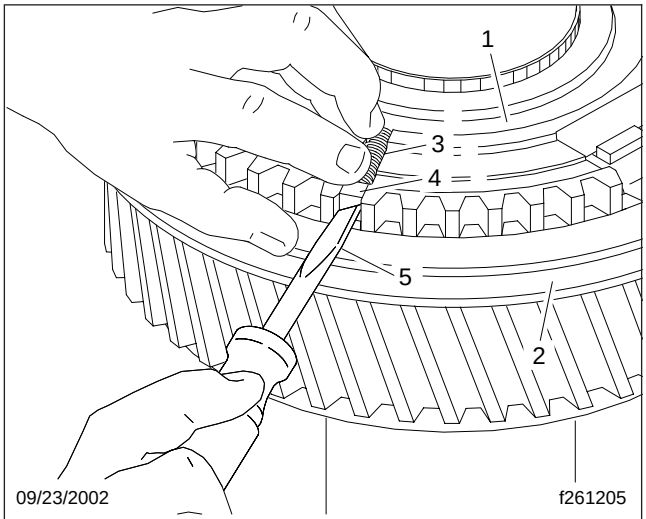


03/02/2005 f261214

If there is resistance, heat the synchro body using a heat gun.

1. Main Shaft
2. Synchro Body
3. Stop Lug
4. Driver
5. 3rd Gear Wheel

Fig. 2, Fitting the Synchro Body



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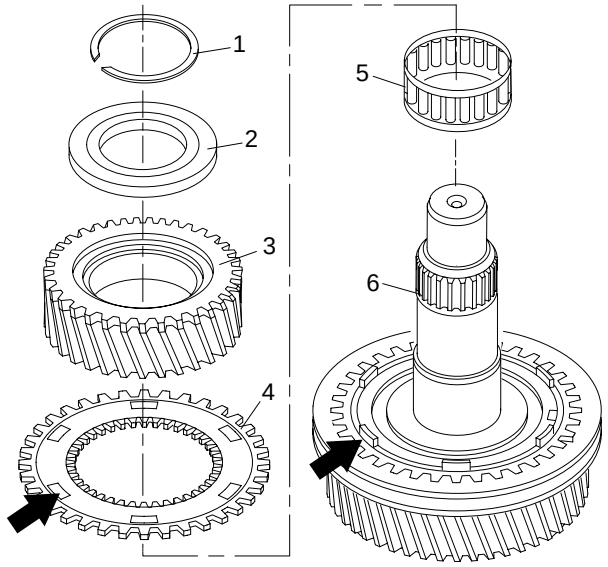
Press in the compression spring until the spring holder engages the tooth of the synchro slide.

1. Synchro Body
2. Synchro Slide Collar
3. Compression Spring
4. Spring Holder
5. Short-Bladed Screwdriver

Fig. 3, Pressing in the Compression Springs

https://truckmanualshub.com/

2. Apply a coating of approved transmission oil to the 4th gear synchro ring. Mount the synchro ring on the outer cup with the stop lugs facing up.
3. Slide the 4th gear inner synchro cone into the synchro ring with the stop lugs down. The stop lugs of the inner cone must fit into the mounts on the outer cup.
4. Apply a coating of approved transmission oil to the needle bearing. Fit the needle bearing onto the main shaft.
5. Mount the driver on the main shaft. The asymmetrical tooth tips must face down and the stop lugs up. See **Fig. 4**.



Mount the 4th gear driver with the asymmetric tooth tips facing down and the stop lugs up.

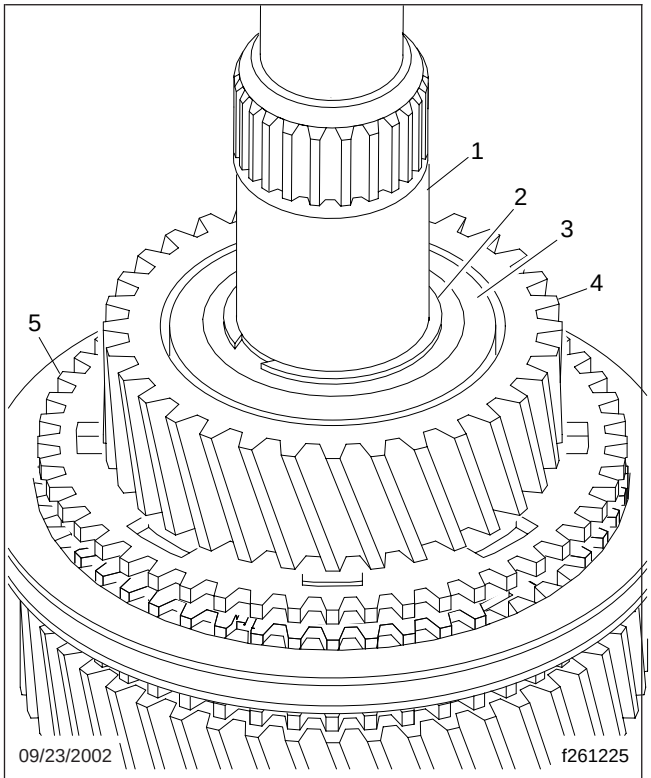
1. 4th Gear Snap Ring
2. Thrust Washer
3. 4th Gear Wheel
4. Driver Teeth
5. Needle Bearing
6. Main Shaft (output end)

Fig. 4, 4th Gear Assembly

6. Mount the 4th gear wheel on the driver. Make sure the slots in the 4th gear wheel engage the stop lugs on the top of the driver.
7. Heat the thrust washer to 176°F (80°C). When heated, press it into the main shaft.

NOTE: Before installing, test the thickness of the snap ring by inserting it into the gap between the main shaft and the thrust washer.

8. Install a new snap ring inside the synchro body. Make sure the snap ring is tight when installed, with no free play. See **Fig. 5**.



1. Main Shaft
2. 4th Gear Snap Ring
3. Thrust Washer
4. 4th Gear Wheel
5. Driver Teeth

Fig. 5, Snap Ring Installed

9. Install the 5th and 6th gears on the main shaft; for instructions, see **Subject 220**.
10. Install the countershaft on the main shaft; for instructions, see **Subject 190**.
11. Install the 2nd gear on the main shaft; for instructions, see **Subject 230**.
12. Install the reverse gear and the 1st gear on the main shaft; for instructions, see **Subject 230**.
13. Install the rear gear case; for instructions, see **Subject 160**.

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Third and Fourth Gear Assembly

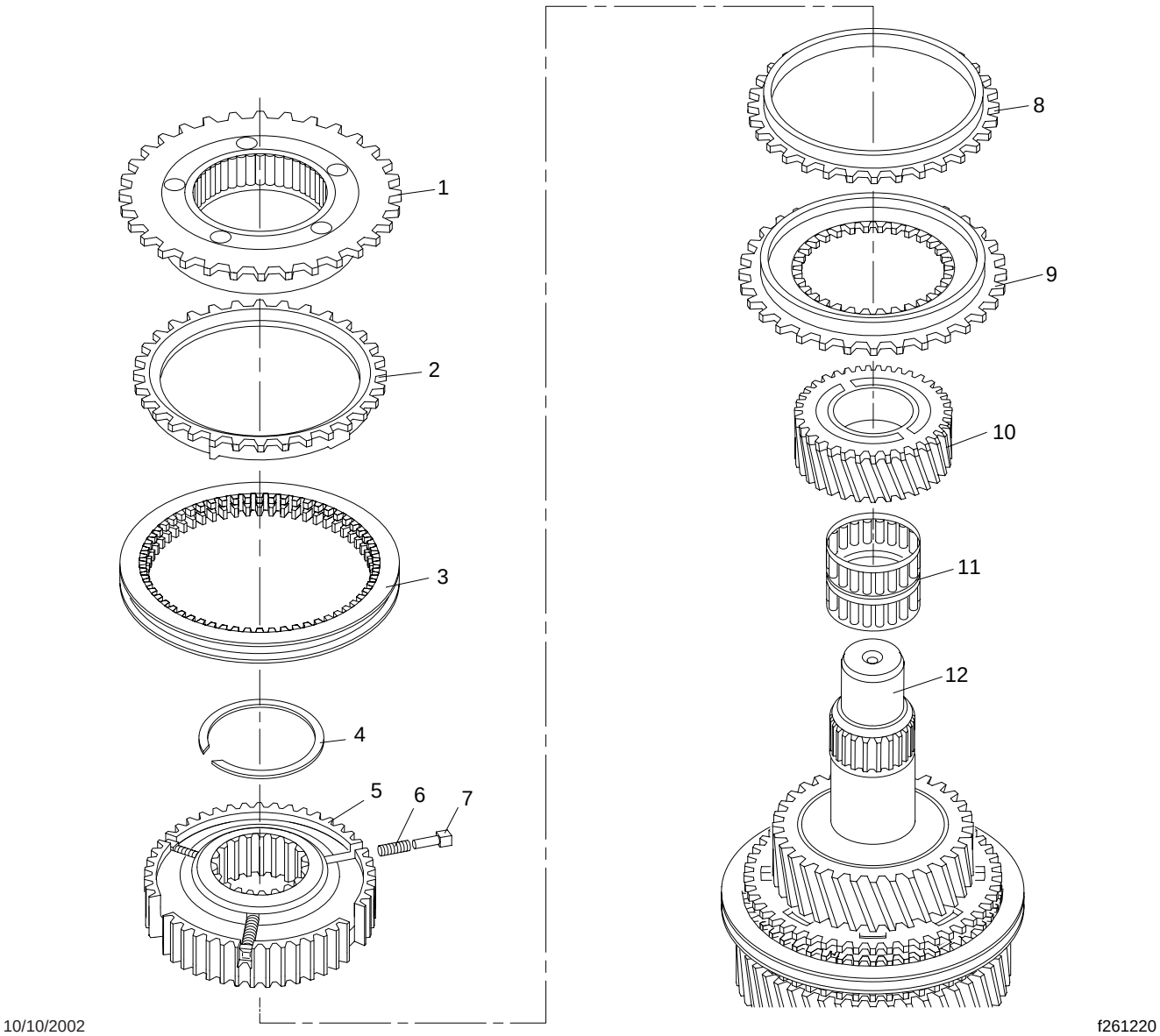
14. Install the front gear case; for instructions, see **Subject 150**.

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Sixth Gear

For an exploded view of this assembly, see **Fig. 1**.

1. Apply a coating of approved transmission oil to the needle bearing. Fit the needle bearing onto the main shaft.



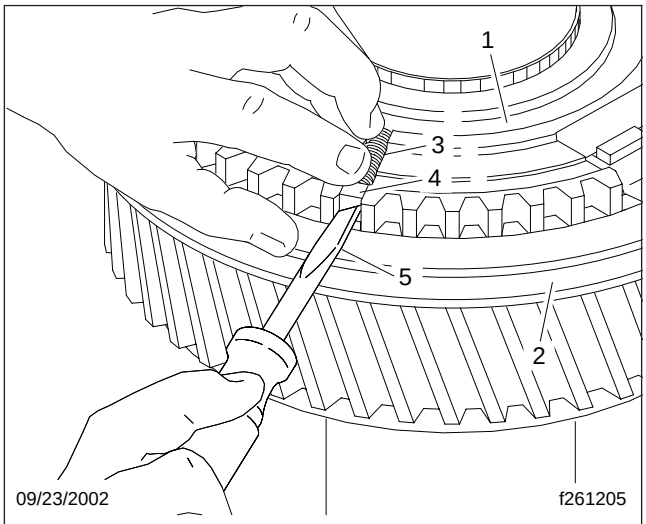
1. 5th Gear Synchro Cone
2. 5th Gear Synchro Ring
3. 5th/6th Gear Synchro Slide Collar
4. Snap Ring
5. 5th/6th Gear Synchro Body
6. Compression Spring
7. Spring Holder
8. 6th Gear Synchro Ring
9. 6th Gear Synchro Cone
10. 6th Gear Wheel
11. 6th Gear Needle Bearing
12. Main Shaft (input end)

Fig. 1, 5th and 6th Gear Assembly

https://truckmanualshub.com/

Sixth and Fifth Gear Assembly

2. Mount the 6th gear wheel over the needle bearing with the undercut teeth facing up.
3. Install the 6th gear synchro cone. The oil grooves on the synchro cone must align with the oil grooves on the 6th gear wheel. See **Fig. 1**.
4. Apply a coating of approved transmission oil to the 6th gear synchro ring. Fit the synchro ring onto the synchro cone.
5. Fit the 5th/6th gear synchro body onto the main shaft. If there is resistance, warm the synchro body using a heat gun. The large stop lugs of the 6th gear synchro ring must mesh with the large recesses in the synchro body.
6. Install a new snap ring inside the synchro body. Make sure the snap ring is tight when installed, with no free play.
7. Install the 5th/6th gear synchro slide collar on the synchro body as far as the stop.
8. Install the three compression springs into the slots in the synchro body. Using a short-bladed screwdriver, press them in until the spring holder engages the tooth of the synchro slide collar. See **Fig. 2**.



Press in the compression spring until the spring holder engages the tooth of the synchro slide collar.

1. Synchro Body
2. Synchro Slide Collar
3. Compression Spring
4. Spring Holder
5. Short-Bladed Screwdriver

Fig. 2, Pressing in the Compression Springs

Fifth Gear

1. Insert the 5th gear synchro ring into the synchro body. The large stop lugs of the 5th gear synchro ring must engage in the large recesses of the synchro body.
2. Insert the 5th gear synchro cone into the 5th gear synchro ring.
3. Move the 5th/6th gear synchro slide collar into neutral position.
4. Install the countershaft on the main shaft; for instructions, see **Subject 180**.
5. Install the 2nd gear on the main shaft; for instructions, see **Subject 230**.
6. Install the reverse gear and the 1st gear on the main shaft; for instructions, see **Subject 230**.
7. Install the rear gear case; for instructions, see **Subject 160**.
8. Install the front gear case; for instructions, see **Subject 150**.

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Second Gear

For an exploded view of this assembly, see **Fig. 1**.

1. Apply a coating of approved transmission oil to the needle bearing. Fit the needle bearing onto the main shaft.
2. Mount the 2nd gear wheel over the needle bearing with the short teeth facing up.
3. Apply a coating of approved transmission oil to the 2nd gear outer synchro cup and 2nd gear synchro ring. Install the outer cup with the stop lugs facing up. Install the 2nd gear inner ring with the stop lugs facing down and engaging the recesses in the 2nd gear wheel.
4. Install the 2nd gear inner synchro cone. The mounts on the synchro cone must engage the stop lugs of the outer cup.
5. Fit the 1st/2nd gear synchro body onto the main shaft. If there is resistance, warm the synchro body using a heat gun. The mounts of the 2nd gear outer synchro cup must engage in the large recesses in the synchro body. See **Fig. 2**.
6. Install a new snap ring and press it into place inside the synchro body. Make sure the snap ring is tight when installed, with no free play.
7. Install the 1st/2nd gear synchro slide collar on the synchro body with the asymmetric tips of the tooth flanks facing up. See **Fig. 3**.

IMPORTANT: On each synchro slide collar, there are three shortened tooth flanks, evenly spaced around the perimeter. The shortened tooth flanks of the synchro slide collar should be lined up with the shortened tooth flanks of the synchro body.

8. Install the three compression springs into the slots in the synchro body. Using a short-bladed screwdriver, press them in until the spring holder engages the tooth of the synchro slide collar. See **Fig. 4**.

First Gear

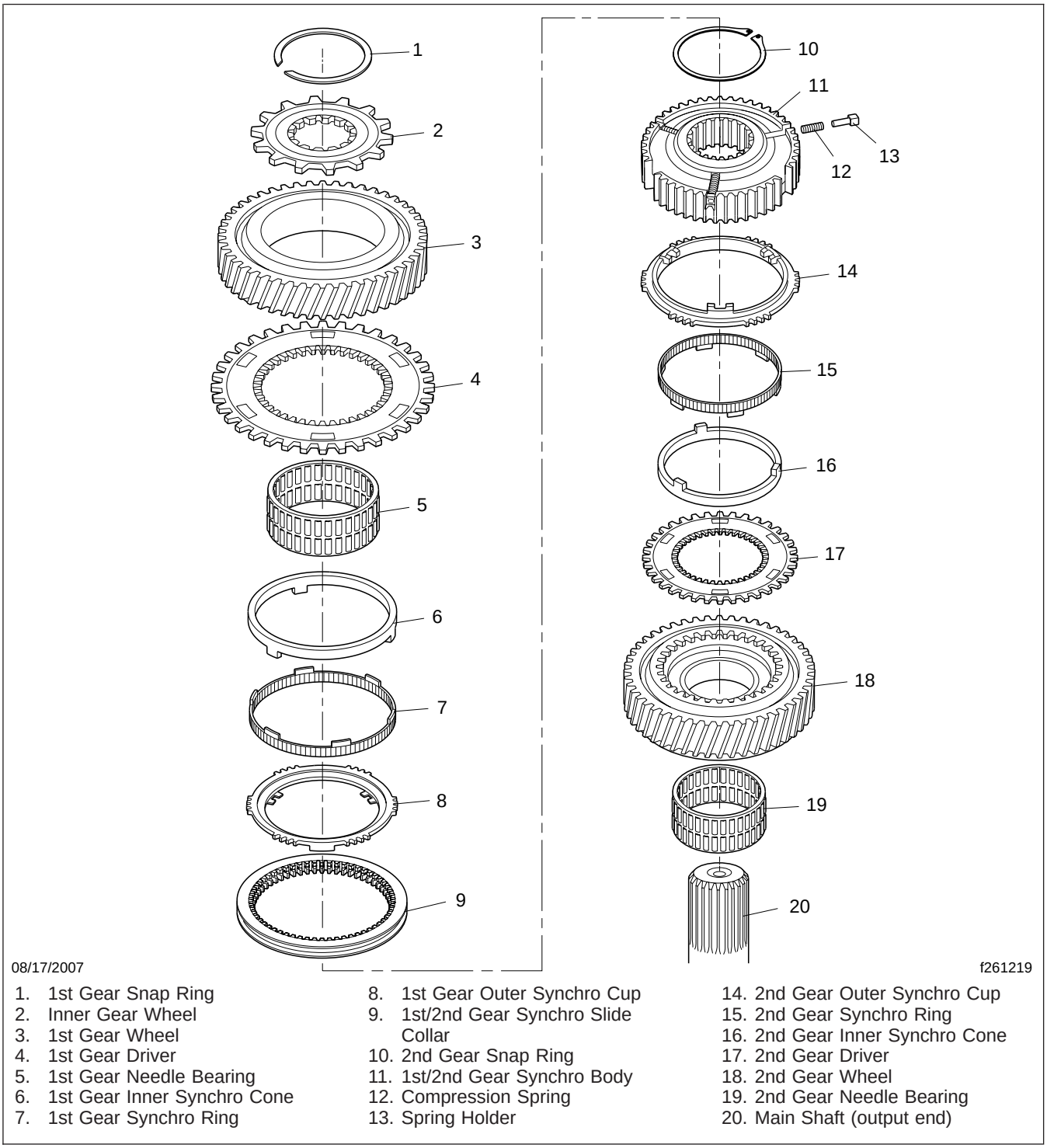
1. Install the 1st gear outer synchro cup on the 1st/2nd gear synchro body. The mounts of the outer cup must engage in the recesses of the synchro body.
2. Apply a coating of approved transmission oil to the synchro ring. Install the ring with the stop lugs facing up. Install the inner cone with the stop lugs facing down and engaging the mounts of the outer cup.
3. Apply a coating of approved transmission oil to the needle bearing. Fit the needle bearing onto the main shaft.
4. Mount the 1st gear wheel over the needle bearing with the helical teeth facing up.
5. Install the inner gear wheel with the rounded teeth facing up.
6. Install a new snap ring and press it into place. Make sure the snap ring is tight when installed, with no free play.

Reverse Gear

1. Install the reverse gear.
2. Install the shift bars and forks.
3. Install the rear gear case; for instructions, see **Subject 120**.
4. Install the front gear case; for instructions, see **Subject 110**.
5. Install the shift mechanism; for instructions, see **Subject 100**.

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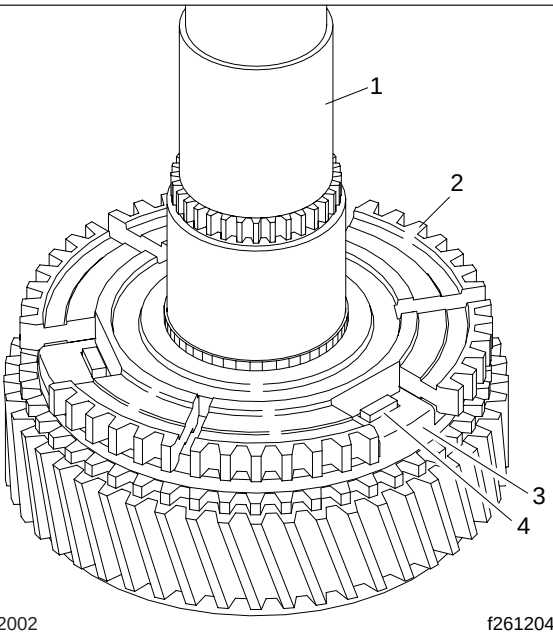
Second, First, and Reverse Gear Assembly



1. 1st Gear Snap Ring
2. Inner Gear Wheel
3. 1st Gear Wheel
4. 1st Gear Driver
5. 1st Gear Needle Bearing
6. 1st Gear Inner Synchro Cone
7. 1st Gear Synchro Ring
8. 1st Gear Outer Synchro Cup
9. 1st/2nd Gear Synchro Slide Collar
10. 2nd Gear Snap Ring
11. 1st/2nd Gear Synchro Body
12. Compression Spring
13. Spring Holder
14. 2nd Gear Outer Synchro Cup
15. 2nd Gear Synchro Ring
16. 2nd Gear Inner Synchro Cone
17. 2nd Gear Driver
18. 2nd Gear Wheel
19. 2nd Gear Needle Bearing
20. Main Shaft (output end)

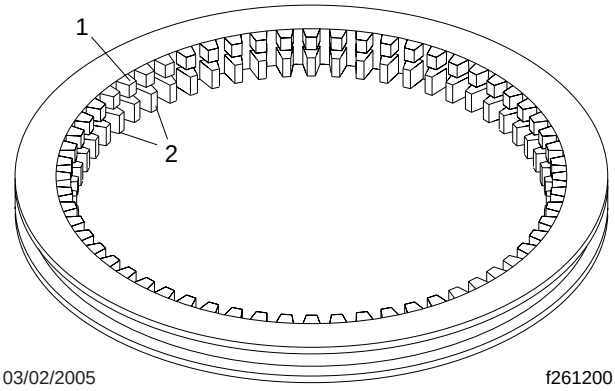
Fig. 1, 1st and 2nd Gear Assembly

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1. Main Shaft
2. 1st/2nd Gear Synchro Body
3. Outer Cup Stop Lug
4. Inner Cone Mount

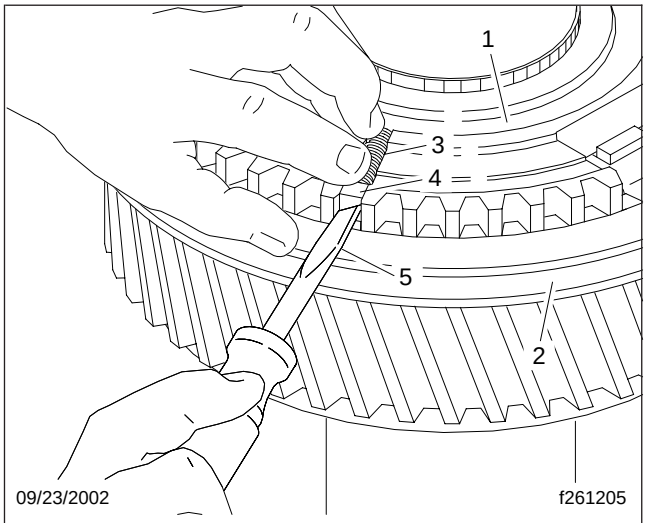
Fig. 2, 2nd Gear Synchronizers



Line up the shortened tooth flanks of the synchro slide collar with the shortened tooth flanks of the synchro body.

1. Shortened Tooth Flank
2. Long Tooth Flanks

Fig. 3, Synchro Slide Collar



Press in the compression spring until the spring holder engages the tooth of the synchro slide collar.

1. Synchro Body
2. Synchro Slide Collar
3. Compression Spring
4. Spring Holder
5. Short-Bladed Screwdriver

Fig. 4, Pressing in the Compression Springs

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Special Tools

A special tool is required for this procedure. See **Table 1**.

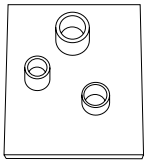
Special Tool for Reverse, First, and Second Gear Disassembly			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580395	Main Shaft/Countershaft Stand	Kent-Moore	J-46732

Table 1, Special Tool for Reverse, First, and Second Gear Disassembly

Fifth/Sixth Gear Inspection

1. Remove the front gear case; for instructions, see **Subject 150**.
2. Remove the rear gear case; for instructions, see **Subject 160**.
3. Remove the reverse gear wheel and needle bearing from the main shaft; for instructions, see **Subject 170**. Do not remove the 1st gear wheel.
4. Place the main shaft on the main shaft/countershaft stand. See **Table 1**.
5. Move the 5th/6th gear synchro slide collar into the neutral position.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

6. Put the 5th gear synchro ring into position to measure the 5th gear synchromesh reserve, as follows.
   - 6.1 Using the synchro slide collar, push the synchro ring up against the 5th gear synchro cone.
   - 6.2 While pushing the synchro slide collar up, press down on the synchro cone and turn it. Verify that the synchro cup and cone are squarely seated, without sliding into gear.

NOTE: This step requires two persons.

7. While one person holds the synchro ring and cone in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 5th gear, as follows. See **Table 2** for specified and minimum dimensions.

Synchromesh Reserve Dimension		
Gear	**Minimum: inch (mm)**	**Specified: inch (mm)**
1st	0.03 (0.7)	0.08 (2.0)
2nd	0.03 (0.7)	0.08 (2.0)
3rd	0.03 (0.7)	0.08 (2.0)
4th	0.03 (0.7)	0.08 (2.0)
5th	0.02 (0.5)	0.06 (1.5)
6th	0.02 (0.5)	0.06 (1.5)

Table 2, Synchromesh Reserve Dimension

   - 7.1 Measure the synchromesh reserve over the entire circumference of the ring.
   - 7.2 Calculate the average value of the synchromesh reserve.
   - 7.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 5th gear synchro ring.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

8. Put the 6th gear synchro ring into position to measure the 6th gear synchromesh reserve, as follows.

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Synchro Ring Wear Limit Inspection

8.1 Using the synchro slide collar, press the 6th gear synchro ring down against the 6th gear wheel.

8.2 While pressing the synchro slide collar down, turn the 6th gear wheel.

NOTE: This step requires two persons.

9. While one person holds the synchro ring and gear wheel in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 6th gear, as follows. See **Table 2** for specified and minimum dimensions.

9.1 Measure the synchromesh reserve over the entire circumference of the ring.

9.2 Calculate the average value of the synchromesh reserve.

9.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 6th gear synchro ring.

Fourth/Third Gear Inspection

1. Move the 3rd/4th gear synchro slide collar into the neutral position.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

2. Put the 4th gear outer synchro cup into position to measure the 4th gear synchromesh reserve, as follows.

2.1 Using the synchro slide collar, push the outer synchro cup up against the 4th gear wheel.

2.2 While pushing the synchro slide collar up, turn the 4th gear wheel. Verify that the synchro cup and cone are squarely seated, without sliding into gear.

NOTE: This step requires two persons.

3. While one person holds the outer synchro cup and gear wheel in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 4th gear, as follows. See **Table 2** for specified and minimum dimensions.

3.1 Measure the synchromesh reserve over the entire circumference of the outer synchro cup.

3.2 Calculate the average value of the synchromesh reserve.

3.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 4th gear synchro ring.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

4. Put the 3rd gear outer synchro cup into position to measure the 3rd gear synchromesh reserve, as follows.

4.1 Using the synchro slide collar, press the outer synchro cup down against the 3rd gear wheel.

4.2 While pressing the synchro slide collar down, turn the 3rd gear wheel.

NOTE: This step requires two persons.

5. While one person holds the outer synchro cup and gear wheel in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 3rd gear, as follows. See **Table 2** for specified and minimum dimensions.

5.1 Measure the synchromesh reserve over the entire circumference of the outer synchro cup.

5.2 Calculate the average value of the synchromesh reserve.

5.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 3rd gear synchro ring.

Second/First Gear Inspection

1. Move the 1st/2nd gear synchro slide collar into the neutral position.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

2. Put the 2nd gear outer synchro cup into position to measure the 2nd gear synchromesh reserve, as follows.

2.1 Using the synchro slide collar, push the outer synchro cup up against the 2nd gear wheel.

2.2 While pushing the synchro slide collar up, turn the 2nd gear wheel. Verify that the

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synchro cup and cone are squarely seated, without sliding into gear.

NOTE: This step requires two persons.

3. While one person holds the outer synchro cup and gear wheel in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 2nd gear, as follows. See **Table 2** for specified and minimum dimensions.
   - 3.1 Measure the synchromesh reserve over the entire circumference of the outer synchro cup.
   - 3.2 Calculate the average value of the synchromesh reserve.
   - 3.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 2nd gear synchro ring.

NOTE: Do not tilt or twist the synchro ring. This can cause the measurement to be incorrect.

4. Put the 1st gear outer synchro cup into position to measure the 1st gear synchromesh reserve, as follows.
   - 4.1 Using the synchro slide collar, press the outer synchro cup down against the 1st gear wheel.
   - 4.2 While pressing the synchro slide collar down, turn the 1st gear wheel.

NOTE: This step requires two persons.

5. While one person holds the outer synchro cup and gear wheel in place, the other person, using a feeler gauge, measures the synchromesh reserve of the 1st gear, as follows. See **Table 2** for specified and minimum dimensions.
   - 5.1 Measure the synchromesh reserve over the entire circumference of the outer synchro cup.
   - 5.2 Calculate the average value of the synchromesh reserve.
   - 5.3 If the average value of the synchromesh reserve is below the minimum dimension, replace the 1st gear synchro ring.
6. Install the reverse gear wheel and needle bearing on the main shaft; for instructions, see **Subject 170**.
7. Install the rear gear case; for instructions, see **Subject 160**.
8. Install the front gear case; for instructions, see **Subject 150**.

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Special Tools

Special tools are required for this procedure. See **Table 1**.

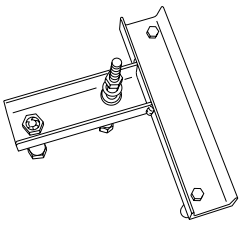
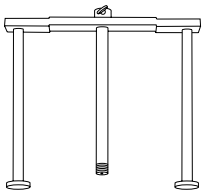
Special Tools for End Play Measurement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580397	Puller/Installer/Stand	Kent-Moore	J-46739
 f580402	Main Shaft End Play Measuring Fixture	Kent-Moore	J-47903

Table 1, Special Tools for End Play Measurement

Measurement

NOTE: Do this procedure whenever the gear case halves, main shaft, bearings, or input shaft are removed. Perform this procedure with the transmission partially assembled, and with the front gear case removed.

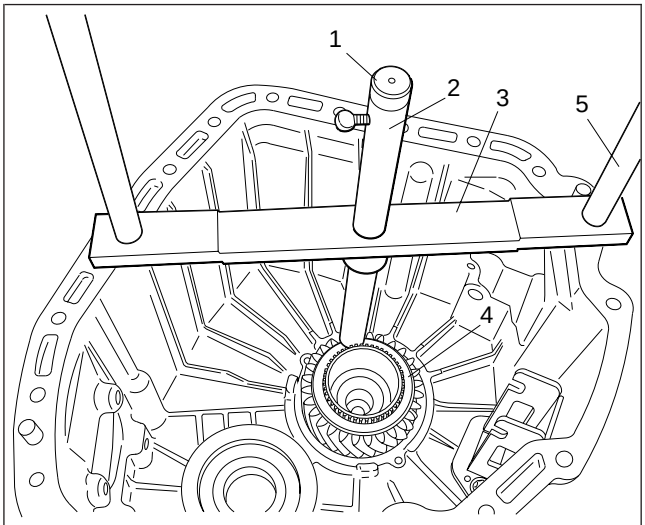
1. Place the front case nose down. Install the rear case on the puller/installer/stand, if not already done.
2. Set up the main shaft end play measuring fixture on the front gear case with the crossbar flat on the gear case flange and its legs in the air. See **Table 1**. Lock down the upper thumbscrew at the point where the center shaft of the measuring fixture just touches the contact surface of the input shaft gear wheel. See **Fig. 1**.
3. Turn the end play measuringfixture over and set it up on the rear gear case with the legs down, resting on the gear case flange.
4. Lock down the lower thumbscrew at the point where the end cap of the measuring fixture just touches the contact surface of the input shaft mating wheel. See **Fig. 2**.
5. Using a feeler gauge, measure the gap between the shaft and the end cap. This gap is the end play. See **Fig. 3**.
6. If the end play is within acceptable limits, continue on to the next step. See **Table 2** for acceptable limits.

   If the end play is less than the acceptable limit, install a thinner thrust washer and repeat the measurements until the end play is acceptable.

   If the end play is more than the acceptable limit, install a thicker thrust washer and repeat the measurements until the end play is acceptable.
7. Install the input shaft; for instructions, see **Subject 120**.
8. Install the front gear case; for instructions, see **Subject 150**.

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Main Shaft End Play Measurement



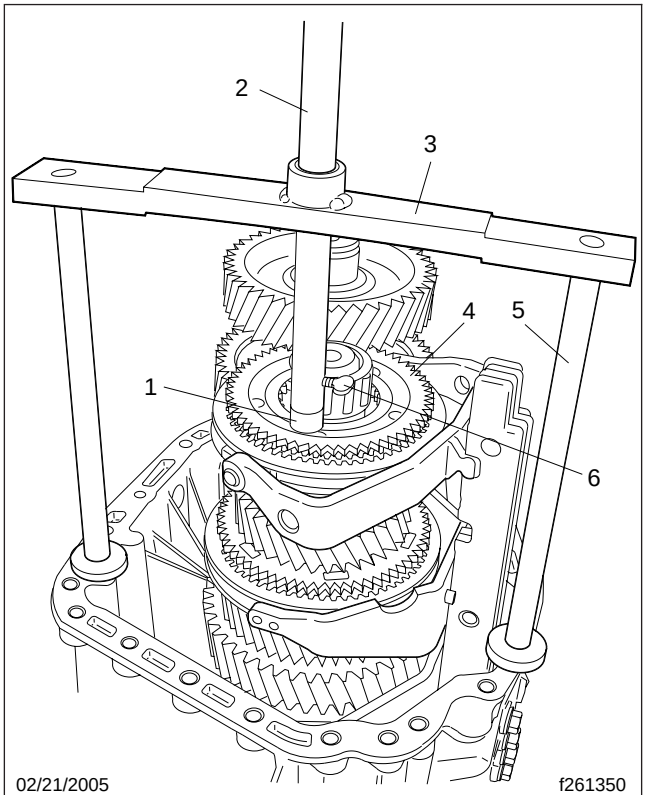
02/18/2005 f261349

1. Measuring Fixture End Cap
2. Measuring Fixture Center Shaft
3. Measuring Fixture Crossbar
4. Input Shaft Gear Wheel
5. Leg of Measuring Fixture

Fig. 1, Taking the First Measurement

Main Shaft End Play Limits		
Model	**Minimum: inch (mm)**	**Maximum: inch (mm)**
520	0.041 (1.05)	0.049 (1.25)
660	0.037 (0.95)	0.049 (1.25)

Table 2, Main Shaft End Play Limits

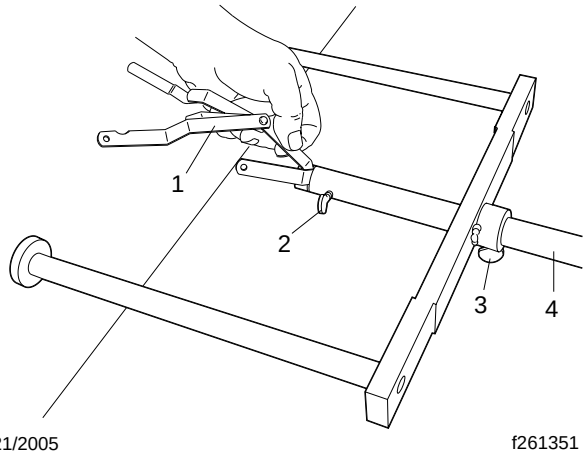


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1. Measuring Fixture End Cap
2. Measuring Fixture Center Shaft
3. Measuring Fixture Crossbar
4. Input Shaft Mating Wheel
5. Leg of Measuring Fixture
6. Lower Thumbscrew

Fig. 2, Taking the Second Measurement

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Using a feeler gauge,measure the gap (arrow) between the center shaft and the end cap.

1. Feeler Gauge
2. Lower Thumbscrew
3. Upper Thumbscrew
4. Measuring Fixture Center Shaft

Fig. 3, Measuring the End Play with a Feeler Gauge

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Specifications

Torque Values, M-B Transmission Removal and Installation			
Fastener	**Size**	**Class**	**Torque: lbf·ft (N·m)**
Bell Housing-to-Timing Case Capscrews	M10 x 1.5	8.8	33 (45)
Clutch Slave Cylinder Bracket Mounting Bolts	M8	8.8	15 (20)
Fuel Crossover Line Mounting Bolts	—	—	95 (129)
Fuel Crossover Line Mounting Clamps	—	—	40 (54)
Midship Bearing Bracket Capscrews	3/4–11	—	95 (129)
Power Takeoff Unit (PTO) Mounting Capscrews	M10	10.9	43 (58)
Reverse Gear Switch	M20	8.8	42 (57)
Shift Lever Mounting Bolt	M10 x 1.5	10.9	50 (68)
Shift Lever Retaining Ring Screws	—	—	28 (38)
Speedometer Sensor Lock	M8	8.8	28 (38)
Starter Lock Switch (optional)	M20	8.8	42 (57)
Transmission Fluid Drain Plug	M24	8.8	42 (57)
Transmission Fluid Fill Plug	M24	8.8	42 (57)
U-Joint End Cap Bolts	3/8–24	—	50 (68)
	1/2–20	—	110 (149)

Table 1, Torque Values, M-B Transmission Removal and installation

Torque Values, M-B Transmission Teardown	
Fastener	**Torque: lbf·ft (N·m)**
Clutch Release Fork Mounting Capscrew	26 (36)
Gear Case Capscrews	22 (30)
Input Shaft Guide Tube Low-Profile Mounting Capscrew	17 (23)
Output Shaft Pressure Plate Mounting Capscrew	190 (258)
Rear Countershaft Cover Capscrew	18 (25)
Shift Rail Cover Capscrew	29 (39)
Shift Rail Detent Bolt	22 (30)
Shift Rod Housing Capscrews	18 (25)
Shift Rod Setscrew	30 (40)
Shifter Pin T60 Capscrew (model 660 only)	88 (120)

Table 2, Torque Values, M-B Transmission Teardown

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Specifications

Gear Ratios		
Model	**Gear**	**Ratio**
MBT520S-6D	1	9.201
	2	5.230
	3	3.145
	4	2.034
	5	1.374
	6	1.000
	R	8.649
MBT660S-6O	1	6.700
	2	3.810
	3	2.290
	4	1.480
	5	1.000
	6	0.730
	R	6.290

Table 3, Gear Ratios

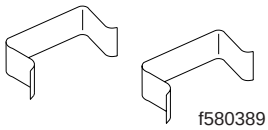
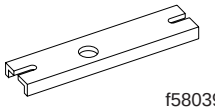
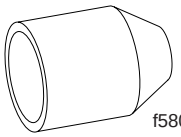
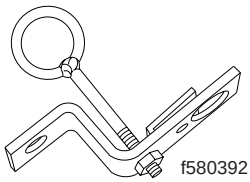
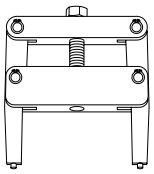
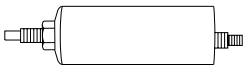
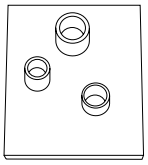
Synchromesh Reserve		
Gear	**Minimum Dimension: inch (mm)**	**Specified Dimension: inch (mm)**
1st	0.03 (0.7)	0. 08 (2.0)
2nd	0.03 (0.7)	0. 08 (2.0)
3rd	0.03 (0.7)	0. 08 (2.0)
4th	0.03 (0.7)	0. 08 (2.0)
5th	0.02 (0.5)	0. 06 (1.5)
6th	0.02 (0.5)	0. 06 (1.5)

Table 4, Synchromesh Reserve

Main Shaft End Play Limits		
Model	**Minimum Dimension: inch (mm)**	**Maximum Dimension: inch (mm)**
520	0.041 (1.05)	0.049 (1.25)
660	0.037 (0.95)	0.049 (1.25)

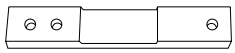
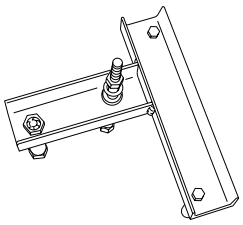
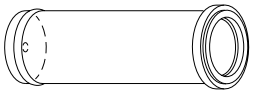
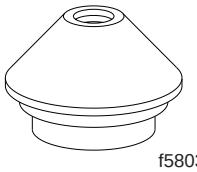
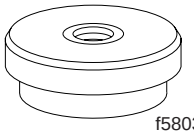
Table 5, Main Shaft End Play Limits

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Special Tools for M-B Transmissions			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580389	Synchro Retainer Clips	Kent-Moore	J-46726
 f580390	Front Gear Case Bridge	Kent-Moore	J-46727
 f580391	Countershaft Guide	Kent-Moore	J-46728
 f580392	Main Shaft/Countershaft Lifting Device	Kent-Moore	J-46729
 f580393	Snap Ring Removal Tool	Kent-Moore	J-46730
 f580394	Reverse Idler Shaft Puller	Kent-Moore	J-46731
 f580395	Main Shaft/Countershaft Stand	Kent-Moore	J-46732

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Specifications

Special Tools for M-B Transmissions			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580396	Countershaft Retainer	Kent-Moore	J-46733
 f580397	Rear Case Puller/Installer/Stand	Kent-Moore	J-46739
 f580401	Input Shaft Seal Installer	Kent-Moore	J-47901
 f580398	Output Shaft Seal Installer	Kent-Moore	J-47863
 f580399	Countershaft Seal Cap Installer	Kent-Moore	J-47901
 f580400	Universal Handle	Kent-Moore	J-8901

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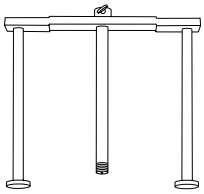
Special Tools for M-B Transmissions			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580402	Main Shaft End Play Measuring Fixture	Kent-Moore	J-47903

Table 6, Special Tools for M-B Transmissions

Standard Shop Tools for M-B Transmission	
Tool Description	**Remarks**
Torx® bit set	Must include a size T60 bit
Inverted-Torx bit set	Must include size E12 and E14 bits
Large snap ring pliers	Similar to Snap-On p/n PR7
Large duck-bill snap ring pliers	Similar to Craftsman p/n 9 47386 or Snap-On p/n SRP4
Seal remover	Similar to Craftsman p/n 9 47645 or Snap-On p/n YA105
A pair of lifting straps of 300 lb capacity or more	A 1" x 4' loop-type strap handles this unit
Large soft-faced dead-blow hammer (5-lb. weight)	Similar to Snap-On p/n BC7A
Large T-bar puller	Similar to OTC p/n 522

Table 7, Standard Shop Tools for M-B Transmission

Service Material Specifications		
Purpose	**Product**	**Color**
Thread-locking Compound	Loctite® 242 or Equivalent	Blue
Sealant	Loctite 509 or Equivalent	Blue to Green
Extreme-Pressure Lubricant	J 23444-A	Dark Gray

Table 8, Service Material Specifications

Transmission Model	Lubricant Type	Refill Capacity:* qt (L)
MBT660S-6O	Mobiltrans SHC® DC	9.5 (9.0)
MBT520S-6D		

* Quantities listed are approximate. Fill the transmission until the lubricant is level with the bottom of the fill hole, with the vehicle in normal operating position.

Table 9, M-B Transmission Approved Lubricant Type and Capacity

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General Information

The Mercedes-Benz AGS Automated Gear Shift transmission is a fully automated manual transmission. It is offered in two 6-speed medium-duty models:

- MBT520-6DA, direct drive, 520 lb·ft torque rating
- MBT660-6OA, overdrive, 660 lb·ft torque rating

The gear case holds 9.5 quarts (9 liters) of oil. MobilTrans SHC® DC is the approved oil.

No clutch pedal is needed to change gears. The clutch is activated by a hydraulic system that also controls the shifting mechanism. After any service, the clutch must be recalibrated.

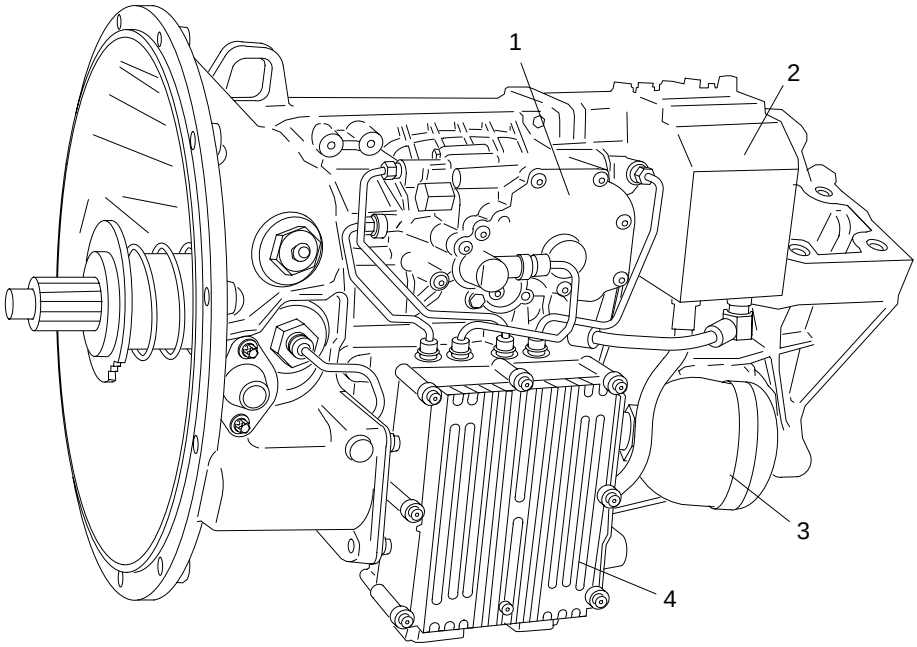
The hydraulic system is a self-contained AGS unit that attaches to the left-hand side of the gear case. See **Fig. 1**.

The AGS unit has four major components:

- The x-y actuator, which controls the movements of the shift mechanism
- The reservoir, which holds the supply of hydraulic fluid
- The pressure accumulator, which maintains a maximum hydraulic pressure of 1230 psi (8500 kPa)
- The central unit, which controls both electrical and hydraulic inputs

The central unit of the AGS contains the transmission control unit (TCU) and the hydraulic body. On the rear of the hydraulic body are a hydraulic pump and an electric motor.

The TCU is the electronic center of the AGS. It controls gear changes and monitors the positions of the clutch and the shift mechanism. It receives requests from the shift lever to change drive modes and gears. It broadcasts error messages to the J1587



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1. X-Y Actuator
2. Reservoir
3. Accumulator
4. Central Unit

Fig. 1, AGS Unit Components

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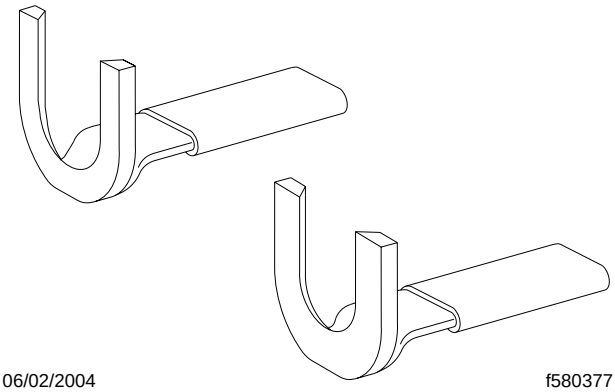
databus. It communicates to the engine and antilock brakes over the J1939 network.

The hydraulic body distributes hydraulic fluid to the clutch, x-y actuator, and accumulator. The hydraulic pump is driven by an electric motor with its own connection to the power distribution module, protected by a 40-amp fuse.

The hydraulic pump comes on automatically when the ignition is turned on, producing a distinctive humming noise that is a characteristic of this transmission. When the noise stops, the hydraulic system is pressurized.

The hydraulic reservoir holds about 1.05 quarts (one liter) of hydraulic fluid. The only fluid used in this system is Pentosin. No other fluid can be substituted.

Both high-pressure and low-pressure hydraulic fittings are not threaded. They can be removed by pressing a brass ring against a soft O-ring and thereby compressing it enough to break the seal and open the line. See **Fig. 2** for the line removal tools.



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NOTE: The tool with the large opening (top) is used to disconnect the low-pressure hoses. The tool with the small opening (bottom) is used to disconnect the high-pressure lines.

Fig. 2, Hydraulic Fitting Disconnect Tools

Certain fasteners used on this transmission contain small amounts of chemical in micro-capsules embedded in the thread. This chemical has sealant and/or thread-locking properties. These fasteners must be replaced at every service for the micro-encapsulated chemical to keep its properties.

IMPORTANT: Do not use Loctite® or sealant on these fasteners.

Principles of Operation

A shift can be requested either manually, by pushing or pulling the SmartShift lever, or automatically. The AGS judges when to shift automatically through information provided by rotational speed (rpm) sensors. One sensor reads input shaft speed (this sensor is located aft of the central unit, on the countershaft). Two rear sensors read output shaft speed and direction of rotation.

When a shift is requested, hydraulic pressure disengages the clutch. A position sensor attached to the clutch release bearing housing ensures smooth disengagement and engagement.

The x-y actuator moves the shift rod in two dimensions (this is why it is called x-y actuation). With the clutch disengaged, the actuator uses hydraulic pressure to move the shift rod until it is over the correct shift rail. Then it turns the shift rod a precise amount so that the shift finger can engage the shift rail for the correct gear. Two shift position sensors, a gear position sensor and a rail position sensor, assure correct positioning of the shift rod and the shift rail.

From this point on, the mechanism operates in exactly the same way as in any other Mercedes-Benz manual transmission. The notch in the shift rail contacts the shift fork, which moves the synchro slide onto the correct gear wheel.

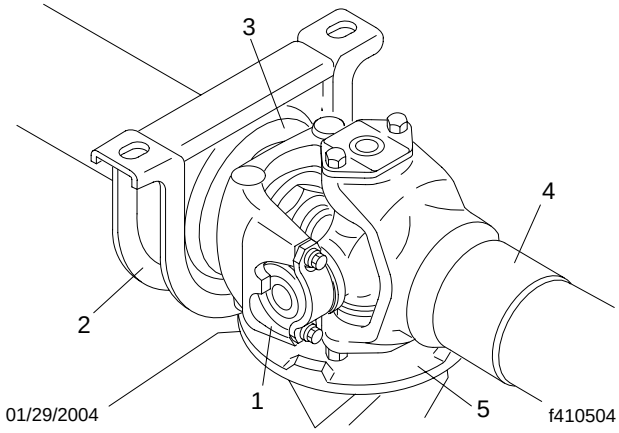
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Removal

1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the rear tires.

IMPORTANT: To prevent loss of hydraulic fluid, depressurize the hydraulic system before removing the transmission.

2. Depressurize the hydraulic system. For detailed procedures, see **Subject 160**.
3. Disconnect the batteries.
4. Disconnect the driveshaft from the transmission. See **Fig. 1**.



1. U-Joint
2. Midship Bracket
3. Midship Bearing
4. Driveshaft
5. Jack

Fig. 1, Midship Bearing

4.1 Support the driveline with a jack underneath the aft midship bearing.

4.2 Remove the bolts from the aft midship bearing bracket.

4.3 Remove the forward midship bracket.

4.4 Remove the transmission yoke U-joint from the transmission.

4.5 Support the disconnected driveshaft.

5. Remove the cab floor plate and cover plate. See **Fig. 2**.
6. Remove all brackets attached to the transmission mounting bolts. Remove all the transmission mounting bolts from the bell housing except for the top two. See **Fig. 3**.
7. Remove the two screws that attach the splash guard to the TCU. See **Fig. 4**.
8. Remove the main vehicle harness (X1 connector) and electric motor harness (X3 connector). Remove tie straps as necessary. See **Fig. 5**.
9. Support the transmission with a jack. See **Fig. 6**.

9.1 Position a transmission jack under the transmission and raise its support plates against the base of the transmission.

9.2 Adjust the support plates to cradle the transmission.

9.3 Using a chain, secure the transmission to the jack.

10. Remove the top two transmission bolts that attach the timing case to the bell housing.

⚠ CAUTION

Do not allow the rear of the transmission to drop, and do not allow the transmission to hang unsupported. Keep the flange of the bell housing parallel (all the way around) to the flange of the timing case, until the input shaft is clear of the flywheel. Taking these precautions will prevent damage to the input shaft, flywheel, and clutch.

11. Remove the transmission. See **Fig. 7**.

11.1 Pull the transmission and jack straight back until the transmission input shaft is clear of the engine.

11.2 If necessary, lower the jack supporting the transmission. It might also be necessary to jack up the truck to get enough clearance to allow the transmission to pass.

IMPORTANT: Watch closely the clearance between the bell housing and the frame rail.

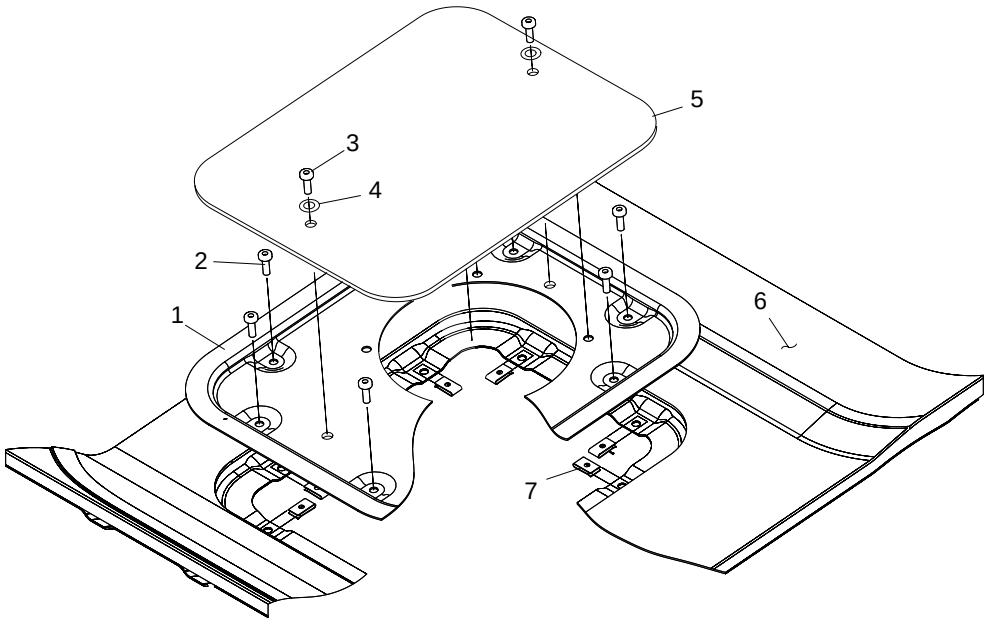
11.3 Pull the transmission out through the space behind the cab.

Installation

IMPORTANT: Before installing the transmission, make sure that the rear tires are chocked and

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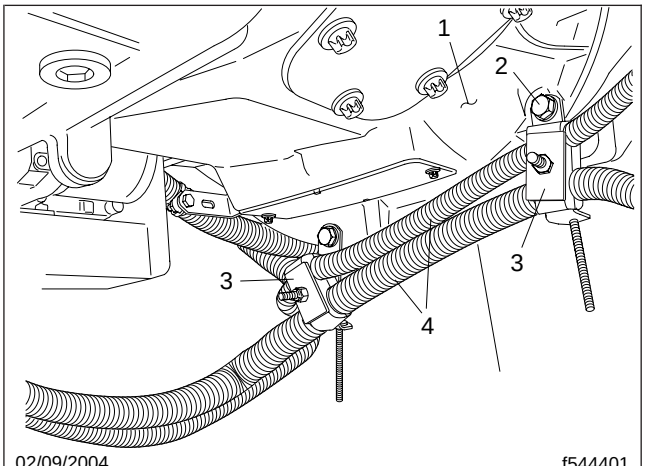
Transmission Removal and Installation



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1. Cover Plate
2. Cover Plate Mounting Bolt
3. Floor Plate Mounting Bolt
4. Washer
5. Floor Plate
6. Cab Floor
7. Spring Clip

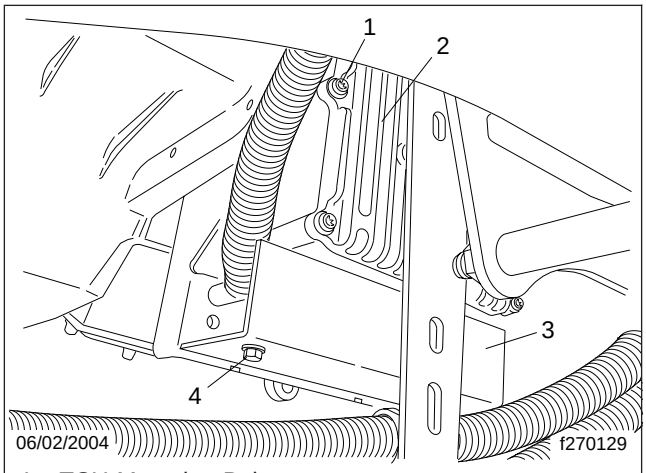
Fig. 2, Floor Access



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1. Bell Housing
2. Transmission Mounting Bolt
3. Battery Cable Bracket
4. Battery Cables

Fig. 3, Battery Cable Brackets

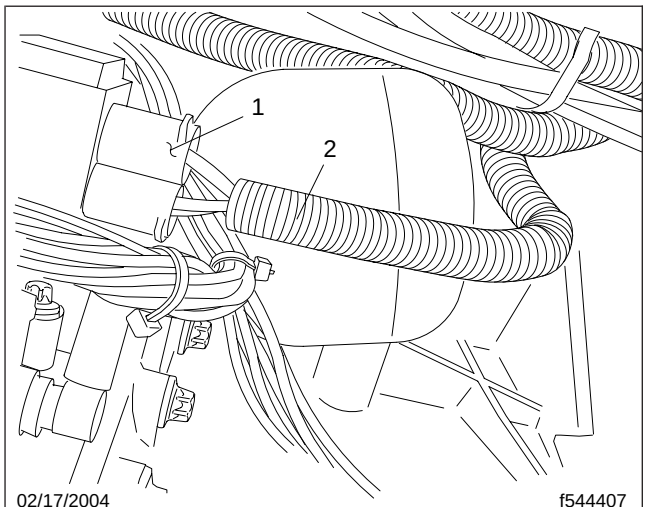


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1. TCU Mounting Bolt
2. TCU
3. Splash Guard
4. Splash Guard Mounting Bolt

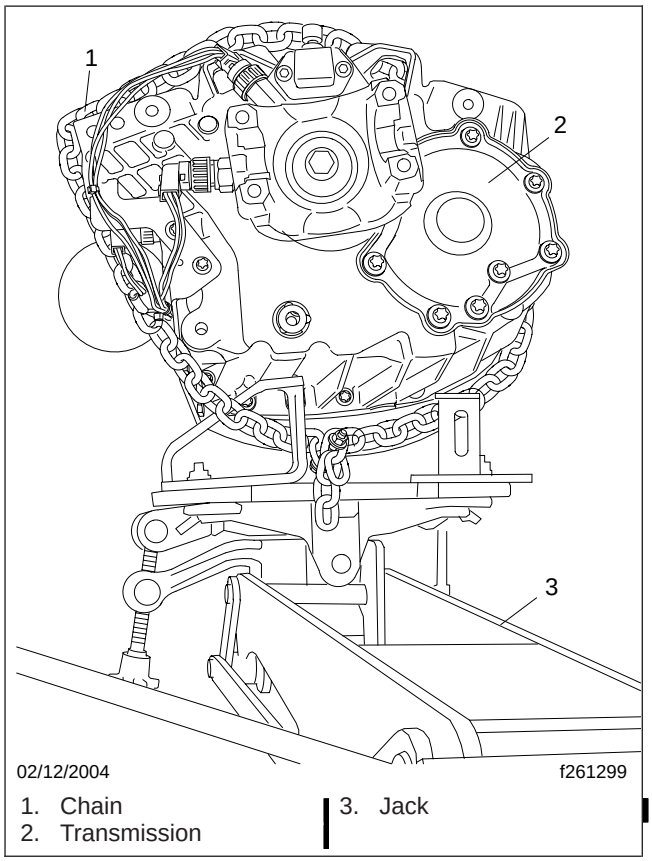
Fig. 4, TCU Splash Guard

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1. X3 Connector
2. Electric Motor Harness

Fig. 5, Harness Connector



1. Chain
2. Transmission
3. Jack

Fig. 6, Supporting the Transmission

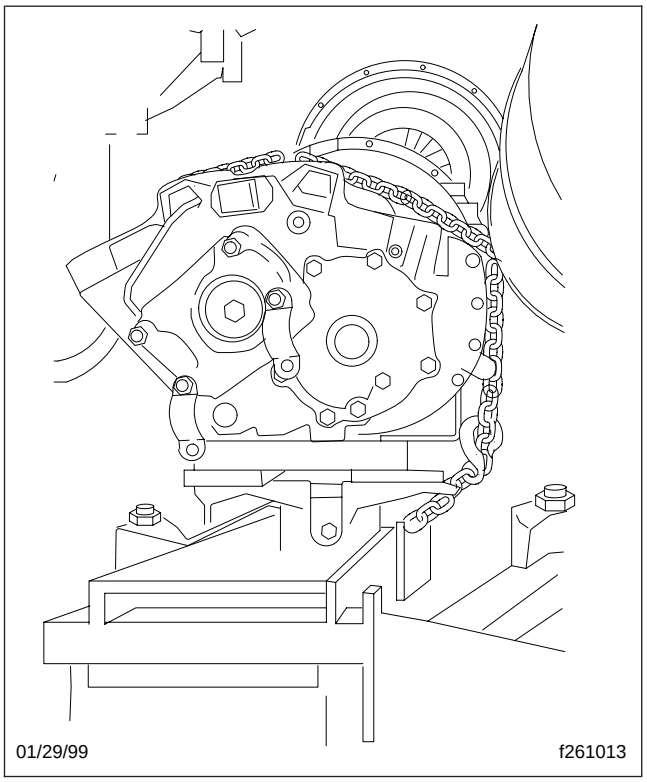


Fig. 7, Removing the Transmission

that the transmission is securely chained to the support plates on the transmission jack.

1. Align the input shaft so that its splines engage the clutch.

   1.1 Align the jack and the transmission behind the engine.

   1.2 Raise the transmission and adjust the angle of the jack until the bell housing and the timing case flange are parallel.

   1.3 Push the transmission and jack straight forward.

   NOTE: The AGS transmission automatically selects neutral when shut off. To make sure the clutch and input shaft are properly aligned, this substep requires two persons.

   1.4 While one person continues to push the transmission forward, the other person uses channel locks or other locking pliers to grip the input shaft and twist it slightly.

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Transmission Removal and Installation

1.5 When the input shaft and the clutch are aligned, work the transmission further towards the engine and line up the bolt holes in the flywheel housing with those in the bell housing.

2. Install the transmission.

2.1 Install the M10 transmission bolts that attach the bell housing to the timing case. Use a crossover pattern.

2.2 While installing the transmission mounting bolts, also install all the bracket(s) on the bell housing, as removed.

2.3 Remove the chain that was used to secure the transmission to the jack; then remove the jack.

2.4 Do a final tightening of the mounting bolts to 33 lbf·ft (45 N·m).

3. Connect the X1 and X3 electrical connectors. Be sure the yellow safety slide on the X1 connector snaps into place.

4. Install the cab floor plate and cover plate. See **Fig. 2**.

5. Connect the driveshaft.

5.1 Slide the front of the driveshaft into the transmission output yoke.

5.2 Install the U-joint end caps on the output yoke. Tighten 3/8-inch end cap bolts to 50 lbf.ft (68 N.m); tighten 1/2-inch end cap bolts to 110 lbf.ft (149 N.m).

5.3 Install the bolts and nuts that attach the midship bearing brackets. Tighten the nuts 91 lbf·ft (123 N·m).

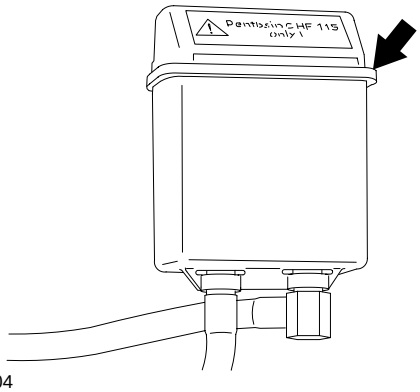
6. Check the hydraulic fluid level and add more Pentosin if needed. See **Fig. 8**. For detailed procedures, see **Subject 150**.

IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

7. Connect the batteries.

8. Bleed the hydraulic system and recalibrate the transmission according to the procedures in **Subject 130**.

9. Check the transmission fluid level. If low, add transmission fluid until it is level with the lower

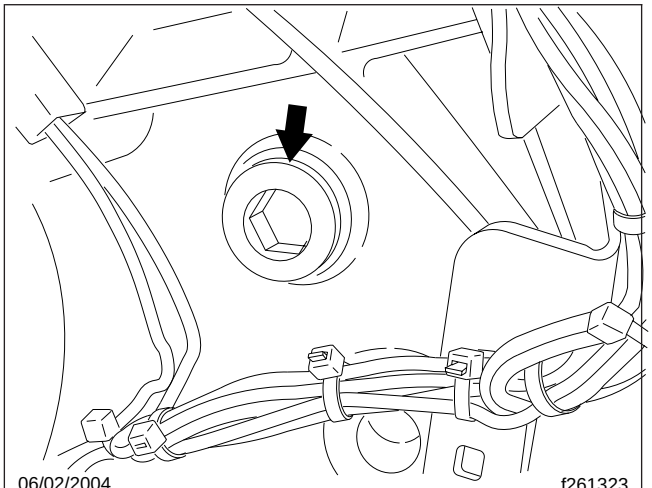


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Fill the reservoir to the level indicated by the arrow.

Fig. 8, Hydraulic Fluid Fill Level

edge of the fill opening. See **Fig. 9** for the location of the fill plug and **Fig. 10** for the correct level. See **Group 26** of the *Acterra® Maintenance Manual* for approved transmission lubricants and lubricant capacities.



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The fill plug is located on the left-hand side of the rear gear case, just behind the accumulator.

Fig. 9, Fill Plug

10. Clean the transmission fill plug and install it in the transmission, along with a new aluminum gasket. Tighten the fill plug 42 lbf·ft (57 N·m).

11. Remove the chocks from the rear tires.

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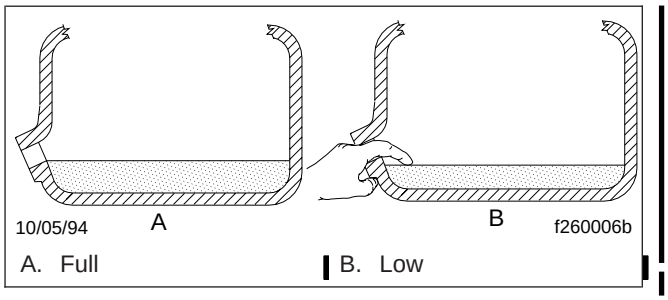


Fig. 10, Transmission Fluid Level Checking

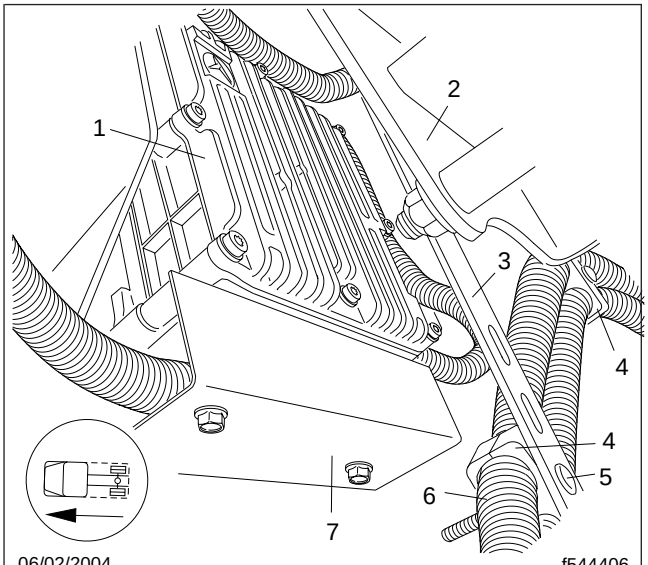
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AGS Transmission Control Unit Replacement

IMPORTANT: To successfully replace the transmission control unit (TCU) while the transmission is installed in the vehicle, there must be at least 2-3/4 inches (70 mm) clearance between the TCU and the frame rail.

Replacement

1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the rear tires.
2. Disconnect the batteries.
3. Before starting the replacement procedure, clean all screws and fittings by spraying with a light penetrating oil.
4. Remove the two capscrews that attach the splash guard to the TCU. See **Fig. 1**.



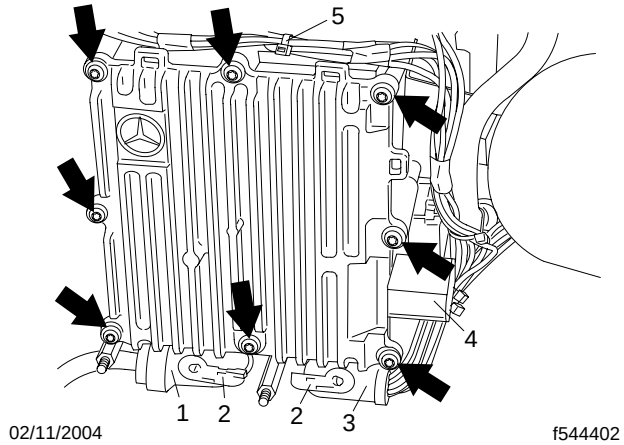
1. TCU
2. Front Hanger Bracket
3. Cable Bracket
4. Cable Clamp
5. Clamp Mounting Bolt
6. Battery Cable
7. Splash Guard

Fig. 1, Area of TCU

5. Disconnect the X1 (main vehicle), X2 (transmission), and X3 (electric motor) electrical connectors from the base and aft side of the TCU. See **Fig. 2**. Remove tie straps and clamps as needed.

IMPORTANT: When cutting tie straps at the top of the TCU, use extreme care. Do not cut the wires in the electrical harness.

6. Remove the eight Torx® screws that attach the TCU to the hydraulic body. Pull the TCU straight back until all the internal connections are disengaged.



Remove the eight Torx screws (arrows) that attach the TCU to the hydraulic body.

1. X1 (main vehicle) Connector
2. Safety Slide
3. X2 (transmission) Connector
4. X3 (electric motor) Connector
5. Tie Strap

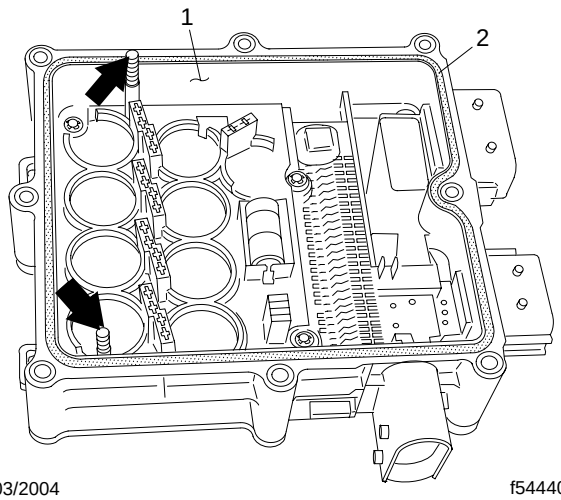
Fig. 2, TCU

NOTE: Expect some resistance as the internal connections disengage.

7. Install the new TCU on the hydraulic body. See **Fig. 3**.
   - 7.1 Align the new seal ring in the groove provided in the inside of the new TCU.
   - 7.2 Coat the seal ring with enough bearing grease to ensure that the seal ring will not fall out of its groove during installation.
   - 7.3 Make sure all spade connectors are straight.
   - 7.4 Square up the TCU on the hydraulic body using the guide pins on the inside of the TCU. This will ensure that the internal connectors line up properly.

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AGS Transmission Control Unit Replacement



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When installing the new TCU, be sure to align the guide pins (arrows).

1. TCU
2. Seal Ring

Fig. 3, TCU Seal Ring

7.5 Check that the seal ring does not get pinched along the line where the TCU meets the hydraulic body.

NOTE: Make sure the TCU is seated firmly on the hydraulic body before installing the mounting screws. Do not use the screws to pull the TCU into position.

7.6 Install the mounting screws and tighten them 44 to 53 lbf·in (500 to 600 N·cm).

8. Attach the electrical connectors. Be sure the yellow slide on the X1 and X2 connector snaps into place. See **Fig. 2**.
9. Install tie straps and cable clamps as needed.
10. Install the splash guard. Tighten the mounting capscrews 17 lbf·ft (23 N·m). See **Fig. 1**.
11. Recalibrate the transmission according to the procedures in **Subject 130**.
12. Remove the chocks from the rear tires.

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Replacement

IMPORTANT: Depressurize the hydraulic system before replacing any of the hydraulic components—such as the Clutch Position Sensor, Gear Position Sensor, Rail Position Sensor, and Fluid Level Sensor.

For detailed hydraulic system depressurization procedures, see **Subject 160**. For a diagram of transmission sensors, see **Fig. 1**.

Clutch Position Sensor

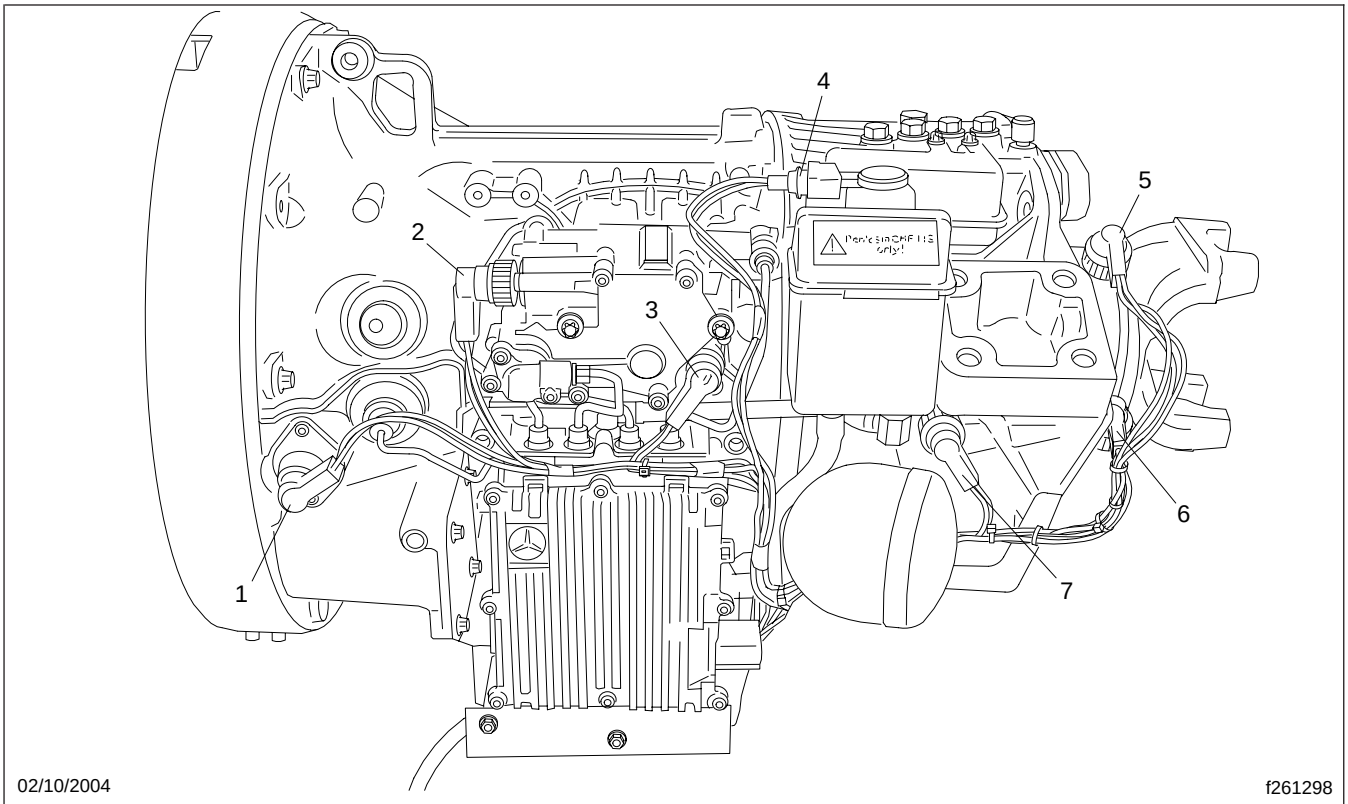
The clutch position sensor is integral to the clutch actuator and cannot be replaced without replacing the clutch actuator. For detailed procedures, see **Subject 210**.

Shift Position Sensors

The shift position sensors, shown in **Fig. 2**, are integral to the x-y actuator and cannot be replaced without replacing the x-y actuator. Replacement of the x-y actuator requires removing the transmission from the vehicle. For detailed procedures, see **Subject 170**.

Fluid Level Sensor

1. Clean around the area of the reservoir cap. Take care not to introduce dirt into the reservoir.
2. If not already done, depressurize the hydraulic system. For detailed procedures, see **Subject 160**.

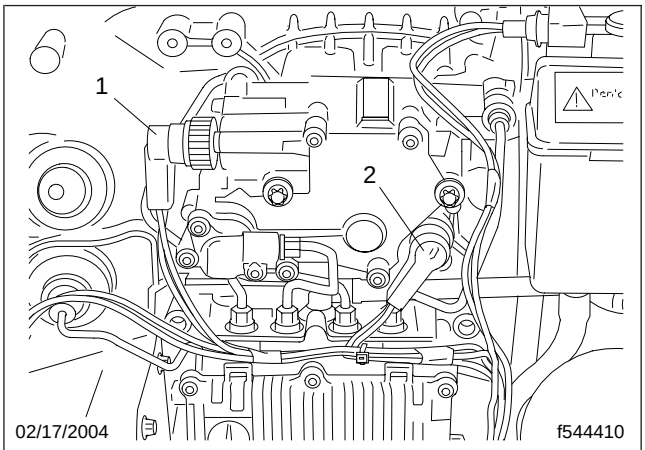


1. Clutch Position Sensor
2. Gear Position Sensor
3. Rail Position Sensor
4. Fluid Level Sensor
5. Output Shaft Speed Sensor #1
6. Output Shaft Speed Sensor #2
7. Input Shaft Speed Sensor

Fig. 1, Transmission Sensors

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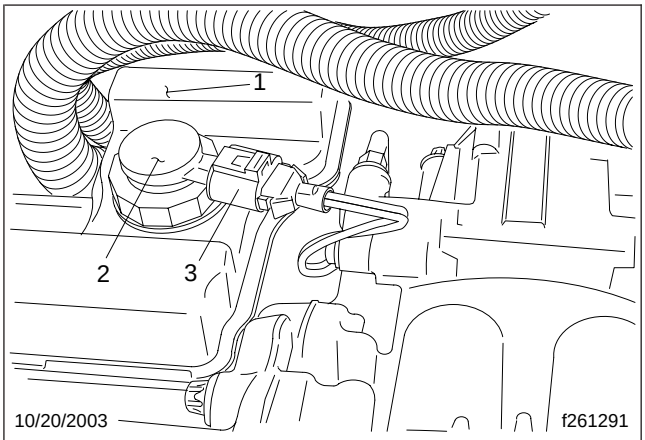
AGS Transmission Sensor Replacement



1. Gear Position Sensor
2. Rail Position Sensor

Fig. 2, Shift Position Sensors

3. Remove the electrical connector from the reservoir cap. See **Fig. 3**.



1. Reservoir
2. Cap
3. Connector

Fig. 3, Fluid Level Sensor

3.1 Insert a small screwdriver into the opening at the top of the connector.

3.2 Pull back (aft) on the clip until it releases. A click can be heard when it releases.

3.3 Remove the connector from the plug on the reservoir cap.

4. Unscrew the reservoir cap, and remove the cap and probe from the hydraulic reservoir.

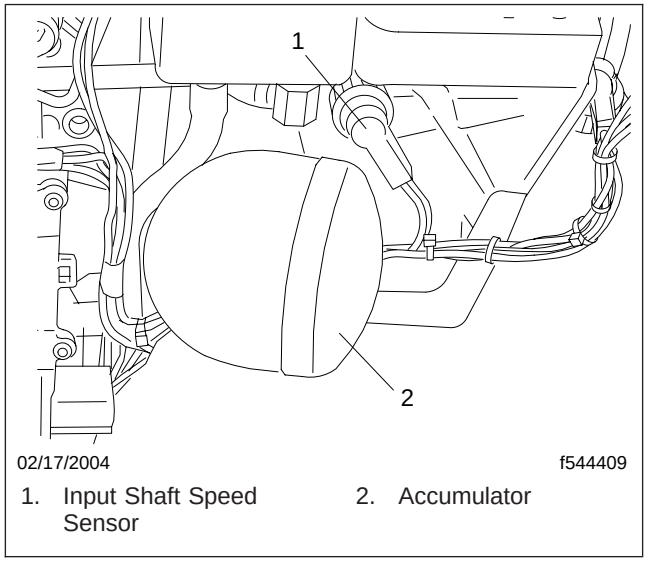
5. Insert a new cap with probe into the hydraulic reservoir.

6. Attach the electrical connector to the new cap and make sure the new cap is tightly fastened.

Speed Sensors

1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the rear tires.

2. Unscrew the electrical connector from the sensor. See **Fig. 4** for the input shaft speed sensor and **Fig. 5** for the two output shaft speed sensors.



1. Input Shaft Speed Sensor
2. Accumulator

Fig. 4, Input Shaft Speed Sensor

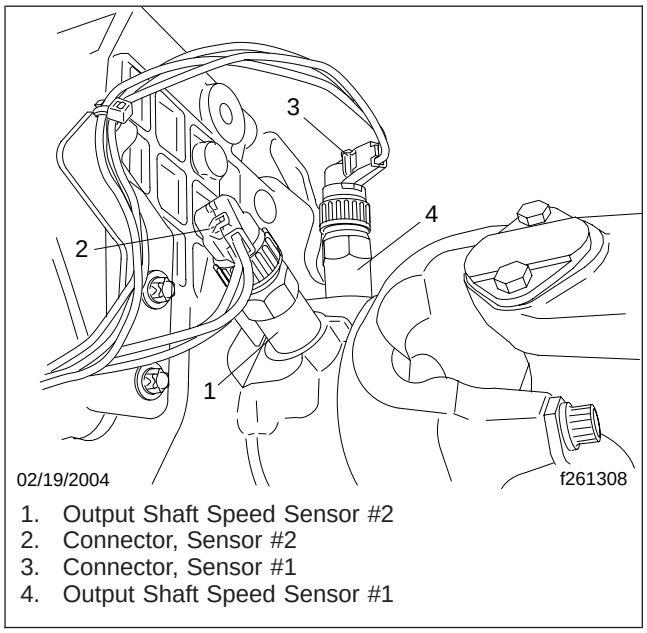
3. Using a wrench, remove the sensor from the rear gear case.

4. Install a new sensor on the rear gear case. Tighten the sensor 28 lbf·ft (38 N·m).

5. Install the electrical connector on the end of the sensor.

6. Remove the chocks from the rear tires.

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1. Output Shaft Speed Sensor #2
2. Connector, Sensor #2
3. Connector, Sensor #1
4. Output Shaft Speed Sensor #1

Fig. 5, Output Shaft Speed Sensors

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Bleeding

IMPORTANT: Bleed the hydraulic system after any repair.

1. Shut down the engine, chock the rear tires, and set the parking brake.

NOTE: To gain access to the reservoir cap, it may be more convenient to open the floor access plate. See **Subject 100** for procedures.

2. Clean around the area of the bleed screw and the reservoir cap. Keep the reservoir cap clean and take care not to introduce dirt into the reservoir.
3. With the hydraulic system depressurized (for detailed procedures, see **Subject 160**), remove the plastic cap from the bleed screw. Insert a clear hose onto the bleed valve on the bell housing. Remove the reservoir cap and place the other end of the hose inside the hydraulic reservoir.

IMPORTANT: Do not start the engine.

4. Turn on the ignition switch and put the transmission into 1st gear.
5. Slowly open the bleed screw. Allow the hydraulic fluid to circulate until no air bubbles are visible and the fluid is clear.
6. Tighten the bleed screw 13 lbf·ft (17 N·m).
7. Remove the bleed hose and install the reservoir cap.
8. Install the plastic cap on the bleed screw.
9. Recalibrate the transmission using the procedure under the heading "Recalibration" in this subject.
10. Check the hydraulic fluid level and add more Pentosin as needed. See **Subject 150** for procedures.

Recalibration

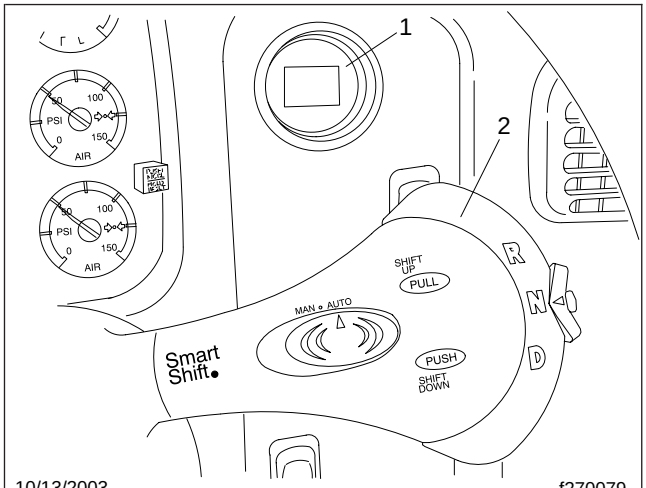
IMPORTANT: Use this procedure when a new transmission is installed, the TCU is replaced, and to correct complaints of rough shifting.

1. Shut down the engine and set the parking brake.
2. Pressurize the hydraulic pump.

   NOTE: As the hydraulic pump builds pressure, you may hear it humming.

   2.1 Turn on the ignition, and wait one minute. Then turn off the ignition, and wait one minute. Verify that the current gear indicator is blank.

   2.2 Again, turn on the ignition, and wait one minute. Then turn off the ignition, and wait one minute. Verify that the current gear indicator is blank.
3. Verify that the current gear indicator is blank. Set the selector switch on the SmartShift control to N (neutral). See **Fig. 1**.



Make sure the current gear indicator is blank and the selector switch is set to N.

1. Current Gear Indicator
2. SmartShift Control

Fig. 1, Ready to Recalibrate

NOTE: For the recalibration procedure to succeed, the selector switch must remain in neutral until instructed differently later in this procedure.

4. With the selector switch in neutral, pull the SmartShift lever up (towards you) and hold it there until instructed to release it later in this procedure.
5. While holding the SmartShift lever up, turn on the ignition. When the letter 'X' displays on the current gear indicator, recalibration is in progress. See **Fig. 2**. Do not start the engine at this time.

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AGS Transmission Bleeding and Recalibration

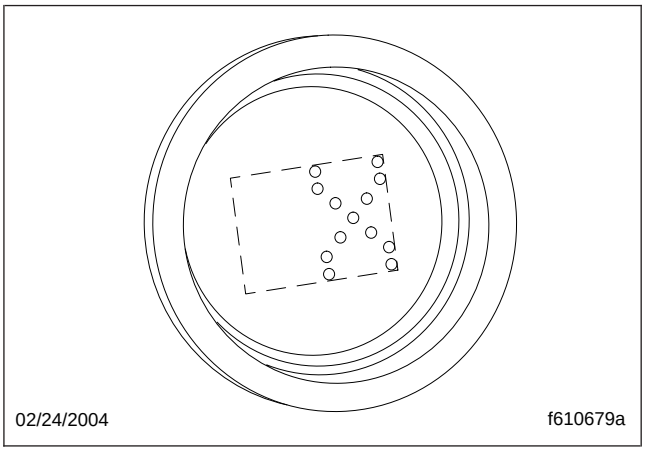


Fig. 2, Recalibration In Progress

NOTE: If the letter 'X' does not appear, turn off the ignition, wait one minute, and try again.

6. Wait for the letter 'N' to display on the current gear indicator and the audible alert to sound. See **Fig. 3**. Start the engine within 10 seconds.

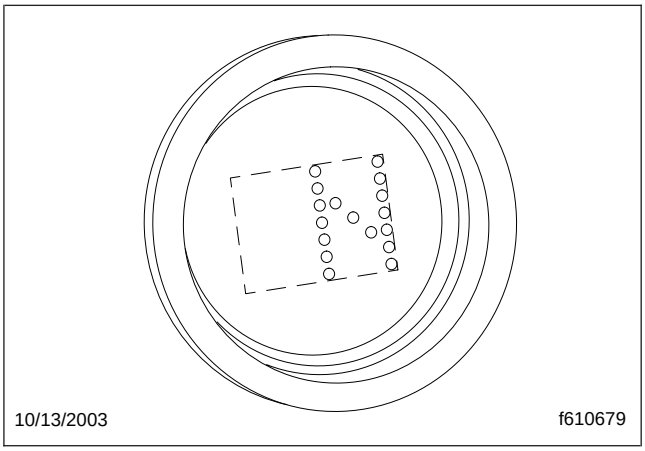


Fig. 3, Neutral Display

7. The next time the alert sounds, release the SmartShift lever and shut down the engine. Wait two minutes, turn on the ignition, and do one of the following:
   - If the current gear indicator displays 'N', proceed to the next step.
   - If the current gear indicator flashes 'SM-N', turn off the ignition and wait two minutes for the display to clear. Then turn on the ignition. If the current gear indicator displays 'N', proceed to the next step. If it flashes 'SM-N', turn off the ignition, wait two minutes or until the display clears, and proceed to the next step.
   - If the current gear indicator flashes 'SM-X', stop, and repeat the recalibration procedure from the beginning.
8. If necessary, turn on the ignition and wait for the letter 'N' to display on the current gear indicator. Now select D on the SmartShift control, and wait for the numeral '1' to display on the current gear indicator. Then select R and wait for 'R' to display on the current gear indicator.

IMPORTANT: If the current gear indicator displays 'SM' or any other problem occurs, repeat the recalibration procedure from the beginning.

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Special Tool

A special tool is required for this procedure. See **Table 1**.

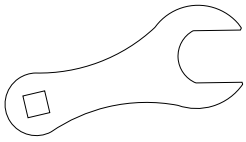
Special Tool for Accumulator Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580381	Accumulator Torque Adaptor	Kent-Moore	J-47291

Table 1, Special Tool for Accumulator Replacement

Replacement

1. Shut down the engine, set the parking brake, and chock the rear tires.

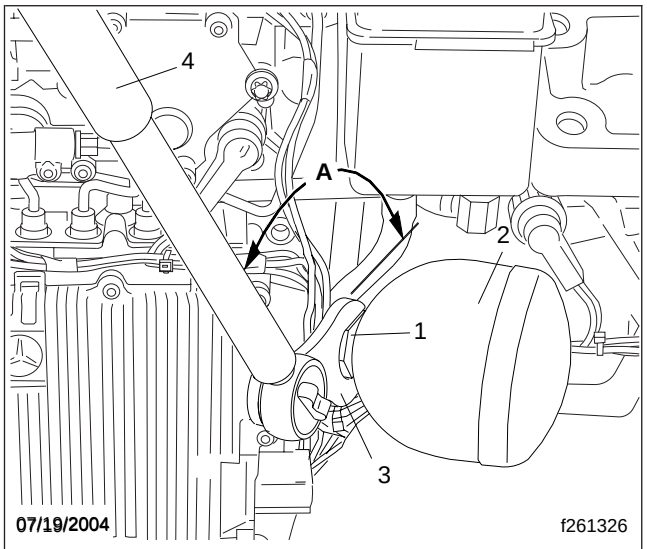
IMPORTANT: Depressurize the hydraulic system before replacing any hydraulic components.

2. Depressurize the hydraulic system. For detailed procedures, see **Subject 160**.

⚠ WARNING

This system is under extremely high pressure. Do not attempt to loosen the accumulator until the system has been depressurized. Hydraulic fluid could spray out at high speed, causing a personal injury.

3. Using a socket wrench and the accumulator torque adaptor (**Table 1**), loosen the M30 fitting on the accumulator.
4. Remove the accumulator from the hydraulic body of the AGS central unit.
5. Install the accumulator. See **Fig. 1**.
   - 5.1 Position the new accumulator on the threaded hole and screw it onto the hydraulic body.
   - 5.2 Assemble the torque wrench and the accumulator torque adaptor (**Table 1**) with the torque adaptor set at a 90-degree angle to the wrench.



To obtain the correct torque, set the torque adaptor at a 90-degree angle to the wrench.

A. 90-degree Angle
1. Fitting, M30
2. Accumulator
3. Accumulator Torque Adaptor
4. Torque Wrench

Fig. 1, Installing the Accumulator

IMPORTANT: If the torque adaptor is not set at a 90-degree angle to the wrench, the M30 fitting will not receive the correct torque.

- 5.3 Using the torque wrench and adaptor assembly, tighten the M30 fitting 55 lbf·ft (75 N·m).

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Accumulator Replacement

6. Check the hydraulic fluid level and add more Pentosin if needed. For detailed procedures, see **Subject 150**.

IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

7. Start the engine and allow the system to pressurize. Shift back and forth a few times from drive to reverse and back to neutral.

NOTE: The first few shifts after draining and refilling the hydraulic system will take longer than usual.

8. Check the hydraulic system for leaks, and repair if necessary. When done, shut down the engine.
9. Remove the chocks from the rear tires.

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Special Tool

A special tool is required for this procedure. See **Table 1**.

Special Tool for Hydraulic Fluid Reservoir Replacement			
Tool	Description	Manufacturer	Part Number
 f580379a	Low-Pressure Hose Disconnect Tool	Kent-Moore	J-47202

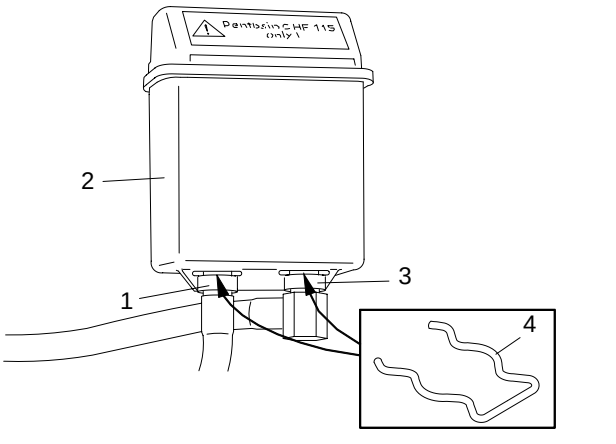
Table 1, Special Tool for Hydraulic Fluid Reservoir Replacement

Replacement

1. Shut down the engine, set the parking brake, and chock the rear tires.

IMPORTANT: Depressurize the hydraulic system before replacing any hydraulic components.

2. Depressurize the hydraulic system. For detailed procedures, see **Subject 160**.
3. Drain the hydraulic fluid. See **Fig. 1**.



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Install the spring clips in the slots provided in the base of the reservoir.

1. Low-Pressure Hose
2. Reservoir
3. Return Hose
4. Spring Clip

Fig. 1, Hydraulic Hoses

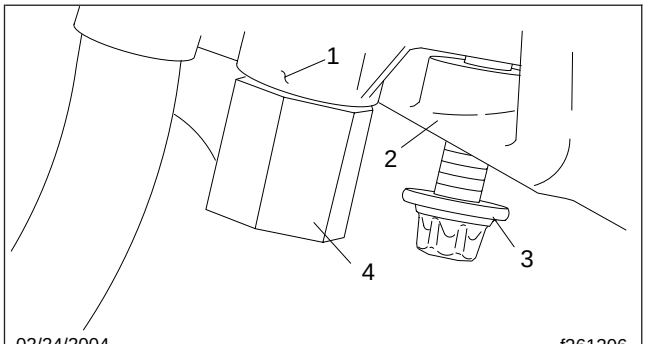
3.1 Place a receptacle under the reservoir to catch the drained fluid.

3.2 Pull out the spring clips that secure the low-pressure hydraulic hoses to the fittings at the base of the reservoir.

3.3 Using the low-pressure hose disconnect tool (**Table 1**), remove the two low-pressure hydraulic hoses from the reservoir.

3.4 Allow the hoses to drain into the container, and cap them when fluid no longer drains out.

4. Carefully remove the inverted-Torx® M8 fastener at the base of the reservoir. Discard this fastener. See **Fig. 2**.



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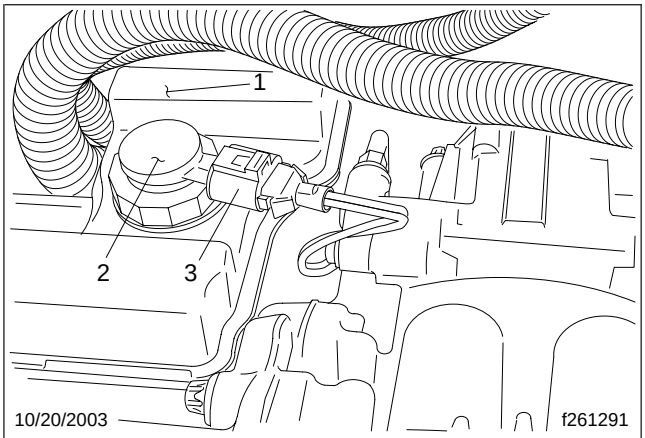
1. Reservoir
2. Lip of Gear Case
3. Fastener, M8
4. Hydraulic Fitting

Fig. 2, Reservoir Base Fastener

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Hydraulic Fluid Reservoir Replacement

5. Remove the electrical connector from the reservoir cap. See **Fig. 3**.



1. Reservoir
2. Reservoir Cap
3. Fluid Level Sensor

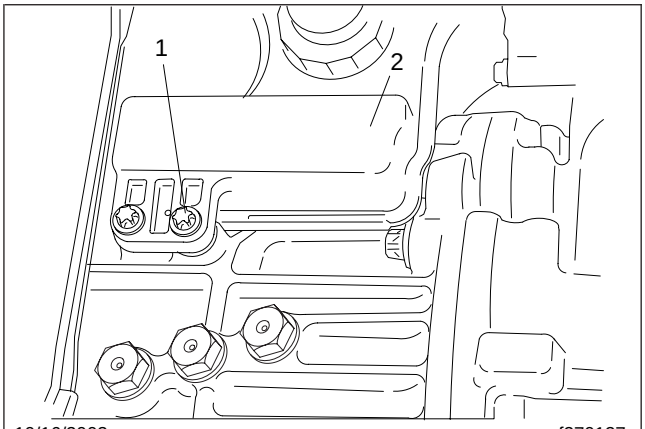
Fig. 3, Reservoir Cap

5.1 Insert a small screwdriver into the opening at the top of the connector.

5.2 Pull back (aft) on the clip until it releases. A click can be heard when it releases.

5.3 Remove the connector from the plug on the reservoir cap.

6. Remove the two inverted-Torx M6 fasteners that attach the top of the reservoir to the transmission gear box. See **Fig. 4**.



1. Fastener, M6
2. Reservoir

Fig. 4, Reservoir Top Fasteners

7. Remove the reservoir from the transmission.
8. Position the new reservoir in the transmission. Install the two M6 fasteners that attach it to the gear box and tighten them 71 lbf·in (800 N·cm).
9. Attach the electrical connector to the reservoir cap. Tug lightly on the connector to make sure it has snapped into place.
10. Install a new M8 fastener into the groove at the base of the reservoir. See **Fig. 2**. Tighten the M8 fastener 11 lbf·ft (18 N·m).

IMPORTANT: Do not use Loctite® or sealant on this fastener.

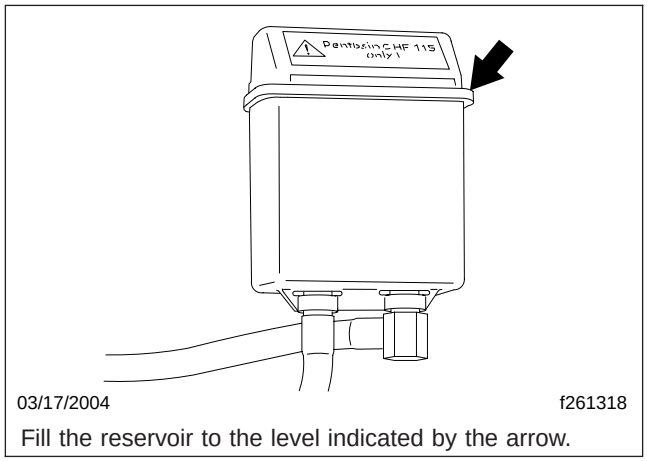
11. Install the low-pressure hydraulic hoses at the base of the reservoir. See **Fig. 1**.

11.1 Install the spring clips in the slots provided.

11.2 Insert the two hydraulic hoses through the spring clips until they snap into place. Tug lightly on the lines to make sure they are securely fastened.

NOTE: After depressurizing, wait five minutes before checking the hydraulic fluid level. This will allow any foam in the fluid to settle.

12. Check the hydraulic fluid level. Add Pentosin as needed until the level reaches the joint between the upper and lower sections of the reservoir. See **Fig. 5**.



Fill the reservoir to the level indicated by the arrow.

Fig. 5, Hydraulic Fluid Fill Level

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IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

13. Start the engine and allow the system to pressurize. Shift back and forth a few times from drive to reverse and back to neutral.

NOTE: The first few shifts after draining and refilling the hydraulic system will take longer than usual.

14. Check the hydraulic system for leaks, and repair if necessary. When done, shut down the engine.
15. Remove the chocks from the tires.

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IMPORTANT: Depressurize the hydraulic system before removing the transmission or replacing any hydraulic components.

Depressurization

Normal Procedure

1. Shut down the engine and set the parking brake.
2. Connect ServiceLink to the vehicle. Start the "AGS Procedures" template and follow the instructions on the screen to depressurize the system. See **Fig. 1**.
   - 2.1 Press the "Start Communications" button.
   - 2.2 Select "Start Diagnostic Mode."
   - 2.3 Select the "Reduce Hyd Pressure" button to depressurize the system.
3. Turn off the ignition switch. Wait for the system to depressurize. When the system depressurizes, the accumulator will dump its fluid into the reservoir, causing an obvious rise in the reservoir level.

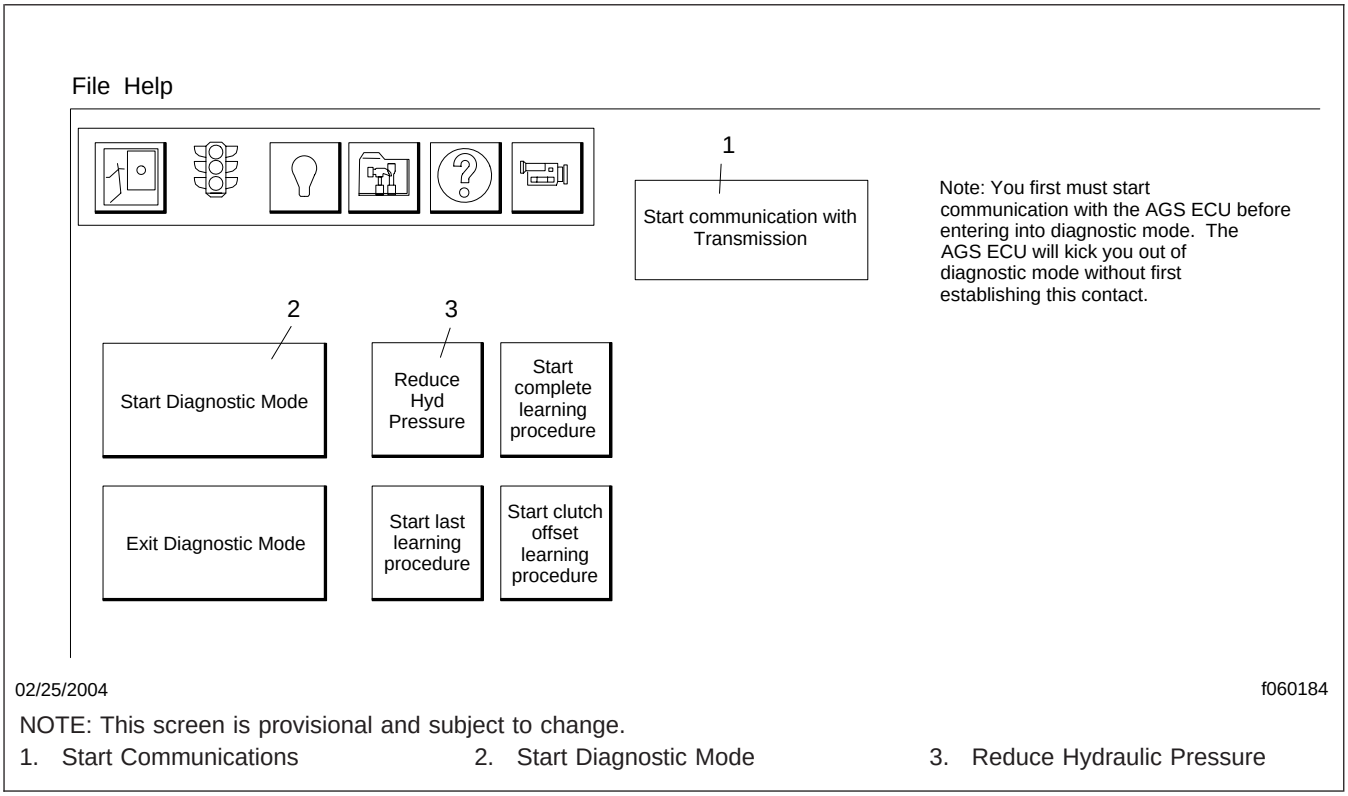
IMPORTANT: If the reservoir level fails to rise, or any other problem prevents the system from depressurizing, use the alternate procedure. Do not use the alternate procedure unless the normal procedure fails.

4. Disconnect ServiceLink from the vehicle.

Alternate Procedure

NOTE: The pressure-limiting valve is designed to be opened a limited number of times. Do not use it routinely to depressurize the system.

1. Open the pressure-limiting valve embedded in the forward side of the x-y actuator. Loosen the



NOTE: This screen is provisional and subject to change.

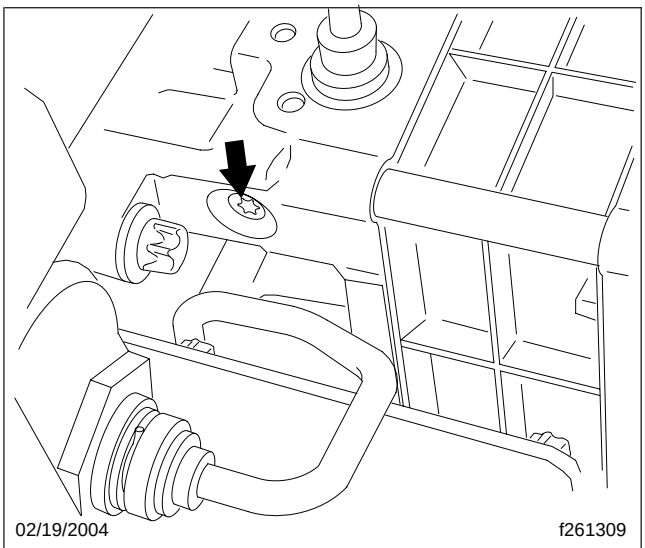
1. Start Communications
2. Start Diagnostic Mode
3. Reduce Hydraulic Pressure

Fig. 1, ServiceLink Depressurization Screen

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AGS Hydraulic System Depressurization

M6 adjusting screw carefully one quarter-turn. See **Fig. 2**.



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If the normal procedure fails, open the pressure-limiting valve by turning the adjusting screw (arrow).

Fig. 2, Alternate Procedure

IMPORTANT: Do not loosen the adjusting screw more than one quarter-turn. If the pressure-limiting valve is opened wider than that, it can cause the accumulator to discharge.

2. Close the M6 adjusting screw when depressurization is complete. Tighten it 62 to 71 lbf·in (700 to 800 N·cm).

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Special Tool

A special tool is required for this procedure. See **Table 1**.

Special Tool for X-Y Actuator Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580379	High-Pressure Line Disconnect Tool	Kent-Moore	J-47201

Table 1, Special Tool for X-Y Actuator Replacement

Replacement

1. Shut down the engine, set the parking brake, and chock the rear tires.

IMPORTANT: Depressurize the hydraulic system before replacing any hydraulic components.

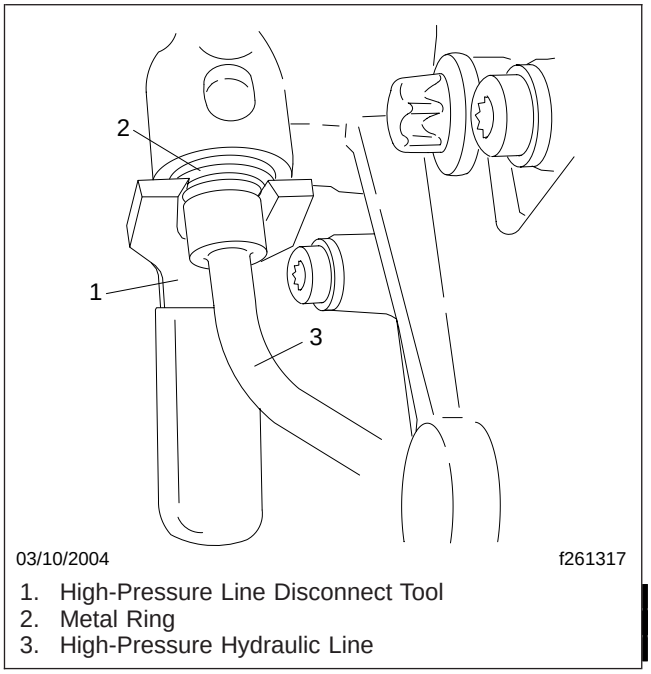
2. Depressurize the hydraulic system. For detailed procedures, see **Subject 160**.

NOTE: Replacement of the x-y actuator requires removing the transmission from the vehicle.

3. Remove the transmission from the vehicle. For detailed procedures, see **Subject 100**.
4. Remove the AGS assembly from the transmission. For detailed procedures, see **Subject 200**.
5. Before starting the replacement procedure, clean all screws and fittings by spraying with a light penetrating oil.
6. Using the high-pressure hydraulic line disconnect tool (**Table 1**), remove the high-pressure hydraulic lines from the actuator. See **Fig. 1**.

    6.1 Mark each line and attachment point with a paint pen for ease of installation.

    6.2 Place the high-pressure line tool in front of the metal ring. Use the tool to pull on the line and shake it slightly until the line comes free.



1. High-Pressure Line Disconnect Tool
2. Metal Ring
3. High-Pressure Hydraulic Line

Fig. 1, Removing the High-Pressure Hydraulic Lines

    6.3 Carefully pull the line away from the attachment point and pull it free of the actuator.

⚠ CAUTION

Be careful not to bend or damage the lines or the O-rings when removing them.

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X-Y Actuator Replacement

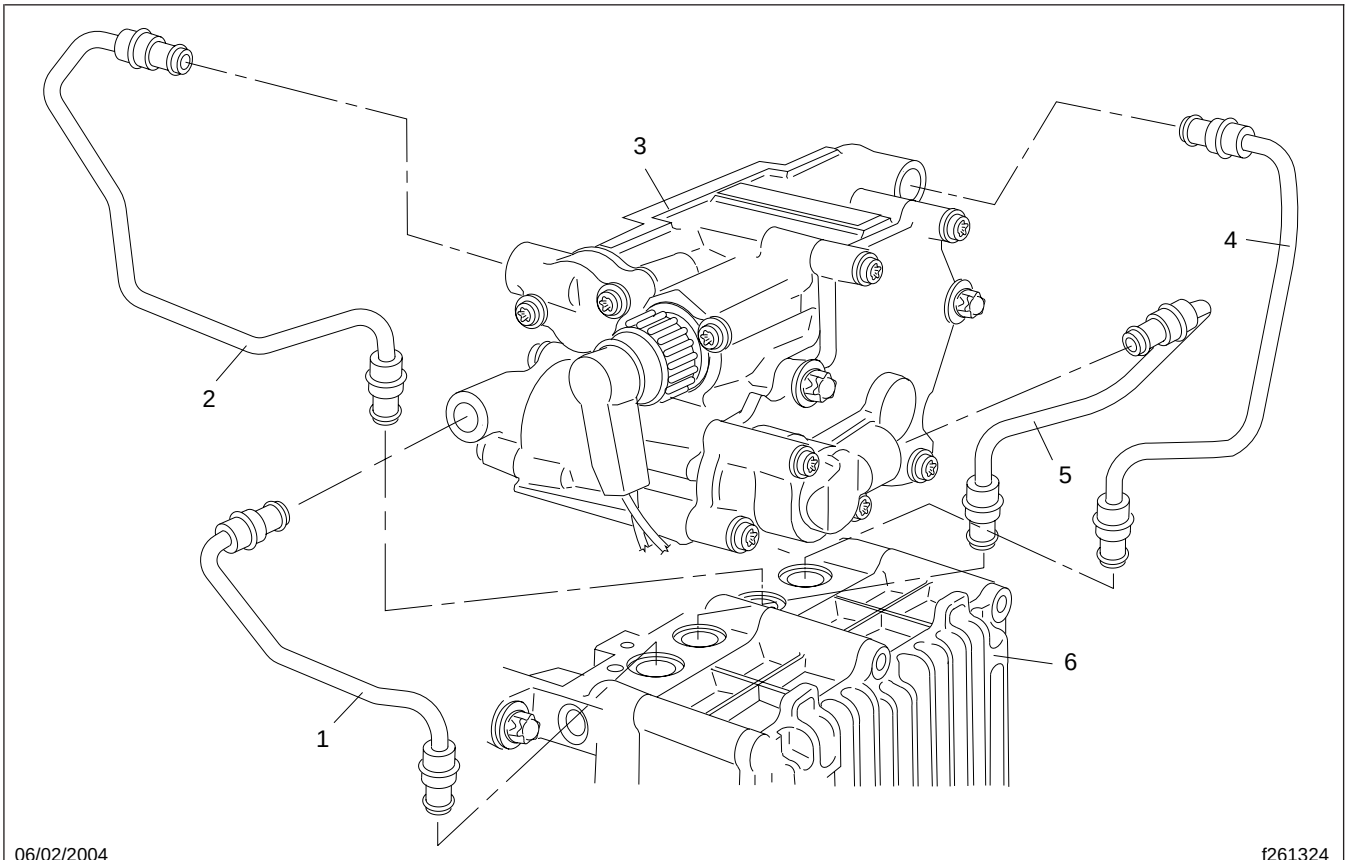
NOTE: Make sure the actuator is seated firmly on the mounting flange. Do not use the mounting capscrews to pull the actuator into position.

7. Install the four inverted-Torx capscrews finger-tight in the actuator. Make sure they are firm all around. Then tighten them 17 lbf·ft (23 N·m).

⚠ CAUTION

Do not twist or bend the hydraulic lines. This will make installation more difficult and could damage the lines.

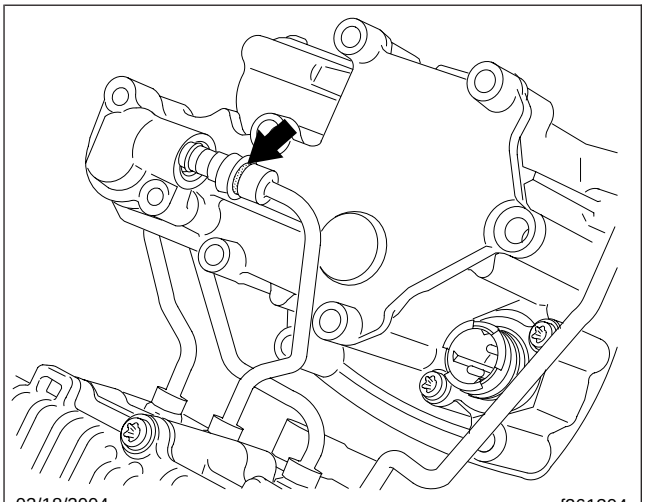
8. Install the hydraulic lines in the actuator, as removed. See **Fig. 2**.
   - 8.1 The lines snap into place with an audible click. When the installation is correct, the outermost O-ring is no longer visible. See **Fig. 3**.
   - 8.2 Tug lightly on each line to make sure it is locked in place.
9. Install the connectors for the two position sensors on the actuator.
10. Install the AGS assembly on the transmission. For detailed procedures, see **Subject 200**.
11. Install the transmission on the vehicle. For detailed procedures, see **Subject 100**.



1. Rail Select Line (high)
2. Gear Select Line (fore)
3. X-Y Actuator
4. Gear Select Line (aft)
5. Rail Select Line (low)
6. Hydraulic Body

Fig. 2, Installation of the Hydraulic Lines

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The outermost O-ring (arrow) is not visible when the line is installed correctly.

Fig. 3, Lines Snapped Into Place

12. Start the engine and allow the system to pressurize. Shift back and forth a few times from drive to reverse and back to neutral.

NOTE: The first few shifts after draining and refilling the hydraulic system will take longer than usual.

13. Check the hydraulic system for leaks, and repair if necessary. When done, shut down the engine.
14. Check the hydraulic fluid level and add more Pentosin as needed. For detailed procedures, see **Subject 150**.

IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

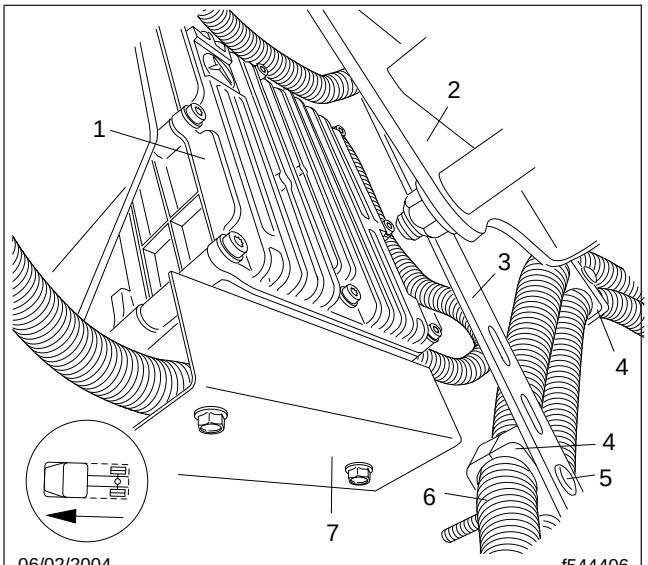
15. Remove the chocks from the rear tires.

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Replacement

NOTE: This procedure can be done with the transmission either installed on, or removed from, the vehicle.

1. Shut down the engine, set the parking brake, and chock the rear tires.
2. Disconnect the batteries.
3. Remove the two capscrews that attach the splash guard to the TCU. See **Fig. 1**.



1. TCU
2. Front Hanger Bracket
3. Cable Bracket
4. Cable Clamp
5. Clamp Mounting Bolt
6. Battery Cable
7. Splash Guard

Fig. 1, Area of TCU

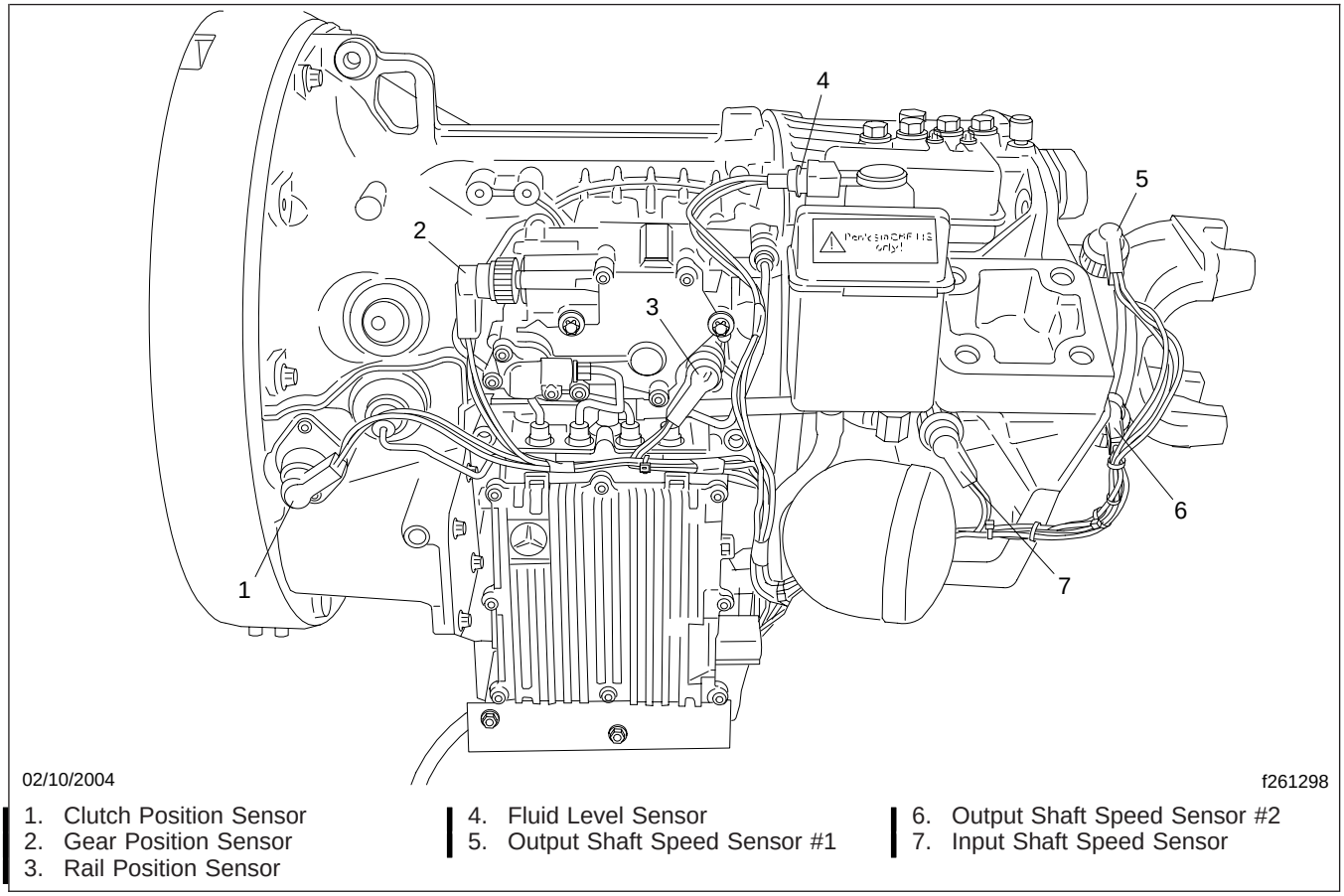
4. Remove the X2 (transmission) connector from the transmission control unit (TCU).
5. Unscrew the electrical connector cap from the clutch position sensor plug on the bell housing. See **Fig. 2**. Using a paint pen, mark the plug and the cap of the connector.

IMPORTANT: Be careful to color-code each connector. If the connectors are not installed in the correct locations, the transmission will not operate properly.

6. Remove the electrical connector from the reservoir cap.
   - 6.1 Insert a small screwdriver into the opening at the top of the connector.
   - 6.2 Pull back (aft) on the clip until it releases. A click can be heard when it releases.
   - 6.3 Remove the connector from the plug on the reservoir cap.
7. Unscrew the electrical connectors from the gear and rail position sensors on the x-y actuator. Using a paint pen, mark the plug and the cap of each connector.
8. Unscrew the electrical connector from the input shaft speed sensor on the left-hand side of the rear gear case just aft of the accumulator. Using a paint pen, mark the plug and the cap of the connector.
9. Unscrew the electrical connectors from the two output shaft speed sensors on the aft end of the rear gear case. Using a paint pen, mark the plug and the cap of the connector.
10. Cut tie straps as needed to remove the harness from the transmission.
11. Lay the old harness next to the new harness on a table. Match up each connector on the new harness with the corresponding connector on the old harness. Use paint pens to mark each connector on the new harness with the color of its corresponding connector on the old harness.
12. Install the X2 (transmission) connector on the aft side of the TCU. Make sure the yellow safety slide snaps into place.
13. Install the two capscrews that attach the splash guard to the TCU.
14. Install the new harness, matching each connector by color. Install new tie straps as needed.
15. Connect the batteries. Start the engine and check the electrical system for proper operation.

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AGS Transmission Harness Replacement



1. Clutch Position Sensor
2. Gear Position Sensor
3. Rail Position Sensor
4. Fluid Level Sensor
5. Output Shaft Speed Sensor #1
6. Output Shaft Speed Sensor #2
7. Input Shaft Speed Sensor

Fig. 2, Transmission Sensors

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Special Tool

A special tool is required for this procedure. See **Table 1**.

Special Tool for AGS Central Unit Replacement			
Tool	Description	Manufacturer	Part Number
 f580379	High-Pressure Line Disconnect Tool	Kent-Moore	J-47201

Table 1, Special Tool for AGS Central Unit Replacement

Replacement

1. Shut down the engine, set the parking brake, and chock the rear tires.

IMPORTANT: Depressurize the hydraulic system before replacing any hydraulic components.

2. Depressurize the hydraulic system. For detailed procedures, see **Subject 160**.

NOTE: Replacement of the AGS central unit requires removing the transmission from the vehicle.

3. Remove the transmission from the vehicle. For detailed procedures, see **Subject 100**.
4. Remove the AGS assembly from the transmission. For detailed procedures, see **Subject 200**.

CAUTION

Make sure the AGS assembly is well supported before working on the hydraulic lines. If necessary, call another person to help support it. The weight of the assembly components could cause damage to the lines.

5. Before starting the replacement procedure, clean all screws and fittings by spraying with a light penetrating oil.
6. Using the high-pressure hydraulic line disconnect tool (**Table 1**), remove the four high-pressure hydraulic lines from the x-y actuator. For procedures, see **Subject 170**.

CAUTION

Be careful not to bend or damage the lines or the O-rings when removing them.

NOTE: The central unit has two parts: in front is the transmission control unit (TCU), and behind it is the hydraulic body.

7. Still using the high-pressure hydraulic line disconnect tool, remove the high-pressure hydraulic lines from the central unit. See **Fig. 1**.

   NOTE: There are five lines that connect to the hydraulic body of the central unit. One line connects to the clutch and four lines connect to the x-y actuator.

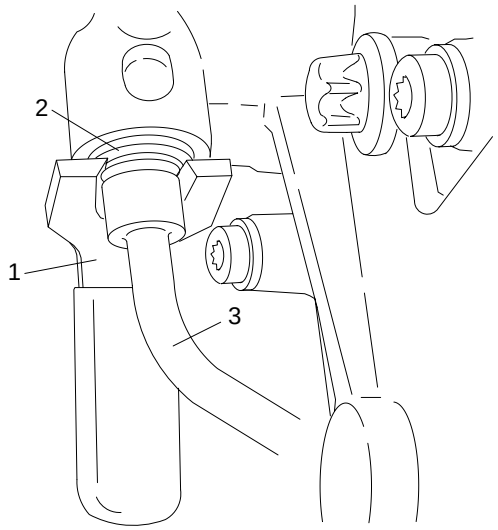
   7.1 Mark each line and attachment point with a paint pen for ease of installation. On the top of the hydraulic body, remove the outer lines first.

   IMPORTANT: Don't use the tool as a lever. Work it in until it is fully engaged and then wiggle it until the line comes free.

   7.2 Place the high-pressure line tool in front of the metal ring. Press down to compress the locking device, then pull outward and shake the tool slightly until the line comes free.

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AGS Central Unit Replacement



1. High-Pressure Line Disconnect Tool
2. Metal Ring
3. High-Pressure Hydraulic Line

Fig. 1, Using the High-Pressure Line Disconnect Tool

7.3 Once all the lines are unlocked, carefully separate the central unit from the rest of the AGS assembly.

CAUTION

Do not twist or bend the hydraulic lines. This will make installation more difficult and could damage the lines.

8. Install the hydraulic lines in the central unit, as removed. See **Fig. 2**.

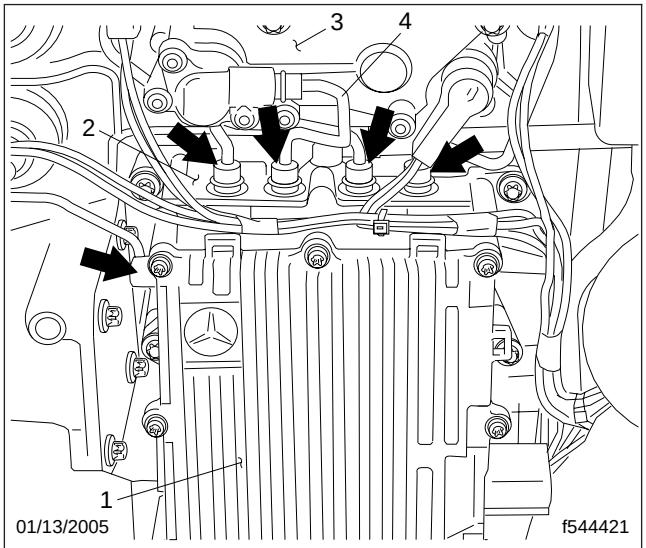
   8.1 The lines snap into place with an audible click. When the installation is correct, the outermost O-ring is no longer visible. See **Fig. 3**.

   8.2 Tug lightly on each line to make sure it is locked in place.

9. Install the high-pressure hydraulic lines on the x-y actuator, as removed. For procedures, see **Subject 170**.

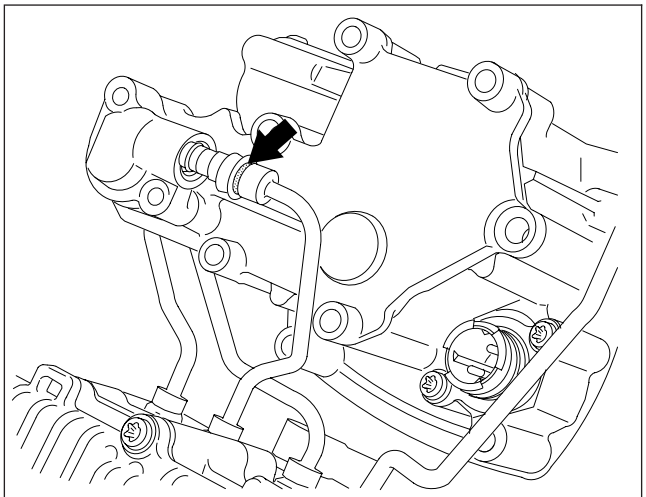
10. Install the AGS assembly on the transmission. For detailed procedures, see **Subject 200**.

11. Install the transmission on the vehicle. For detailed procedures, see **Subject 100**.



1. TCU
2. Hydraulic Body
3. X-Y Actuator
4. Hydraulic Line

Fig. 2, Hydraulic Lines on the Central Unit



The outermost O-ring (arrow) is not visible when the line is installed correctly.

Fig. 3, Lines Snapped Into Place

12. Start the engine and allow the system to pressurize. Shift back and forth a few times from drive to reverse and back to neutral.

NOTE: The first few shifts after draining and refilling the hydraulic system will take longer than usual.

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13. Check the hydraulic system for leaks, and repair if necessary. When done, shut down the engine.
14. Check the hydraulic fluid level and add more Pentosin as needed. For detailed procedures, see **Subject 150**.

IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

15. Remove the chocks from the rear tires.

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Special Tools

Special tools are required for this procedure. See **Table 1**.

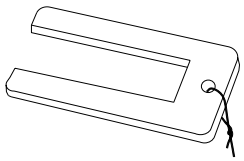
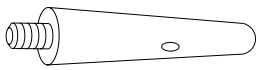
Special Tools for AGS Assembly Installation			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580380	Shift Finger Alignment Fork	Kent-Moore	J-47204
 f580382	Shift Mechanism End Guide	Kent-Moore	J-47203

Table 1, Special Tools for AGS Assembly Installation

Removal

1. Shut down the engine, set the parking brake, and chock the rear tires.

IMPORTANT: Depressurize the hydraulic system before replacing any hydraulic components.

2. Depressurize the hydraulic system. For detailed procedures, see **Subject 160**.

NOTE: Removal and installation of the AGS assembly requires removing the transmission from the vehicle.

3. Remove the transmission from the vehicle. For detailed procedures, see **Subject 100**.
4. Remove the two capscrews that attach the splash guard to the transmission control unit (TCU). See **Subject 110** for instructions.
5. Disconnect the X1 (main vehicle) and X3 (electric motor) electrical connectors from the base and aft side of the TCU. Using a paint pen, mark the plug and the cap of the connector for installation reference. Remove tie straps and clamps as needed.
6. Remove the electrical connectors from the clutch position sensor at the bell housing, and from the three speed sensors on the rear gear case. Using a paint pen, mark the plug and the cap of the connector for installation reference.
7. Remove the high-pressure clutch hydraulic line from the bell housing. For procedures, see **Subject 120**.
8. Remove the accumulator. For detailed procedures, see **Subject 140**.
9. Remove the hydraulic fluid reservoir. For detailed procedures, see **Subject 150**.

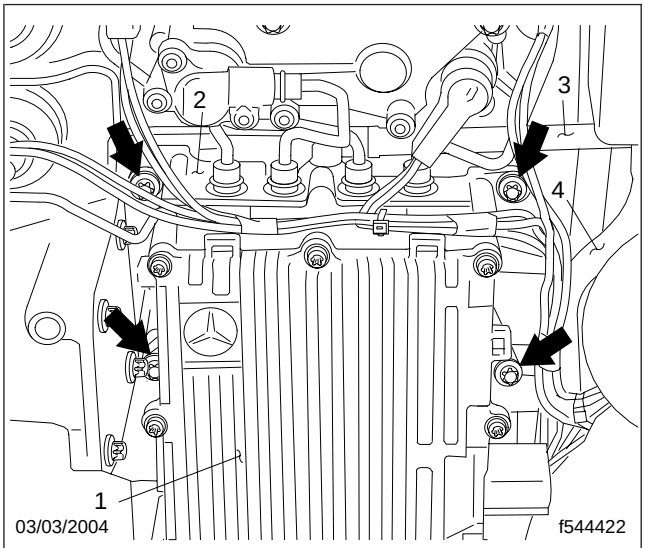
NOTE: The central unit has two parts: in front is the TCU and behind it is the hydraulic body.

10. Remove the four inverted-Torx® capscrews that attach the central unit to the transmission. See **Fig. 1**.
11. Remove the four inverted-Torx capscrews that attach the x-y actuator to the transmission. See **Fig. 2**.

NOTE: The two upper capscrews are 110 mm (4.3 inches) long; the two lower capscrews are 60 mm (2.4 inches) long.

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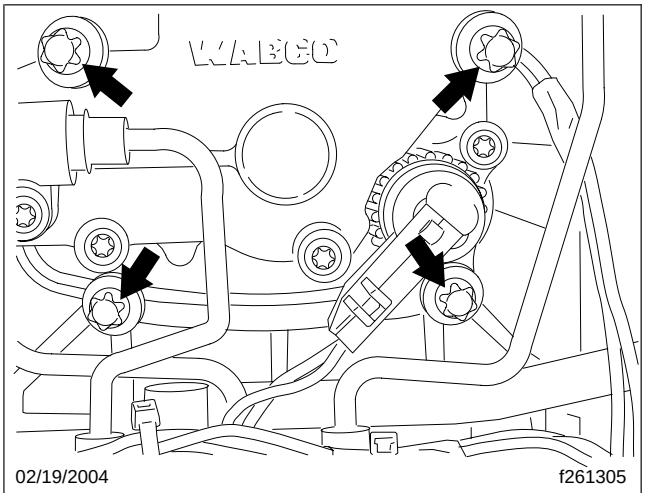
AGS Assembly Removal and Installation



Remove the four inverted-Torx capscrews (arrows) that attach the central unit to the transmission.

1. Hydraulic Body
2. Transmission Control Unit (TCU)
3. Low-Pressure Return Hose
4. Low-Pressure Supply Hose

Fig. 1, AGS Central Unit Mounting Capscrews



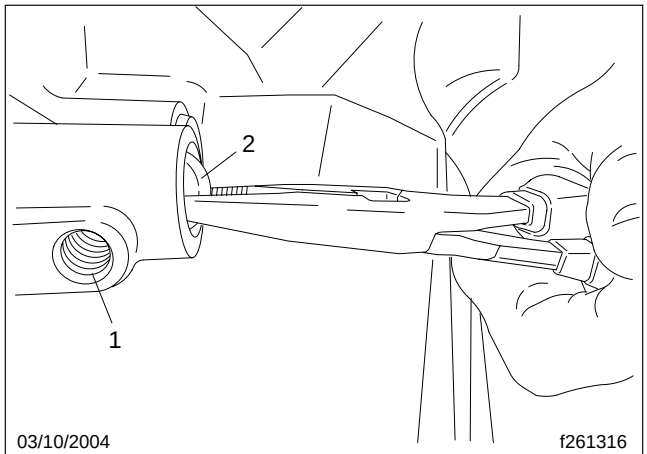
Remove the four large inverted-Torx capscrews (arrows) that attach the x-y actuator to the transmission.

Fig. 2, X-Y Actuator Mounting Capscrews

12. Remove the x-y actuator assembly from the front gear case.

12.1 From the right-hand side of the transmission, remove the setscrew that holds the end of the shift rod.

12.2 Remove the sheet metal shift cover at the end of the shift cover housing. See **Fig. 3**. Tap the shift cover with a drift to dislodge it, then pull it out of the shift cover housing with pliers. Discard this shift cover.



1. Setscrew Hole
2. Shift Cover

Fig. 3, Removing the Shift Cover

12.3 Pull the actuator assembly, complete with the shift rod, out of the front gear case.

IMPORTANT: If there is difficulty in separating the x-y actuator from the gear case, install the shift mechanism end guide on the end of the shift rod. Then use a rubber mallet to pound gently on the end guide until the actuator comes free.

13. Carefully remove the entire AGS assembly from the transmission.

14. If necessary due to wear, file around the setscrew bore at the end of the shift rod. When finished filing, be sure to remove any metal scraps, shavings, or other residue.

Installation

1. Using the shift finger alignment fork (**Table 1**), align the shift finger. See **Fig. 4**. Leave the fork in place until the shift rod is installed in the front

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gear case. Screw the shift mechanism end guide (**Table 1**) onto the shift rod.

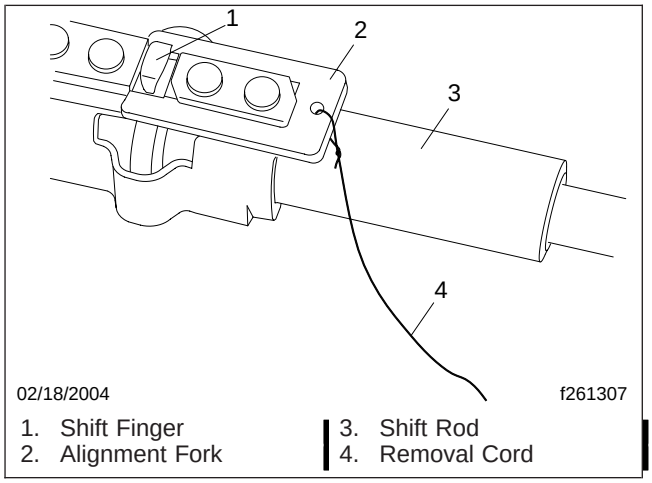


Fig. 4, Alignment of the Shift Finger

NOTE: Turn the shift rod to make sure the countersunk bore for the setscrew is rotated at a 90-degree angle away from the shift finger.

2. Install the actuator assembly in the front gear case.

   2.1 Clean the mating surface between the actuator assembly and the front gear case. Coat the mating surface with Loctite® 509 or equivalent sealing compound.

   2.2 Insert the actuator assembly into the front gear case. Make sure that the removal cord attached to the end of the alignment fork is accessible.

   NOTE: For ease of entry, it helps to tip the shift fork slightly downwards and to the rear.

   2.3 When the shift rod is in far enough to engage the shift finger, there will be about a 2-inch (50-mm) gap between the back of the x-y actuator and the mating surface on the front gear case. Use the removal cord to pull out the alignment fork.

   2.4 Set the x-y actuator against the mating surface. If necessary, turn the shift rod in a clockwise direction until the setscrew bore is visible through the hole provided.

   2.5 Install the M12 setscrew in the countersunk bore in the shift rod, but do not tighten it yet. See **Fig. 5**.

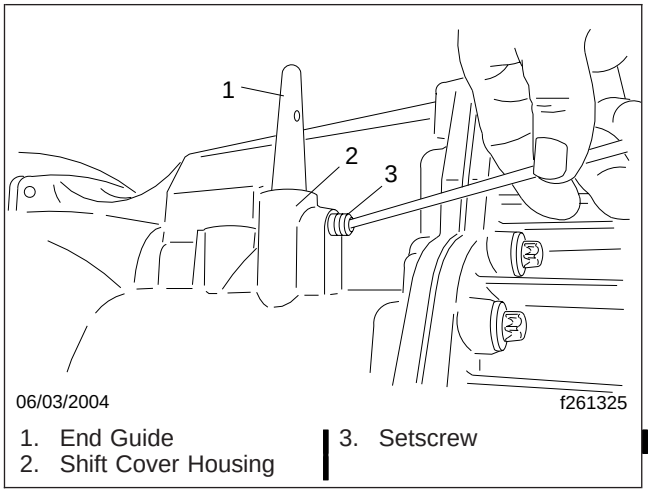


Fig. 5, Installing the Setscrew

   2.6 When the shift rod is all the way in, unscrew the end guide.

   2.7 Turn the shift rod until the indent on the end of the shift rod is at the 9 o'clock position. See **Fig. 6**.

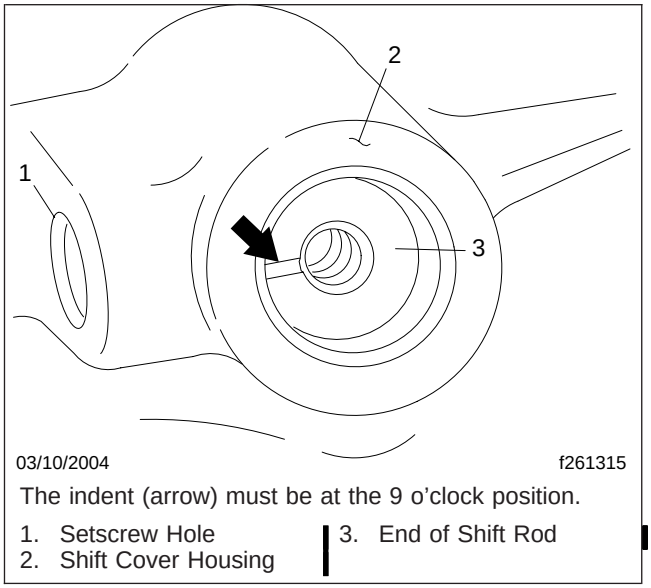


Fig. 6, Indent at Shift Rod End

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AGS Assembly Removal and Installation

2.8 Before tightening, make sure the setscrew is firmly seated in the shift rod. Tighten the setscrew 22 lbf·ft (30 N·m).

2.9 Press a new shift cover onto the shift cover housing.

3. Install the hydraulic fluid reservoir. For detailed procedures, see **Subject 150**.
4. Install the accumulator. For detailed procedures, see **Subject 140**.
5. Install the high-pressure clutch hydraulic line, as removed.
6. Coat the threads of the four inverted-Torx actuator mounting capscrews with Loctite 509 or equivalent thread-locking compound. Install the four capscrews on the x-y actuator and tighten them 17 lbf·ft (23 N·m).
7. Coat the threads of the four inverted-Torx central unit mounting capscrews with Loctite 509 or equivalent thread-locking compound. Install the four capscrews on the central unit and tighten them 17 lbf·ft (23 N·m).
8. Connect all the electrical connectors, as removed.
9. Bleed the hydraulic system. For procedures, see **Subject 130**.
10. Add Pentosin as needed until the level reaches the joint between the upper and lower sections of the reservoir. For detailed procedures, see **Subject 150**.

IMPORTANT: Use only Pentosin in the hydraulic reservoir. No other fluid can be substituted.

11. Install the splash guard before installing the transmission. Tighten the mounting screws 17 lbf·ft (23 N·m). See **Subject 110** for instructions.
12. Install the transmission on the vehicle. For detailed procedures, see **Subject 100**.
13. Start the engine and allow the system to pressurize. Shift back and forth a few times from drive to reverse and back to neutral.

NOTE: The first few shifts after draining and refilling the hydraulic system will take longer than usual.

14. Check the hydraulic fluid level and add more Pentosin as needed. For detailed procedures, see **Subject 150**.
15. Check the hydraulic system for leaks, and repair if necessary. When done, shut down the engine.
16. Remove the chocks from the rear tires.

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Replacement

IMPORTANT: Depressurize the hydraulic system before replacing any hydraulic components.

1. Depressurize the hydraulic system. For detailed procedures, see **Subject 160**.

NOTE: Replacement of the clutch actuator requires removing the transmission from the vehicle.

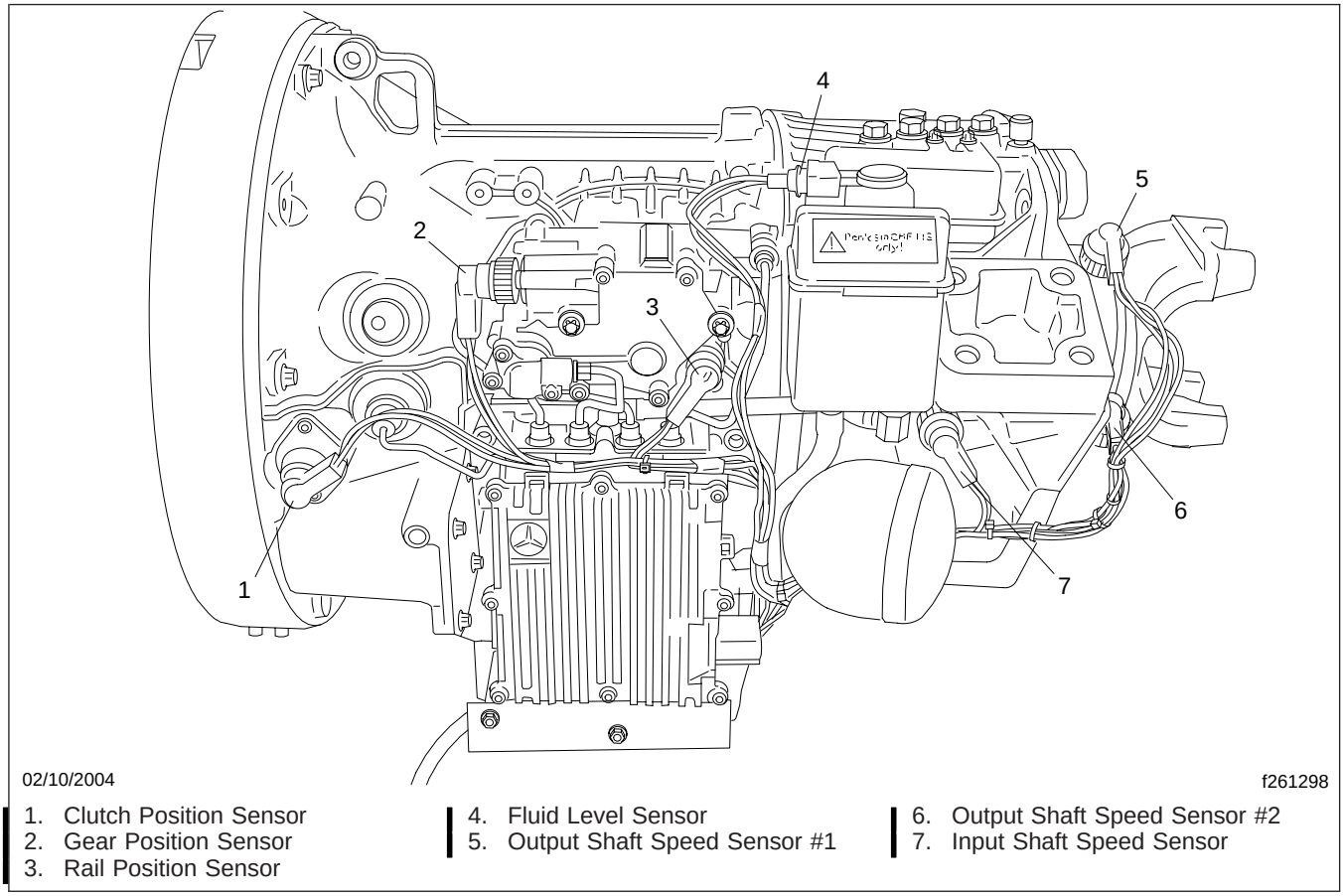
2. Remove the transmission from the vehicle. For detailed procedures, see **Subject 100**.
3. Unlock the electrical connector cap from the clutch position sensor. See **Fig. 1**. Turn the lock collar on the connector plug 90 degrees counterclockwise and remove it. Then remove the connector plug and the position sensor wire from the bell housing.
4. Loosen the clutch actuator capscrews, but do not remove them yet.
5. Lift up the spring clip from the hydraulic line and carefully pull the hydraulic line straight out, using a minimum of force. See **Fig. 2**.
6. Remove the clutch actuator (release bearing housing and concentric slave cylinder). See **Fig. 3**.
   - 6.1 Remove both 30-mm hexhead hydraulic fittings from the bell housing.
   - 6.2 Remove the clutch actuator capscrews that attach the clutch actuator to the bell housing.
   - 6.3 Slide the clutch actuator off the transmission input shaft.
7. Slide the clutch actuator onto the input shaft. Install the clutch actuator on the bell housing.
   - 7.1 Install new clutch actuator capscrews and tighten them 17 lbf·ft (23 N·m).

   IMPORTANT: Do not use Loctite® or sealant on these fasteners.

   - 7.2 Connect the hydraulic line and the fitting that attaches it to the bell housing. Make sure the spring clip engages properly.
   - 7.3 Install the bleed screw and the fitting that attaches it to the bell housing.
   - 7.4 Attach the sensor wire, connector, and connector plug assembly to the bell housing. Lock the electrical connector cap onto the connector plug.
   - 7.5 Tighten all hydraulic fittings 37 lbf·ft (50 N·m).
8. Install the transmission in the vehicle. For detailed procedures, see **Subject 100**.

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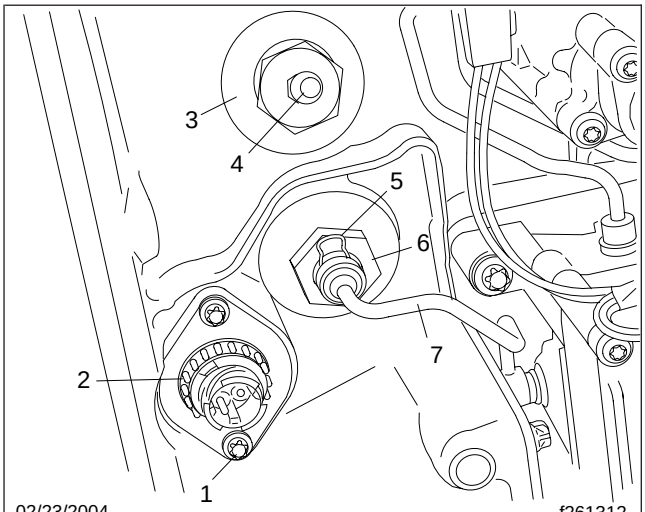
Clutch Actuator Replacement



1. Clutch Position Sensor
2. Gear Position Sensor
3. Rail Position Sensor
4. Fluid Level Sensor
5. Output Shaft Speed Sensor #1
6. Output Shaft Speed Sensor #2
7. Input Shaft Speed Sensor

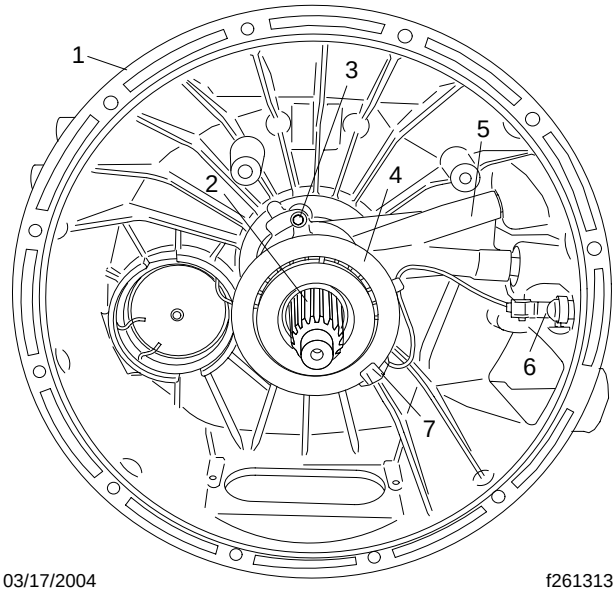
Fig. 1, Transmission Sensors

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1. Mounting Plate Capscrew
2. Connector Plug
3. 30-mm Hexhead Hydraulic Bleed Fitting
4. Bleed Screw
5. Spring Clip
6. 30-mm Hexhead Hydraulic Pressure Fitting
7. Hydraulic Line

Fig. 2, Clutch Components on Bell Housing



1. Lip of Bell Housing
2. Input Shaft
3. Clutch Actuator Mounting Capscrew
4. Release Bearing Housing
5. Concentric Slave Cylinder
6. Position Sensor Connector
7. Clutch Position Sensor

Fig. 3, Clutch Actuator

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IMPORTANT: Always use ServiceLink when attempting to diagnose problems with the AGS (Automated Gear Shift) transmission.

How To Start

To gain a baseline for troubleshooting when there is no definite problem, the malfunction is erratic or intermittent, or to determine the general health of the electrical system, start with the electrical pre-test in **Subject 301**.

In a few cases there will be a definite problem and no J1587 fault code will be sent (engine will not crank, no information on gear display, fluid level fault). For these problems, see the appropriate table in **Subject 301**.

But in most cases, the J1587 fault code is the starting point for the troubleshooting procedures. See **Table 1** to find information for SID fault codes. See **Table 2** to find information for PID fault codes.

Before starting any procedures, use ServiceLink to depressurize the AGS hydraulic system. For detailed procedures, see **Subject 160**.

Fault Code Guide

To troubleshoot a given fault code, look up the subject number in **Table 1** (for SIDs) and **Table 2** (for PIDs). Follow the procedures for that fault code until the fault is corrected.

Fault Code Guide (MID 130 SIDs)				
SID	**FMI**	**Text Message**	**Failure Reason**	**Procedure**
18	02	Prim Selector Erratic	The shift lever does not shift gears.	See **Subject 302**.
33	03	MultiPress Ind Short Hi	The hydraulic pressure sensor circuit is shorted to power.	See **Subject 303**.
33	04	MultiPress Ind Short Lo	The hydraulic pressure sensor circuit is shorted to ground.	See **Subject 303**.
33	05	MultiPress Ind OPEN	The hydraulic pressure sensor circuit is open.	See **Subject 303**.
52	05	Hydraulic Sys OPEN	The hydraulic pump circuit is open.	See **Subject 304**.
52	07	Hydraulic Sys NoRESPONSE	The hydraulic pressure does not increase even though the hydraulic pump is activated.	See **Subject 304**.
52	11	Clutch Act Not Known	The hydraulic pump temperature is too high.	See **Subject 304**.
55	00	Clutch Act HIGH	The clutch is too hot.	See **Subject 305**.
55	07	Clutch Act NoRESPONSE	The clutch does not operate properly.	See **Subject 305**.
55	13	Clutch Act Calibrate	The clutch needs to be calibrated.	See **Subject 305**.
231	02	SAE J1939 Datalink Erratic	The J1939 datalink is not communicating properly.	See **Subject 306**.
231	09	SAE J1939 Datalink UPDATE	The J1939 datalink has timed out.	See **Subject 306**.
231	12	SAE J1939 Datalink Bad	The J1939 datalink is not communicating with the transmission.	See **Subject 306**.
251	00	POWER SUPPLY HIGH	The power supply voltage is too high.	See **Subject 307**.
251	01	POWER SUPPLY Low	The power supply voltage is too low.	See **Subject 307**.
251	05	POWER SUPPLY OPEN	There is no power to the transmission with the engine running.	See **Subject 307**.
251	14	POWER SUPPLY RSRVD	The power supply is not properly grounded.	See **Subject 307**.
253	02	Calibration Memory Erratic	The transmission needs to be recalibrated.	See **Subject 308**.
253	12	Calibration Memory Bad	The transmission needs to be recalibrated.	See **Subject 308**.
253	13	Calibration Memory Calibrate	The transmission needs to be recalibrated.	See **Subject 308**.
253	14	Calibration Memory RSRVD	The transmission needs to be recalibrated.	See **Subject 308**.

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General Troubleshooting

Fault Code Guide (MID 130 SIDs)				
SID	**FMI**	**Text Message**	**Failure Reason**	**Procedure**
254	04	Controller Short Lo	The TCU is shorted to ground.	See **Subject 309**.
254	05	Controller OPEN	The TCU has an open circuit.	See **Subject 309**.
254	11	Controller Not Known	The TCU AUTO mode software module has an error.	See **Subject 309**.
254	12	Controller Bad	The TCU has a hardware problem.	See **Subject 309**.
254	13	Controller Calibrate	The TCU has a software memory problem.	See **Subject 309**.

Table 1, Fault Code Guide (SIDs)

Fault Code Guide (MID 130 PIDs)				
PID	**FMI**	**Text Message**	**Failure Reason**	**Procedure**
33	02	Erratic	The clutch position sensor gives invalid data.	See **Subject 310**.
33	03	Short Hi	The clutch position sensor circuit is shorted to power.	See **Subject 310**.
33	04	Short Lo	The clutch position sensor circuit is shorted to ground.	See **Subject 310**.
33	05	OPEN	The clutch position sensor circuit is open.	See **Subject 310**.
33	14	RSRVD	The clutch position sensor gives incorrect resistance readings.	See **Subject 310**.
59	02	Shift FNGR Gear Erratic	The shift rod position sensor gives invalid data.	See **Subject 311**.
59	03	Shift FNGR Gear Short Hi	The gear position sensor circuit is shorted to power.	See **Subject 311**.
59	04	Shift FNGR Gear Short Lo	The gear position sensor circuit is shorted to ground.	See **Subject 311**.
59	05	Shift FNGR Gear OPEN	The gear position sensor circuit is open.	See **Subject 311**.
59	14	Shift FNGR Gear RSRVD	The gear position sensor gives incorrect resistance readings.	See **Subject 311**.
60	02	Shift FNGR Rail Erratic	The rail position sensor circuit gives invalid data.	See **Subject 312**.
60	03	Shift FNGR Rail Short Hi	The rail position sensor circuit is shorted to power.	See **Subject 312**.
60	04	Shift FNGR Rail Short Lo	The rail position sensor circuit is shorted to ground.	See **Subject 312**.
60	05	Shift FNGR Rail OPEN	The rail position sensor circuit is open.	See **Subject 312**.
60	14	Shift FNGR Rail RSRVD	The rail position sensor gives incorrect resistance readings.	See **Subject 312**.
64	09	Dir Switch Update	The output shaft speed sensor is not providing accurate directional information.	See **Subject 313**.
64	11	Dir Switch Not Known	The output shaft speed sensor is not providing accurate directional information.	See **Subject 313**.
158	00	Volts (BattSw) HIGH	The voltage in the ignition power circuit is too high.	See **Subject 314**.
158	01	Volts (BattSw) Low	The voltage in the ignition power circuit is too low.	See **Subject 314**.
161	02	In shaft SPEED Erratic	The input shaft speed sensor circuit gives invalid data.	See **Subject 315**.
161	03	In shaft SPEED Short Hi	The input shaft speed sensor circuit is shorted to power.	See **Subject 315**.
161	04	In shaft SPEED Short Lo	The input shaft speed sensor circuit is shorted to ground.	See **Subject 315**.
161	05	In shaft SPEED OPEN	The input shaft speed sensor circuit is open.	See **Subject 315**.
161	08	In shaft SPEED Update	The input shaft speed sensor circuit is broadcasting an abnormal frequency.	See **Subject 315**.

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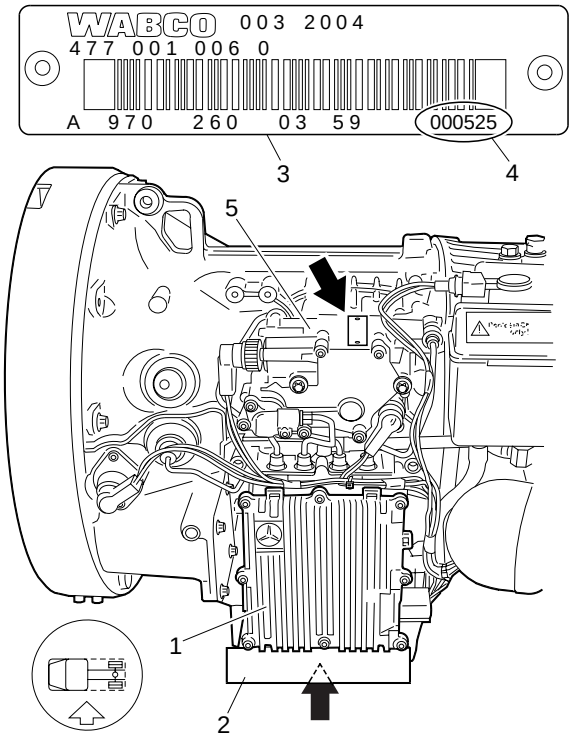
Fault Code Guide (MID 130 PIDs)				
PID	**FMI**	**Text Message**	**Failure Reason**	**Procedure**
162	02	RANGE Selected Erratic	The transmission is not properly calibrated.	See **Subject 316**.
163	02	RANGE Attained Erratic	The gears do not shift properly.	See **Subject 316**.
191	02	OUTPUT SPEED Erratic	One or both of the output shaft speed sensor circuits give invalid data.	See **Subject 317**.
191	05	OUTPUT SPEED OPEN	One or both of the output shaft speed sensor circuits are open.	See **Subject 317**.
191	08	OUTPUT SPEED SIGNAL	There is no signal coming from one or both output shaft speed sensors.	See **Subject 317**.
191	14	OUTPUT SPEED RSRVD	The output shaft speed sensor is providing invalid data.	See **Subject 317**.

Table 2, Fault Code Guide (PIDs)

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IMPORTANT: Always use ServiceLink when attempting to diagnose problems with the automated gear shift (AGS) transmission.

In most cases, the J1587 fault code is the starting point for the troubleshooting procedures. See **Subject 300** for a list of fault codes and the location of troubleshooting procedures for each code.



NOTE: The TCU and X-Y Actuator each have their own WABCO identification plate (arrows) with unique serial numbers.

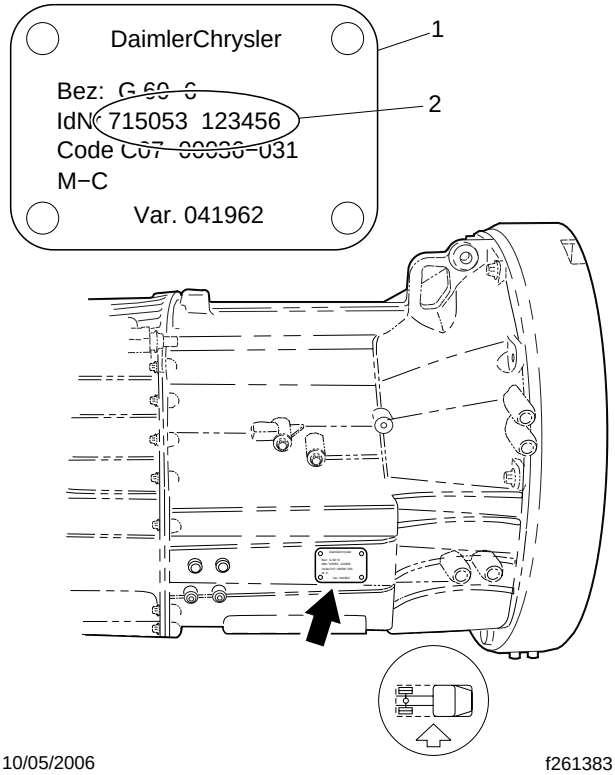
1. TCU (Transmission Control Unit)
2. Splash Guard
3. WABCO Identification Plate
4. Serial Number
5. X-Y Actuator

Fig. 1, Serial Numbers for TCU and X-Y Actuator

Electrical Pre-Test Instructions

Before starting any procedures, use ServiceLink to depressurize the AGS hydraulic system. For detailed procedures, see **Subject 160**.

Use the electrical pre-test instructions given in **Table 1** as a baseline for troubleshooting when there is no definite problem, the malfunction is erratic or intermittent, or as an informational step to determine the general health of the electrical system. To record your findings, a result sheet is provided at the end of this subject. For locations of serial numbers, see **Fig. 1** and **Fig. 2**.



1. Transmission Identification Plate
2. Serial Number

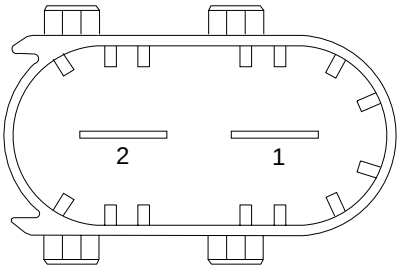
Fig. 2, Transmission Serial Number

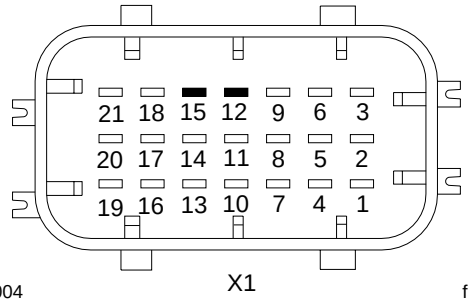
NOTE: To see the identification plate on the TCU it may be necessary to remove the splash guard.

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Troubleshooting Without Fault Codes

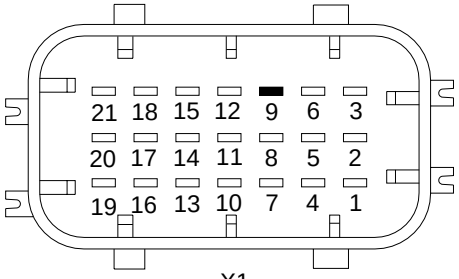
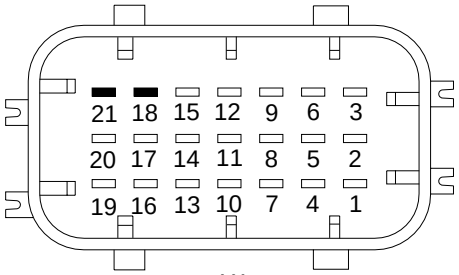
<table>
<tr><th colspan="3">Electrical Pre-Test</th></tr>
<tr><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td>Make sure that the selector switch on the SmartShift lever is set to N. Turn on the ignition switch to power up the transmission.

NOTE: If the hydraulic pump starts up with its characteristic humming noise, this means the main power cables are OK (see the steps below to check the X3 connector).</td><td>The current gear indicator does not power up normally. No fault codes display.</td><td>Troubleshoot the current gear indicator. See Table 4.</td></tr>
<tr><td></td><td>The current gear indicator goes through its normal power-up sequence, ending by displaying "N."</td><td>Turn off the ignition switch and go to the next row in the table.</td></tr>
<tr><td>With the ignition switch off, check the voltage at the battery.</td><td>Voltage is less than 11 or greater than 13 volts.</td><td>Charge or replace the battery. For battery charging procedures, see Section 54.03, Subject 150.</td></tr>
<tr><td></td><td>Voltage is between 11 and 13 volts.</td><td>Go to the next row in the table.</td></tr>
<tr><td>Remove the X3 (electric motor 2-pin) connector from the transmission control unit (TCU). Check the electric motor power circuit.</td><td colspan="2"> 

06/01/2004 X3 f544485</td></tr>
<tr><td>Check for voltage between pin 1 (power circuit 232) of the X3 connector and the battery ground terminal.</td><td>Voltage drops more than 0.2 volts from the voltage measured at the battery.</td><td>Repair or replace the wiring as needed. See Section 54.00, Subject 100.</td></tr>
<tr><td></td><td>Voltage is within 0.2 volts of the voltage measured at the battery.</td><td>Go to the next row in the table.</td></tr>
<tr><td>Check for resistance between pin 2 (ground) of the X3 connector and the battery ground terminal.</td><td>Resistance is greater than 0.3 ohms.</td><td>Repair or replace the wiring as needed. See Section 54.00, Subject 100.</td></tr>
<tr><td></td><td>Resistance is 0.3 ohms or less.</td><td>Go to the next row in the table.</td></tr>
<tr><td>Remove the X1 (vehicle 21-pin) connector from the transmission control unit (TCU). Check the battery power circuit.</td><td colspan="2"> 

07/16/2004 X1 f544483b</td></tr>
</table>

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Electrical Pre-Test		
Procedure	**Result**	**Action**
Check for voltage from pins 12 and 15 (battery power circuit 232D) of the X1 connector to the battery ground terminal.	Voltage drops more than 0.2 volts from the voltage measured at the battery.	Repair or replace the wiring as needed. See **Section 54.00, Subject 100**.
	Voltage is within 0.2 volts of the voltage measured at the battery.	Go to the next row in the table.
Turn on the ignition switch. Check the ignition power circuit.	 07/16/2004 X1 f544483c	
Check for voltage from pin 9 (ignition power circuit 232E) of the X1 connector to the battery ground terminal.	Voltage drops more than 0.2 volts from the voltage measured at the battery.	Repair or replace the wiring as needed. See **Section 54.00, Subject 100**.
	Voltage is within 0.2 volts of the voltage measured at the battery.	Go to the next row in the table.
Turn off the ignition switch. Check the ignition ground circuit.	 07/21/2004 X1 f544483d	
With the ignition switch off, check for resistance between pins 18 and 21 (ground) of the X1 connector and the battery ground terminal.	Resistance is greater than 0.3 ohms.	Repair or replace the wiring as needed. See **Section 54.00, Subject 100**.
	Resistance is 0.3 ohms or less.	Go to the next row in the table.

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Troubleshooting Without Fault Codes

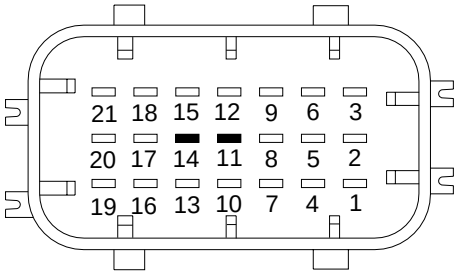
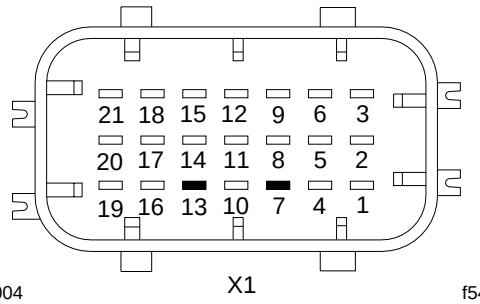
Electrical Pre-Test		
Procedure	**Result**	**Action**
Turn off the ignition switch. Check the J1587 wiring.		
Check for DC voltage from pins 11 and 14 (J1587 datalink) of the X1 connector to the battery ground terminal. NOTE: If the meter cannot display the rapidly shifting DC voltage, measure AC voltage instead.	Voltage is less than 1 or more than 4 volt(s) for DC (less than 1 or more than 3 for AC).	Troubleshoot the J1587 datalink.
	Voltage is between 1 and 4 volts for DC (1–3 volts AC).	Turn off the ignition switch and go to the next row in the table.
Turn on the ignition switch. Check the J1939 wiring.		
With the ignition switch off, remove the X1 connector from the TCU and check for resistance between pins 7 and 13 (J1939 datalink).	Resistance is less than 55 or greater than 65 ohms.	Troubleshoot the J1939 datalink. See Sterling **Service Bulletin 54-16**.
	Resistance is between 55 and 65 ohms.	The vehicle has passed the electrical pre-test. Troubleshoot active fault codes, if any.

Table 1, Electrical Pre-Test

Troubleshooting Tables, No Fault Codes

In a few cases there will be a definite problem and no J1587 fault code will be sent.

- If the engine will not crank and there are no transmission fault codes, see **Table 2**.
- If the current gear indicator displays "FL," and the CHECK TRANS light comes on, there is a low fluid level fault. See **Table 3**. Low fluid level faults do not generate a J1587 fault code.
- If the transmission is fully functional, but there is no information on the current gear indicator, see **Table 4**.

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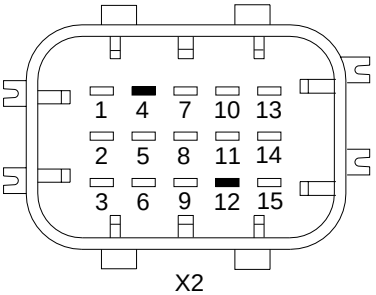
No J1587 Fault Code—The Engine Will Not Crank		
Procedure	**Result**	**Action**
Make sure that the selector switch on the SmartShift lever is set to N. Power up the transmission.	The current gear display shows "N."	Verify that relay RG is functioning properly.
	There is a J1587 fault code in MID 128 (engine) for missing J1939 information.	Check the wiring for loose terminals and corroded connector pins.
	The gear display is blank and there is no response to the J1587 roll call. The hydraulic pump does not come on.	Check pin 9 on the X1 connector to verify the presence of ignition voltage.
	There is a J1587 roll call and it reports other ECUs but not the TCU.	Go to the next row in the table.
Remove the X1 connector and check it for bent or missing pins.	Pins are damaged or missing.	Straighten bent pins and replace a damaged connector.
	The connector is intact and serviceable.	Go to the next row in the table.
Check fuses NN and LL, and verify whether relay RG is functioning properly.	Either or both fuses are blown.	Replace any blown fuses.
	The fuses are good.	Go to the next row in the table.
Check the datalink communication again.	There is no datalink communication.	Check for a wiring problem (most likely at a common connector).
	The datalink is OK.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet. See **Fig. 3**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Engine Will Not Crank

No J1587 Fault Code—"FL" on Current Gear Indicator; CHECK TRANS Light Illuminates*		
Problem	**Remedy**	
	Procedure	**Result/Action**
The hydraulic fluid level is low.	Use ServiceLink to check the hydraulic fluid level.	If the fluid level is low, add Pentosin to the hydraulic reservoir.

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Troubleshooting Without Fault Codes

No J1587 Fault Code—"FL" on Current Gear Indicator; CHECK TRANS Light Illuminates*		
Problem	**Remedy**	
	Procedure	**Result/Action**
The fluid level sensor is defective.	Disconnect the sensor connector from the reservoir cap. Check for continuity across pins 1 and 2 of the sensor connector. NOTE: When the reservoir is full, the float in the sensor rises up, and the two pins in the connector create a complete circuit.	If no continuity, replace the sensor. See **Subject 150**.
Turn off the ignition switch. Check the fluid level sensor wiring.	 07/16/2004 X2 f544484l	
The wiring between the TCU and the fluid level sensor is defective.	Check resistance from pin 4 on the X2 connector to pin 2 on the sensor connector. Check resistance from pin 12 on the X2 connector to pin 1 on the sensor connector.	If no resistance, repair or replace the X2 transmission harness. See **Subject 180**.
There is an internal electrical failure in the TCU.	Check the TCU for leakage or damage.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet. See **Fig. 3**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

* Even though the CHECK TRANS light illuminates, it is normal to see no active fault code.

Table 3, Low Fluid Level Indication

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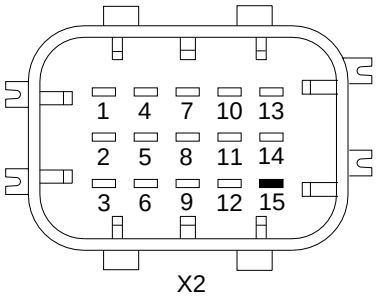
No J1587 Fault Code—Transmission Fully Functional; No Information on Current Gear Indicator			
Problem	**Remedy**		
	Procedure	**Result**	**Action**
The wiring from the X1 connector to the current gear indicator is defective.	Power up the transmission.	The current gear indicator displays "--."	Repair or replace the X1 connector harness as needed. See **Section 54.00, Subject 100**.
		The current gear indicator displays something other than "--."	See the messsages in **Table 5** for possible error codes.
Remove the X2 connector. Check the speed sensor wiring.		 08/11/2005 f544484m	
The wiring from the output shaft speed sensor to the current gear indicator is shorted to ground.	Check the wiring between pin 15 on the X2 connector and pin 1 on *both* speed sensors.	Both speed sensors are shorted to ground.	Replace the X2 wiring harness. See **Subject 180**.
		At least one speed sensor is OK.	Go to the next row in the table.
The wiring from the X1 connector to the J1587 datalink is defective.	Check for J1587 communication on ServiceLink.	AGS2 is not reporting on ServiceLink.	Repair or replace the X1 connector wiring as needed. See **Section 54.00, Subject 100**.
		AGS2 is reporting on ServiceLink.	Go to the next row in the table.
The current gear indicator or its wiring is defective.	Check the wiring from the current gear indicator to power, ground, and the J1587 datalink.	The wiring is damaged.	Repair or replace the power, ground, or J1587 datalink wiring as needed. See **Section 54.00, Subject 100**.
		The wiring is OK.	Replace the current gear indicator.

Table 4, Transmission Fully Functional; No Information on Current Gear Indicator

AGS Messages on the Current Gear Indicator	
Code	**Error**
SM	System Malfunction (this is a code that could affect driveability)
CO	Clutch Overload (clutch has begun to overheat)
FL	Low Hydraulic Fluid Level

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Troubleshooting Without Fault Codes

AGS Messages on the Current Gear Indicator	
Code	**Error**
X	Undefined Gear Position
	Incomplete Calibration
	Gear or Rail Position Sensor Error
"—"	No J1587 Communication
"(blank screen)"	No Power to Gear Display
	No J1587 Communication
N	Normal Operation (neutral gear)
R	Normal Operation (reverse gear)
1-6	Normal Operation (forward gears)

Table 5, AGS Messages on the Current Gear indicator

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VIN: _____ Mileage: _____ Date: _____

Serial Numbers			
TCU:		X−Y Actuator:	
AGS:			

ABS Codes: (136)	SID/PID	FMI	Eng Codes: (128)	SID/PID	FMI

Pentosin level: (with system depressurized)	Full ☐ / Empty ☐	Below seam ☐ inches ____	Above seam ☐ inches ____	Gear display power up:	Yes ☐	No ☐	Gear display show "N":	Yes ☐	No ☐

Customer complaint description:	

Battery voltage:		Battery voltage at X3 pin 1:		Ground at X3 pin 2:	
Key power at X1 pin 9:		Battery voltage at X1 pins 12 & 15:		Ground at X1 pins 18 & 21:	

J1587 Datalink good:	OK ☐	Failed ☐	J1939 Datalink good:	OK ☐	Failed ☐

Notes: _____

_____

_____

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Fig. 3, Electrical Pre-Test Result Sheet

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SmartShift Fault

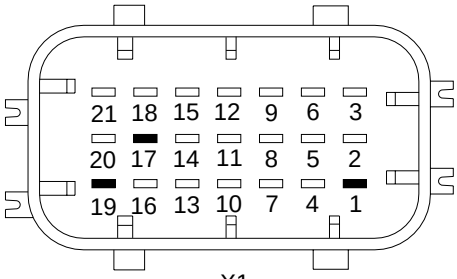
There is one SmartShift fault covered in these procedures. In addition to the troubleshooting table, two tables of resistance values are provided.

- For SID 18, FMI 02, see **Table 1** for procedures and pin identification.
- To check resistance on the SmartShift up/downshift circuit, see **Table 2**.
- To check resistance on the SmartShift gear selection circuit, see **Table 3**.

SID 18, FMI 02—The Shift Lever Does Not Shift Gears

Failure Reason:

- There is a defect in the shift lever.
- There is a defect in the wiring.
- There is a defect in the TCU.



07/16/2004 f544483

Procedure	Result	Action
On the SmartShift control lever, move the slide switch to AUTO and the selector switch to N. Remove connector X1 from the transmission control unit (TCU). Do not remove the connector from the SmartShift lever. Check for resistance between pin 1 (circuit 464C) and pin 17 (circuit 464A).	Open circuit or value out of range	Check the wiring for loose terminals and corroded connector pins.
	11K to 12K ohms	Go to the next row in the table.
Check for resistance between pin 1 (circuit 464C) and pin 19 (circuit 464B).	Open circuit or value out of range	Check the wiring for loose terminals and corroded connector pins.
	345 to 385 ohms	Go to the next row in the table.
Remove the three-pin connector from the SmartShift lever. Check for resistance between pin 1 (circuit 464C) and pin 17 (circuit 464A).	Short circuit	Repair or replace the wiring as needed (see **Section 54.00, Subject 100**).
	11K to 12K ohms	Go to the next row in the table.
Check for resistance between pin 1 (circuit 464C) and pin 19 (circuit 464B).	Short circuit	Repair or replace the wiring as needed (see **Section 54.00, Subject 100**).
	345 to 385 ohms	Go to the next row in the table.

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SmartShift Fault (SID 18)

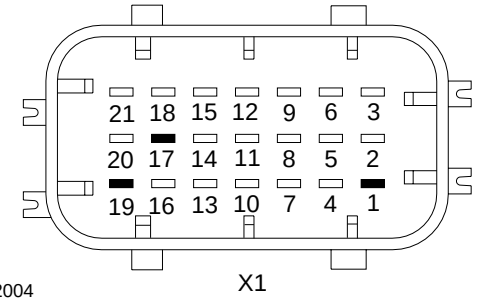
SID 18, FMI 02—The Shift Lever Does Not Shift Gears		
Failure Reason: • There is a defect in the shift lever. • There is a defect in the wiring. • There is a defect in the TCU.	 07/16/2004 f544483	
Procedure	**Result**	**Action**
If intermittent faults persist, check resistance values at other positions of the SmartShift lever. Use the pins on the SmartShift lever connector and see **Table 2** and **Table 3**. If available, use a SmartShift lever known to be good to check the correct resistance values.	SmartShift failure	Replace the SmartShift lever (see **Section 26.05, Subject 100**).
	SmartShift OK	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Shift Lever Does Not Shift Gears

Resistance Check for the Up/Downshift Circuit (Pin A to Pin C)	
Slide Switch + Lever Position	**Reading: kOhm**
AUTO	10.969–12.084
MAN	2.838–3.020
MAN + Up	0.527–0.564
MAN + Down	1.142–1.213
AUTO + Up	0.611–0.653
AUTO + Down	1.628–1.729

Table 2, Resistance Check for the Up/Downshift Circuit

Resistance Check for the Gear Selection Circuit (Pin B to Pin C)	
Selector Switch Position	**Reading: kOhm**
R	2.922–3.100
N	0.342–0.389
D	0.576–0.670

Table 3, Resistance Check for the Gear Selection Circuit

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Hydraulic Pressure Sensor Faults

There are three hydraulic pressure sensor faults covered in these procedures. The same troubleshooting procedure is used for all.

- For SID 33, FMI 03, FMI 04, and FMI 05, see **Table 1** for procedures.

SID 33, FMI 03, 04, 05—The Pressure Sensor Is Shorted or Open		
Failure Reason: • The contacts on the pressure sensor terminal are not straight. • There is a defect in the pressure sensor. • There is a defect in the TCU.		
Procedure	**Result**	**Action**
Do a visual check of the pressure sensor connector.	The pressure sensor contacts are bent or crooked.	Straighten any bent pins or plugs.
	The contacts are OK.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Pressure Sensor Is Shorted or Open

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Hydraulic Pump Faults

There are three hydraulic pump faults covered in these procedures. FMI 05 and FMI 07 are covered by the same troubleshooting procedure.

When both fault codes (SID 52 FMI 05 and SID 52 FMI 07) are active at the same time, a wiring problem is the most likely cause.

- For SID 52, FMI 05 and FMI 07, see **Table 1** for procedures.
- For SID 52, FMI 11, see **Table 2** for procedures.

SID 52, FMI 05, 07—The Hydraulic Pump Pressure Does Not Increase

Failure Reason:

- The hydraulic fluid level is low.
- The hydraulic system is leaking.
- There is air in the hydraulic system.
- The fuse in connector X3 is blown.
- The accumulator has failed.
- The pump or pressure sensor has failed.
- The hydraulic lines are pinched, kinked, or blocked.
- The TCU has failed.

Problem	Remedy	
	Procedure	Action
The hydraulic fluid level is low.	Check the hydraulic fluid level.	Add Pentosin to the hydraulic reservoir.
There are leaks in the hydraulic system.	Do a visual check of the hydraulic system for leaks and loose fittings. Tug on all the hydraulic fittings to make sure they are properly fastened.	Replace any leaking or damaged tubing. Make sure all the hydraulic fittings are properly fastened. See **Subject 200** for procedures.
There is air in the hydraulic system.	Bleed the hydraulic system. See **Subject 130** for procedures.	Test the hydraulic pump and make sure the pressure does increase.
The hydraulic pump circuit is open.	Check the 40-amp fuse. Remove the X3 connector and check the wiring at both pins.	Replace the 40-amp fuse if necessary. Repair or replace the wiring if necessary.
The pressure accumulator has failed.	Check the pressure accumulator for leaks or damage.	Replace the pressure accumulator. See **Subject 140** for procedures.

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Hydraulic Pump Faults (SID 52)

SID 52, FMI 05, 07—The Hydraulic Pump Pressure Does Not Increase		
Failure Reason: • The hydraulic fluid level is low. • The hydraulic system is leaking. • There is air in the hydraulic system. • The fuse in connector X3 is blown. • The accumulator has failed. • The pump or pressure sensor has failed. • The hydraulic lines are pinched, kinked, or blocked. • The TCU has failed.		
Problem	**Remedy**	
	Procedure	**Action**
The pump or pressure sensor has failed, or there is an internal electrical failure in the TCU.	Check the AGS central unit for leakage or damage.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Hydraulic Pump Pressure Does Not Increase

SID 52, FMI 11—The Hydraulic Pump Temperature Is Too High		
Failure Reason: • The pump motor has been operating for too long. • There has been a failure of the hydraulic system.		
Problem	**Remedy**	
	Procedure	**Action**
The pump motor is overheated.	Wait. Allow the motor to cool.	If the fault goes away, and there are no other active fault codes, no action is needed.

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SID 52, FMI 11—The Hydraulic Pump Temperature Is Too High		
Failure Reason: • The pump motor has been operating for too long. • There has been a failure of the hydraulic system.		
Problem	**Remedy**	
	Procedure	**Action**
There has been a failure of the hydraulic system. Failure is persistent and continues under all conditions.	Check the hydraulic system for leaks and troubleshoot other fault codes.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Hydraulic Pump Temperature Is Too High

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Clutch Actuator Faults

There are three clutch actuator faults covered in these procedures. Each one requires a different troubleshooting procedure. FMI 00 is often a temporary fault that goes away when the clutch is allowed to cool.

- For SID 55, FMI 00, see **Table 1** for procedures.
- For SID 55, FMI 07, see **Table 2** for procedures.
- For SID 55, FMI 13, see **Table 3** for procedures.

SID 55, FMI 00—The Clutch Is Too Hot*			
Failure Reason: • The clutch has temporarily overheated due to excessive use. • There is a fault in the clutch actuator sensor. • There is a mechanical defect in the clutch system.			
Problem	**Procedure**	**Result**	**Action**
The clutch is too hot. NOTE: Excessive clutch use may have been caused by maneuvering in heavy traffic or using the clutch to hold the truck on a hill.	Allow the clutch to cool.	Fault code goes away after clutch has cooled.	No corrective action is needed.
		Fault code does not go away after clutch has cooled.	Go to the next step in the table.
There is a problem with an output shaft speed sensor.	Check for other MID 130 (transmission) fault codes.	Other fault codes are active.	Troubleshoot the other active fault codes.
		No other fault codes are active.	Go to the next step in the table.
The clutch is slipping.	Test drive the vehicle. Is the fault code active during normal driving conditions (without a lot of gear changes)?	The fault code remains active.	Check the mechanical components of the clutch system. See **Section 25.02**.

* When this fault appears, it is usual to see the CHECK TRANS light illuminate and "CO" (clutch overload) display on the current gear indicator.

Table 1, The Clutch Is Too Hot

SID 55, FMI 07—The Clutch Does Not Operate Properly			
Failure Reason: • The hydraulic system is leaking. • There is a defect in the clutch actuator. • There is a mechanical defect in the clutch system. • There is a mechanical defect in the solenoid valves of the AGS central unit.			
Problem	**Procedure**	**Result**	**Action**
There are other active transmission faults.	Check for other MID 130 fault codes.	Other fault codes are active.	Troubleshoot the other active fault codes.
		No other fault codes are active.	Go to the next step in the table.

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Clutch Actuator Faults (SID 55)

SID 55, FMI 07—The Clutch Does Not Operate Properly			
Failure Reason: • The hydraulic system is leaking. • There is a defect in the clutch actuator. • There is a mechanical defect in the clutch system. • There is a mechanical defect in the solenoid valves of the AGS central unit.			
Problem	**Procedure**	**Result**	**Action**
The hydraulic system is leaking or fluid flow is restricted to the clutch actuator.	Do a visual check of the fluid lines for leaks, kinked lines, or blockage.	Leaks, kinked lines, or blockage is found.	Make sure all lines are tight. Replace any damaged components.
		There are no defects in the fluid lines.	Go to the next step in the table.
The clutch is slipping.	Test drive the vehicle. Does the system respond well to a wide range of driving condition and gear changes?	There are problems changing gears (shuddering, noises, slow to shift).	Check the mechanical components of the clutch system. See **Section 25.02**.
		There are no problems.	Replace the clutch actuator. See **Subject 120**.
There is a mechanical defect in the solenoid valves.	Test drive the vehicle. Is the fault code active during normal driving conditions (without a lot of gear changes)?	The fault code remains active.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).
		No fault codes.	Complete a learning procedure using ServiceLink.

Table 2, The Clutch Does Not Operate Properly

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Clutch Actuator Faults (SID 55)

SID 55, FMI 13—The Clutch Needs To Be Calibrated			
Failure Reason: • The clutch is not calibrated properly. • There is a mechanical defect in the clutch system.			
Problem	**Procedure**	**Result**	**Action**
Missing or incomplete clutch calibration (often occurs after service procedures such as clutch replacement, clutch actuator replacement, or engine/transmission separation).	Complete a learning procedure using either ServiceLink or the SmartShift control. To complete a learning procedure using the SmartShift control: 1. Ensure that the parking brake is set. 2. With the ignition turned off, pull and hold the SmartShift control toward steering wheel. NOTE: The SmartShift control must be kept in this position until the gear display clears at the end of the procedure. 3. Turn on the ignition. The normal warm up procedure will initiate and an 'X' will display on the current gear indicator. Your transmission may be heard shifting. 4. Wait until the current gear indicator displays an 'N' (about 30 seconds) and an audible alert sounds. Start the engine within 10 seconds of the audible alert. 5. The engine will raise a few rpm, then fall back to idle, and an audible alert will sound. Turn off the engine within 10 seconds of audible alert. When the gear display clears, this procedure is complete. NOTE: If during this procedure an 'SM' or 'X' (after the warm up procedure) appears in the gear display, stop, turn off the ignition, and wait for the gear display to go dark. Then start over. This may need to be repeated several times.	The fault is no longer active.	No action is needed.
		The fault is still active.	Go to the next step in the table.
There are other active transmission faults.	Check for other MID 130 fault codes.	Other fault codes are active.	Troubleshoot the other active fault codes.
		No other fault codes are active.	Check the mechanical components of the clutch system. See **Section 25.02**.

Table 3, The Clutch Needs To Be Calibrated

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J1939 Datalink Faults

There are three J1939 datalink faults covered in these procedures. If more than one of these faults is active, check FMI 12 first for best results. This can often resolve the other two faults as well.

- For SID 231, FMI 02, see **Table 1** for procedures.
- For SID 231, FMI 09, see **Table 2** for procedures.
- For SID 231, FMI 12, see **Table 3** for procedures and pin identification.

SID 231, FMI 02—The J1939 Datalink Is Not Communicating Properly			
Failure Reason: • There has been a failure in the data content received by the J1939 datalink from the other control units (engine ECU, ABS ECU). • The J1939 wiring is defective. • There is interference from other control units on the J1939 datalink.			
Problem	**Procedure**	**Result**	**Action**
There is no power to the transmission.	Check for fault code SID 231, FMI 09 and/or SID 231, FMI 12.	SID 231, FMI 09 and/or 12 are (is) active.	Troubleshoot SID 231, FMI 09 and/or 12. See **Table 2** and/or **Table 3**.
		SID 231, FMI 09 and 12 are not active.	Go to the next step in the table.
The J1939 data are not plausible.	Check the J1939 datalink connections to other systems, particularly the engine (MID 128) and the antilock brakes (MID 136).	There are other problems with the J1939 datalink.	Troubleshoot the J1939 datalink. See Sterling **Service Bulletin 54-16**.

Table 1, The J1939 Datalink Is Not Communicating Properly

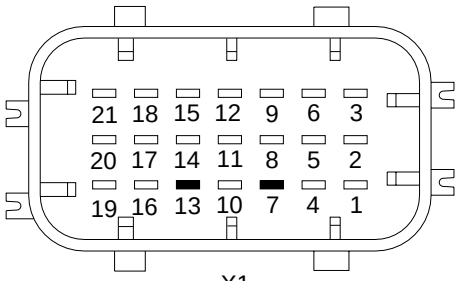
SID 231, FMI 09—The J1939 Datalink Message Has Timed Out			
Failure Reason: • The J1939 datalink is not receiving messages from other control units (engine ECU, ABS ECU). • The J1939 wiring is defective. • There is interference from other control units on the J1939 datalink.			
Problem	**Procedure**	**Result**	**Action**
The power supply has been interrupted.	Check for fault code SID 231, FMI 12.	SID 231, FMI 12 is active.	Troubleshoot SID 231, FMI 12. See **Table 3**.
		SID 231, FMI 12 is not active.	Go to the next step in the table.
Other active fault codes are causing a breakdown in J1939 communications.	Check for other active fault codes in other systems.	Other active fault codes are found.	Troubleshoot the other active fault codes.
		No other active fault codes are found.	Go to the next step in the table.

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J1939 Datalink Faults (SID 231)

SID 231, FMI 09—The J1939 Datalink Message Has Timed Out			
Failure Reason: • The J1939 datalink is not receiving messages from other control units (engine ECU, ABS ECU). • The J1939 wiring is defective. • There is interference from other control units on the J1939 datalink.			
Problem	**Procedure**	**Result**	**Action**
The J1939 data are not plausible.	Check the J1939 datalink connections to other systems, particularly the engine (MID 128) and the antilock brakes (MID 136).	There are other problems with the J1939 datalink.	Troubleshoot the J1939 datalink. See Sterling **Service Bulletin 54-16**.

Table 2, The J1939 Datalink Message Has Timed Out

SID 231, FMI 12—The J1939 Datalink Is Not Communicating With the Transmission			
Failure Reason: • The J1939 datalink has defective components. • The terminating resistors on the J1939 backbone are missing, or there are extra resistors. • The J1939 wiring is defective. • The signal on the J1939 datalink is distorted. • There is a defect in the TCU.		 07/16/2004 X1 f544483a	
Problem	**Procedure**	**Result**	**Action**
Pins on the connector have been bent or damaged.	Remove the X1 connector. Visually inspect the pins and connector.	The connector has been damaged.	Straighten any bent pins. Repair or replace the connector.
		The connector has not been damaged.	Go to the next step in the table.
The J1939 datalink is defective.	With the X1 connector removed, check for resistance between pin 7 and pin 13.	The resistance is less than 54 or more than 66 ohms.	Troubleshoot the J1939 datalink. See Sterling **Service Bulletin 54-16**.
		The resistance is between 54 and 66 ohms.	Go to the next step in the table.
There is a short circuit in the J1939 wiring.	With the X1 connector removed, check for resistance between pin 7 and all other pins on the connector.	A short circuit is found.	Check the J1939 wiring behind pins 7 and 13 and repair it as needed.
		An open circuit is found.	Go to the next step in the table.

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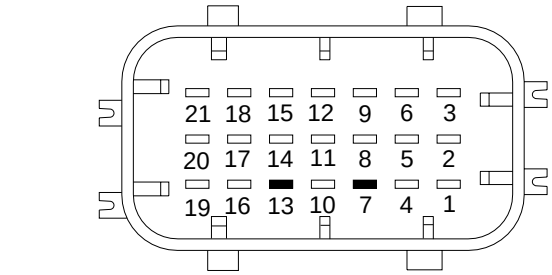
SID 231, FMI 12—The J1939 Datalink Is Not Communicating With the Transmission			
Failure Reason: • The J1939 datalink has defective components. • The terminating resistors on the J1939 backbone are missing, or there are extra resistors. • The J1939 wiring is defective. • The signal on the J1939 datalink is distorted. • There is a defect in the TCU.		 07/16/2004 X1 f544483a	
Problem	**Procedure**	**Result**	**Action**
There is a wiring failure in the TCU.	With the X1 connector removed, check whether other systems have the identical fault code active (SID 231, FMI 12).	SID 231, FMI 12 is active for other systems (MIDs).	Troubleshoot the J1939 datalink for the other systems. See Sterling **Service Bulletin 54-16**.
		This fault is not active for other systems (MIDs).	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 3, The J1939 Datalink Is Not Communicating With the Transmission

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Battery Power Supply Faults

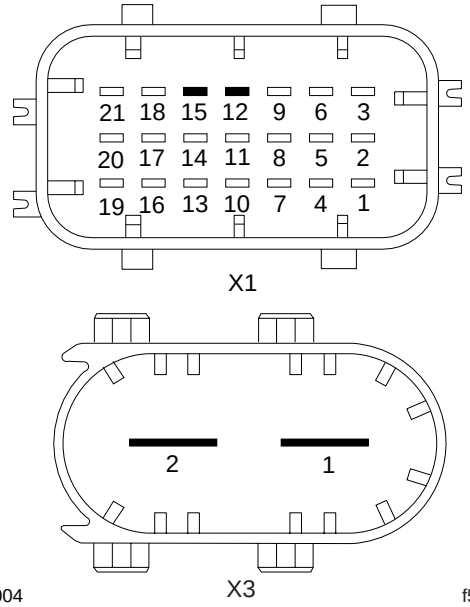
There are four battery power supply faults covered in these procedures. Each one requires a different electrical test.

- For SID 251, FMI 00, see **Table 1** for procedures and pin identification.
- For SID 251, FMI 01, see **Table 2** for procedures and pin identification.
- For SID 251, FMI 05, see **Table 3** for procedures and pin identification.
- For SID 251, FMI 14, see **Table 4** for procedures and pin identification.

SID 251, FMI 00—The Battery Voltage Is Too High

Failure Reason:

- There is a failure of the vehicle charging system.
- External power connected to the vehicle for a jump start.
- Voltage spikes on the battery power and/or ground circuits.



Procedure	Results	Action
Remove the X3 connector. Start the engine and check the voltage between plug 1 and plug 2 on the female connector.	The voltage is greater than 16V and constant for more than one second with the engine running.	Check the vehicle charging system. See **Group 15**.
	The voltage is greater than 8V and less than 15.9V.	Go to the next step in the table.

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Battery Power Supply Faults (SID 251)

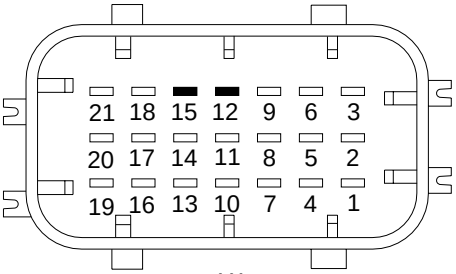
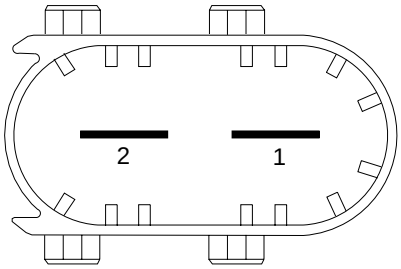
SID 251, FMI 00—The Battery Voltage Is Too High		
Failure Reason: • There is a failure of the vehicle charging system. • External power connected to the vehicle for a jump start. • Voltage spikes on the battery power and/or ground circuits.	 X1  X3 07/16/2004 f544485a	
Procedure	**Results**	**Action**
Remove the X1 connector. Start the engine and check the voltage to ground from plug 12 and plug 15 on the female connector.	The voltage is greater than 16V and constant for more than one second with the engine running.	Check the vehicle charging system. See **Group 15**.
	The voltage is greater than 8V and less than 15.9V.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Battery Voltage Is Too High

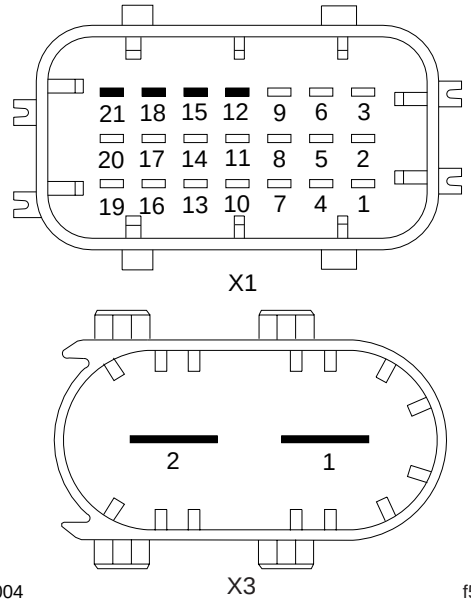
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Battery Power Supply Faults (SID 251)

SID 251, FMI 01—The Battery Voltage Is Too Low

Failure Reason:

- There is a failure of the vehicle charging system.
- The power circuits lack continuity to ground.
- Voltage drops on the battery power and/or ground circuits.



Procedure	Results	Action
Check the 5-amp fuse at position LL and the 10-amp fuse at position NN in the fuse box under the hood. Check the 40-amp maxifuse on hydraulic pump circuit.	One or more fuses are blown.	Replace any blown fuses.
	The fuses are OK.	Go to the next step in the table.
Start the engine. Remove the X1 and X3 connectors. Check for steady battery voltage from plug 12 and plug 15 on the X1 female connector to pin 1 on the X3 connector.	The voltage is greater than 16V and constant for more than one second with the engine running.	Check the vehicle charging system. See **Group 15** for charging system coverage.
	The voltage is greater than 8V and less than 15.9V.	Go to the next step in the table.

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Battery Power Supply Faults (SID 251)

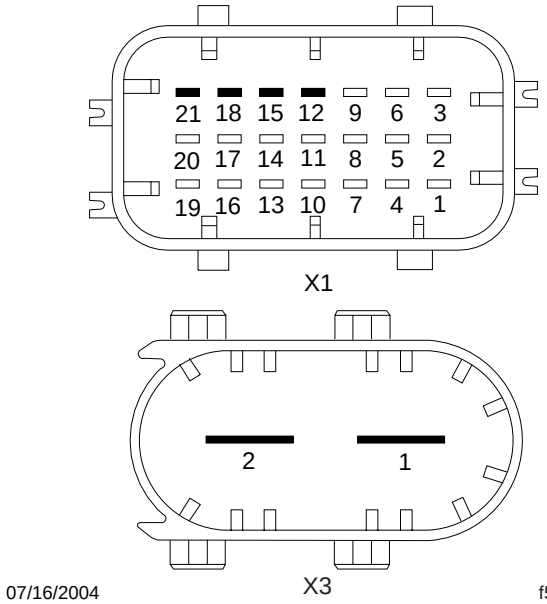
SID 251, FMI 01—The Battery Voltage Is Too Low		
Failure Reason: • There is a failure of the vehicle charging system. • The power circuits lack continuity to ground. • Voltage drops on the battery power and/or ground circuits.		
Procedure	**Results**	**Action**
With the engine running, check for continuity to ground from plug 18 and plug 21 on the X1 female connector to pin 2 on the X3 connector.	No continuity is present.	Repair or replace the wiring as needed. See **Section 54.00, Subject 100**.
	Continuity is present.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Battery Voltage Is Too Low

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Battery Power Supply Faults (SID 251)

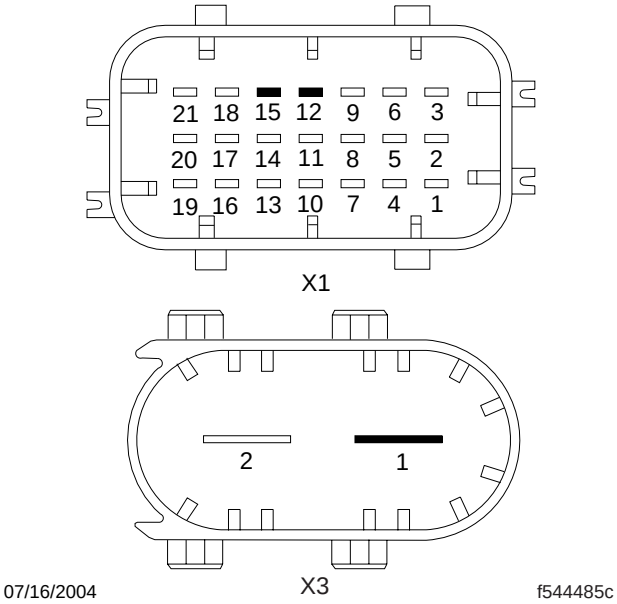
SID 251, FMI 05—There Is No Power to the Transmission With the Engine Running		
Failure Reason: • A fuse is blown. • There is a defect in the wiring.		
Procedure	**Results**	**Action**
Check the 5-amp fuse at position LL and the 10-amp fuse at position NN in the fuse box under the hood. Check the 40-amp maxifuse on hydraulic pump circuit.	One or more fuses are blown.	Replace any blown fuses.
	The fuses are OK.	Go to the next step in the table.
Start the engine. Remove the X1 and X3 connectors. Check for steady battery voltage from plug 12 and from plug 15 on the X1 female connector to pin 1 on the X3 connector.	The circuit is open.	Repair or replace the wiring as needed. See **Section 54.00, Subject 100**.
	The voltage is greater than 1V.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 3, There Is No Power to the Transmission With the Engine Running

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Battery Power Supply Faults (SID 251)

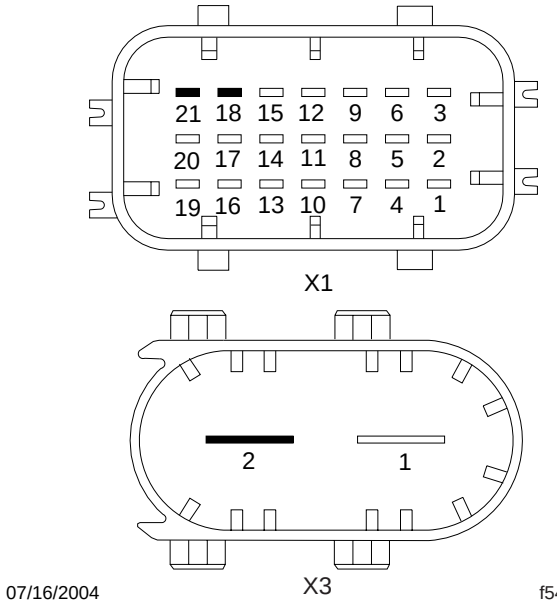
SID 251, FMI 14—The Power Supply Is Not Properly Grounded		
Failure Reason: • There is a defect in the wiring. • There is a defect in the TCU.		
Procedure	**Results**	**Action**
With the engine running, check for continuity to ground from plug 18 and plug 21 on the X1 female connector to pin 2 on the X3 male connector.	No continuity is found.	Repair or replace the wiring as needed. See **Section 54.00, Subject 100**.
	Continuity is found.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 4, The Power Supply Is Not Properly Grounded

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Calibration Memory Faults

There are four calibration memory faults covered in these procedures. The same troubleshooting procedure is used for all.

- For SID 253, FMI 02, FMI 12, FMI 13, and FMI 14, see **Table 1** for procedures.

SID 253, FMI 02, 12, 13, 14—The Transmission Needs To Be Recalibrated		
Failure Reason: • There is a failure of programmable memory. • The transmission has not been properly calibrated, or the calibration procedure failed. • The TCU has suffered an internal electrical failure.		
Procedure	**Result**	**Action**
Complete a learning procedure using either ServiceLink or the SmartShift control. To complete a learning procedure using the SmartShift control: 1. Ensure that the parking brake is set. 2. With the ignition turned off, pull and hold the SmartShift control toward steering wheel. NOTE: The SmartShift control must be kept in this position until the gear display clears at the end of the procedure. 3. Turn on the ignition. The normal warm up procedure will initiate and an 'X' will display on the current gear indicator. Your transmission may be heard shifting. 4. Wait until the current gear indicator displays an 'N' (about 30 seconds) and an audible alert sounds. Start the engine within 10 seconds of the audible alert. 5. The engine will raise a few rpm, then fall back to idle, and an audible alert will sound. Turn off the engine within 10 seconds of audible alert. When the gear display clears, this procedure is complete. NOTE: If during this procedure an 'SM' or 'X' (after the warm up procedure) appears in the gear display, stop, turn off the ignition, and wait for the gear display to go dark. Then start over. This may need to be repeated several times.	Calibration is successful.	No further action is needed.
	Calibration fails.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Transmission Needs To Be Recalibrated

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Transmission Control Unit Faults

There are five transmission control unit (TCU) faults covered in these procedures. FMI 04 and FMI 05 are covered by the same procedure.

- For SID 254, FMI 04 and FMI 05, see **Table 1** for procedures.
- For SID 254, FMI 11, see **Table 2** for procedures.
- For SID 254, FMI 12, see **Table 3** for procedures.
- For SID 254, FMI 13, see **Table 4** for procedures.

SID 254, FMI 04, 05—The TCU Is Shorted to Ground or Open		
Failure Reason: • There is a short circuit to ground in the solenoid valve. • There is an open circuit in the solenoid valve.		
Procedure	**Results**	**Action**
Turn the ignition switch off and wait for the current gear indicator to power down. Turn the switch on and check to see if the fault is still active.	The fault has become inactive.	No action is needed.
	The fault is still active.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The TCU Is Shorted to Ground or Open

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Transmission Control Unit Faults (SID 254)

SID 254, FMI 11—The TCU AUTO Mode Software Module Has an Error			
Failure Reason: • The engine ECU is not providing valid data. • There is faulty data in programmable memory (EEPROM). • The SmartShift lever is defective. • One of the shift position sensors (gear or rail) has failed. • One of the output shaft speed sensors has failed. • The transmission is not properly calibrated. • There is a defect in the brake pedal switch. • There is a defect in the throttle pedal switch.			
Problem	**Remedy**		
	Procedure	**Result**	**Action**
The TCU is receiving faulty data.	Check for other MID 130 fault codes.	Other fault codes are active.	Troubleshoot the other active fault codes.
		No other fault codes are active.	Go to the next step in the table.
The transmission needs to be recalibrated.	Complete a learning procedure using either ServiceLink or the SmartShift control. To complete a learning procedure using the SmartShift control: 1. Ensure that the parking brake is set. 2. With the ignition turned off, pull and hold the SmartShift control toward steering wheel. NOTE: The SmartShift control must be kept in this position until the gear display clears at the end of the procedure. 3. Turn on the ignition. The normal warm up procedure will initiate and an 'X' will display on the current gear indicator. Your transmission may be heard shifting. 4. Wait until the current gear indicator displays an 'N' (about 30 seconds) and an audible alert sounds. Start the engine within 10 seconds of the audible alert. 5. The engine will raise a few rpm, then fall back to idle, and an audible alert will sound. Turn off the engine within 10 seconds of audible alert. When the gear display clears, this procedure is complete. NOTE: If during this procedure an 'SM' or 'X' (after the warm up procedure) appears in the gear display, stop, turn off the ignition, and wait for the gear display to go dark. Then start over. This may need to be repeated several times.	The fault is no longer active.	No further action is needed.
		The fault is still active.	Go to the next step in the table.

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SID 254, FMI 11—The TCU AUTO Mode Software Module Has an Error			
Failure Reason: • The engine ECU is not providing valid data. • There is faulty data in programmable memory (EEPROM). • The SmartShift lever is defective. • One of the shift position sensors (gear or rail) has failed. • One of the output shaft speed sensors has failed. • The transmission is not properly calibrated. • There is a defect in the brake pedal switch. • There is a defect in the throttle pedal switch.			
Problem	**Remedy**		
	Procedure	**Result**	**Action**
The brake pedal switch is defective.	Use the ServiceLink AGS template to check the functionality of the brake pedal switch.	The template does not show brake pedal activation.	Check the function of the brake pedal. See **Section 25.02** for procedures.
		The template shows brake pedal activation.	Go to the next step in the table.
The throttle pedal switch is defective.	Use the ServiceLink AGS template to check the functionality of the throttle pedal switch.	The template does not show throttle pedal activation.	Check the function of the throttle pedal. See **Section 25.02** for procedures.
		The template shows throttle pedal activation.	Contact Freightliner Technical Service Support.

Table 2, The TCU AUTO Mode Software Module Has an Error

SID 254, FMI 12—The TCU Has a Hardware Problem			
Failure Reason: • There is a short circuit to ground in the external power supply. • There is a short circuit to ground through the output shaft speed sensor. • There has been an internal hardware failure of the TCU.			
Problem	**Remedy**		
	Procedure	**Result**	**Action**
The power supply is short-circuited to ground.	Remove the X1 connector. Check for short circuit to ground from pin 6.	The current gear indicator displays something other than "N" and/or there are speed sensor error codes.	Repair or replace the wiring as needed. See **Section 54.00, Subject 100**.
		The current gear indicator displays "N."	Go to the next step in the table.

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Transmission Control Unit Faults (SID 254)

SID 254, FMI 12—The TCU Has a Hardware Problem			
Failure Reason: • There is a short circuit to ground in the external power supply. • There is a short circuit to ground through the output shaft speed sensor. • There has been an internal hardware failure of the TCU.			
Problem	**Remedy**		
	Procedure	**Result**	**Action**
The power supply is short-circuited through the output shaft speed sensor.	Remove the X2 connector. Check for short circuit to ground from pin 15.	There are no active speed sensor (PID 191) error codes.	Repair or replace the wiring as needed. See **Section 54.00, Subject 100**.
		There are active speed sensor (PID 191) error codes.	Go to the next step in the table.
There has been an internal electrical problem of the TCU.	Turn off the ignition switch, wait for the current gear indicator to power down, and turn the ignition switch on again.	The fault is no longer active.	Troubleshoot the other active fault codes.
		The fault is still active.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 3, The TCU Has a Hardware Problem

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SID 254, FMI 13—The TCU Has a Software Memory Problem			
Failure Reason: • There has been an internal software failure of the TCU.			
Problem	**Remedy**		
	Procedure	**Result**	**Action**
There has been an internal electrical problem of the TCU.	Turn off the ignition switch, wait for the current gear indicator to power down, and turn the ignition switch on again.	The fault is no longer active.	Continue to monitor the TCU.
		The fault is still active.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 4, The TCU Has a Software Memory Problem

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Clutch Position Sensor Faults

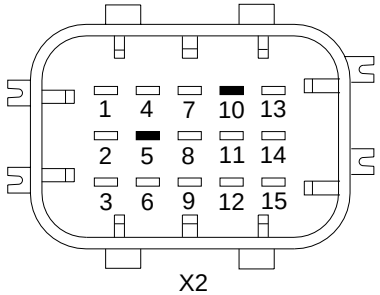
There are five clutch position sensor faults covered in these procedures. Each one requires a separate electrical test.

- For PID 33, FMI 02, see **Table 1** for procedures and pin identification.
- For PID 33, FMI 03, see **Table 2** for procedures and pin identification.
- For PID 33, FMI 04, see **Table 3** for procedures and pin identification.
- For PID 33, FMI 05, see **Table 4** for procedures and pin identification.
- For PID 33, FMI 14, see **Table 5** for procedures and pin identification.

PID 33, FMI 02—The Clutch Position Sensor Is Providing Invalid Data

Failure Reason:

- There is a defect in the wiring.
- There is a defect in the clutch position sensor.
- There is a defect in the TCU.



Problem	Procedure	Result	Action
Pins on the X2 connector or the clutch position sensor connector are not making good contact.	Do the "Harness Visual Check, Clutch Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The clutch position sensor is not providing the correct resistance data.	Remove the clutch position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 35.8 or greater than 126.2 ohms.	Replace the clutch actuator. See **Subject 120**.
		The resistance is between 35.8 and 126.2 ohms.	Go to the next row in the table.
The transmission harness has an open circuit.	With the sensor wiring disconnected, remove the X2 connector from the TCU. Check for resistance on the female connectors from X2 connector plug 10 to sensor connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	With the transmission harness wiring disconnected, check for resistance on the female connectors from X2 connector plug 5 to sensor connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next row in the table.

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Clutch Position Sensor Faults (PID 33)

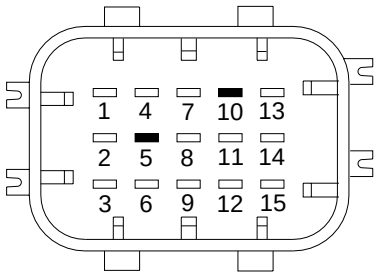
PID 33, FMI 02—The Clutch Position Sensor Is Providing Invalid Data			
Failure Reason: • There is a defect in the wiring. • There is a defect in the clutch position sensor. • There is a defect in the TCU.			
Problem	**Procedure**	**Result**	**Action**
The transmission harness or the TCU has a wiring problem.	With the transmission harness wiring still disconnected, check for shorts on the X2 female connector from plug 10 to plug 15.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	In a similar manner, continue to check for shorts on the X2 female connector from plug 5 to plugs 1, 2, 4, 7, 10, 13, and 15.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All the circuits are open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Clutch Position Sensor Is Providing Invalid Data

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Clutch Position Sensor Faults (PID 33)

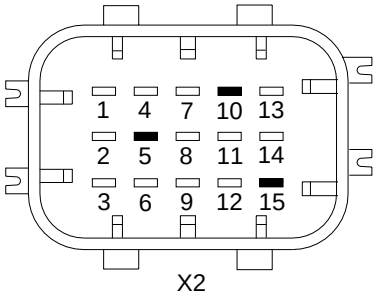
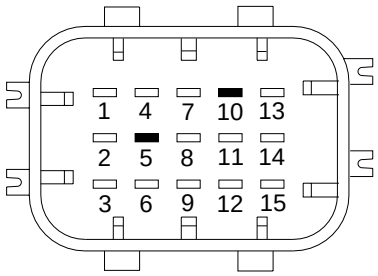
PID 33, FMI 03—The Clutch Position Sensor Circuit Is Shorted to Power			
Failure Reason: • There is a defect in the wiring. • There is a defect in the TCU.			
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the clutch position sensor connector are not making good contact.	Do the "Harness Visual Check, Clutch Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The transmission harness or TCU has a wiring problem.	Turn off the ignition and wait for the gear display to power down. Remove the X2 connector from the TCU. Check on the female connector from plug 15 to plug 5 for a short circuit.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	With the X2 connector removed, check on the female connector from plug 15 to plug 10 for a short circuit.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Clutch Position Sensor Circuit Is Shorted to Power

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Clutch Position Sensor Faults (PID 33)

PID 33, FMI 04—The Clutch Position Sensor Circuit Is Shorted to Ground			
Failure Reason: • There is a defect in the wiring. • There is a defect in the clutch position sensor. • There is a defect in the TCU.		 07/16/2004 X2 f544484b	
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the clutch position sensor connector are not making good contact.	Do the "Harness Visual Check, Clutch Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The clutch position sensor is not providing the correct resistance data.	Remove the clutch position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 35.8 or greater than 126.2 ohms.	Replace the clutch actuator. See **Subject 120**.
		The resistance is between 35.8 and 126.2 ohms.	Go to the next row in the table.

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Clutch Position Sensor Faults (PID 33)

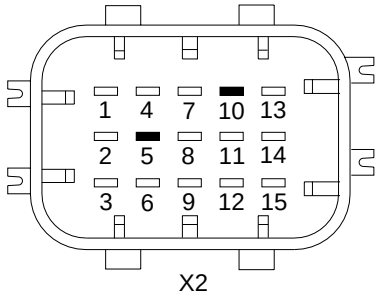
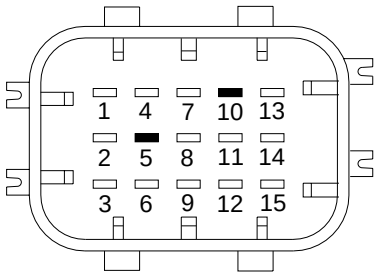
PID 33, FMI 04—The Clutch Position Sensor Circuit Is Shorted to Ground			
Failure Reason: • There is a defect in the wiring. • There is a defect in the clutch position sensor. • There is a defect in the TCU.		 07/16/2004 X2 f544484b	
Problem	**Procedure**	**Result**	**Action**
The transmission harness or the TCU has a wiring problem.	With the sensor wiring disconnected, remove the X2 connector from the TCU. Check plugs 5 and 10 on the female connector for short circuit to ground.	A short to ground is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	In a similar manner, continue to check for shorts on the female connector from plug 5 to plugs 1, 2, 4, 7, and 13.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 3, The Clutch Position Sensor Circuit Is Shorted to Ground

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Clutch Position Sensor Faults (PID 33)

PID 33, FMI 05—The Clutch Position Sensor Circuit Is Open			
Failure Reason: • There is a defect in the wiring. • There is a defect in the clutch position sensor. • There is a defect in the TCU.		 07/16/2004 X2 f544484b	
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the clutch position sensor connector are not making good contact.	Do the "Harness Visual Check, Clutch Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The clutch position sensor is not providing the correct resistance data.	Remove the clutch position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 35.8 or greater than 126.2 ohms.	Replace the clutch actuator. See **Subject 120**.
		The resistance is between 35.8 and 126.2 ohms.	Go to the next row in the table.

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Clutch Position Sensor Faults (PID 33)

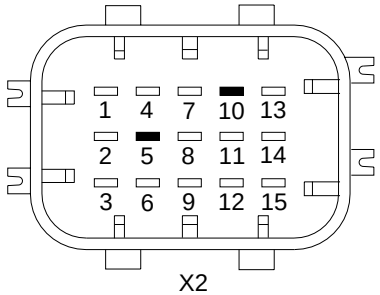
PID 33, FMI 05—The Clutch Position Sensor Circuit Is Open			
Failure Reason: • There is a defect in the wiring. • There is a defect in the clutch position sensor. • There is a defect in the TCU.		 07/16/2004 X2 f544484b	
Problem	**Procedure**	**Result**	**Action**
The transmission harness or the TCU has a wiring problem.	Check for resistance on the female connectors from X2 connector plug 10 to sensor connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 5 to sensor connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 4, The Clutch Position Sensor Circuit Is Open

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Clutch Position Sensor Faults (PID 33)

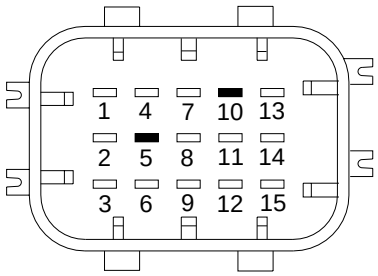
PID 33, FMI 14—The Clutch Position Sensor Gives Incorrect Resistance Readings			
Failure Reason: • The resistance values broadcast on the datalink are not plausible. • There is a defect in the wiring. • There is a defect in the clutch position sensor. • There is a defect in the TCU.		 07/16/2004 f544484b	
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the clutch position sensor connector are not making good contact.	Do the "Harness Visual Check, Clutch Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The clutch position sensor is not providing the correct resistance data.	Disconnect the rail position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 35.8 or greater than 126.2 ohms.	Replace the clutch actuator. See **Subject 120**.
		The resistance is between 35.8 and 126.2 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 5, The Clutch Position Sensor Gives Incorrect Resistance Readings

Harness Visual Check, Clutch Position Sensor

1. Remove the X2 female connector from the TCU. Check the plugs on the connector. If any plug(s) in the connector is damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.
2. Check the pins on the X2 male connector. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the TCU. See **Subject 110** for procedures.

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3. Remove the female connector from the clutch position sensor. If any plug(s) in the connector is damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.
4. Check the pins on the male connector of the clutch position sensor. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the clutch actuator assembly. See **Subject 120** for procedures.

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Gear Position Sensor Faults

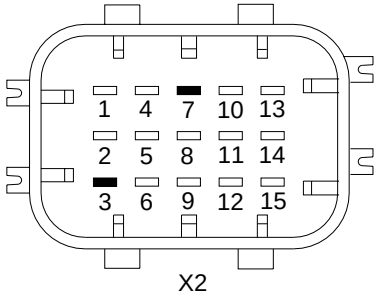
There are five gear position sensor faults covered in these procedures. Each one requires a separate electrical test.

- For PID 59, FMI 02, see **Table 1** for procedures and pin identification.
- For PID 59, FMI 03, see **Table 2** for procedures and pin identification.
- For PID 59, FMI 04, see **Table 3** for procedures and pin identification.
- For PID 59, FMI 05, see **Table 4** for procedures and pin identification.
- For PID 59, FMI 14, see **Table 5** for procedures and pin identification.

PID 59, FMI 02—The Gear Position Sensor Is Providing Invalid Data

Failure Reason:

- There is a defect in the wiring.
- There is a defect in the gear position sensor.
- There is a defect in the TCU.

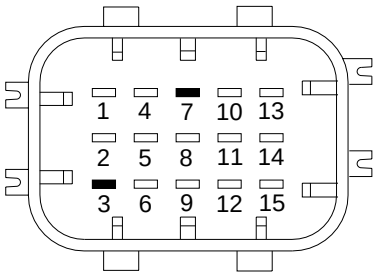


07/16/2004 f544484d

Problem	Procedure	Result	Action
Pins on the X2 connector or the gear position sensor connector are not making good contact.	Do the "Harness Visual Check, Gear Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The gear position sensor is not providing the correct resistance data.	Disconnect the gear position sensor wiring. Check for resistance between pins 1 and 2 of the gear position sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).
		The resistance is between 34 and 122 ohms.	The sensor is OK. Go to the next row in the table.

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Gear Position Sensor Faults (PID 59)

<table>
<tr><th colspan="4">PID 59, FMI 02—The Gear Position Sensor Is Providing Invalid Data</th></tr>
<tr><td colspan="2">Failure Reason:
There is a defect in the wiring.
There is a defect in the gear position sensor.
There is a defect in the TCU.</td><td colspan="2"> 

07/16/2004 X2 f544484d</td></tr>
<tr><th>Problem</th><th>Procedure</th><th>Result</th><th>Action</th></tr>
<tr><td rowspan="4">The transmission harness has an open circuit.</td><td rowspan="2">With the sensor wiring disconnected, remove the X2 connector from the TCU. Check for resistance on the female connectors from X2 connector plug 7 to sensor connector plug 2.</td><td>The circuit is open.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>There is measurable resistance of 0.5 to 1.5 ohms.</td><td>Go to the next resistance check.</td></tr>
<tr><td rowspan="2">With the transmission harness wiring disconnected, check for resistance on the female connectors from X2 connector plug 3 to sensor connector plug 1.</td><td>The circuit is open.</td><td>Replace the transmission harness. See Subject 180.</td></tr>
<tr><td>There is measurable resistance of 0.5 to 1.5 ohms.</td><td>Go to the next row in the table.</td></tr>
</table>

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Gear Position Sensor Faults (PID 59)

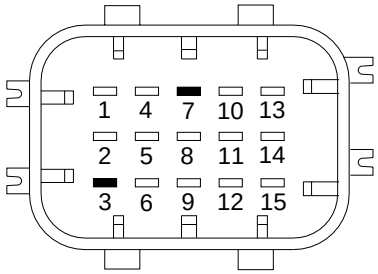
PID 59, FMI 02—The Gear Position Sensor Is Providing Invalid Data			
Failure Reason: • There is a defect in the wiring. • There is a defect in the gear position sensor. • There is a defect in the TCU.		 07/16/2004 X2 f544484d	
Problem	**Procedure**	**Result**	**Action**
The transmission harness or the TCU has a wiring problem.	With the transmission harness wiring still disconnected, check for shorts on the X2 female connector from plug 7 to plug 15.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	In a similar manner, continue to check for shorts on the X2 female connector from plug 3 to plugs 1, 2, 4, 7, 10, 13, and 15.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All the circuits are open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Gear Position Sensor Is Providing Invalid Data

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Gear Position Sensor Faults (PID 59)

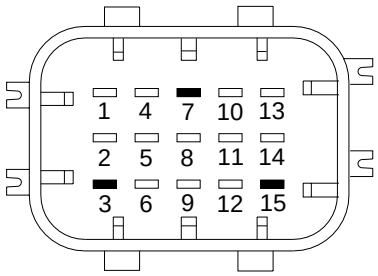
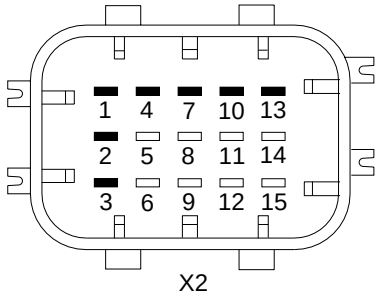
PID 59, FMI 03—The Gear Position Sensor Circuit Is Shorted to Power			
Failure Reason: • There is a defect in the wiring. • There is a defect in the TCU.			
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the gear position sensor connector are not making good contact.	Do the "Harness Visual Check, Gear Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The transmission harness or the TCU has a wiring problem.	Turn off the ignition and wait for the gear display to power down. Remove the X2 connector from the TCU. On the female connector, check plug 15 to plug 3 for a short circuit.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	With the X2 connector removed, check plug 15 to plug 7 on the X2 female connector for a short circuit.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Gear Position Sensor Circuit Is Shorted to Power

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Gear Position Sensor Faults (PID 59)

PID 59, FMI 04—The Gear Position Sensor Circuit Is Shorted to Ground	
Failure Reason: • There is a defect in the wiring. • There is a defect in the gear position sensor. • There is a defect in the TCU.	 07/16/2004 X2 f544484f

Problem	Procedure	Result	Action
Pins on the X2 connector or the gear position sensor connector are not making good contact.	Do the "Harness Visual Check, Gear Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The gear position sensor is not providing the correct resistance data.	Remove the gear position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Replace the x-y actuator. See **Subject 170**.
		The resistance is between 34 and 122 ohms.	Go the next row in the table.

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Gear Position Sensor Faults (PID 59)

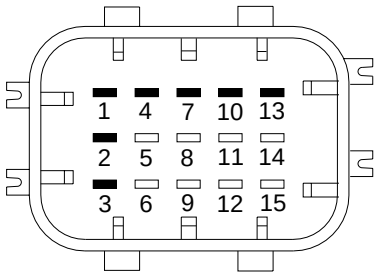
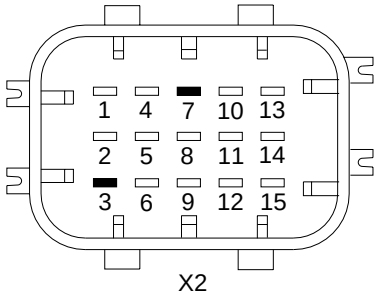
PID 59, FMI 04—The Gear Position Sensor Circuit Is Shorted to Ground			
Failure Reason: • There is a defect in the wiring. • There is a defect in the gear position sensor. • There is a defect in the TCU.			
Problem	**Procedure**	**Result**	**Action**
The transmission harness or the TCU has a wiring problem.	With the sensor wiring disconnected, remove the X2 connector from the TCU. Check plugs 3 and 7 on the female connector for short circuit to ground.	The circuit is shorted to ground.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	In a similar manner, continue to check for shorts on the X2 female connector from plugs 3 and 7 to plugs 1, 2, 4, 10, and 13.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 3, The Gear Position Sensor Circuit Is Shorted to Ground

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Gear Position Sensor Faults (PID 59)

PID 59, FMI 05—The Gear Position Sensor Circuit Is Open			
Failure Reason: • There is a defect in the wiring. • There is a defect in the gear position sensor. • There is a defect in the TCU.		 07/16/2004 X2 f544484d	
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the gear position sensor connector are not making good contact.	Do the "Harness Visual Check, Gear Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The gear position sensor is not providing the correct resistance data.	Remove the gear position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Replace the x-y actuator. See **Subject 170**.
		The resistance is between 34 and 122 ohms.	Go to the next row in the table.

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Gear Position Sensor Faults (PID 59)

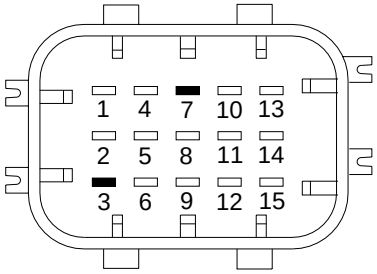
PID 59, FMI 05—The Gear Position Sensor Circuit Is Open			
Failure Reason: • There is a defect in the wiring. • There is a defect in the gear position sensor. • There is a defect in the TCU.			
Problem	**Procedure**	**Result**	**Action**
The transmission harness or the TCU has a wiring problem.	Check for resistance on the female connectors from X2 connector plug 7 to sensor connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 3 to sensor connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 4, The Gear Position Sensor Circuit Is Open

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Gear Position Sensor Faults (PID 59)

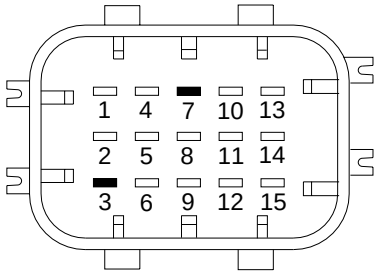
PID 59, FMI 14—The Gear Position Sensor Gives Incorrect Resistance Readings			
Failure Reason: • The resistance values broadcast on the datalink are not plausible. • There is a defect in the wiring. • There is a defect in the gear position sensor. • There is a defect in the TCU.		 07/16/2004 X2 f544484d	
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the gear position sensor connector are not making good contact.	Do the "Harness Visual Check, Gear Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The gear position sensor is not providing the correct resistance data.	Disconnect the gear position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Replace the x-y actuator. See **Subject 170**.
		The resistance is between 34 and 122 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 5, The Gear Position Sensor Gives Incorrect Resistance Readings

Harness Visual Check, Gear Position Sensor

1. Remove the X2 female connector from the TCU. Check the plugs on the connector. If any plug(s) in the connector is damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.
2. Check the pins on the X2 male connector. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the TCU. See **Subject 110** for procedures.

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Gear Position Sensor Faults (PID 59)

3. Remove the female connector from the gear position sensor. If any plug(s) in the connector is damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.
4. Check the pins on the male connector of the gear position sensor. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the x-y actuator assembly. See **Subject 170** for procedures.

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Rail Position Sensor Faults

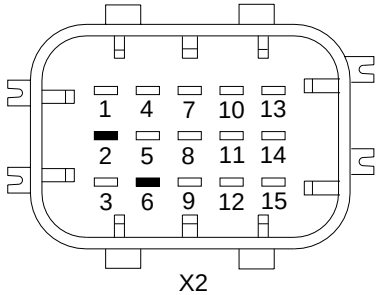
There are five rail position sensor faults covered in these procedures. Each one requires a separate electrical test.

- For PID 60, FMI 02, see **Table 1** for procedures and pin identification.
- For PID 60, FMI 03, see **Table 2** for procedures and pin identification.
- For PID 60, FMI 04, see **Table 3** for procedures and pin identification.
- For PID 60, FMI 05, see **Table 4** for procedures and pin identification.
- For PID 60, FMI 14, see **Table 5** for procedures and pin identification.

PID 60, FMI 02—The Rail Position Sensor Is Providing Invalid Data

Failure Reason:

- There is a defect in the wiring.
- There is a defect in the rail position sensor.
- There is a defect in the TCU.



07/16/2004 f544484g

Problem	Procedure	Result	Action
Pins on the X2 connector or the rail position sensor connector are not making good contact.	Do the "Harness Visual Check, Rail Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The rail position sensor is not providing the correct resistance data.	Disconnect the rail position sensor wiring. Check for resistance between pins 1 and 2 of the rail position sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Replace the x-y actuator. See **Subject 170**.
		The resistance is between 34 and 122 ohms.	Go to the next row in the table.
The transmission harness has an open circuit.	With the sensor wiring disconnected, remove the X2 connector from the TCU. Check for resistance on the female connectors from X2 connector plug 6 to sensor connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	With the transmission harness wiring disconnected, check for resistance on the female connectors from X2 connector plug 2 to sensor connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next row in the table.

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Rail Position Sensor Faults (PID 60)

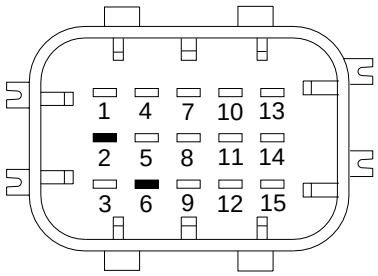
PID 60, FMI 02—The Rail Position Sensor Is Providing Invalid Data			
Failure Reason: • There is a defect in the wiring. • There is a defect in the rail position sensor. • There is a defect in the TCU.		 07/16/2004 X2 f544484g	
Problem	**Procedure**	**Result**	**Action**
The transmission harness or the TCU has a wiring problem.	With the transmission harness wiring still disconnected, check for shorts on the X2 female connector from plug 2 to plug 15.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	In a similar manner, continue to check for shorts on the X2 female connector from plug 6 to plugs 1, 2, 4, 7, 10, 13, and 15.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All the circuits are open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Rail Position Sensor Is Providing Invalid Data

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Rail Position Sensor Faults (PID 60)

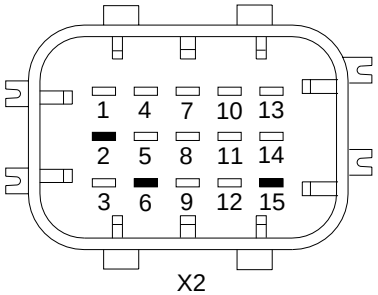
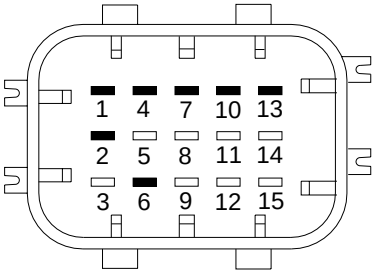
PID 60, FMI 03—The Rail Position Sensor Circuit Is Shorted to Power			
Failure Reason: • There is a defect in the wiring. • There is a defect in the TCU.			
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the rail position sensor connector are not making good contact.	Do the "Harness Visual Check, Rail Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The transmission harness or the TCU has a wiring problem.	Turn off the ignition and wait for the gear display to power down. Remove the X2 connector from the TCU. On the female connector, check plug 15 to plug 2 for a short circuit.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	With the X2 connector removed, check plug 15 to plug 6 on the X2 female connector for a short circuit.	A short circuit is found.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Rail Position Sensor Circuit Is Shorted to Power

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Rail Position Sensor Faults (PID 60)

PID 60, FMI 04—The Rail Position Sensor Circuit Is Shorted to Ground			
Failure Reason: • There is a defect in the wiring. • There is a defect in the rail position sensor. • There is a defect in the TCU.		 08/11/2005 X2 f544484i	
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the rail position sensor connector are not making good contact.	Do the "Harness Visual Check, Rail Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The rail position sensor is not providing the correct resistance data.	Remove the rail position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).
		The resistance is between 34 and 122 ohms.	Go to the next row in the table.

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Rail Position Sensor Faults (PID 60)

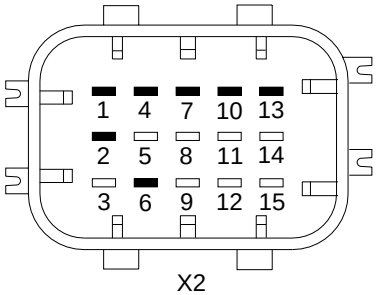
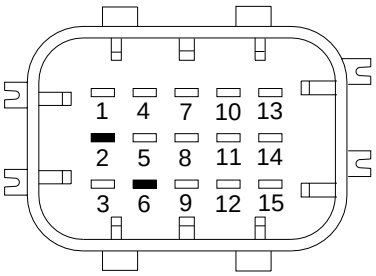
PID 60, FMI 04—The Rail Position Sensor Circuit Is Shorted to Ground			
Failure Reason: • There is a defect in the wiring. • There is a defect in the rail position sensor. • There is a defect in the TCU.		 08/11/2005 X2 f544484i	
Problem	**Procedure**	**Result**	**Action**
The transmission harness or the TCU has a wiring problem.	With the sensor wiring disconnected, remove the X2 connector from the TCU. Check plugs 2 and 6 on the female connector for short circuit to ground.	The circuit is shorted to ground.	Replace the transmission harness. See **Subject 180**.
		The circuit is open.	Go to the next short circuit check.
	In a similar manner, continue to check for shorts on the X2 female connector from plug 6 to plugs 1, 4, 7,10, and 13.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 3, The Rail Position Sensor Circuit Is Shorted to Ground

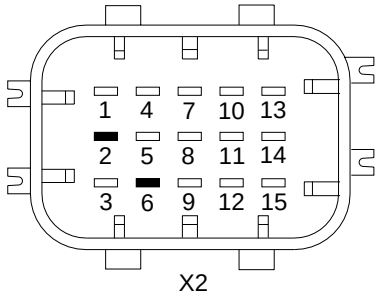
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Rail Position Sensor Faults (PID 60)

PID 60, FMI 05—The Rail Position Sensor Circuit Is Open			
Failure Reason: • There is a defect in the wiring. • There is a defect in the rail position sensor. • There is a defect in the TCU.		 07/16/2004 X2 f544484g	
Problem	**Procedure**	**Result**	**Action**
Pins on the X2 connector or the rail position sensor connector are not making good contact.	Do the "Harness Visual Check, Rail Position Sensor."	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
The rail position sensor is not providing the correct resistance data.	Remove the rail position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	The resistance is less than 34 or greater than 122 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).
		The resistance is between 34 and 122 ohms.	Go to the next row in the table.

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Rail Position Sensor Faults (PID 60)

PID 60, FMI 05—The Rail Position Sensor Circuit Is Open	
Failure Reason: • There is a defect in the wiring. • There is a defect in the rail position sensor. • There is a defect in the TCU.	 07/16/2004 f544484g

Problem	Procedure	Result	Action
The transmission harness or the TCU has a wiring problem.	Check for resistance on the female connectors from X2 connector plug 2 to sensor connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 6 to sensor connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 4, The Rail Position Sensor Circuit Is Open

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Rail Position Sensor Faults (PID 60)

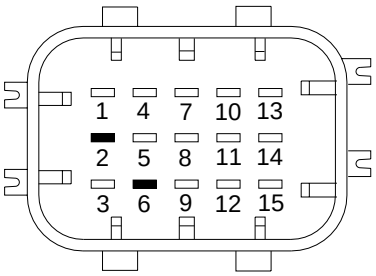
PID 60, FMI 14—The Rail Position Sensor Gives Incorrect Resistance Readings		
Failure Reason: • The resistance values broadcast on the datalink are not plausible. • There is a defect in the wiring. • There is a defect in the rail position sensor. • There is a defect in the TCU.		
Problem	**Procedure**	**Action**
Pins on the X2 connector or the rail position sensor connector are not making good contact.	Do the "Harness Visual Check, Rail Position Sensor."	If the connectors and/or pins are damaged, soiled, worn, broken, or corroded, replace the damaged components.
		If all connectors and pins are OK, go to the next row in the table.
The rail position sensor is not providing the correct resistance data.	Disconnect the rail position sensor wiring. Check for resistance between pins 1 and 2 of the sensor connector.	Contact Mercedes-Benz Transmissions Service Support with the resistance values, AGS codes, and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 5, The Rail Position Sensor Gives Incorrect Resistance Readings

Harness Visual Check, Rail Position Sensor

1. Remove the X2 female connector from the TCU. Check the plugs on the connector. If any plug(s) in the connector is damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.
2. Check the pins on the X2 male connector. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the TCU. See **Subject 110** for procedures.
3. Remove the female connector from the rail position sensor. If any plug(s) in the connector is damaged, soiled, worn, broken, or corroded, replace the connector. If no female connectors are available, replace the transmission wiring harness. See **Subject 180** for procedures.
4. Check the pins on the male connector of the rail position sensor. If any pin(s) on the connector is damaged, soiled, worn, broken, or corroded, replace the x-y actuator assembly. See **Subject 170** for procedures.

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Vehicle Direction Signal Faults

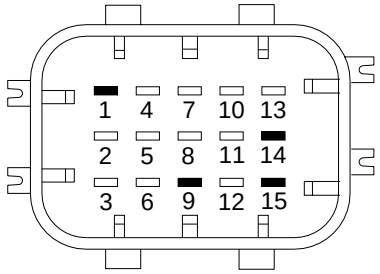
There are two vehicle direction signal faults covered in these procedures. There is one procedure to correct both faults.

- For PID 64, FMI 09, see **Table 1** for procedures.
- For PID 64, FMI 11, see **Table 1** for procedures.

PID 64, FMI 09, 11—The Output Shaft Speed Sensor Is Not Providing Accurate Data

Failure Reason:

- There is a defect in one or both of the output shaft speed sensors.
- There is a defect in the wiring.
- There is a defect in the TCU.



07/16/2004 f544484k

Problem	Remedy		
	Procedure	Result	Action
One or both of the sensors is damaged or broken.	Do a visual check of both speed sensors.	A sensor is damaged or broken.	Replace the affected sensor. See **Subject 120**.
		Both sensors are OK.	Go to the next row in the table.
One or both of the sensors is loose.	Check both speed sensors for tightness.	A sensor is loose.	Tighten the affected sensor 28 lbf·ft (38 N·m).
		Both sensors are firmly attached and tightened to the correct specifications.	Go to the next row in the table.
One or both of the sensors has a wiring problem.	Check the sensor wiring.	A sensor is wired wrong.	Wire the affected sensor correctly.
		Both sensors are wired correctly.	Go to the next row in the table.
Pins on the X2 connector are not making good contact.	Disconnect the transmission harness from the X2 connector. Do a visual check of the X2 connector halves (both male and female).	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.
Pins on the output shaft speed sensor connectors are not making good contact.	Disconnect the transmission harness from the two sensor connectors. Do a visual check of both sensor connector halves (both male and female).	Connectors and/or pins are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		All connectors and pins are OK.	Go to the next row in the table.

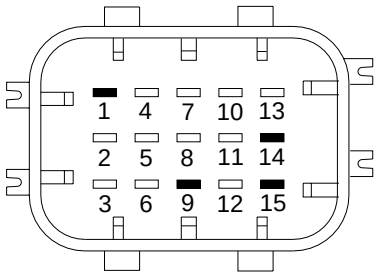
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Vehicle Direction Signal Faults (PID 64)

PID 64, FMI 09, 11—The Output Shaft Speed Sensor Is Not Providing Accurate Data

Failure Reason:

- There is a defect in one or both of the output shaft speed sensors.
- There is a defect in the wiring.
- There is a defect in the TCU.



Problem	Remedy		
	Procedure	**Result**	**Action**
The wiring of the #1 output shaft speed sensor (at the 11:00 position) has an open circuit.	With the sensor wiring still disconnected, check for resistance on the female connectors from X2 connector plug 1 to output shaft speed sensor #1 connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 15 to output shaft speed sensor #1 connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 14 to output shaft speed sensor #1 connector plug 4.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next row in the table.
The wiring of the #2 output shaft speed sensor (at the 9:00 position) has an open circuit.	With the sensor wiring still disconnected, check for resistance on the female connectors from X2 connector plug 1 to output shaft speed sensor #2 connector plug 2.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 15 to output shaft speed sensor #2 connector plug 1.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next resistance check.
	Check for resistance on the female connectors from X2 connector plug 9 to output shaft speed sensor #2 connector plug 3.	The circuit is open.	Replace the transmission harness. See **Subject 180**.
		There is measurable resistance of 0.5 to 1.5 ohms.	Go to the next row in the table.

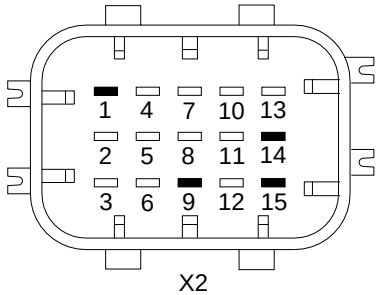
https://truckmanualshub.com/

Vehicle Direction Signal Faults (PID 64)

PID 64, FMI 09, 11—The Output Shaft Speed Sensor Is Not Providing Accurate Data

Failure Reason:

- There is a defect in one or both of the output shaft speed sensors.
- There is a defect in the wiring.
- There is a defect in the TCU.



Problem	Remedy		
	Procedure	**Result**	**Action**
There is a short circuit in the output shaft speed sensor wiring.	With the sensor wiring still disconnected, check for a short circuit on the female connectors from X2 connector plug 1 to X2 connector plugs 3, 5, 6, 9, 11, 12, 14, and 15.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Go to the next short circuit check.
	Check for a short circuit on the female connectors from X2 connector plug 9 to X2 connector plugs 2, 3, 4, 5, 6, 7, 10, 11, 12, and 13.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Go to the next short circuit check.
	Check for a short circuit on the female connectors from X2 connector plug 14 to X2 connector plugs 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, and 13.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Go to the next short circuit check.
	Check for a short circuit on the female connectors from X2 connector plug 15 to X2 connector plugs 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, and 14.	There are one or more short circuits.	Replace the transmission harness. See **Subject 180**.
		All circuits are open.	Go to the next row in the table.

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Vehicle Direction Signal Faults (PID 64)

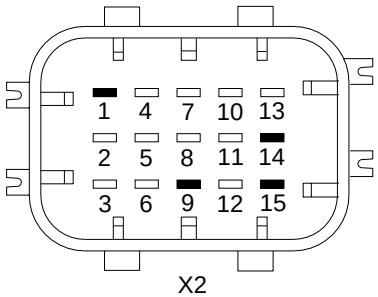
PID 64, FMI 09, 11—The Output Shaft Speed Sensor Is Not Providing Accurate Data			
Failure Reason: • There is a defect in one or both of the output shaft speed sensors. • There is a defect in the wiring. • There is a defect in the TCU.			
Problem	**Remedy**		
	Procedure	**Result**	**Action**
There is a wiring problem that affects either the output shaft speed sensors or the TCU.	With the wiring still disconnected, check the fault code again.	The fault code is still active.	Replace both sensors. See **Subject 120**.
		The fault code is no longer active.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Output Shaft Speed Sensor Is Not Providing Accurate Data

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Ignition Power Supply Faults

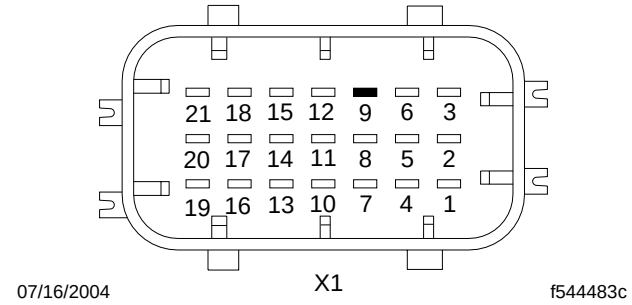
There are two ignition power circuit faults covered in these procedures. Each one requires a different electrical test.

- For PID 158, FMI 00, see **Table 1** for procedures and pin identification.
- For PID 158, FMI 01, see **Table 2** for procedures and pin identification.

PID 158, FMI 00—The Voltage in the Ignition Power Circuit Is Too High

Failure Reason:

- There is a problem in the vehicle starting and/or charging system.
- There is a defect in the wiring.



Problem	Remedy		
	Procedure	**Result**	**Action**
The battery voltage is too high.	Disconnect the X1 connector. Check voltage from plug 9 (on the female connector) to ground.	Voltage is more than 14V and remains constant for more than one second.	Check the starting and charging system on the vehicle.
		Voltage is between 12V and 14V.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Voltage in the Ignition Power Circuit Is Too High

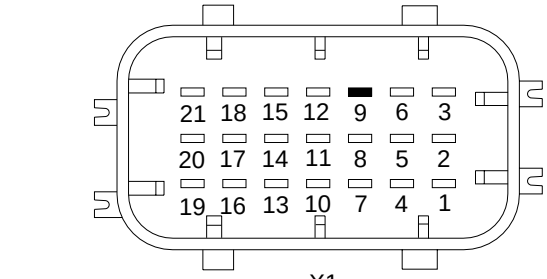
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Ignition Power Supply Faults (PID 158)

PID 158, FMI 01—The Voltage in the Ignition Power Circuit Is Too Low

Failure Reason:

- The battery needs charging or replacing.
- There is a defect in the wiring.
- There is a defect in the TCU.



Problem	Remedy		
	Procedure	**Result**	**Action**
The battery voltage is too low.	With the engine running, disconnect the X1 connector. Check voltage from plug 9 (on the female connector) to ground.	Voltage is less than 12V and remains constant for more than one second.	Charge or replace the battery. See **Section 54.03**.
		Voltage is between 12V and 14V.	Go to the next step.
Pins on the X1 connector are not making good contact.	Disconnect the vehicle harness from the X1 connector. Do a visual check of the X1 connector halves (both male and female).	On the female half, the connector and/or plugs are damaged, soiled, worn, broken, or corroded.	Replace the damaged components.
		On the male half, the connector and/or pins are damaged, soiled, worn, broken, or corroded.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).
		All connectors and pins are OK.	

Table 2, The Voltage in the Ignition Power Circuit Is Too Low

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Input Shaft Speed Sensor Faults

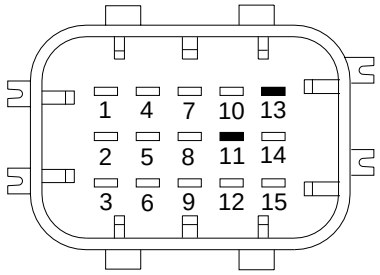
There are five input shaft speed sensor faults covered in these procedures. One troubleshooting procedure is used to correct FMI 02, 03, 04, and 05. A separate procedure is used for FMI 08.

- For PID 161, FMI 02, 03, 04, and 05, see **Table 1** for procedures.
- For PID 161, FMI 08, see **Table 2** for procedures.

PID 161, FMI 02, 03, 04, 05—The Input Shaft Speed Sensor Circuit Gives Invalid Data, Is Shorted, or Open

Failure Reason

- There is a defect in the input shaft speed sensor.
- There is a defect in the wiring.
- There is a defect in the TCU.
- The resistance values broadcast on the datalink are not plausible.



07/16/2004 f544484j

Procedure	Result	Action
Turn off the ignition switch and wait for the current gear display to power down. Remove the X2 connector from the TCU. At room temperature, measure the resistance between pins 11 and 13.	Resistance is less than 900 or more than 1200 ohms.	Go to the next row in the table and check for a defective sensor.
	Resistance is between 900 and 1200 ohms.	Go to the bottom row in the table and check for a defective wiring harness or TCU.
Unlock the connector cap from the sensor. At room temperature, measure the resistance between the two pins of the sensor.	Resistance is less than 900 or more than 1200 ohms.	Replace the input shaft speed sensor (see **Subject 120**).
	Resistance is between 900 and 1200 ohms.	Go to the bottom row in the table.

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Input Shaft Speed Sensor Faults (PID 161)

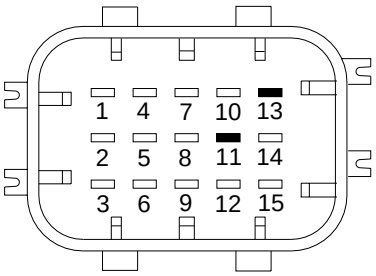
PID 161, FMI 02, 03, 04, 05—The Input Shaft Speed Sensor Circuit Gives Invalid Data, Is Shorted, or Open		
Failure Reason • There is a defect in the input shaft speed sensor. • There is a defect in the wiring. • There is a defect in the TCU. • The resistance values broadcast on the datalink are not plausible.	 07/16/2004 X2 f544484j	
Procedure	**Result**	**Action**
Check the transmission wiring harness between the TCU and the sensor for damage.	Damage is found.	Replace the transmission wiring harness (see **Subject 180**).
	No damage is found.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Input Shaft Speed Sensor Circuit Gives Invalid Data, Is Shorted, or Open

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Input Shaft Speed Sensor Faults (PID 161)

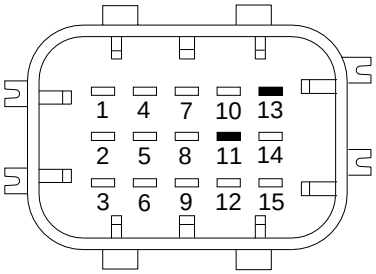
PID 161, FMI 08—The Input Shaft Speed Sensor Is Broadcasting an Abnormal Frequency		
Failure Reason • There is a defect in the input shaft speed sensor. • The input shaft speed sensor is improperly mounted. • There is a defect in the TCU. • The datalink does not recognize the transmission type.		
Procedure	**Result**	**Action**
Remove and inspect the speed sensor.	The sensor is damaged.	Replace the input shaft speed sensor if necessary and mount it correctly. See **Subject 120** for procedures.
	The sensor is OK, but the fault code is still active.	Go the next row in the table.
Remove the X2 connector and start the engine. Test for AC voltage between pins 11 and 13.	The AC voltage is less than 1.10V or more than 1.14V.	Replace the input shaft speed sensor. See **Subject 120** for procedures.
	The AC voltage is between 1.10V and 1.14V.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Input Shaft Speed Sensor Is Broadcasting an Abnormal Frequency

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Transmission Range Faults

Transmission Range-Selected Faults (PID 162)

There is one transmission range-selected fault covered in these procedures.

- For PID 162, FMI 02, see **Table 1** for procedures.

Transmission Range-Attained Faults (PID 163)

There is one transmission range-attained fault covered in these procedures.

- For PID 163, FMI 02, see **Table 2** for procedures.

PID 162, FMI 02—The Transmission Is Not Properly Calibrated			
Failure Reason: • The gears are caught in an intermediate position. • The transmission software does not allow shifting.			
Problem	**Remedy**		
	Procedure	**Result**	**Action**
There are other active transmission faults.	Check for other MID 130 fault codes.	Other fault codes are active.	Troubleshoot the other active fault codes.
		No other fault codes are active.	Go to the next step in the table.
The transmission needs to be recalibrated.	Complete a learning procedure using either ServiceLink or the SmartShift control. To complete a learning procedure using the SmartShift control: 1. Ensure that the parking brake is set. 2. With the ignition turned off, pull and hold the SmartShift control toward steering wheel. NOTE: The SmartShift control must be kept in this position until the gear display clears at the end of the procedure. 3. Turn on the ignition. The normal warm up procedure will initiate and an 'X' will display on the current gear indicator. Your transmission may be heard shifting. 4. Wait until the current gear indicator displays an 'N' (about 30 seconds) and an audible alert sounds. Start the engine within 10 seconds of the audible alert. 5. The engine will raise a few rpm, then fall back to idle, and an audible alert will sound. Turn off the engine within 10 seconds of audible alert. When the gear display clears, this procedure is complete. NOTE: If during this procedure an 'SM' or 'X' (after the warm up procedure) appears in the gear display, stop, turn off the ignition, and wait for the gear display to go dark. Then start over. This may need to be repeated several times.	The fault is no longer active.	No further action is needed.
		The fault is still active.	Contact Freightliner Technical Service Support.

Table 1, The Transmission Is Not Properly Calibrated

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Transmission Range Faults (PID 162 and 163)

PID 163, FMI 02—The Gears Do Not Shift Properly			
Failure Reason: • There is a defect in the TCU. • There is a defect in the speed sensor. • There is a defect in the actuator. • The transmission software is not properly programmed. • The datalink does not recognize the transmission type.			
Problem	**Remedy**		
	Procedure	**Result**	**Action**
There are other active transmission faults.	Check for other MID 130 fault codes.	Other fault codes are active.	Troubleshoot the other active fault codes.
		No other fault codes are active.	Go to the next step in the table.
There is a transmission software problem.	Using the ServiceLink diagnostics template, view the different gear positions, check that the clutch opens and closes, and that the x-y actuator moves from reverse, 1st, and 2nd gears.	The x-y actuator responds properly and the fault clears.	No further action is needed.
		The fault is still active.	Go to the next step in the table.
There is component damage in the transmission.	Do a visual inspection of the x-y actuator, the hydraulic system, and the transmission shift system.	Damaged components are found.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130).
		No damaged components are found.	2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 2, The Gears Do Not Shift Properly

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Output Shaft Speed Sensor Faults (PID 191)

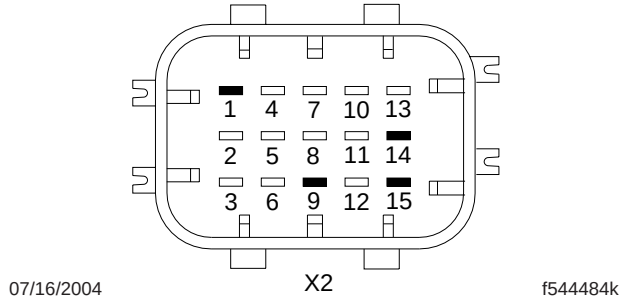
There are four output shaft speed sensor faults covered in these procedures. One troubleshooting procedure is used to correct FMI 02, 05, and 08. A separate procedure is used for FMI 14.

- For PID 191, FMI 02, 05, and 08 see **Table 1** for procedures and pin identification.
- For PID 191, FMI 14, see **Table 2** for procedures.

PID 191, FMI 02, 05, 08—The Output Shaft Speed Sensor Circuit Gives Invalid Data, Is Open, or Not Broadcasting a Signal

Failure Reason:

- The TCU has a hardware problem.
- The sensor is mounted too loose (air gap too big).
- The sensor connectors are damaged or bent.
- The wiring harness has had an electrical failure.
- Either one of the sensors or the TCU has failed.



Procedure	Results	Action
Turn on the ignition switch and wait for the current gear display to power up.	Fault code SID 254, FMI 12 is active.	Go to **Subject 309** and troubleshoot SID 254, FMI 12.
	SID 254, FMI 12 is not active.	Go to the next row in the table.
Remove both output shaft speed sensors. Reinstall and tighten the sensor 28 lbf·ft (38 N·m).	The fault clears after a test drive.	No further action needed.
	The fault remains active.	Go to the next row in the table.
Turn off the ignition switch and wait for the current gear display to power down. Remove both sensor connectors and visually inspect the pins.	The connector pins are damaged or bent.	Repair or replace the damage.
	There is no damage to either connector.	Go to the next row in the table.
Check the upper sensor for continuity: (1) X2 connector pin 1 to sensor pin 2; (2) X2 connector pin 15 to sensor pin 1; (3) X2 connector pin 14 to sensor pin 4.	There is an open circuit.	Replace the transmission wiring harness (see **Subject 180**).
	The wiring is OK.	Go to the next row in the table.
Check the lower sensor for continuity: (1) X2 connector pin 1 to sensor pin 2; (2) X2 connector pin 15 to sensor pin 1; (3) X2 connector pin 9 to sensor pin 3.	There is an open circuit.	Replace the transmission wiring harness (see **Subject 180**).
	The wiring is OK.	Go to the next row in the table.
Check all four pins of each sensor connector for voltage and for continuity to ground.	Voltage or continuity is found.	Replace the transmission wiring harness (see **Subject 180**).
	There is zero voltage and no continuity.	Go to the next row in the table.

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Output Shaft Speed Sensor Faults (PID 191)

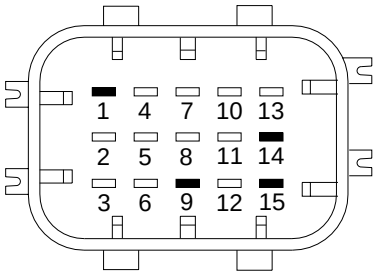
PID 191, FMI 02, 05, 08—The Output Shaft Speed Sensor Circuit Gives Invalid Data, Is Open, or Not Broadcasting a Signal		
Failure Reason: • The TCU has a hardware problem. • The sensor is mounted too loose (air gap too big). • The sensor connectors are damaged or bent. • The wiring harness has had an electrical failure. • Either one of the sensors or the TCU has failed.		
Procedure	**Results**	**Action**
Using a sensor known to be good, replace each sensor in turn (see **Subject 120** for procedures).	The fault becomes inactive.	No further action needed.
	The fault is still active.	Contact Mercedes-Benz Transmissions Service Support with the AGS codes and results of the electrical pre-test. NOTE: One hour of troubleshooting time is alloted for printing the AGS codes and completing the electrical pre-test. 1. Using ServiceLink, print the AGS codes (130). 2. Complete the electrical pre-test result sheet in **Subject 301**. 3. With the results, contact Mercedes-Benz Transmissions Service Support by fax (503.961.8435), email (MBTServiceSupport@Freightliner.com), or phone (503.745.4965 or 503.745.4988).

Table 1, The Output Shaft Speed Sensor Circuit Gives Invalid Data, Is Open, or Not Broadcasting a Signal

PID 191, FMI 14—The Output Shaft Speed Sensor Is Providing Invalid Data		
Failure Reason • The antilock brake system (ABS) is not broadcasting wheel speed data. • There is a defective output shaft speed sensor.		
Remedy		
Procedure	**Result**	**Action**
Check for other PID 191 fault codes.	Other PID 191 fault codes are active.	Troubleshoot PID 191. See **Table 1**.
	No other PID 191 fault codes are active.	Go to the next row in the table.

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Output Shaft Speed Sensor Faults (PID 191)

PID 191, FMI 14—The Output Shaft Speed Sensor Is Providing Invalid Data		
Failure Reason • The antilock brake system (ABS) is not broadcasting wheel speed data. • There is a defective output shaft speed sensor.		
Remedy		
Procedure	**Result**	**Action**
Check for active fault codes in MID 136 (ABS).	Active MID 136 fault codes are found.	Troubleshoot the ABS system (see the applicable section in **Group 42**).

Table 2, The Output Shaft Speed Sensor Is Providing Invalid Data

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For a schematic of the AGS transmission wiring behind the X2 (transmission) connector, see **Fig. 1**. For a schematic of the AGS transmission wiring behind the X1 (main vehicle) and X3 (electric motor) connectors, see the current revision of drawing G06-52771.

For a list of special tools, see **Table 1**.

For transmission installation torque values, see **Table 2**.

For AGS assembly torque values, see **Table 3**.

For AGS transmission gear ratios, see **Table 4**.

For a list of proprietary fault codes viewable on ServiceLink, see **Table 5**.

For a list of learning procedure errors, see **Table 6**.

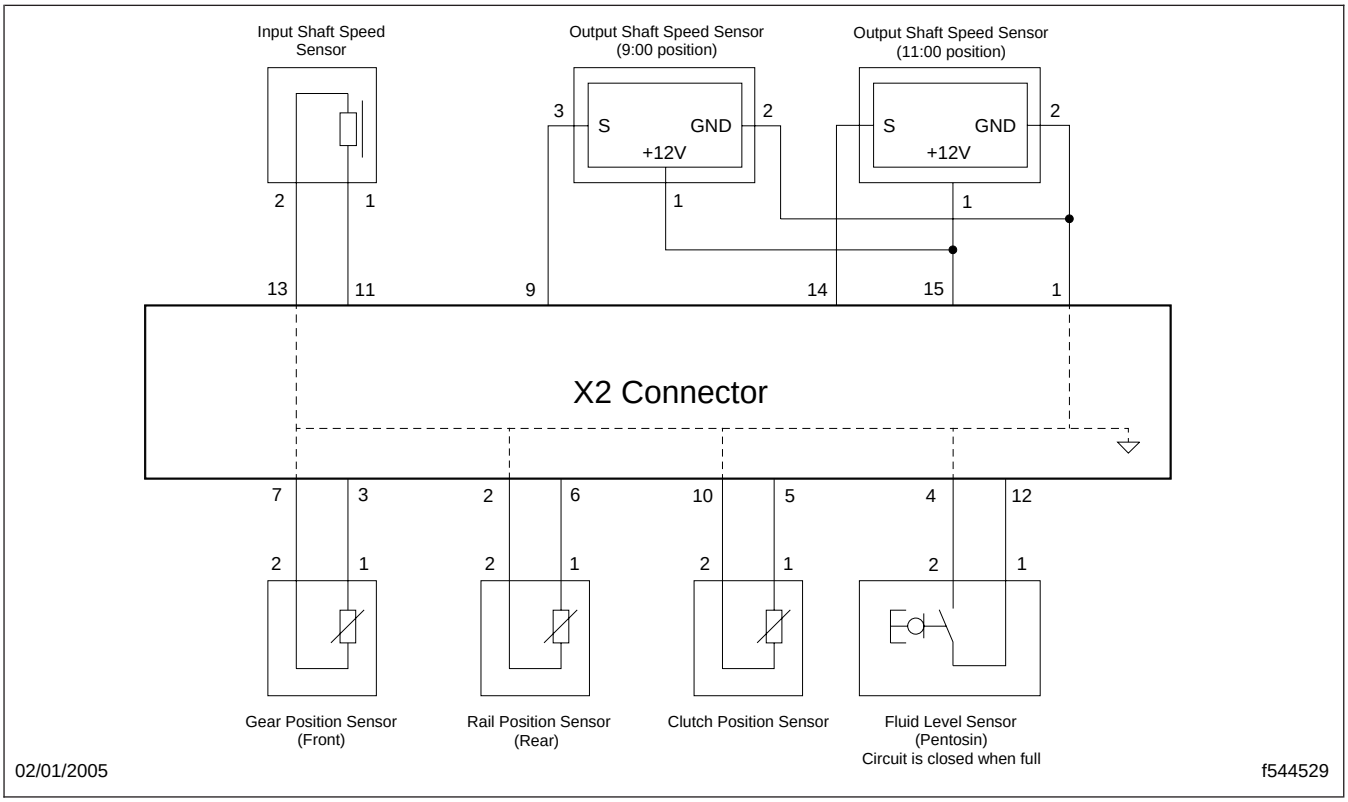


Fig. 1, AGS Transmission Wiring, X2 Connector

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Specifications

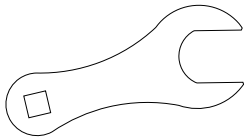
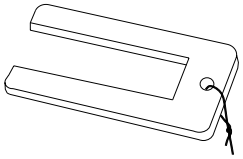
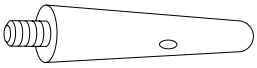
Special Tools for AGS Transmission			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580381	Accumulator Torque Adaptor	Kent-Moore	J-47291
 f580379a	Low-Pressure Hose Disconnect Tool	Kent-Moore	J-47202
 f580379	High-Pressure Line Disconnect Tool	Kent-Moore	J-47201
 f580380	Shift Finger Alignment Fork	Kent-Moore	J-47204
 f580382	Shift Mechanism End Guide	Kent-Moore	J-47203

Table 1, Special Tools for AGS Transmission

Transmission Installation Torque Values			
Description	**Size**	**Class**	**Torque: lbf·ft (N·m)**
Midship Bearing Bracket Capscrews	3/4–11	—	91 (123)
Power Takeoff Unit (PTO) Mounting Capscrews	M10	10.9	43 (58)
Transmission Fluid Drain Plug	M24	—	42 (57)
Transmission Fluid Fill Plug	M24	—	42 (57)
Transmission Mounting Bolts	M10 x 1.5	8.8	33 (45)

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Transmission Installation Torque Values			
Description	**Size**	**Class**	**Torque: lbf·ft (N·m)**
U-Joint End Cap Bolts	3/8–24	—	50 (68)
	1/2–20	—	110 (149)

Table 2, Transmission Installation Torque Values

AGS Assembly Torque Values			
Description	**Size**	**Torque: lbf·ft (N·m)**	**Torque: lbf·in (N·cm)**
Accumulator Hydraulic Fitting	M30	59 (80)	—
X-Y Actuator Mounting Capscrews	M8	17 (23)	—
AGS Central Unit Mounting Capscrews	M8	17 (23)	—
Clutch Actuator Hydraulic Fittings	M30	37 (50)	—
Clutch Actuator Mounting Capscrews	M8	17 (23)	—
Pressure-Limiting Valve Adjusting Screw	M6	—	63–71 (700–800)
Reservoir Base Fasteners	M8	11 (15)	—
Reservoir Top Fasteners	M6	—	71 (800)
Rotational Speed (RPM) Sensors	—	28 (38)	—
Shift Rod Setscrew	M12	22 (30)	—
Transmission Control Unit (TCU) Mounting Screws	M8	—	44–53 (500–600)
TCU Splash Guard Mounting Capscrews	M8	17 (23)	—

Table 3, AGS Assembly Torque Values

AGS Transmission Gear Ratios		
Model	**Gear**	**Ratio**
MBT520-6DA	1	9.201
	2	5.230
	3	3.145
	4	2.034
	5	1.374
	6	1.000
	R	8.649

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Specifications

AGS Transmission Gear Ratios		
Model	**Gear**	**Ratio**
MBT660-6OA	1	6.700
	2	3.810
	3	2.290
	4	1.480
	5	1.000
	6	0.730
	R	6.290

Table 4, AGS Transmission Gear Ratios

AGS Proprietary Fault Codes (J1708)	
Fault Code	**Description**
3000109	High voltage supply voltage—external (connector X1/12 and X1/15)
3000113	High voltage ignition key line—external (connector X1/9)
3000209	Low voltage supply voltage—external (connector X1/12 and X1/15)
3000213	Low voltage ignition key line—external (connector X1/9)
3001210	EEPROM parameter values error—internal
3001510	Clutch displacement control module parameter error—internal
3001781	Clutch calibration offset off limit—internal
3002009	Open load supply voltage—external (connector X1/12 and X1/15)
3002016	Open load/Short circuit VCC temperature sensor circuit board—internal
3002017	Open load/Short circuit VCC temperature sensor pump—internal
3002116	Short circuit GND temperature sensor circuit board—internal
3002117	Short circuit GND temperature sensor pump—internal
3002214	Short circuit VCC peripherals supply—external (connector X2/15)
3003001	EBC1 message timeout—external (J1939)
3003101	EEC1 message timeout—external (J1939)
3003201	EEC2 message timeout—external (J1939)
3003301	EEC3 message timeout—external (J1939)
3003401	ERC1 message timeout—external (J1939)
3003501	Wheel speed information message timeout—external (J1939)
3003601	CruiseControl (VCU) message timeout—external (J1939)
3003701	CruiseControl (bulkhead) message timeout—external (J1939)
3003801	Engine configuration message timeout—external (J1939)
3003901	Retarder configuration message timeout—external (J1939)
3004001	Component identification message timeout—external (J1939)
3004101	PTO information message timeout—external (J1939)

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AGS Proprietary Fault Codes (J1708)	
Fault Code	**Description**
3006101	Incorrect engine data—external (J1939)
3006201	Timeout converted engine data for clutch module (low priority)—internal
3006701	Incorrect retarder data—external (J1939)
3006801	Incorrect ABS data—external (J1939)
3006901	Incorrect internal data—internal
3007001	Incorrect clutch module data—internal
3007101	Incorrect automated gear shift module data—internal
3007201	Incorrect internal data—internal
3008881	Clutch overload—internal
3009280	Plausibility error actual transmission gear ratio—internal
3009710	Test software—internal
3009810	Test electronic—internal
3009910	Test bench mode activated—internal
3010390	Automatic module: signal group cruise control / retarder—internal
3010690	Automatic module: signal output speed—internal
3010790	Automatic module: signal group MR—internal
3010890	Automatic module: signal group gear ratio—internal
3010990	Automatic module: learning values engine—internal
3011081	Plausibility error intended clutch position can not be reached within specified time—internal
3011090	Automatic module: learning values transmission—internal
3011310	Clutch calibration data missing/error—internal
3011410	Clutch parameter error—internal
3011590	Automatic module: signal group shifting time—internal
3011690	Automatic module: signal group ABS—internal
3011790	Automatic module: signal group pedal activation—internal
3011890	Automatic module: signal group lever—internal
3011990	Automatic module: error target system—internal
3012014	Open load peripherals supply—external (connector X2/15)
3012019	Plausibility error valve relay V-V2 on—internal
3012035	Open load power stage solenoid valve (clutch open 1)—internal
3012036	Open load power stage solenoid valve (clutch open 2)—internal
3012037	Open load power stage solenoid valve (clutch close 1)—internal
3012038	Open load power stage solenoid valve (clutch close 2)—internal
3012050	Open load speed sensor transmission output (DZ1)—external (connector X2/14)
3012051	Open load speed sensor transmission input—external (connector X2/11)
3012052	Open load speed sensor transmission output (D3)—external (connector X2/9)

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Specifications

AGS Proprietary Fault Codes (J1708)	
Fault Code	**Description**
3012090	Automatic module: system identification gearshift module—internal
3012114	Short circuit to GND peripherals supply—external (connector X2/15)
3012118	Plausibility error valve relay V-V1 off—internal
3012119	Plausibility error valve relay V-V2 off—internal
3012136	Short circuit GND power stage solenoid valve (clutch open 2)—internal
3012138	Short circuit GND power stage solenoid valve (clutch close 2)—internal
3012151	Short circuit GND speed sensor transmission input—external (connector X2/11
3012251	Short circuit VCC speed sensor transmission input—external (connector X2/11)
3012461	Hydraulic level too low external—external
3016201	Timeout converted engine data for clutch module (medium priority)—internal
3016401	Timeout driving direction information—internal
3016501	Timeout internal communication shift module to clutch module (medium priority)—internal
3018681	Plausibility error clutch open request while inlet valves are closed—internal
3018781	Plausibility error clutch open request while outlet valves are closed—internal
3019480	Plausibility error driving direction—internal
3019621	SmartShift lever data invalid—external (connector X1/8, X1/11, X1/14)
3019650	Tooth signal interruption speed sensor transmission output (DZ1)—external (connector X2/14)
3019651	Tooth signal interruption speed sensor transmission input—external (connector X2/11)
3019652	Tooth signal interruption speed sensor transmission output (D3)—external (connector X2/9)
3020110	High voltage distance sensor supply—internal
3020111	Power supply high voltage—external (connector X3/1)
3020210	Low voltage distance sensor supply—internal
3020211	Power supply low voltage—external (connector X3/1)
3021010	Flash checksum error—internal
3021110	EEPROM calibration values error—internal
3021610	Clutch displacement offset failure—internal
3022011	Supply voltage open load—external (connector X3/1)
3022012	Open load GND connection—external (connector X1/18 and X1/21)
3022015	Open load pressure sensor signal—internal
3022018	Plausibility error valve relay V-V1 on—internal
3022020	Open load GND pump motor—external (connector X3/2)
3022030	Open load power stage solenoid valve (selection direction R)—internal
3022031	Open load power stage solenoid valve (selection direction 5/6)—internal
3022032	Open load power stage solenoid valve—internal
3022033	Open load power stage solenoid valve (gear direction 1,3,5)—internal
3022034	Open load power stage solenoid valve (pressure regulation)—internal

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AGS Proprietary Fault Codes (J1708)	
Fault Code	**Description**
3022041	Open load distance sensor (gear)—internal
3022042	Open load distance sensor (selection)—internal
3022044	Open load distance sensor (clutch)—internal
3022060	Open loop power stage pump motor—internal
3022115	Short circuit GND pressure sensor signal—internal
3022130	Short circuit GND power stage solenoid valve (selection direction R)—internal
3022131	Short circuit GND power stage solenoid valve (selection direction 5/6)—internal
3022132	Short circuit GND power stage solenoid valve (gear direction R,2,4,6)—internal
3022133	Short circuit GND power stage solenoid valve (gear direction 1,3,5)—internal
3022134	Short circuit GND power stage solenoid valve (pressure regulation)—internal
3022135	Short circuit GND power stage solenoid valve (clutch open 1)—internal
3022137	Short circuit GND power stage solenoid valve (clutch close 1)—internal
3022141	Short circuit GND distance sensor (gear)—internal
3022142	Short circuit GND distance sensor (selection)—internal
3022144	Short circuit GND distance sensor (clutch)—internal
3022160	Short circuit GND power stage pump motor—internal
3022215	Short circuit VCC pressure sensor signal—internal
3022241	Short circuit VCC distance sensor (gear)—internal
3022242	Short circuit VCC distance sensor (selection)—internal
3022244	Short circuit VCC distance sensor (clutch)—internal
3022317	Over temperature power stage pump motor—internal
3022590	Automatic module: no signal vehicle speed—internal
3022690	Automatic module: signal group MR (high priority)—internal
3022790	Automatic module: signal group gear ratio (high priority)—internal
3022890	Automatic module: learning values engine (high priority)—internal
3022990	Automatic module: learning values transmission (high priority)—internal
3024341	Erratic distance sensor (gear)—internal
3024342	Erratic distance sensor (selection)—internal
3024344	Erratic distance sensor (clutch)—internal
3024441	Wrong coil resistance value distance sensor (gear)—internal
3024442	Incorrect coil resistance value distance sensor (selection)—internal
3024444	Incorrect coil resistance value distance sensor (clutch)—internal
3024610	Timeout displacement sensor value—internal
3026001	CAN bus off—external (connector X1/13 and X1/7)
3026301	Timeout converted engine data for clutch module (high priority)—internal
3026501	Timeout internal communication shift module to clutch module (high priority)—internal

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Specifications

AGS Proprietary Fault Codes (J1708)	
Fault Code	**Description**
3027401	No J1939 communication—internal / external (connector X1/13 and X1/7)
3027501	Timeout internal communication shift module to clutch module (high priority)—internal
3028581	Clutch displacement control failure—internal
3029180	No calculation of redundant transmission output speed—internal
3029380	Incorrect transmission type—internal
3029580	Plausibility error pressure build up—internal

Table 5, AGS Proprietary Fault Codes (J1708)

Learning Procedure Errors	
Error	**Description**
56	Offset of clutch position out of range
57	Offset of pressure modulation valve out of range
58	Gear position "neutral" out of range
61	Low gear position out of range
62	High gear position out of range
63	Low select position out of range
66	High select position out of range
68	Valve or sensor failure
69	Vehicle is moving
70	Low voltage or high voltage
71	Clutch open/closed
72	Stalk lever position changed during learning procedure
73	Type of gear box invalid
74	Park brake not activated
76	Engine is running
77	Engine torque invalid or out of range
78	Engine was not started in time
80	Accelerator pedal not idle
82	Countershaft speed not zero

Table 6, Learning Procedure Errors

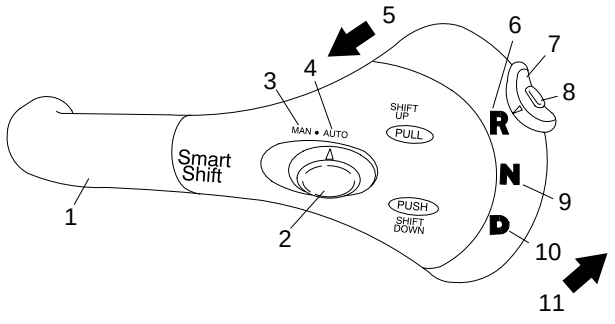
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General Information

The SmartShift™ transmission shift control is an electronic transmission control device. It is applicable to automated mechanical transmissions and is required with the Mercedes-Benz AGS automated gear shift, and Eaton® Fuller® AutoShift™ and UltraShift™ transmissions. It replaces either the typical floor-mounted shift lever or dash-mounted pushbutton control.

The SmartShift control mounts to the right-hand side of the steering column and is operated by the driver's right hand. There are two versions of the control:

- See **Fig.1** for the AGS control.
- See **Fig.2** for the Eaton Fuller control.



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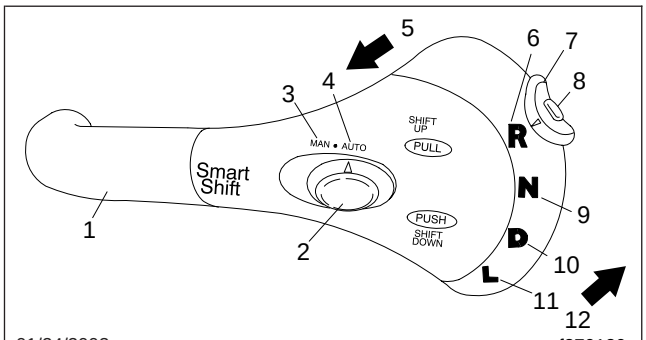
To upshift manually, pull the control up (towards you). To downshift manually, push the control down (away from you).

1. SmartShift Control
2. Slide Switch (forward driving mode switch)
3. MAN Position (of slide switch)
4. AUTO Position (of slide switch)
5. Upshift Direction
6. Reverse Position (of selector switch)
7. Selector Switch
8. Neutral Lock Button
9. Neutral Position (of selector switch)
10. Drive Position (of selector switch)
11. Downshift Direction

Fig. 1, SmartShift Control (with AGS transmission)

SmartShift accepts driver requests for transmission functions and transmits them through hard wiring to the transmission control unit (TCU). SmartShift is a true shift-by-wire system.

SmartShift offers two main advantages over conventional transmission control devices. Usable cab space is increased and access to the sleeper is improved by removing the shift lever from the floor. Because of the steering column mounting, the transmission control is within fingertip reach of the steering wheel, which enhances safety.



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To upshift manually, pull the control up (towards you). To downshift manually, push the control down (away from you).

1. SmartShift Control
2. Slide Switch (forward driving mode switch)
3. MAN Position (of slide switch)
4. AUTO Position (of slide switch)
5. Upshift Direction
6. Reverse Position (of selector switch)
7. Selector Switch
8. Neutral Lock Button
9. Neutral Position (of selector switch)
10. Drive Position (of selector switch)
11. Low Position (of selector switch)
12. Downshift Direction

Fig. 2, SmartShift Control (with Eaton Fuller automated transmissions)

In automatic drive mode, forward drive gears are shifted automatically, without driver interaction. On SmartShift, a slide switch allows the driver to choose between automatic and manual forward driving modes. In manual mode the driver has direct control over gear shifts.

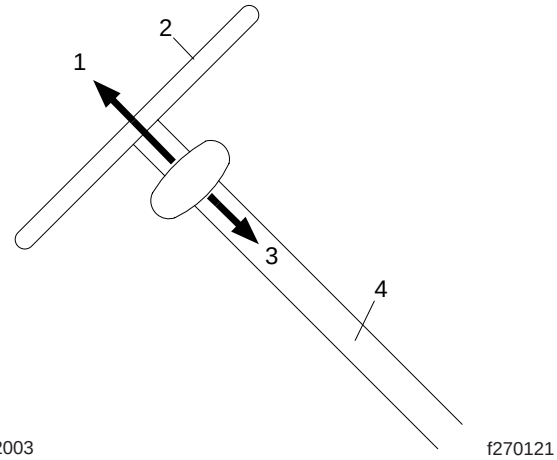
Manual gear shifts are accomplished by a momentary pull or push on the control in the plane perpendicular to the steering wheel. See **Fig.3**. All shifts into reverse (R) are done manually.

Pull upward (toward you) on the control to upshift and push downward (away from you) to downshift. The control is spring-loaded and returns to mid-position when released after an upshift or downshift.

The selector switch is located at the end of the control. There are two different versions:

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1. Upshift (in manual mode, pull upward)
2. Steering Wheel
3. Downshift (in manual mode, push downward)
4. Steering Column

Fig. 3, SmartShift Control Operation

- With AGS, the selector switch has three positions (R, N, D). See **Fig.1**.
- With the Eaton Fuller transmissions, the selector switch has four positions (R, N, D, L). See **Fig.2**.

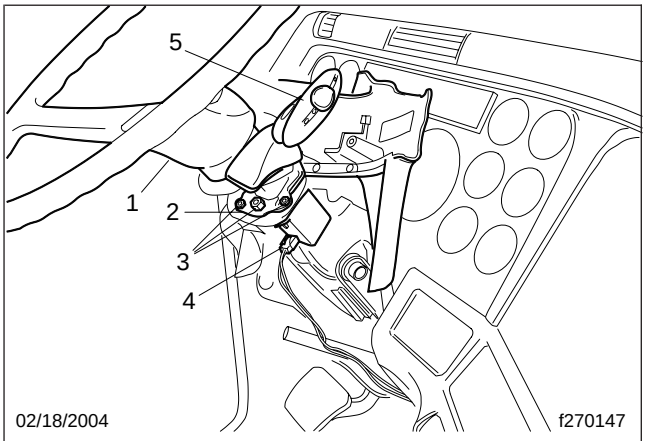
Embedded in the selector switch is a small neutral lock button to prevent accidental shifts into gear from neutral (N). Any time you shift through N, press the neutral lock button to move the switch from N to another gear, such as drive (D), low (L), or reverse (R). When shifting to N, it is not necessary to press the neutral lock button.

NOTE: On AGS and UltraShift, all vehicles have the neutral lock button. On AutoShift, only vehicles built after November 2002 have the neutral lock button.

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Replacement

1. Shut down the engine, set the parking brakes and chock the rear tires.
2. Remove the steering column covers. For detailed procedures, see **Section 46.02**, Subject 130.
3. Disconnect the electrical connector from the lever. See **Fig.1**.



1. Steering Wheel
2. Shift Lever Bracket
3. Nuts and Bolts
4. Electrical Connector
5. Shift Lever

Fig. 1, SmartShift Lever Replacement

4. Remove the three bolts that secure the shift lever to the bracket on the column.
5. Remove the shift lever.
6. Position the new lever on the steering column and secure it using the nuts and bolts previously removed.
7. Connect the electrical connector to the shift lever.
8. Install the steering column covers, as removed.
9. Remove the chocks from the rear tires.

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General Information

The following information is provided to help determine whether a potential transmission problem is actually the transmission or possibly the Freightliner SmartShift® Transmission Shift Control.

For Eaton Fuller AutoShift transmissions, follow the procedures in this subject for resistance checking and Freightliner SmartShift testing using DataLink Monitor and dash displays. For Mercedes-Benz Automated Gear Shift (AGS) transmissions, see **Section 26.03, Subject 302**.

To determine which transmission is installed on the vehicle, check the shift pattern decal on the dash or visor.

For Eaton Fuller AutoShift, the four-position selector switch is marked "R-N-D-L". A slide switch is present. See **Fig. 1**.

For Mercedes-Benz AGS, the three-position selector switch is marked "R-N-D". A slide switch is present. See **Fig. 2**.

Resistance checks at the SmartShift connector can help determine connection problems.

DataLink Software can be used to test the SmartShift control. The tests require a ServiceLink computer connected to the vehicle.

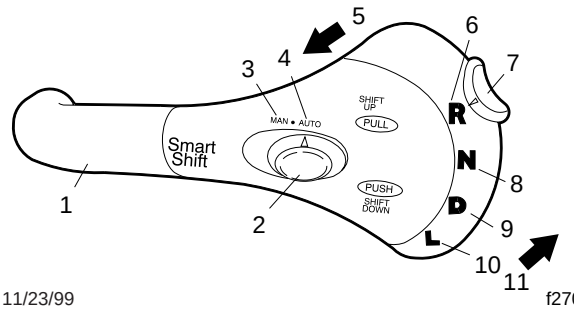
Shift Control Resistance Checking

Parts

Parts for Wire Extension*		
Part Number	**Description**	**Qty.**
PAC12110847	Metri-Pack Terminal	3
PAC12047767	Connector Terminal	3
48-02493-184	18GA GTX Wire, Yellow	3 ft x 3
PAC12047781	3-Pin Connector	1
PAC12047783	Connector Lock	1

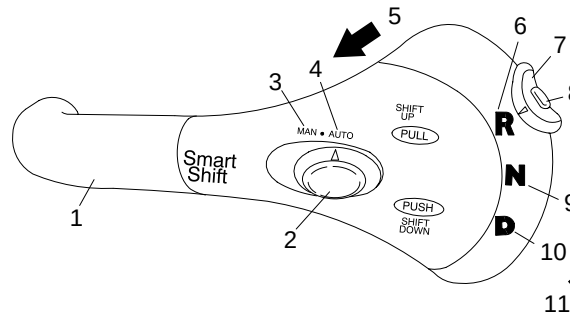
* Parts are available through the PDCs.

Table 1, Parts for Wire Extension



1. SmartShift Control
2. Slide Switch (forward driving mode switch)
3. MAN Position (on slide switch)
4. AUTO Position (on slide switch)
5. Upshift Direction
6. Reverse Position (on selector switch)
7. Selector Switch
8. Neutral Position (on selector switch)
9. Drive Position (on selector switch)
10. Low Position (on selector switch)
11. Downshift Direction

Fig. 1, SmartShift Control (with Eaton Fuller AutoShift)



1. SmartShift Control
2. Slide Switch (forward driving mode switch)
3. MAN Position (on slide switch)
4. AUTO Position (on slide switch)
5. Upshift Direction
6. Reverse Position (on selector switch)
7. Selector Switch
8. Neutral Lock Button
9. Neutral Position (on selector switch)
10. Drive Position (on selector switch)
11. Downshift Direction

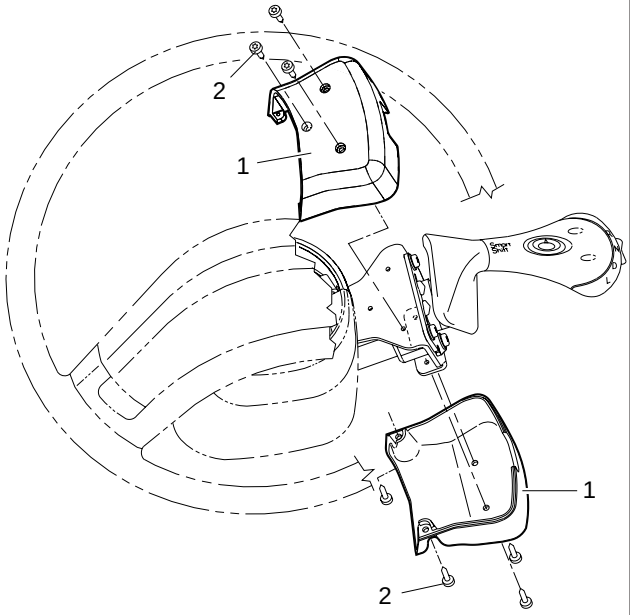
Fig. 2, SmartShift Control (with Mercedes-Benz AGS)

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Troubleshooting

Procedure

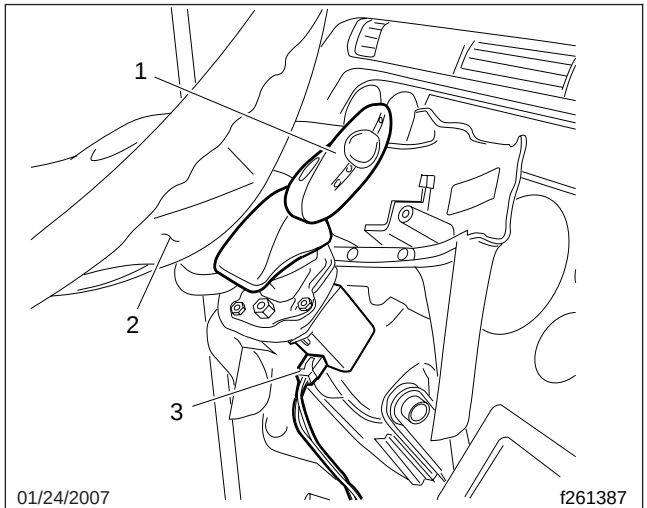
1. Shut down the engine, apply the parking brake, and chock the tires.
2. Remove the screws that secure the SmartShift control covers, and separate the forward and rear panels to access the shift control. See **Fig. 3**.
3. Disconnect the electrical connector from the plug on the shift control unit. See **Fig. 4**.



1. SmartShift Control Cover
2. Screw

Fig. 3, Steering Column Panel

4. Assemble the wire extension from the parts in **Table 1** to allow for easy resistance testing, as follows.
   - 4.1 Crimp the connector terminals at the end of each 3-foot (1-meter) wire.
   - 4.2 Assemble the 3-pin connector with the connector terminals and connector lock.
   - 4.3 Crimp the Metri-Pack terminals on the other end of the wires.



1. Shift Control
2. Steering Wheel
3. Electrical Connector

Fig. 4, SmartShift Components

5. Plug the wire extension into the plug on the shift control unit. See **Fig. 5** for SmartShift terminal positions.

NOTE: Using this new wire extension prevents the need to remove the shift control.

6. Check the resistance at the other end of the wires. See **Fig. 6**. Use **Table 2** and **Table 3**.

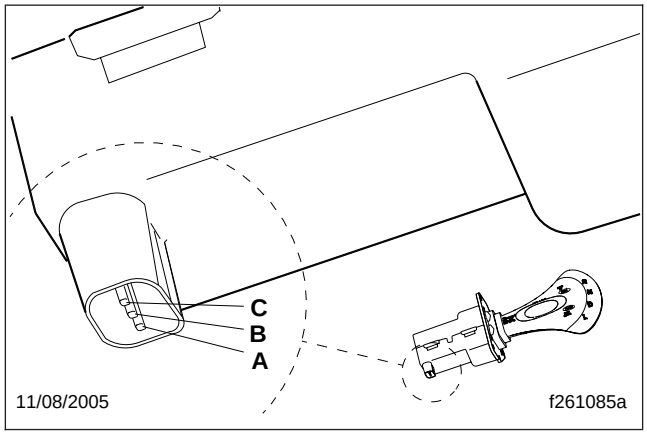
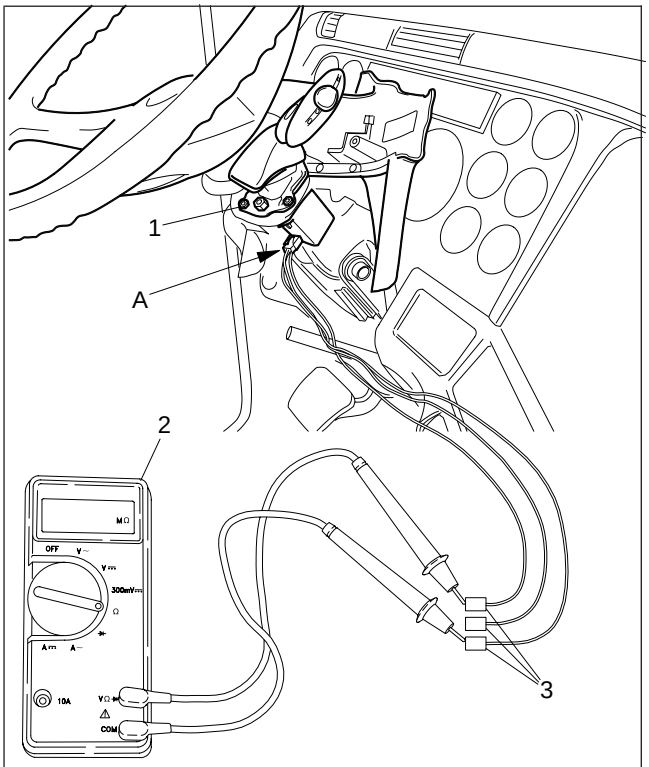


Fig. 5, SmartShift Terminal Positions

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A. Plug the newly assembled wire extension into the plug on the shift control unit.

1. Shift Control Unit
2. Digital Multimeter (set to ohms)
3. Metri-Pack Terminals (at wire ends)

Fig. 6, Resistance Checking at Shift Control

Resistance at Positions B and C	
Selector Switch Position	**Reading: kOhm**
R	2.947–3.067
N	0.347–0.361
D	0.606–0.630
L	1.65–1.72

Table 2, Resistance at Positions B and C

Resistance at Positions A and C	
Slide Switch + Lever Position	**Reading: kOhm**
Manual	2.865–2.981

Resistance at Positions A and C	
Slide Switch + Lever Position	**Reading: kOhm**
Manual + Up	0.531–0.553
Manual + Down	1.150–1.197
Auto	11.27–11.73

Table 3, Resistance at Positions A and C

7. After checking the resistance, unplug the wire extension, and reconnect the electrical connector.
8. Install the steering column trim panels.
9. Remove the chocks from the tires.

SmartShift Control Checking Using DataLink Monitor (DLM)

The AutoShift DataLink Monitor template (see **Fig. 7**) will display the current vehicle status and will reflect change in status. Vehicle information is retrieved from the transmission ECU on the datalink. The monitor can also be used to verify readings on the instrument panel.

1. With the wheels chocked, start the engine.
2. Connect the service computer to the engine and start ServiceLink.
3. Click on the **Transmission** icon on the left screen.
4. Click on the **Templates** tab. An overview of available templates will be shown.
5. Click on **SmartShift with Eaton AutoShift**.

NOTE: To test the shift control using the datalink, the vehicle can be placed into a mode that allows the gears to be shifted without the engine running. The following step explains how to enter that mode.

6. Turn the ignition OFF, then turn the ignition back ON, but don't start the engine. The transmission controller will still be in the Engine ON mode, thereby allowing the gears to be shifted.
7. Test the operation of the shift control for Reverse (R) and Neutral (N), as follows.

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Troubleshooting

7.1 Select R on the selector switch. In the *Range Selected* field of the template an R should be displayed.

7.2 Select N on the selector switch. In the *Range Selected* field of the template an N should be displayed.

8. Test the operation of the shift control for Drive (D), as follows.

8.1 Select D on the selector switch and turn the slide switch (reading "Automatic/ Manual") to Automatic. In the *Range Selected* field of the template, a D should be displayed.

8.2 With the selector switch still on D, toggle the slide switch from Automatic to Manual and back. Confirm that the *Range Selected* field shows a D while in Automatic and an H (High) while in Manual.

8.3 While in Manual mode, change the selector switch to L (Low) and confirm that the *Range Selected* field changes from H to L.

9. Test upshifting and downshifting, as follows.

9.1 With the selector switch on D, pull and hold the shift control lever. The *Up-Shift Req.* field will turn green and read ON for 3 seconds.

9.2 Push and hold the shift control lever. The *Down-Shift Req.* field will turn green and read ON for 3 seconds.

NOTE: A blinking display indicates that the transmission is attempting to shift into the gear position. A solid display shows the current gear position attained.

10. When the selector switch is in any position but N (Neutral), the *Ign. Interrupted* field on the Monitor template will read YES.

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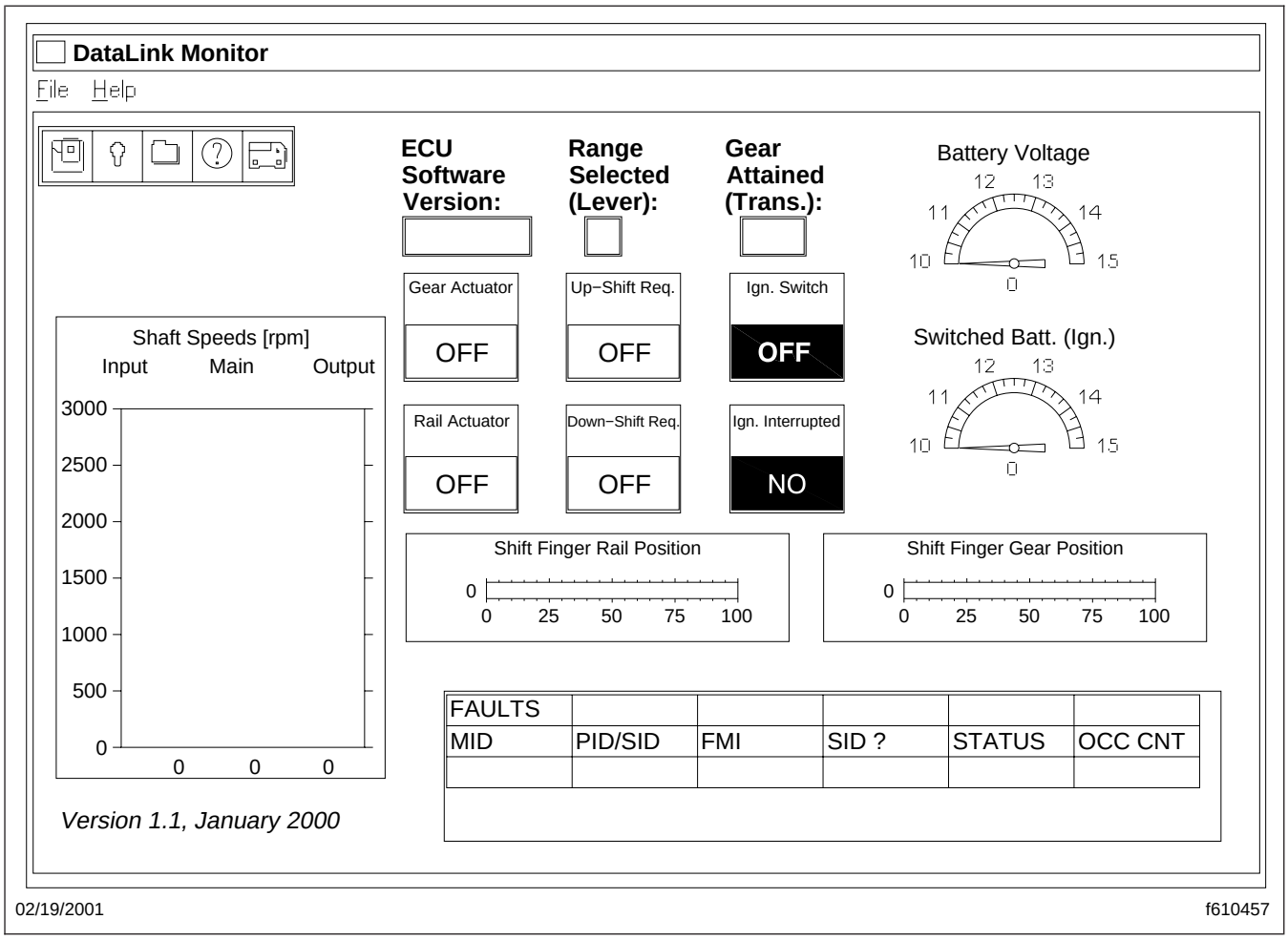


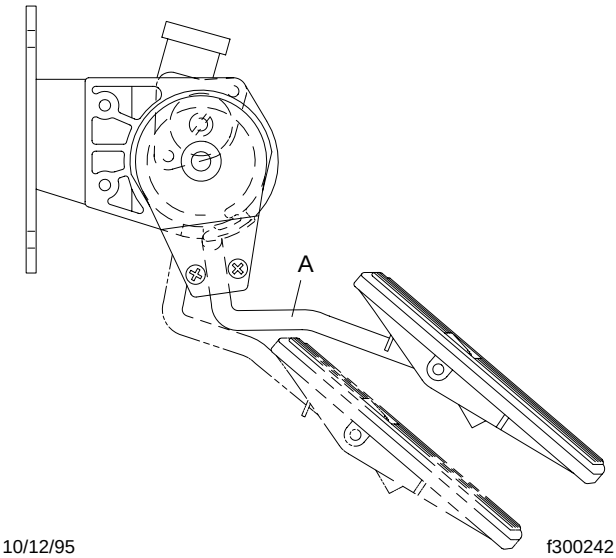
Fig. 7, DataLink Monitor Template for Eaton Fuller AutoShift

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General Information

Throttle Pedal Assembly

Acterra vehicles use a Williams brand electronic throttle pedal. See **Fig. 1** and **Fig. 2**. The suspended pedal assembly mounts to the inside of the cab bulkhead and communicates with the engine through a wiring harness.



A. Idle Position

Fig. 1, Electronic Throttle Pedal, Side View

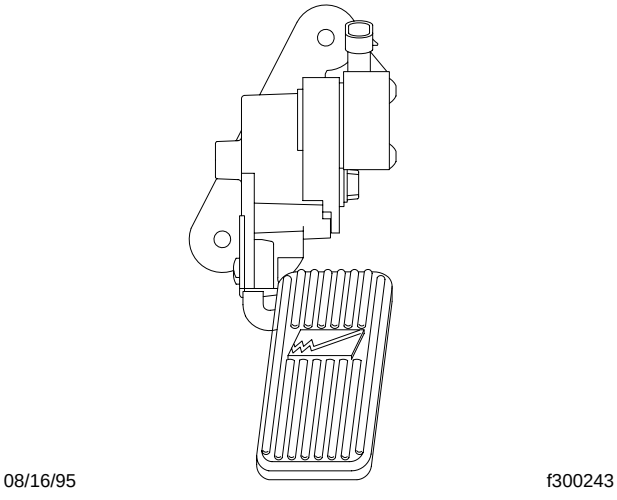


Fig. 2, Electronic Throttle Pedal, Front View

As the driver presses on the pedal, the pedal lever is forced downward, rotating the pinion gear which meshes with the throttle position sensor.

The sensor, attached to the inboard side of the assembly, monitors how far the pinion gear rotates. As the driver presses on the pedal, the sensor signals the electronic engine control to deliver the appropriate amount of fuel to the engine.

When the driver stops pressing on the pedal, return springs within the pedal assembly bring the pedal back to the original idle position. Only the pedal sensor is serviceable. If any other part of the pedal malfunctions, replace the entire pedal assembly.

Throttle Position Sensor

The throttle position sensor (TPS) is an electromechanical device that converts the mechanical input from the throttle pedal assembly into an electrical signal proportional to the input of the pedal. This electrical signal is fed to the engine ECU, which uses the signal to manage engine and engine accessory operations.

Two types of throttle position sensors are used on electronic engines:

- A ratiometric sensor produces a linear voltage output in proportion to pedal input. The engine ECU uses a converter circuit to turn the analog voltage into a digital "count."
- A pulse-width modulated (PWM) sensor generates a series of discrete voltage pulses. The width of the pulses is proportional to the pedal position. A narrower pulse width indicates a smaller throttle pedal request and a wider pulse width indicates a larger pedal request. The pulse width is termed the "duty cycle" of the TPS.

The linear-type sensor is used on Cummins and Mercedes-Benz engines. The PWM sensor is used on Caterpillar engines.

The TPS can also provide an idle validation signal (IVS). At present, an IVS is only available on vehicles equipped with Cummins electronic engines. The IVS is a single-pole, dual-throw switch integral with the TPS. When the throttle pedal returns to idle, the IVS moves to the "idle" position to tell the engine ECU that the pedal has returned to idle. When the throttle pedal is moved off of idle, the IVS moves to an "off idle" position to tell the engine ECU that the pedal is

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no longer in the idle position. Unlike a switch, there is a transition point on the TPS where a high resistance between the IVS common lead and either of the output leads may appear.

When properly installed, the TPS does not operate in either the lower or the upper 10 to 15 percent of the full range of travel. The output signal from the TPS can never be 0 volts or equal the supply voltage from the engine. If such a condition should occur, the engine ECU will report a TPS problem.

The input signal from the TPS to the engine ECU is converted to binary data for engine management requirements. Caterpillar and Cummins engines convert the actual TPS position to a percentage TPS value. The percentage TPS value is scaled so that the values represent the sensor position in the allowed range of travel. A 0 percent value (3 percent for Caterpillar engines) corresponds to idle. A 100 percent value corresponds to full throttle. Raw data may be available for diagnosis, but percentage TPS values are displayed by the diagnostic tools and appear in troubleshooting manuals.

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Electronic Throttle Pedal Removal and Installation

Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries.

⚠ WARNING

To prevent personal injury, always wear eye protection and use caution when servicing pedal assemblies. Springs under tension could release suddenly and cause personal injury.

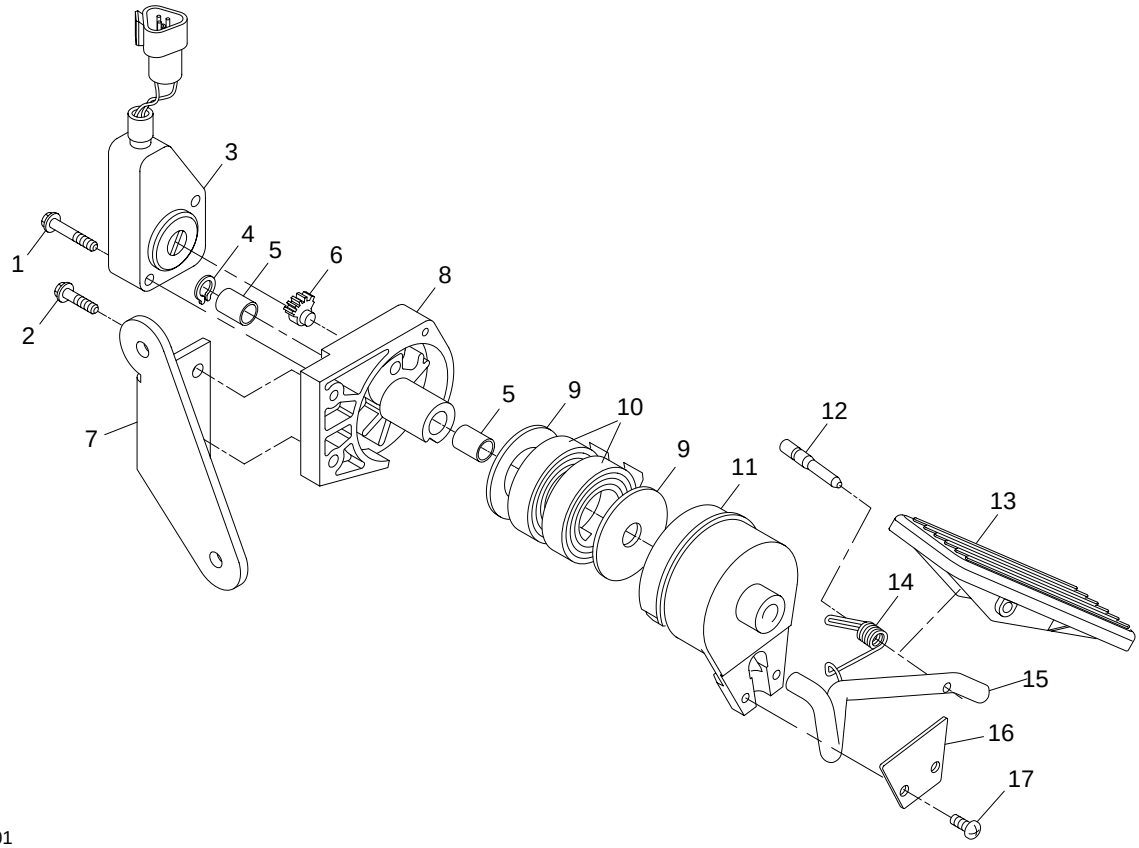
3. Remove the throttle pedal. See **Fig. 1**.
   - 3.1 Remove the carpeting from around the pedal mounting, if necessary.
   - 3.2 Disconnect the electrical harness.
   - 3.3 Remove the two hexhead screws that secure the mounting plate to the cab floor.
   - 3.4 Remove the pedal assembly from the vehicle.

Installation

1. Install the throttle pedal. See **Fig. 1**.
   - 1.1 Position the pedal assembly on the cab floor and install the two hexhead screws.
   - 1.2 Connect the electrical harness.
   - 1.3 Install the carpeting around the pedal mounting, if necessary.
2. Connect the batteries.
3. Remove the chocks from the rear tires.
4. Test drive the vehicle and ensure that the throttle pedal operates properly.

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Electronic Throttle Pedal Removal and Installation



1. No. 10–32 UNF-2A x 1.25-Inch Screw
2. 1/4–20 x 0.75-Inch Hexhead Screw
3. Sensor
4. Grip Ring
5. Bushing
6. Pinion Gear
7. Mounting Plate
8. Throttle Base
9. Spacer Washers
10. Throttle Springs
11. Housing
12. Pedal Pin
13. Pedal
14. Pedal Return Spring
15. Pedal Lever
16. Saddle Clamp
17. No. 10–32 UNF-2A x 0.50-Inch Screw

Fig. 1, Electronic Throttle Pedal Assembly, Exploded View

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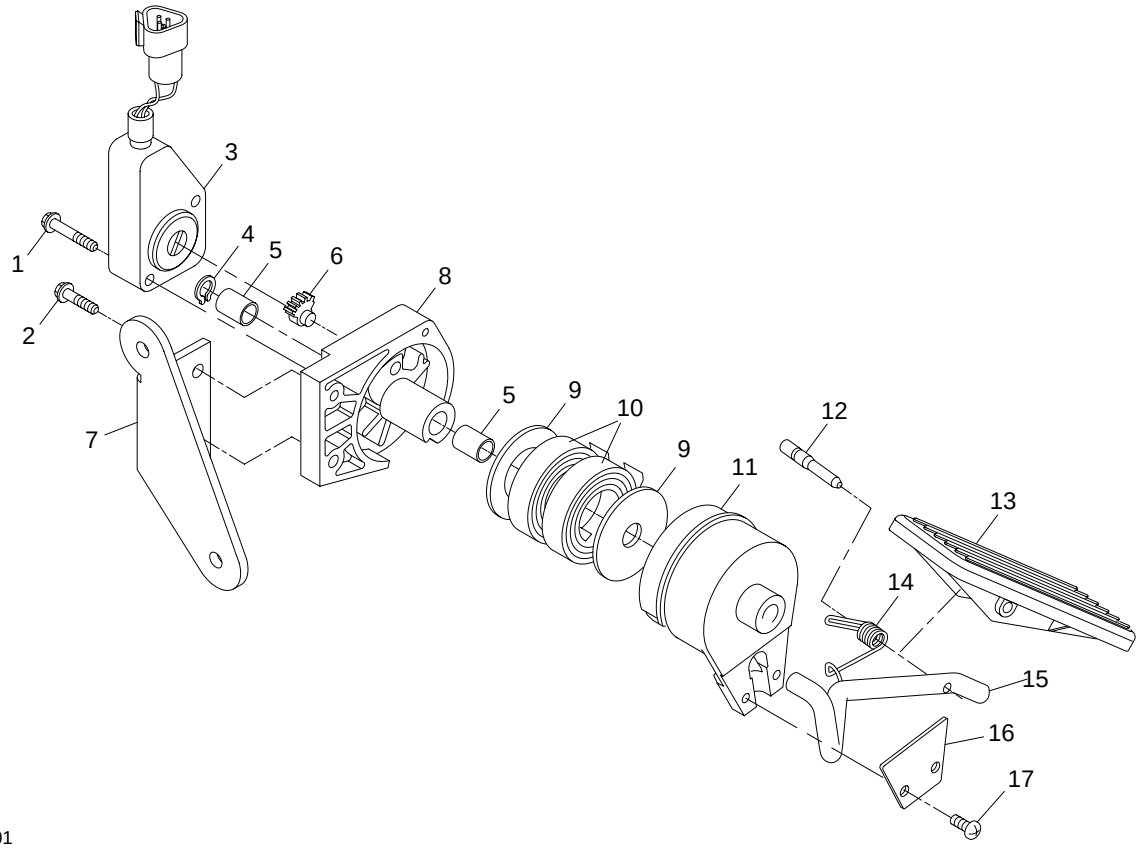
Throttle Pedal Sensor Replacement

Replacement

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Disconnect the batteries.

NOTE: The sensor is not a serviceable part. If the sensor is malfunctioning, replace it.

3. Remove the sensor. See **Fig. 1**.
   - 3.1 Remove the two screws that hold the sensor to the throttle base.
   - 3.2 Disconnect the wiring harness from the throttle pedal sensor.
4. Install the sensor.
   - 4.1 Align the sensor with the pinion gear.
   - 4.2 Rotate the sensor so that the mounting holes line up. Secure the sensor with the



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1. No. 10–32 UNF-2A x 1.25-Inch Screw
2. 1/4–20 x 0.75-Inch Hexhead Screw
3. Sensor
4. Grip Ring
5. Bushing
6. Pinion Gear
7. Mounting Plate
8. Throttle Base
9. Spacer Washers
10. Throttle Springs
11. Housing
12. Pedal Pin
13. Pedal
14. Pedal Return Spring
15. Pedal Lever
16. Saddle Clamp
17. No. 10–32 UNF-2A x 0.50-Inch Screw

Fig. 1, Williams Electronic Throttle Pedal, Exploded View (typical)

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Throttle Pedal Sensor Replacement

mounting screws and tighten 15 to 20 lbf·in (160 to 220 N·cm).

4.3 Connect the wiring harness to the sensor.

5. Connect the batteries.
6. Remove the chocks from the tires.
7. Test drive the vehicle and make sure the throttle pedal sensor operates properly.

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Throttle Pedal Sensor Timing (Caterpillar CFE Engine)

Sensor Timing

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Loosen the two screws that hold the sensor to the throttle base.
3. Connect the Caterpillar Digital Diagnostic Tool to the vehicle's electronic data link. With the pedal in the idle position, adjust the sensor by rotating the housing until the reader displays the correct output of 10 to 22 percent of duty cycle.

⚠ CAUTION

Do not overtighten the sensor screws. Overtightening the screws can damage the sensor.

4. After the sensor is adjusted to the correct specifications, tighten the two sensor screws 15 to 20 lbf·in (169 to 226 N·cm).
5. Tighten the wiring harness clamps.
6. Remove the chocks from the tires.

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Troubleshooting Procedures

CAUTION

The throttle pedal assembly is designed so that the throttle position sensor (TPS) will not reach the internal stop points when it is mounted to the pedal assembly. Very little sensor rotational adjustment is available once the TPS is installed. Attempting to modify the TPS, in an effort to gain adjustment range, or forcing the TPS shaft beyond the internal stop points will result in severe damage to the TPS.

The TPS used with Caterpillar engines is a pulse-width modulated (PWM) sensor. It cannot be properly diagnosed with a digital multimeter set to measure voltage, resistance, or continuity. A multimeter capable of measuring "duty cycle" can be used to view the TPS output. Caterpillar engine diagnostic tools are recommended for viewing the percentage TPS reported by the engine ECU. Attempting to diagnose a PWM sensor assembly without the proper tools will result in damage to the TPS.

Common Problems and Indications

A number of symptoms may indicate, but not conclusively, a problem with the throttle pedal, TPS, or wiring to the electronic engine. Possible symptoms include:

- Low power or poor acceleration;
- The programmed top speed not being met;
- The engine sticks at idle;
- The engine brake or engine retarder does not function;
- Slow deceleration;
- The CHECK ENGINE light comes on;
- An engine fault code appears, indicating a TPS problem.

Symptoms can disappear when the TPS is replaced, however, the TPS may not be faulty. A thorough diagnosis of the entire TPS system must be performed to ensure that a TPS is faulty.

Preliminary Checks

1. Using the particular engine manufacturer's diagnostic software and tools, verify that the TPS is operating properly. For Cummins engines, also verify idle validation signal (IVS) inputs. See **Table 1**.

IMPORTANT: **Table 1** is a guide for common engine installations. It is necessary to verify the correct information for the specific engine installed in the vehicle.

2. If the engine manufacturer's diagnostic software and tools produce the readings shown in **Table 1**, the TPS is not at fault. If you are unable to produce the readings shown in **Table 1**, go to the next step.
3. Verify that the TPS is wired properly. See **Table 2**.

IMPORTANT: Reversing the TPS signal line and the ground line can result in a percentage TPS reading that does not change, and may also produce a fault code at the engine ECU. Reversing the TPS signal line and the +V supply line can prevent the TPS signal from reaching 100 percent. Reversing the +V supply line and the common line will result in the TPS providing "inverted" pedal information, or not working at all. Verify circuit positions and circuit designations in the engine ECU connector using the engine manufacturer's troubleshooting documentation.

NOTE: On Caterpillar engines, swapping any circuits may cause the TPS not to operate.

4. Check the voltage to the TPS. See **Table 3** for TPS connector pin locations.

IMPORTANT: The ignition key must be in the ON position. For Cummins engines, disconnect the TPS connector at the TPS. For Caterpillar and Mercedes-Benz engines, use or fabricate a breakout harness. After diagnosis, clear any historical TPS fault codes to prevent misdiagnosis in the future.

NOTE: It is normal for the engine to report fault codes when the TPS connector is disconnected.

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Troubleshooting

⚠ CAUTION

Do not perform the tests in steps 5, 6, and 7 on the PWM sensor used with Caterpillar engines. Doing so may result in serious damage to the TPS.

5. If you do not read the voltages shown in **Table 3**, test resistance on the +V supply and common circuits between the TPS and the engine connectors. Disconnect the OEM harness connector at the engine ECU.

IMPORTANT: For Caterpillar engines, also disconnect the TPS connector from the TPS. Ensure that the ignition key is in the OFF position before making any tests.

6. If a resistance greater than 10 ohms is read, there is a potential wiring problem. Correct any wiring problem before attempting further tests. If a wiring problem is discovered and repaired, go back and repeat step 1 to determine if this was the only problem.

NOTE: If circuit resistance is 10 ohms or less but the voltage is below that listed in **Table 3**, the engine ECU is probably faulty. If both voltage and circuit resistance are within spec, go to the next step.

7. For Cummins TPS, check the resistance of the TPS at the OEM harness connector with a digital multimeter. Before making measurements, reconnect the TPS connector to the TPS. Leave the OEM harness connector disconnected. See **Table 4** for acceptable readings.

8. Inspect and make sure that all connector pins at the TPS sensor, frontwall, and engine ECU are free of corrosion and are not bent or damaged. Inspect and make sure that the connections between the pins and the wires are secure and also free of corrosion.

NOTE: If the TPS does not return to idle, one of two conditions exists. Either the IVS is faulty or the TPS signal voltage or PWM duty cycle, recorded by the engine ECU, is dropping significantly after the engine has calibrated the idle position.

9. On Cummins engines only, check and ensure that the IVS is working properly. If a problem is found with the IVS, replace the TPS with a new unit or one known to be good and continue testing. If no problem is found, go to the next step.

10. Remove the pedal assembly from the floor. Loosen (but do not remove) the TPS mounting screws. By hand, rotate the TPS sensor assembly as far as possible. Tighten the mounting screws securely. Check the operation of the TPS again.

NOTE: In some cases, it may be necessary to exchange the existing TPS with another because the TPS and pedal assembly tolerances result in an idle position too close to the edge of acceptable operation. In this situation, the TPS is probably not faulty and may perform acceptably in another pedal.

11. If the engine will not reach rated speed or recognize full throttle, the cause is something other than the TPS. Check the engine ECU parameters and reset them if necessary. Check and ensure that the TPS is wired correctly. Remove the TPS from the pedal assembly and move the pedal through the full range of operation. Watch the operation of the TPS actuator tab. Make sure that no parts are binding or broken.

12. If the TPS does not leave idle, check IVS operation (if so equipped) and ensure that the switch transitions from the idle to the off-idle state. Also, check for a signal on the appropriate wires at the engine ECU for both idle and off-idle states. On vehicles not equipped with an IVS, check and make sure that the TPS is connected correctly to the engine.

13. If the problem has still not been resolved, the problem is not with the TPS. See the engine manufacturer's service literature for further guidance.

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Diagnostic Software/Tool Readings		
Engine	**Pedal Position**	**Reading**
Caterpillar *	Idle	3% TPS
	Full Throttle	100% TPS
	Between Idle/Full Throttle	Varies Smoothly Between 3% and 100%
Cummins *	Idle	0% TPS, IVS On-Idle
	Full Throttle	100% TPS, IVS Off-Idle
	Between Idle/Full Throttle	Varies Smoothly Between 0% and 100% IVS Transitions Between On-Idle and Off-Idle At, or Before, 15% TPS
Mercedes-Benz	Idle	0% TPS
	Full Throttle	100% TPS
	Between Idle/Full Throttle	Varies Smoothly Between Idle and Full Throttle Values

* The ECM converts raw TPS data to % TPS.

Table 1, Diagnostic Software/Tool Readings

Throttle Position Sensor (TPS) Wiring			
Engine	**Engine Manufacturer Circuit**	**TPS Connector Pin**	**Engine ECU Connector**
Caterpillar CFE	C985 (+V Supply)	A	35
	C993 (Common)	B	29
	C986 (TPS Signal)	C	37
Cummins ISB/ISC	N18 (+V Supply)	C	29
	N19 (Common)	B	19
	N11 (TPS Signal)	A	30
MBE900	440P+ (+V Supply)	C	9 (VCU)
	440P– (Common)	B	14 (VCU)
	440T (TPS Signal)	A	11 (VCU)

Table 2, Throttle Position Sensor (TPS) Wiring

TPS Connector Pin Locations			
Engine	**TPS +V Supply**	**TPS Common (Ground)**	**Voltage**
Caterpillar	Pin A	Pin B	+8V ± 0.5V
Cummins	Pin C	Pin B	+5V ± 0.5V
MBE900	Pin C	Pin B	+5V ± 0.5V

Table 3, TPS Connector Pin Locations

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Troubleshooting

TPS Resistance at OEM Connector Harness (Cummins engines only)			
Measurement	**From**	**To**	**Value**
TPS Total Resistance	+V Supply	Common	2000 to 3000 Ohms
TPS Signal to Common at Idle	TPS Signal	Common	200 to 500 Ohms (13% ± 2% of TPS Total Resistance)
TPS Signal to +V Supply at Idle	TPS Signal	+V Supply	1800 to 2500 Ohms and Less Than TPS Total Resistance
TPS Signal Over Pedal Travel Range	TPS Signal	+V Supply	Should Change Smoothly from High to Low Resistance Values as the Pedal Moves from Idle to Wide-Open Throttle
	TPS Signal	Common	Should Change Smoothly from Low to High Resistance Values as the Pedal Moves from Idle to Wide-Open Throttle

Table 4, TPS Resistance at OEM Connector Harness (Cummins engines only)

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General Information

IMPORTANT: This workshop manual *does not* cover the procedures and calculations necessary to perform frame modifications. For information on frame modifications, be sure to consult with the Sterling Engineering Department.

The main body of the frame can be either two heat-treated or non-heat-treated steel frame rails secured together by crossmembers. See **Fig. 1**. The frame assembly is supported on the front and rear axles, and supports the rest of the chassis and body.

Both frame rails have identical specifications. Each has an upper flange, lower flange, and web (the surface area between the flanges). The inside area of the frame rail is called the channel. See **Fig. 2**.

Crossmembers control axial rotation and longitudinal motion of the rails, and reduce torsional stress transmitted from one rail to the other. Crossmembers are also used for vehicle component mounting, and for protection of the wires and tubing that are routed from one side of the vehicle to the other.

FRAME STATIONS

A frame station is a reference point along each frame rail from which the location of each component (mounted on that frame rail) is measured. There are two frame stations along the frame rails: station zero and station 1000. See **Fig. 3**.

There is no identifying mark for station zero; it is located 1.6 inches (40 mm) forward of the forward end of the frame rail, and 11.4 inches (290 mm) forward of the centerline of the front suspension's forward spring pin. Station 1000 is located 39.4 inches (1000 mm) to the rear of station zero, and is directly above the centerline of the front axle.

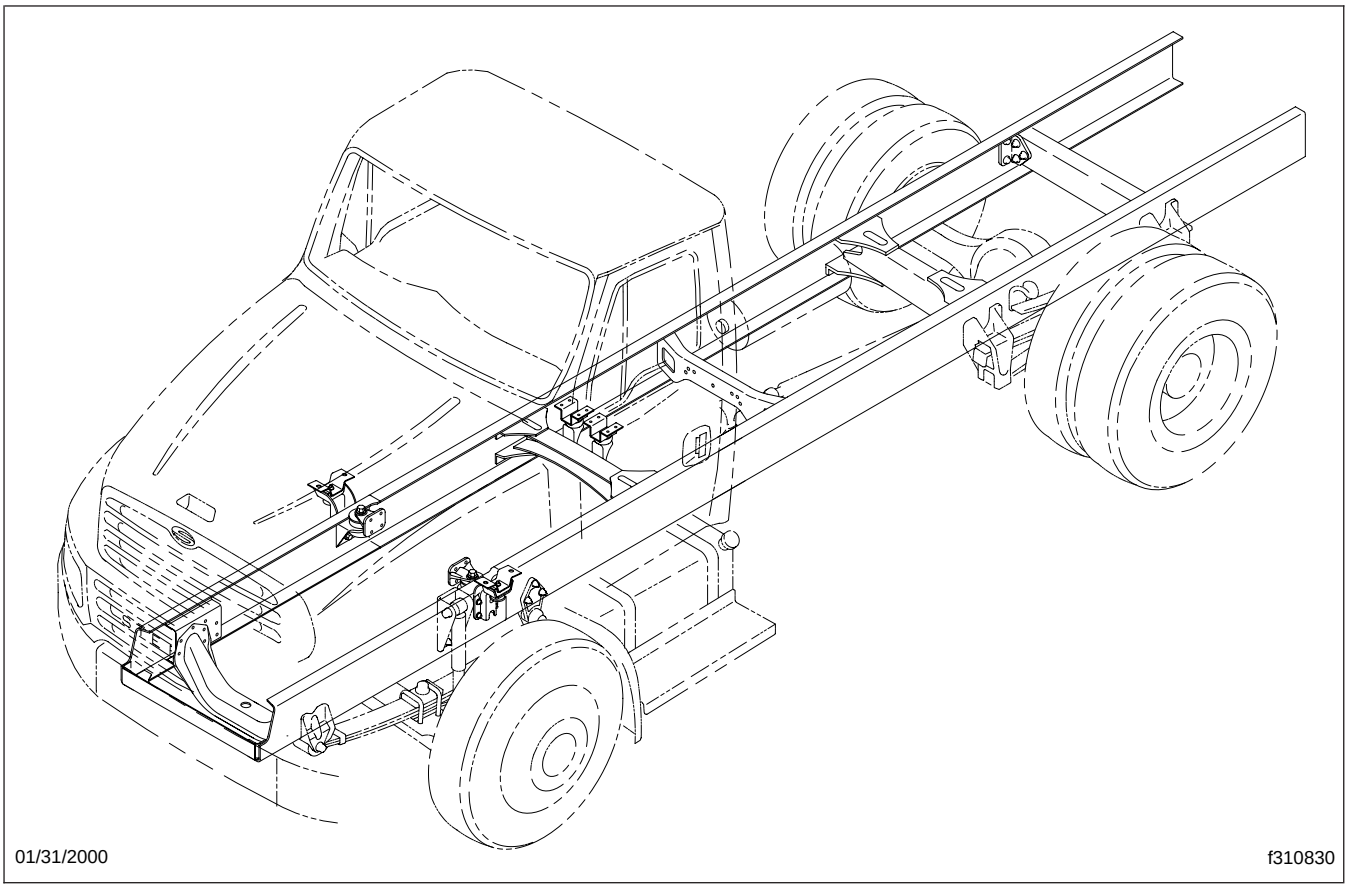


Fig. 1, Frame Assembly

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General Information

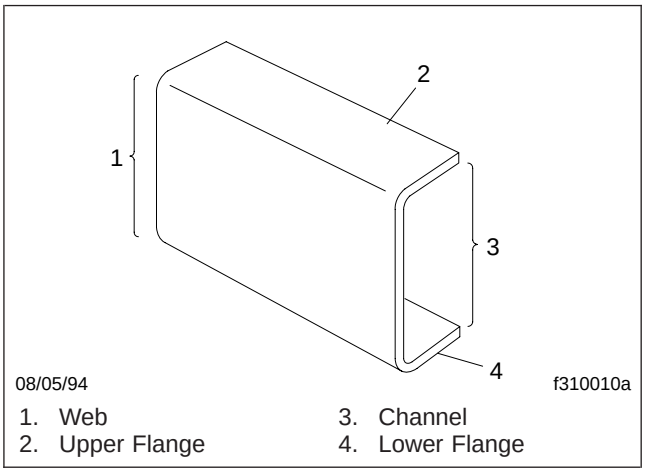


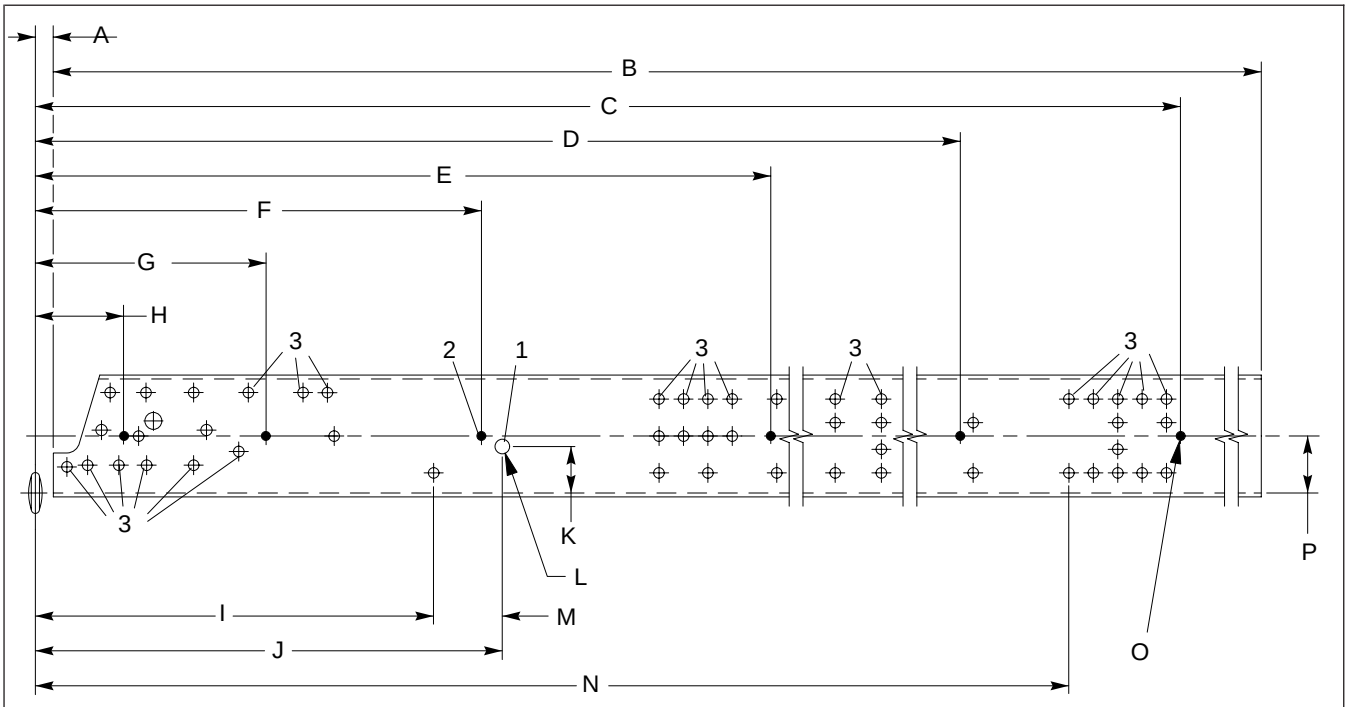
Fig. 2, Frame Terminology

Station 1000 is used when station zero is not accessible because of vehicle assembly. Station 1000 is identified by a 1-1/16 inch (27 mm) diameter hole near the bottom third of the frame rail web. A bulkhead fitting for the air or hydraulic brake lines is installed in the hole.

The vehicle's frame drilling chart lists the location of each frame rail component. For example: if a component is given a location of 850, then that component is installed on the frame rail 33-15/32 inches (850 mm) aft of station zero, or 5-29/32 inches (150 mm) forward of station 1000.

In addition to frame stations zero and 1000, each frame rail has six manufacturing holes along the centerline of the frame rail web. All six holes are 5/8-inch (16-mm) diameter. See **Fig. 3**. These holes can be used for location and measurement in the same manner as the hole at frame station 1000.

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A. 1.5748 in (40 mm)
B. ±0.197 in (Length ±5 mm)
C. 103.480 in (2628.4 mm)
D. 85.480 in (2171.2 mm)
E. 61.480 in (1561.6 mm)
F. 37.480 in (952 mm)
G. 19.480 in (494.8 mm)
H. 7.480 in (190 mm)
1. Hole at Frame Station 1000
2. 6 Each Manufacturing Holes
I. 33.4646 in (850 mm)
J. 39.3701 in (1000 mm)
K. 3-3/4 in (95.5 mm)
L. 1-1/16 in (27 mm) Diameter
M. 5.9055 in (150 mm)
N. 94.4882 in (2400 mm)
O. 5/8 in (16 mm) Diameter
P. 4-3/4 in (120.5 mm)
3. Component Mounting Holes

Fig. 3, Frame Stations, Left-Side Frame Rail Shown, Right-Side Symmetrical

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General Handling

Whenever the frame rails are lifted or moved, take care to avoid anything that may scratch, cut, or damage the exposed frame assembly. Cushion all chain hoists or cable slings with a section of heavy hose. If the frame rail is raised with a jack, place a block of wood between the jack and the frame rail.

Never heat the frame rails for straightening purposes; such work should be done cold.

⚠ CAUTION

Heating the frame rails to straighten them will reduce the strength of the rail, which can result in structural failure of the frame rail.

Use pencil lines or soapstone marking for any work that requires marking of the frame rail. High visibility can be obtained by first chalking the surface of the frame rail, then making the pencil marks.

⚠ CAUTION

Before performing any electric welding on a vehicle, disconnect the battery power and ground cables and any electronic control units (ECUs) installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs.

Sterling vehicle components that typically use ECUs include electronic engine, electronic automatic transmission, and ABS (antilock braking system).

For any ECU with a battery power harness, disconnect its ground terminal from the chassis ground, and disconnect its power terminal from the battery positive post. Or else disconnect the main connection at the ECU.

Apply Alumilastic® Compound or a paintable, air-cured synthetic rubber or moisture-cured polyurethane, flexible weather-sealant between any dissimilar metal surfaces that contact each other (except nuts, bolts, and zinc or cadmium plated washers), regardless of whether the surfaces are primed or painted.

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Repairing Cracks

IMPORTANT: In most cases, cracked or damaged frame rails should be replaced. In some cases it may be necessary to repair minor damage; before attempting any repairs, contact your regional service representative for approval.

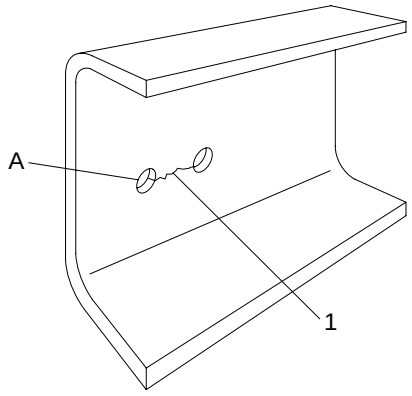
CAUTION

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Components that typically use ECUs include electronic engine, electronic automatic transmission, and ABS (antilock braking system).

For any ECU with a battery power harness, disconnect the ground terminal from the chassis ground and the power terminal from the battery positive post, or disconnect the main connection at the ECU.

1. Drill a 1/8 inch (3 mm) diameter hole at each end of the crack to prevent further spreading. See **Fig. 1**.

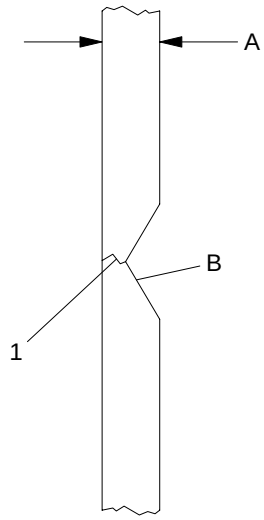


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A. 1/8 inch (3 mm) Diameter Hole
2. Crack

Fig. 1, Preventing Cracks from Spreading

2. Grind a v-groove at the crack to a depth of two thirds of the stock thickness. See **Fig. 2**.



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A. Frame Rail Thickness
B. Grind a v-groove to two-thirds the depth of the stock thickness.
1. Crack

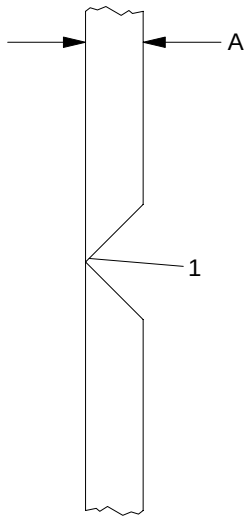
Fig. 2, Cross-Section View

NOTE: If it will not be possible to grind both sides of the frame rail, then grind the v-groove on one side to the full depth of the stock thickness. See **Fig. 3**.

3. Clamp a copper or aluminum bar on the opposite side of the groove. The bar will act as a "chill" strip, keeping the heat from spreading to the surrounding area of the frame rail. See **Fig. 4**. Deposit the weld material using the applicable welding method described in this section.
4. Grind the weld flush with the frame rail. See **Fig. 5**.
5. Cut a deep enough v-groove on the opposite side of the frame rail to reach the weld metal. See **Fig. 6**.
6. Clamp the "chill" strip on the opposite side of the groove. See **Fig. 7**. Weld the v-groove, as instructed above. Make full penetration of the weld.
7. Grind the weld flush with the frame rail. See **Fig. 8**.

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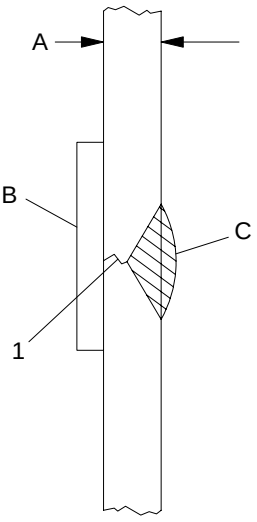
Frame Rail Repair



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A. Frame Rail Thickness
1. V-groove (full depth)

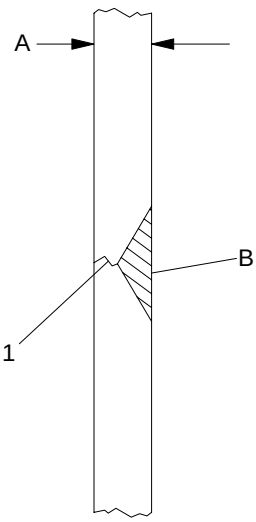
Fig. 3, Full Depth Groove



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A. Frame Rail Thickness
B. Clamp the "chill" strip on the opposite side of the groove.
C. Deposit weld material.
1. Crack

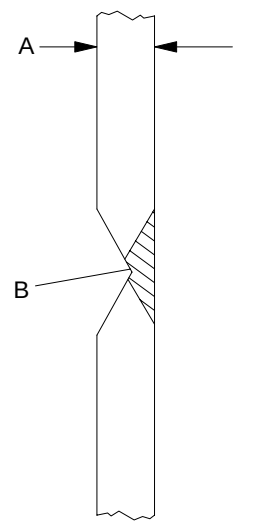
Fig. 4, Using a Chill Strip



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A. Frame Rail Thickness
B. Grind the weld flush with the frame rail.
1. Crack

Fig. 5, Weld Ground Flush



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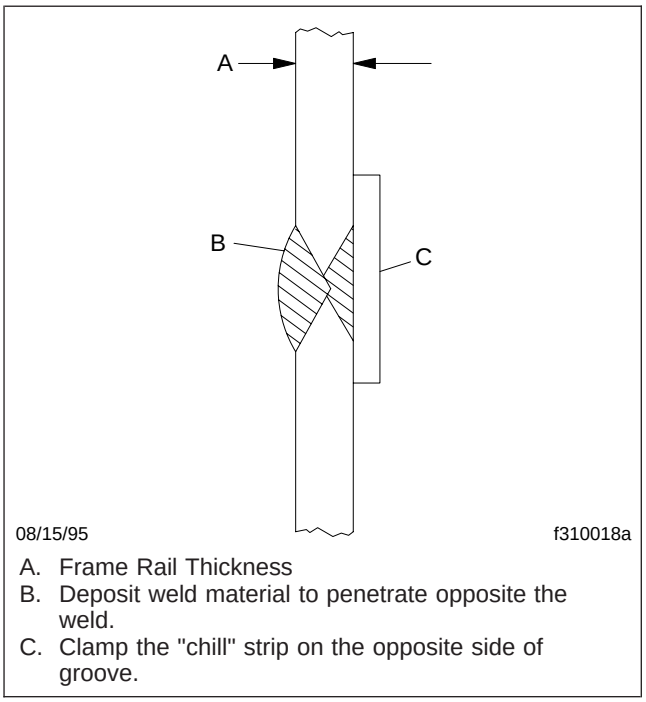
A. Frame Rail Thickness
B. Grind a v-groove deep enough to reach the weld.

Fig. 6, Cross-Section View

Filling Unused Holes

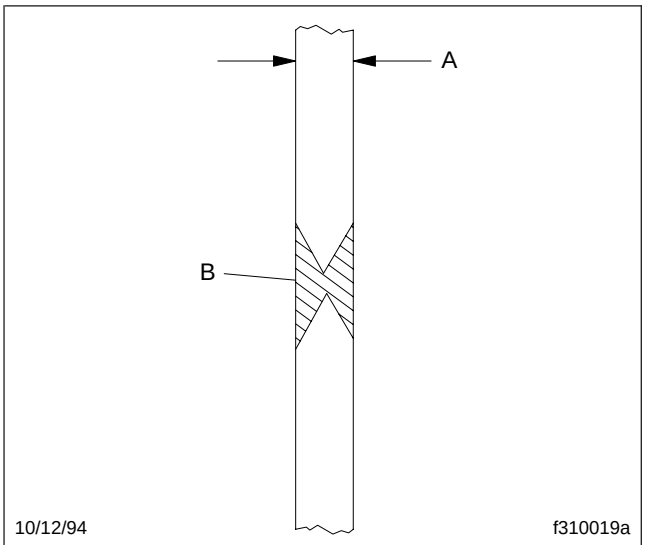
1. Fill all unused holes in the frame assembly with the applicable nut, washer, and bolt combination.

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A. Frame Rail Thickness
B. Deposit weld material to penetrate opposite the weld.
C. Clamp the "chill" strip on the opposite side of groove.

Fig. 7, Second Weld



A. Frame Rail Thickness
B. Grind the weld flush with the frame rail.

Fig. 8, Second Weld Ground Flush

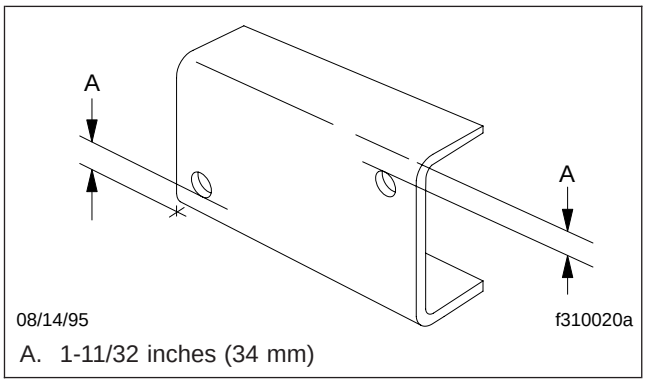
2. If the diameter of a hole is less than 3/8 inch (10 mm), enlarge it to 3/8 inch (10 mm), and fill it with the applicable nut, washer, and bolt combination.
3. Tighten the fasteners to the applicable torque value. For proper frame fastening instructions, refer elsewhere in this group.

Drilling Holes

During vehicle manufacture, holes are drilled or punched in the frame rail only as specified on the vehicle frame drilling chart. If any additional holes need to be drilled, contact your regional service representative for approval.

A single exception to this rule is that holes may be drilled for tubing clips and the like through the web portion of the channel only, with the following restrictions:

- The *edge* (not the center) of the hole must be no closer than 1-11/32 inches (34 mm) from the outer face of the flange. See **Fig. 9** for the minimum distance to the flanges that holes can be placed on the web.
- Material between the centerline of the hole and the outside of the upper or lower flange must be at least 2-13/32 inches (60 mm).
- Minimum material between hole centerlines must be 2 inches (50 mm).
- All attaching fasteners must be Grade 8. Flat washers must be made with high strength steel.
- The minimum material between the rear suspension bracket and the end of the frame must be at least 2 inches (50 mm).
- Holes between the front axle centerline and the rear axle centerline cannot exceed 3/4 inch (19 mm).



A. 1-11/32 inches (34 mm)

Fig. 9, Minimum Distance for Drilling Holes

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Crossmember Removal and Installation

Removal

The placement of crossmembers affects the overall stability of the frame. If a crossmember is being eliminated, added, or relocated, Sterling dealers must contact their Regional Service Office for instructions and approval. All others must contact a Sterling dealership, which will contact the Regional Service Office for approval.

IMPORTANT: Before removing any crossmember, note the direction, size and type of all fasteners that attach the crossmember to the frame rail and that attach other parts to the crossmember. Also note which direction the open channel of the crossmember is facing for installation reference.

NOTE: If a welded five-piece crossmember must be removed, it must be cut in two and replaced with a bolted five-piece crossmember. See **Fig. 1** and **Fig. 2**.

WELDED FIVE-PIECE CROSSMEMBER **(See Fig. 1)**

NOTE: This procedure is for the removal of a welded five-piece crossmember to be replaced with a bolted five-piece crossmember.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. If any air brake valve is attached to the crossmember, drain the air reservoirs and remove the valve(s) from the crossmember.

   Remove any clamps that attach air lines or wiring to the crossmember. Secure the lines or wires away from the crossmember.
3. If the back-of-cab crossmember is being removed, support the cab (at its normal ride height), the fuel tank(s), and the cab-access steps as applicable. Remove the fasteners that attach the rear cab support brackets to the crossmember.
4. If rear suspension brackets are attached to the frame rails with the same fasteners that attach the crossmember, support the rear of the frame at its normal ride height using safety stands.
5. Using a cutting torch, cut the crossmember channel in two. A 3-inch (76-mm) cut will make removal easier.
6. Remove the fasteners that attach the crossmember halves to the frame rails and remove the crossmember.

REAR-CLOSING CROSSMEMBER **(See Fig. 3)**

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. If so equipped, remove the backup alarm from the crossmember.

   If any air brake valve is attached to the crossmember, drain the air reservoirs and remove the valve(s) from the crossmember.

   Remove any clamps that attach air lines or wiring to the crossmember.

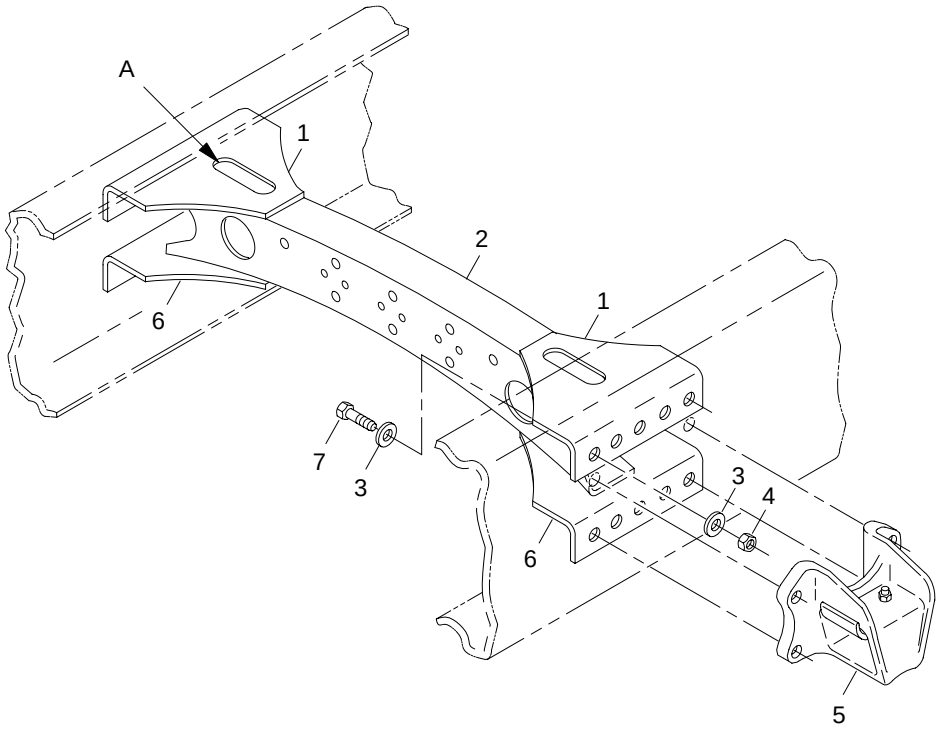
   If the leveling valve for an AirLiner suspension is attached to the crossmember, remove the valve. For instructions, see **Group 32** in this manual.
3. Remove the fasteners that attach the crossmember to the front angle brackets.
4. If rear suspension brackets are attached to the frame rails with the same fasteners that attach the angle brackets, support the rear of the frame at its normal ride height using safety stands.
5. Remove the fasteners that attach the rear angle brackets to each frame rail. Remove, as an assembly, the rear brackets and the crossmember.
6. If needed, remove the front angle brackets and their fasteners. If applicable, after removing the fasteners, remove the rear suspension brackets from the springs.

SPLAYED CROSSMEMBER **(See Fig. 4)**

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. If removing a midship bearing crossmember, support the driveline on a safety stand. Remove the fasteners that attach the midship bearing bracket to the crossmember.
3. Unbolt the crossmember from both frame rails.

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Crossmember Removal and Installation



A. Welded (typical at all 4 gussets)
1. Upper Gusset
2. Channel
3. Hardened Steel Flatwasher
4. 5/8–11 Locknut
5. Rear Suspension Bracket
6. Lower Gusset
7. 5/8–11 Grade 8 Bolt

Fig. 1, Welded Five-Piece Crossmember Assembly

4. At one end of the crossmember, use a deadblow hammer to tap against its curved side (the closed side of the channel) until the crossmember is no longer wedged in the frame. Remove the crossmember.

Overslung Crossmember (See Fig. 5)

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Remove the half-fender from the left side of the vehicle.
3. Provide support underneath both fuel tanks.
4. From underneath the chassis, remove the two 5/8–11 fasteners that attach each side of the crossmember to its mounting brackets.
5. Remove the overslung crossmember by rotating it down and outward on the left side of the vehicle.

Installation

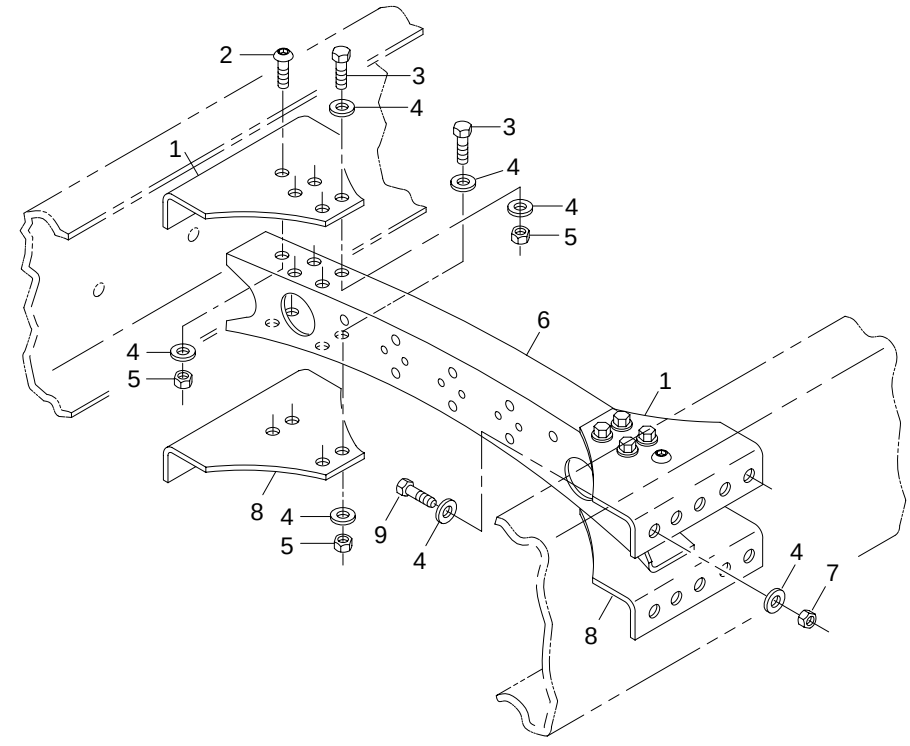
BOLTED FIVE-PIECE CROSSMEMBER (See Fig. 2)

NOTE: This procedure is for the installation of a bolted five-piece crossmember to replace a five-piece welded crossmember.

1. Attach one upper gusset to the crossmember channel. Tighten the fasteners snug, but not to their final torque value.
2. Install the crossmember channel and gusset in the frame rails with its open channel facing the

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Crossmember Removal and Installation



1. Upper Gusset
2. 1/2–13 Button-Head Capscrew
3. 1/2–13 Grade 8 Hexbolt
4. Hardened Steel Flatwasher
5. 1/2–13 Locknut
6. Crossmember Channel
7. 5/8–11 Locknut
8. Lower Gusset
9. 5/8–11 Grade 8 Hexbolt

Fig. 2, Bolted Five-Piece Crossmember Assembly

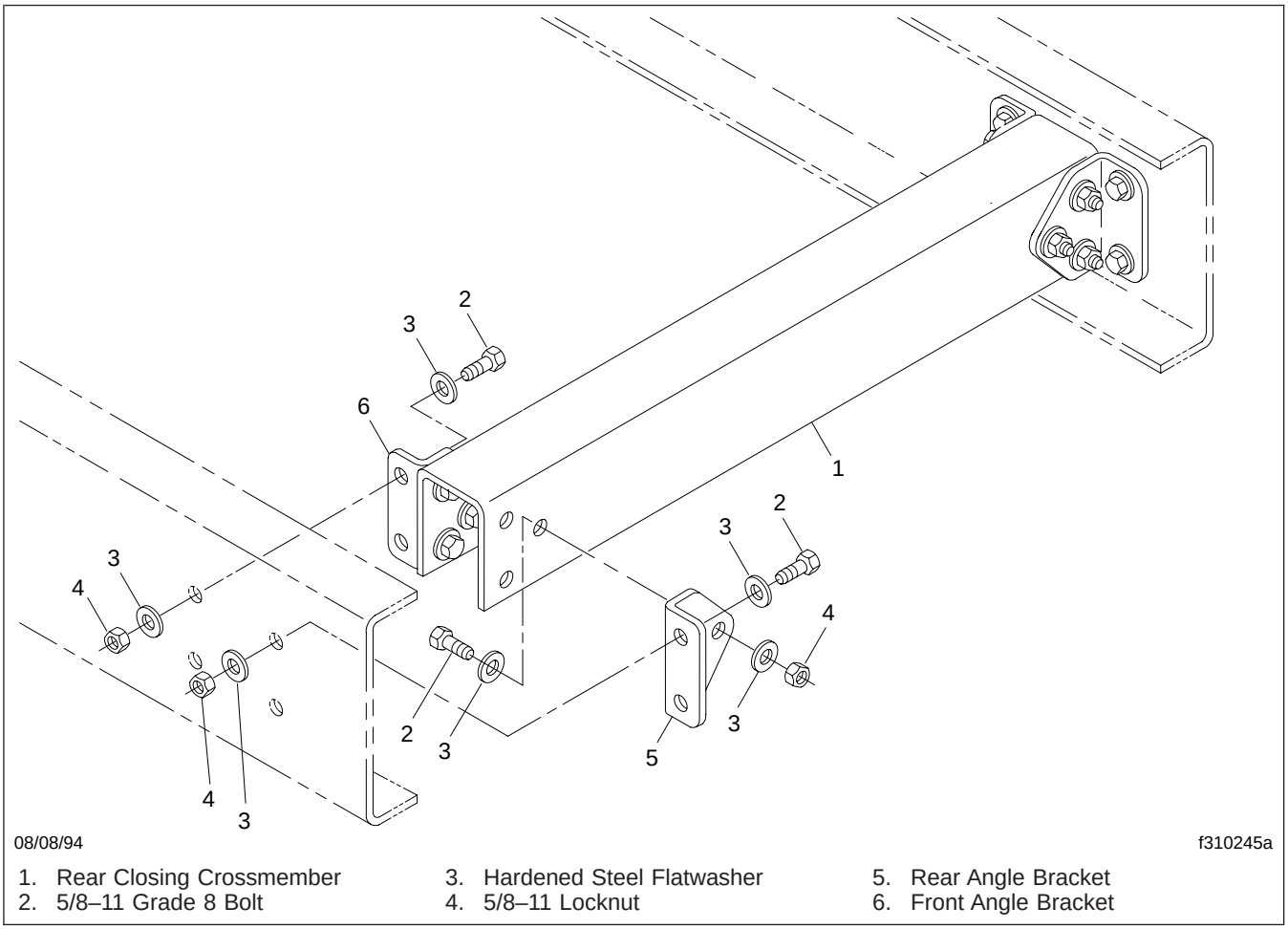
same direction that was noted during removal. Position the crossmember so its channel is supported on the lower flanges of both frame rails.

3. Attach the other upper gusset to the crossmember channel. Tighten the fasteners snug, but not to their final torque value.
4. Tighten the locknuts on the button-head capscrews at the outboard end of both upper gussets 68 lbf·ft (92 N·m).
5. Using a deadblow hammer, tap the crossmember up into place. Align the mounting holes of the upper gussets with the holes in the frame rails. Install the fasteners, but do not tighten them.
6. Install the lower gussets on the crossmember channel, but do not tighten the fasteners at this time. Install the fasteners that attach the lower gussets to the frame rails.
7. Tighten the fasteners that attach the gussets to the frame rails 136 lbf·ft (184 N·m). Tighten the fasteners that attach the gussets to the crossmember channel 68 lbf·ft (92 N·m).
8. If any air brake valve was attached to the crossmember, install the valve(s) on the crossmember.

   Install any clamps that attach air lines or wiring to the crossmember.
9. If the back-of-cab crossmember was replaced, install the fasteners that attach the rear cab support brackets to the crossmember. Tighten the cab support bracket fasteners 68 lbf·ft (92 N·m). Remove the supports from under the cab, fuel tanks and cab-access steps.
10. Remove the chocks from the rear tires.

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Crossmember Removal and Installation



1. Rear Closing Crossmember
2. 5/8–11 Grade 8 Bolt
3. Hardened Steel Flatwasher
4. 5/8–11 Locknut
5. Rear Angle Bracket
6. Front Angle Bracket

Fig. 3, Rear Closing Crossmember Installation

REAR-CLOSING CROSSMEMBER

(See Fig. 3)

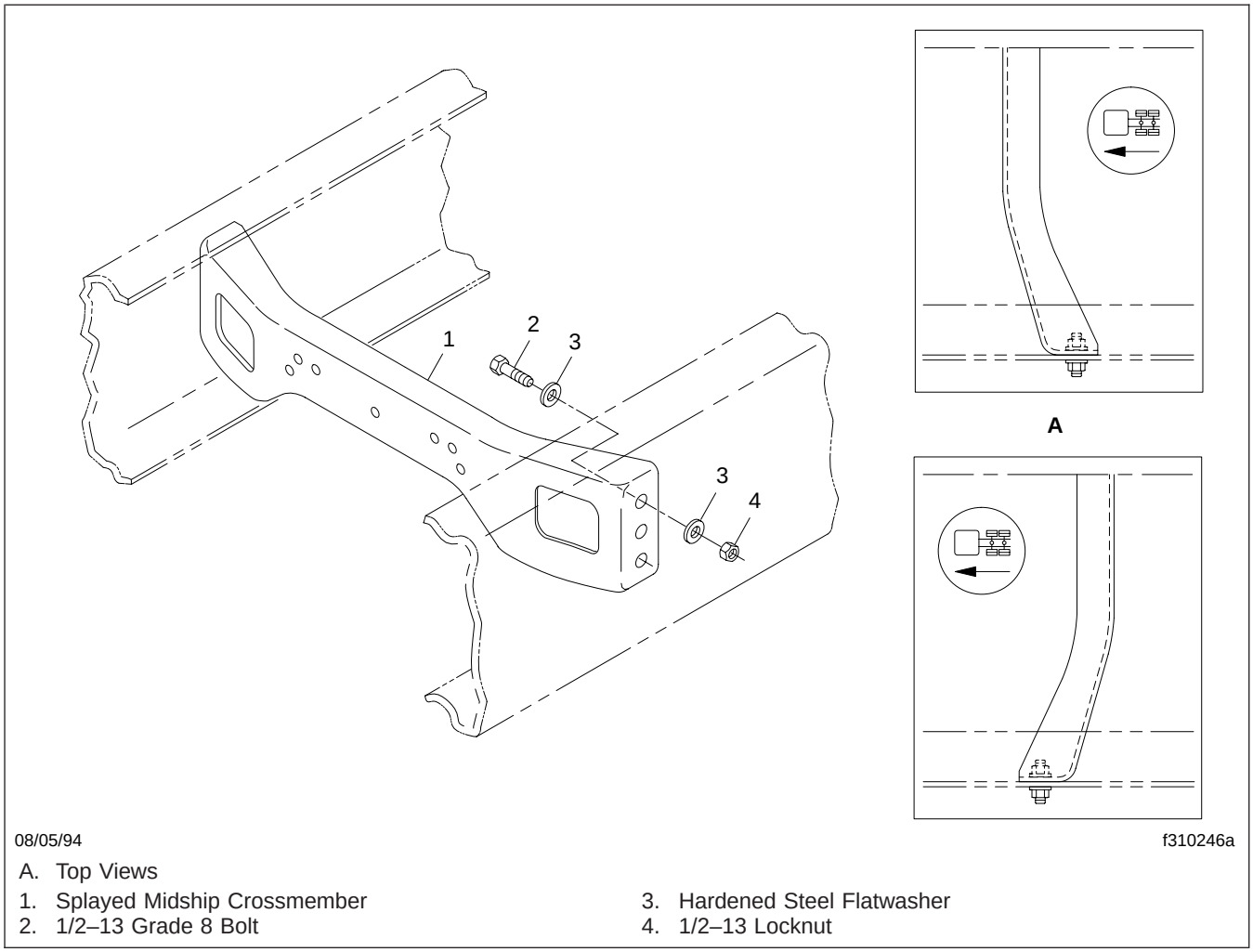
1. If they were removed, install the front angle brackets and their fasteners, but do not tighten the fasteners at this time. If applicable, install the rear suspension brackets on the springs.
2. Slide the crossmember into the opening at the rear of the frame rails. Turn it upright to position it against the front angle brackets.
3. Attach the rear angle brackets to the frame rails, but do not tighten the fasteners at this time.
4. Install but do not tighten the fasteners that attach the crossmember to the front angle brackets.
5. If they were removed from the rear-closing crossmember, install any air brake valves and securely tighten the fasteners.

   If so equipped, install the backup alarm.

   Install any clamps that attach air lines or wiring to the crossmember.

   If the leveling valve for an AirLiner suspension was removed from the crossmember, install the leveling valve. For instructions, see **Group 32** in this manual.
6. Tighten the fasteners that attach the angle brackets to the frame rails. Tighten the fasteners that attach the crossmember to the angle brackets. Tighten all fasteners 136 lbf·ft (184 N·m).

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A. Top Views
1. Splayed Midship Crossmember
2. 1/2–13 Grade 8 Bolt
3. Hardened Steel Flatwasher
4. 1/2–13 Locknut

Fig. 4, Splayed Crossmember

7. Remove the chocks from the rear tires.

SPLAYED CROSSMEMBER (See Fig. 4)

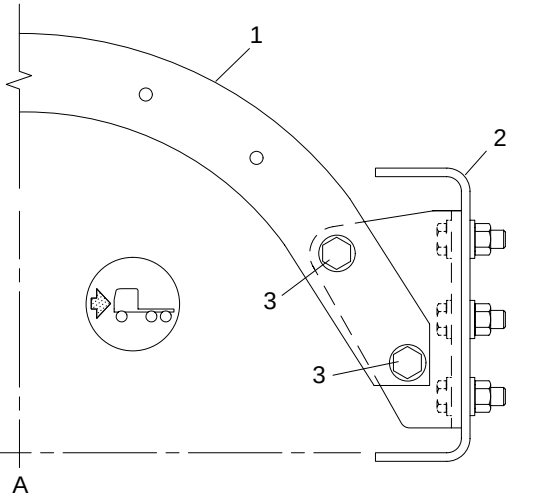
1. Install the crossmember in the frame rails with its open channel facing the same direction that was noted during removal. Align the mounting holes at one end of the crossmember with the holes in the frame rail.

NOTE: With the crossmember not straight across in the frame rails, and the holes not aligned on the opposite end, the holes at that end will be in approximate alignment.

2. Install the fasteners in that end of the crossmember and frame rail, but tighten the locknuts finger-tight only.
3. At the other end of the crossmember, use a deadblow hammer to tap against its straight side, until the crossmember is straight across in the frame rails and the mounting holes at both ends are in alignment with the holes in the frame rails.
4. If a midship bearing crossmember is being installed, install the fasteners that attach the midship bearing bracket to the crossmember. Remove the safety stands that supported the driveline.

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Crossmember Removal and Installation



03/27/96 f310534

A. Chassis Centerline
1. Overslung Crossmember
2. Left Frame Rail
3. 5/8–11 Capscrew, Flatwasher, Locknut

Fig. 5, Overslung Crossmember

5. Tighten all of the fasteners to their applicable torque values.
6. Remove the chocks from the rear tires.

OVERSLUNG CROSSMEMBER

(See Fig. 5)

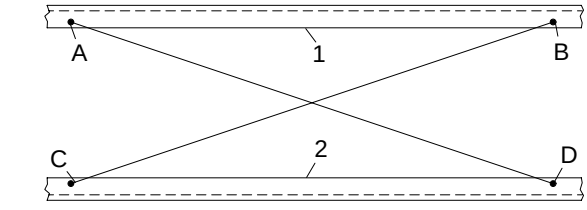
1. Rotate the new crossmember into place from the left side.
2. Place the crossmember on the rear surface of the mounting brackets.
3. Install the 5/8–11 mounting fasteners (bolt heads facing forward). Tighten the fasteners 136 lbf·ft (184 N·m).
4. Install the half-fender on the left side of the vehicle. Tighten the fasteners 12 lbf·ft (16 N·m).
5. Remove the chocks from the rear tires.

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Alignment

Frame rail alignment is checked by measuring the distances from two sets of points on the upper (or lower) flanges of the frame rails. See **Fig. 1**. The rear set of points must be as far back as possible from the forward set of points. There must be no interference, along or between the frame rails, that would prevent measuring from any one of the four points to the other three points. If the upper flanges are being used for the measurements, the fifth wheel and deck plate (as equipped) must be removed.

There are no marks or bolt holes in the upper or lower flanges of the frame rails. Therefore, the points must be projected from the frame station marks, manufacturing holes, or component attachment holes in the frame rail webs. See **Fig. 2**.



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A. Right Forward Point
B. Right Rear Point
C. Left Forward Point
D. Left Rear Point
1. Right Frame Rail
2. Left Frame Rail

Fig. 1, Frame Rail Alignment Measurement Points

IMPORTANT: Use a pencil or soapstone to make all lines, points, or other marks. Do not use any marker or tool that will scratch the surface of the frame rail. Use a machinist's square to project all points from the webs to the upper (or lower) flanges, and to measure inboard from the outside face of the frame rails.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. For each frame rail, project the exact vertical centerline of the 5/8-inch (16-mm) manufacturing hole at frame station 2628.4, from the frame web to the upper (or lower) flange, and mark it with a line across the flange.

   If, because of interference, the manufacturing hole at frame station 2628.4 cannot be used, choose and mark another matched set of points.

   2.1 Determine how far forward that the upper (or lower) flanges of both frame rails are clear.

   2.2 Find a matched set of bolt holes on the frame rail webs, that are aligned with, or just rearward of, the front of the clear area on the flanges. The bolt holes must be in exactly the same location in each frame rail.

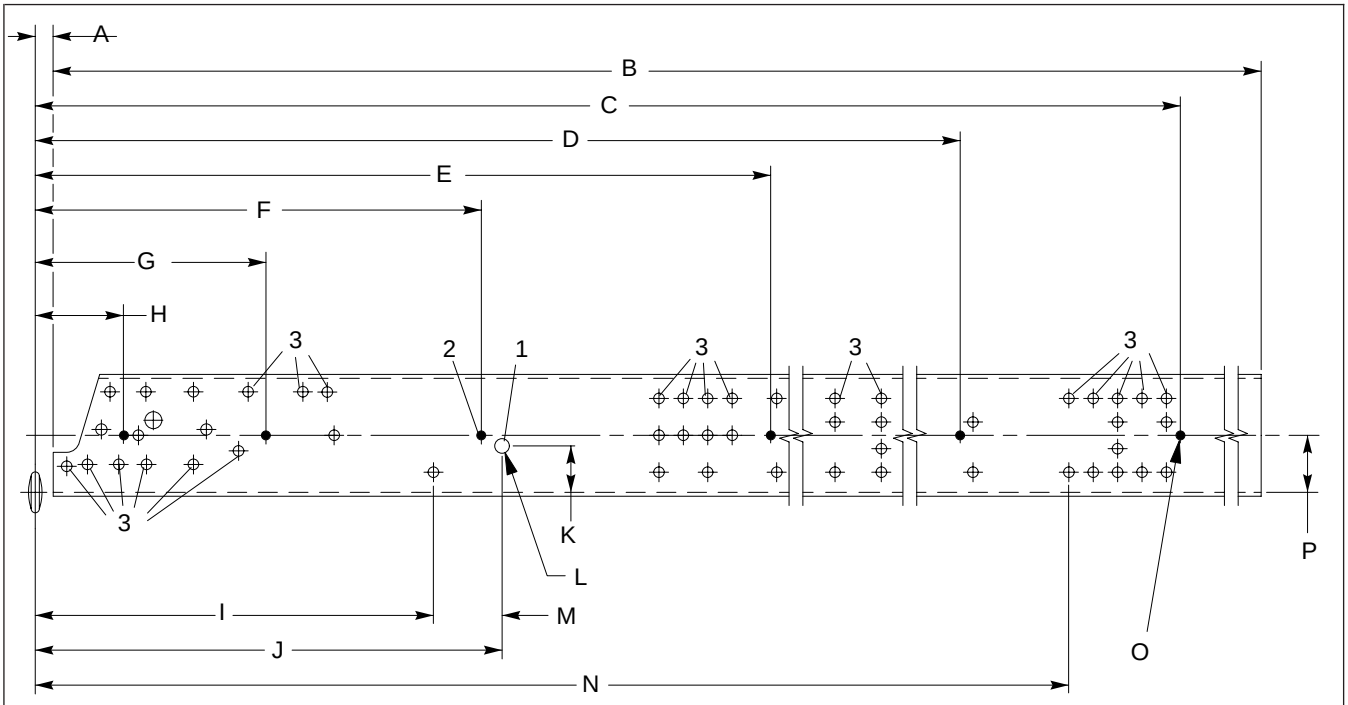
   2.3 Project the exact vertical centerline of each bolt hole, and mark a line across the upper (or lower) flange of its respective frame rail.
3. Find the exact center of the width of each flange, and mark the point on each projected line. This will be the forward set of points. The forward points must be in identical locations on both frame rails.
4. If needed and as equipped, remove the fifth wheel and deck plate. See the applicable section in this Group for instructions.
5. Measure along each frame rail, to find a set of holes *at least* 72 inches (180 cm) rearward from the forward set of points. The holes must be in exactly the same location in each frame rail.

IMPORTANT: If, because of interference, the distance must be less than 72 inches (180 cm), the distance must be the maximum that is possible.

6. Project the exact vertical centerline of each bolt hole, and mark a line across the upper (or lower) flange of its respective frame rail.
7. Along each line, measure and mark a point 2 inches (5 cm) inboard from the outside face of its respective frame rail. The rear points must be in identical locations on both frame rails.
8. Measure the distance from the forward point on one frame rail to the rear point on the opposite frame rail. See **Fig. 1**. Measure the distance from the other forward point to the rear point on its opposite frame rail. Compare the two measurements.

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Frame Rail Alignment



A. 1.5748 in (40 mm)
B. ±0.197 in (Length ±5 mm)
C. 103.480 in (2628.4 mm)
D. 85.480 in (2171.2 mm)
E. 61.480 in (1561.6 mm)
F. 37.480 in (952 mm)
G. 19.480 in (494.8 mm)
H. 7.480 in (190 mm)
I. 33.4646 in (850 mm)
J. 39.3701 in (1000 mm)
K. 3-3/4 in (95.5 mm)
L. 1-1/16 in (27 mm) Diameter
M. 5.9055 in (150 mm)
N. 94.4882 in (2400 mm)
O. 5/8 in (16 mm) Diameter
P. 4-3/4 in (120.5 mm)

1. Hole at Frame Station 1000
2. 6 Each Manufacturing Holes
3. Component Mounting Holes

Fig. 2, Frame Rail Hole Distances, Left-Side Shown, Right-Side Opposite

If the values differ by more than 1/8 inch (3 mm), proceed with the next step.

If the measurements are within 1/8 inch (3 mm) of each other, the frame rails do not need to be aligned. Go to the step for fifth wheel and deck installation.

9. Loosen *all* of the frame fasteners enough to allow movement of the parts when force is applied.

IMPORTANT: To align the frame rails, the frame must have all of the crossmembers in place, but the attachment fasteners should *not* be tightened.

10. Using a large hammer and a large wooden block, place the block against the rear end of the frame rail that had its rear point the greater distance from its opposite rail's front point. Tap the block until the measurements are within 1/8 inch (3 mm) of each other.
11. Tighten all of the frame fasteners, starting at the middle of the frame and working alternately toward both ends. Tighten all fasteners to their applicable torque values. For instructions, see **Group 00**.
12. Again, check the frame rail alignment.

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13. When the measurements are within specifications, install the fifth wheel and deck plate (as equipped). For instructions, see the applicable section in this Group.
14. If the frame rails needed aligning, check the axle alignment. For instructions, see the appropriate suspension section in **Group 32**.
15. Remove the chocks from the rear tires.

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Frame Fasteners

Either Huckbolts® or grade 8 hexhead bolts and grade C prevailing torque locknuts are used for frame attachments. See **Fig. 1** and **Fig. 2**. For attachments where clearance is minimal, low-profile hexhead bolts and grade C prevailing torque locknuts are used. For some components, grade 8.2 flanged hexhead bolts and grade G prevailing torque locknuts are used for frame attachments. See **Fig. 3**. Prevailing torque locknuts of all three bolt types have distorted sections of threads to provide torque retention.

When nonflanged hexhead bolts and locknuts are used on an attached aluminum part, a hardened flatwasher is required to prevent the bolt head or nut from embedding in the part.In general, hardened washers are used to distribute the load, and to prevent localized overstressing of the frame rails, brackets, and other parts. They are placed directly against the part, under the nut or bolt head. These special hardened washers are used on frame rails, and for the engine rear supports, rear suspension brackets, and fifth wheel mountings. They are cadmium-or zinc-plated, and have a hardness rating of 38 to 45 HRC.

Flanged hexhead bolts and locknuts have integral flanges which eliminate the need for washers on steel and aluminum surfaces.The fasteners are placed directly against the frame where the part is attached.

HEXHEAD BOLT REPLACEMENT

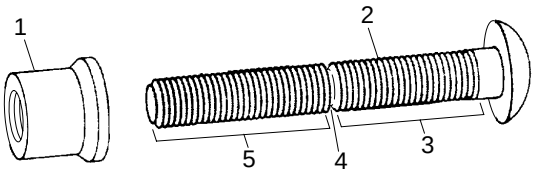
Replace hexhead bolts and locknuts with identical fasteners. See the *Sterling Parts Book* for fastener specifications.

Apply Alumilastic® compound, or an equivalent, to all bolts, nuts, and washers that contact aluminum parts.

⚠ CAUTION

Failure to apply Alumilastic compound or an equivalent, to areas where aluminum and steel parts contact each other could lead to corrosion of the metals, resulting in damage to the frame or parts.

Never hammer or screw bolts into place. Align the holes of the frame and the part being attached to it, so that the nut and bolt surfaces are flush against the frame and the part. For bolts 4 inches (102 mm) or less in length, make sure that at least 1-1/2 threads and no more than 5/8-inch (16 mm) bolt length extend through the self-locking nut after it has been tightened. For bolts longer than 4 inches (102 mm), allow a minimum of 3 threads and a maximum of 3/4-inch (19-mm) bolt length.



04/23/93 f230018

1. Collar
2. Huckbolt
3. Locking Grooves
4. Breakneck
5. Pulling Grooves

Fig. 1, Huckbolt Fastener

HUCKBOLT REMOVAL

Huckbolt HP 8® frame fasteners have parallel locking grooves on the lockbolt pintail. See **Fig. 1**. The swaged collar cannot be unscrewed. Use the Huck Collar Cutter to remove HP8 fasteners. If the Collar Cutter is not available, split the collar with an air chisel while supporting the opposite side of the collar with an anvil. See **Fig. 4**. Drive out the lockbolt with a punch. Discard the fastener after removing it.

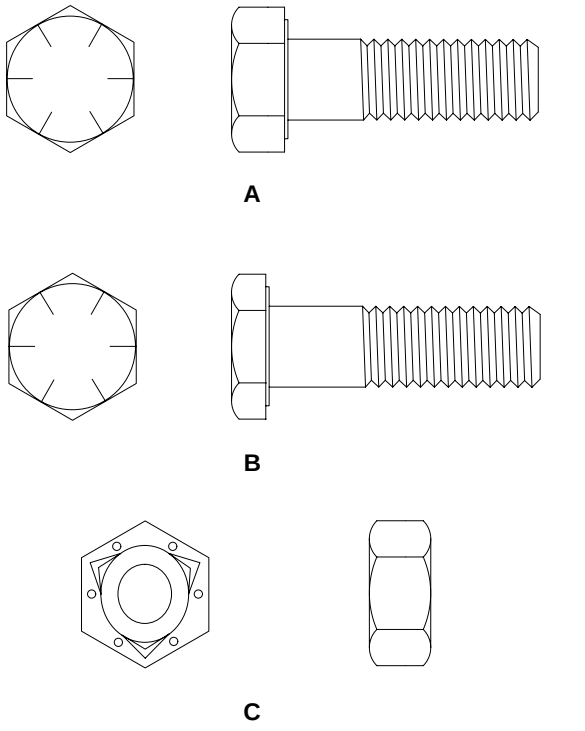
HUCK-FIT® frame fasteners have locking threads instead of grooves; the collar can be removed using a standard impact wrench and sockets. Discard the fastener after removing it.

⚠ CAUTION

Never attempt to reuse any Huck fastener that has been removed. Even though HUCK-FIT fasteners can be removed with a socket wrench, they cannot be correctly installed again. Reusing any Huck frame fastener can result in damage to the vehicle frame or components attached to the frame.

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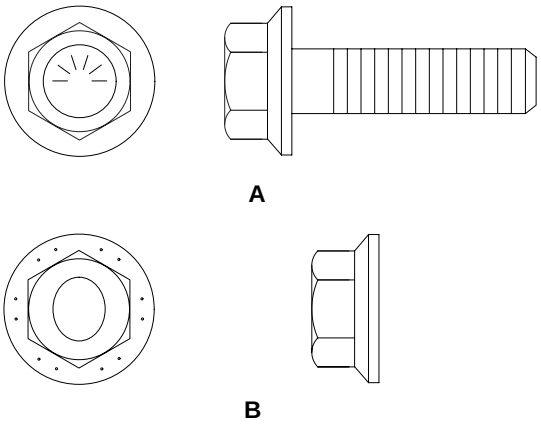
Frame Fasteners



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A. Grade 8 Hexbolt
B. Grade 8 Low-Profile Hexbolt
C. Grade C Prevailing Torque Locknut

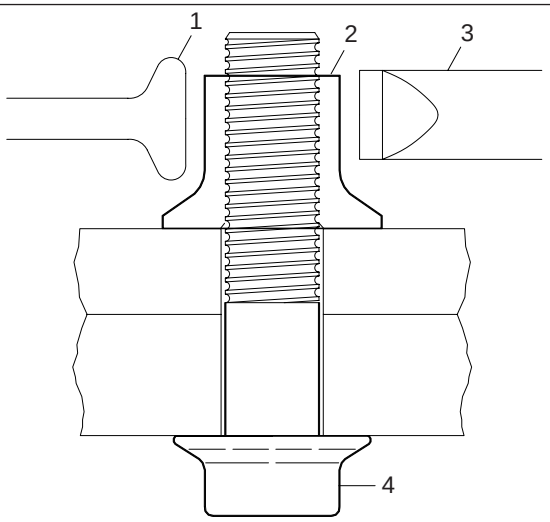
Fig. 2, Hexhead Fasteners



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A. Grade 8.2 Flanged Bolt
B. Grade G Prevailing Torque Locknut

Fig. 3, Flanged Hexhead Fasteners



08/15/95 f310081b

1. Anvil
2. Lockbolt Collar
3. Chisel
4. Lockbolt

Fig. 4, Huckbolt Removal

HUCKBOLT INSTALLATION

NOTE: Huckbolts cannot be installed without the proper Huckbolt installation equipment.

1. Insert the pintail through the prepared hole in the frame or other component. See **Fig. 5**.
2. Place the collar over the pintail.
3. Place the Huck installation tool nose assembly over the pintail. See **Fig. 6**. The pintail pulling grooves ratchet into the chuck jaws which securely grip the pintail.
4. As the installation tool trigger is pulled, the tool piston and chuck jaws move rearward, pulling on the pintail, seating the bolt head and closing the gap between the work surfaces. As pulling on the pintail continues, the collar is swaged into the locking grooves on the pintail; and the collar is lengthened, developing clamping force. See **Fig. 7**.
5. The pintail breaks, freeing the nose assembly anvil from the swaged collar. See **Fig. 8**.

NOTE: Most Huck fasteners have a constriction, the breakneck, which determines the point

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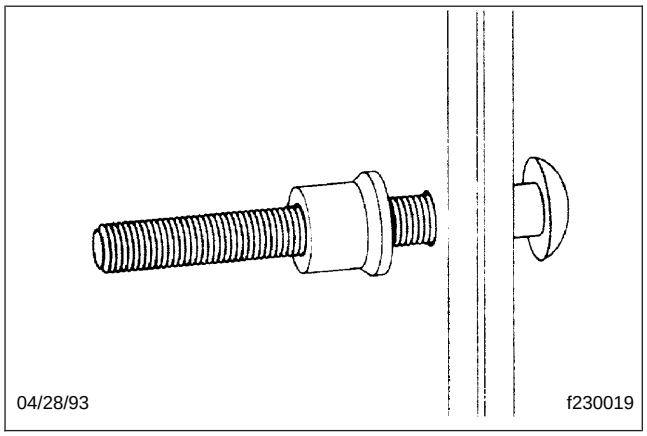


Fig. 5, Pintail and Collar

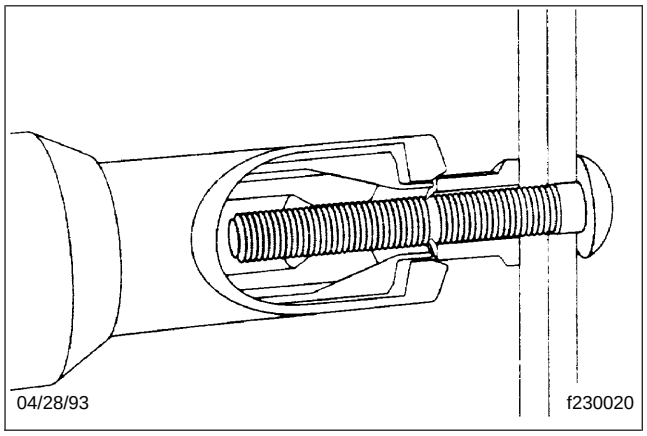


Fig. 6, Huck Installation Tool Nose on Pintail

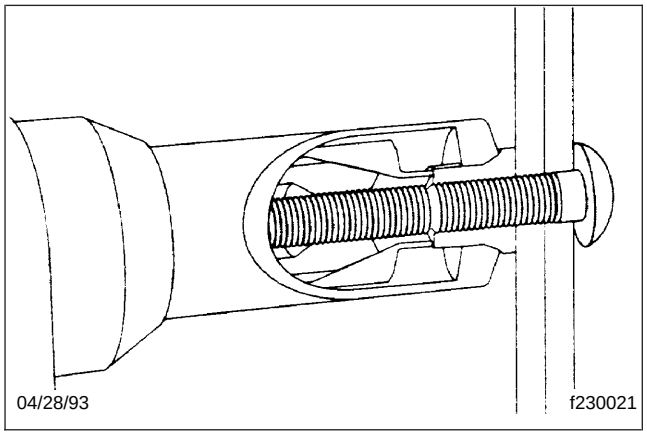


Fig. 7, Locking the Collar on the Huckbolt

where the pintail breaks free. See **Fig. 1**. MAGNA-GRIP® fasteners do not have this breakneck; the pintail should break flush with the top of the collar. No more than two grooves should be visible on the collar after installation. See **Fig. 9** for examples of acceptable and unacceptable MAGNA-GRIP pintail breaks.

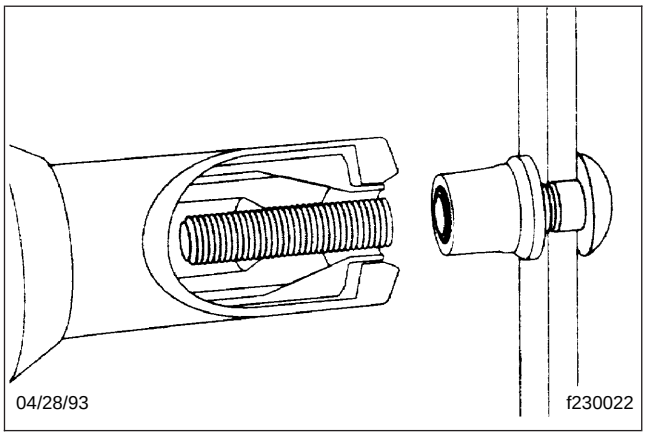


Fig. 8, Breaking the Pintail

FRAME FASTENER TIGHTENING

⚠ CAUTION

Continued vehicle operation with loose fasteners could result in component, bracket and frame damage.

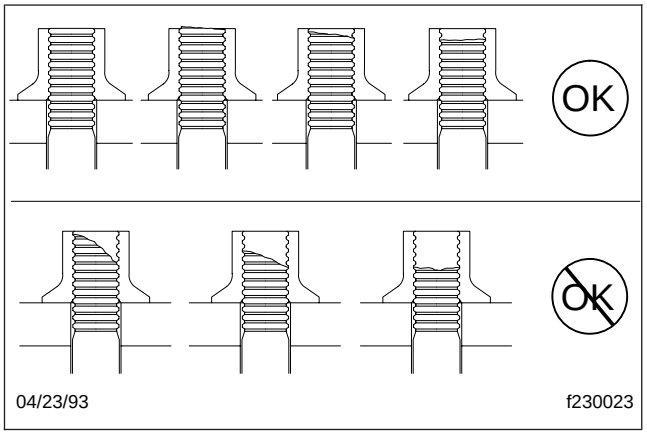


Fig. 9, Pintail Break Examples

Tighten hexhead bolts and locknuts periodically to offset the effects of "bedding in" (seating). See the

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Frame Fasteners

Maintenance Schedule and Group 31 in the *Acterra Maintenance Manual* for intervals.

When tightening the fasteners, tighten the nut, not the bolt head. This will give a true torque reading by eliminating bolt body friction. For torque specifications, see Group 00 in the *Acterra Maintenance Manual*.

NOTE: Huck fasteners do not require periodic tightening.

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General Information

MODEL XA–351 TOP PLATE

NOTE: The part number prefix for the stationary fifth wheel is FW35.

The Holland 3500 series XA–351 fifth wheels are applicable for general over-the-road use. They are designed to pull trailers having a 2-inch SAE J700b kingpin. They have a capacity of 150,000 lbf (667 000 N) maximum drawbar pull and 55,000 lbf (244 652 N) maximum vertical load. These fifth wheels are available in two different mounting assemblies: the Kompensator®; and the stationary mount.

The stationary mount fifth wheels are available with four different mounting bracket styles, which include:

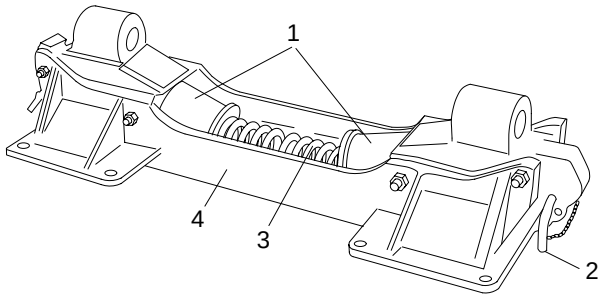
- A bracket with a mounting base for over-the-frame mounting;
- A bracket with a mounting angle for over-the-frame mounting;
- A bracket for angle mounting (designed to be welded to the angle) for over-the-frame mounting;
- And, a bracket for outboard angle mounting.

The mounting brackets use nylon-lined "up-shock" bushings. These fifth wheels come in a variety of heights to accommodate many applications.

The Kompensator fifth wheel is equipped with a stationary mounting bracket. This fifth wheel is designed for rigid trailers that do not flex during torsional loading. It provides torsional stress relief and promotes vehicle stability with trailers that have an unusually high center of gravity (where the center of gravity is up to 44 inches [111 cm] above the top plate surface). This unique cradle design provides side-to-side movement to help relieve the torque and twist of the trailer. Spring cushions act as a restoring force to provide stability after absorbing the strain and pressure of the load. Additionally, it keeps the center of compensation above the fifth wheel bearing surface and centered between the frame rails. All models are available with an optional "lock-out" feature to restrict compensation for applications that do not require compensation. See **Fig. 1**.

The 3500 series top plate consists of:

- The cast steel top plate;
- The bracket pin mount;



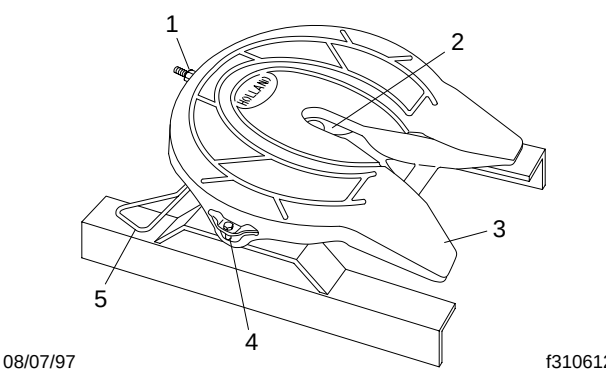
09/08/97 f310627

1. Urethane Cushions
2. Optional Lockout
3. Compression Springs
4. Kompensator Cradle Design Mounting Bracket

Fig. 1, The Kompensator Cradle

- The release handle;
- The infinite lock adjustment nut;
- And the kingpin lock mechanism.

See **Fig. 2**.



08/07/97 f310612

1. Infinite Lock Adjustment Nut
2. Kingpin Lock
3. Cast Steel Top Plate
4. Bracket Pin Mount
5. Release Handle

Fig. 2, XA-351 Fifth Wheel

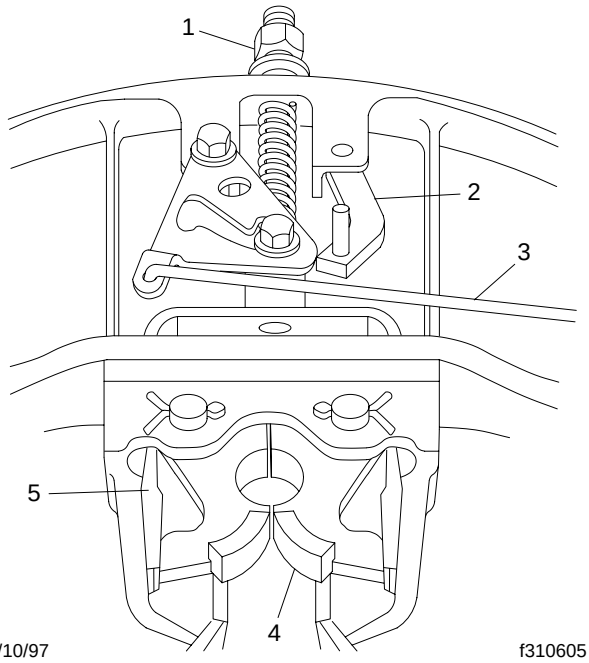
The kingpin lock mechanism consists of:

- The infinite lock adjustment nut;
- The secondary lock;
- The release handle;
- The type "B" forged steel split lock;
- And, the yoke.

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General Information

See **Fig. 3**.



1. Infinite Lock Adjustment Nut
2. Secondary Lock (Automatic Shown)
3. Release Handle
4. Lock Jaws
5. Yoke

Fig. 3, Kingpin Lock Mechanism (bottom view)

When the yoke is retracted, the two spring-loaded lock halves separate as the kingpin enters the lock mechanism. When the yoke engages, the final forward motion of the kingpin forces the lock to close in a 360 degree grip around the shoulder and neck of the kingpin. After the yoke is engaged (positioned between the lock halves and the tapered rib members of the top plate casting), the secondary lock moves behind the yoke. For fifth wheels with an automatic secondary lock, the kingpin is released by manually operating the release handle. For fifth wheels with a manual secondary lock, the kingpin is released by pulling the secondary release handle, hooking the secondary release handle to the top plate casting and manually operating the primary release handle. For high coupling protection, a one step rear lock is incorporated into the split lock. For increased durability of the kingpin lock mechanism, the infinite lock adjustment positions are available to compensate for wear in both the kingpin and the lock jaws.

See the *Acterra Driver's Manual* for complete operating instructions.

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Model XA–351 Top Plate Removal and Disassembly

⚠ WARNING

All fifth wheel maintenance, adjustment, and rebuilding must be done only by a qualified mechanic. Improper or incomplete procedures could result in loss of trailer connection during vehicle travel, possibly causing bodily injury and property damage.

Fifth wheel rebuild kits are available for servicing the 3500 series XA–351 fifth wheels. For the rebuild kits, the part numbers include:

- RK–351AL (left-side release with automatic secondary lock);
- RK–351A02L (left-side release with manual secondary lock);
- RK–351A (right-side release with automatic secondary lock);
- RK–351A02 (right-side release with manual secondary lock).

These fifth wheel rebuild kits contain all the replacement parts, except: the fifth wheel top plate, the bracket assembly rubber bushings, the bracket assembly bushing pins, and the bracket assembly bushing pin capscrews and locknuts. See **Fig. 1**.

Rebuilding the fifth wheel may be unnecessary. Review **Troubleshooting, 300** before rebuilding the fifth wheel. If the troubleshooting section does not correct the problem, then the fifth wheel may need rebuilding.

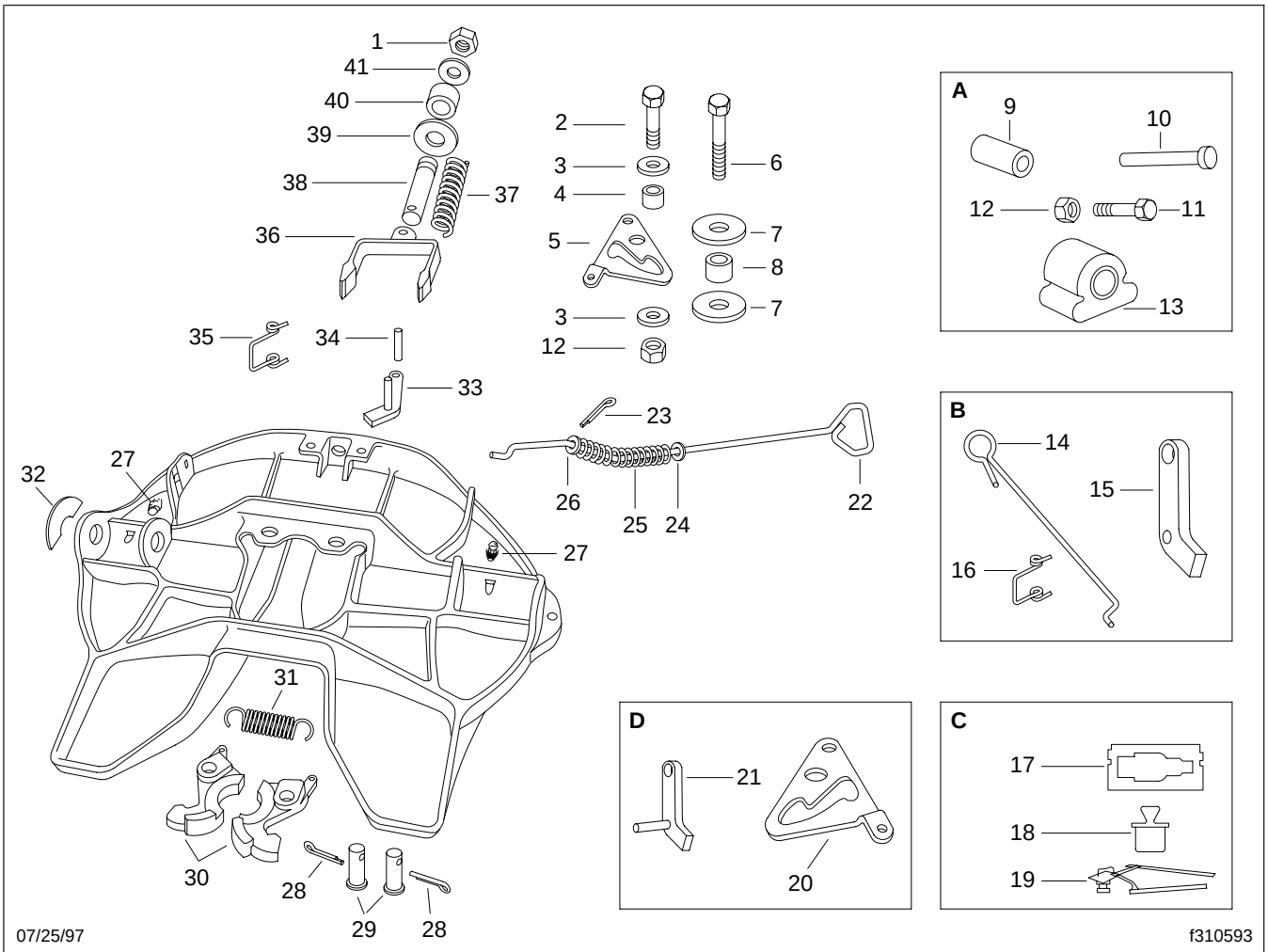
While disassembling the fifth wheel, check it for cracks and for missing or damaged parts. Discard all used components.

Removal and Disassembly

1. Steam clean the top plate.
2. Remove the top plate from the bracket assembly.
   - 2.1 Loosen and remove the 1/2–20 bushing pin capscrews and locknuts from the top plate.
   - 2.2 Remove the bushing pins from the bracket assembly. See **Fig. 2**.
   - 2.3 Using an overhead hoist, lift the fifth wheel from the bracket assembly and tractor frame.
3. Disassemble the secondary lock.
   - 3.1 Turn the fifth wheel upside down with the locks open.
   - 3.2 Using a suitable driver and hammer, drive the 1/2-inch by 2-3/4 inch roll pin from the top plate and the secondary lock. See **Fig. 3**.
   - 3.3 If the fifth wheel has an automatic secondary lock, proceed to the next substep, otherwise, remove the manual secondary release handle by passing the "S" bend of the release handle through the large hole in the secondary lock and then through the guide hole. See **Fig. 4**.
   - 3.4 Remove the secondary lock.
4. Disassemble the cam plate.
   - 4.1 Loosen and remove the 5/8-inch capscrew from the threaded hole in the yoke. Remove the washers, and the roller from the cam plate. See **Fig. 5**.
   - 4.2 Loosen and remove the 1/2-inch capscrew and nut from the top plate lug. Remove the washers, and the roller from the cam plate. See **Fig. 6**.
   - 4.3 Remove the release handle by passing the "S" bend of the release handle through the large hole in the raised tab of the cam plate and through the top plate casting hole. See **Fig. 6**.
5. Disassemble the yoke.
   - 5.1 Slide the yoke shaft assembly away from the yoke, through the compression spring, and out of the top plate casting. See **Fig. 7**.
   - 5.2 Remove the compression spring and remove the yoke.
6. Disassemble the lock.
   - 6.1 Remove the cotter pins from the lockpins.
   - 6.2 Using a suitable driver and hammer, drive the lockpins out of the casting. See **Fig. 8**. This will free the lock jaws assembly. Remove the lock jaws and lock spring.

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Model XA–351 Top Plate Removal and Disassembly



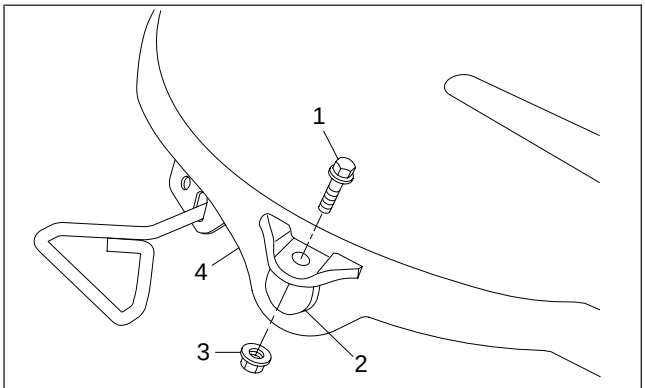
A. Bushing Pin Assembly
B. Manual Secondary Lock Assembly
C. Fifth Wheel Accessories
D. Right Hand Secondary Lock Assembly

1. Locknut, 3/4–16
2. Capscrew, 1/2–20 x 1–3/4
3. Washer, 1–3/4" o.d. x 9/16" i.d.
4. Roller, 1/2" i.d.
5. Cam Plate (left-hand)
6. Capscrew, 5/8–18 x 3/4
7. Washer, 2–5/8 x 21/32
8. Roller, 5/8" i.d.
9. Rubber Bushing (brackets manufactured prior to 5/82)
10. Bracket Bushing Pin
11. Capscrew, 1/2–20 x 1–1/4
12. Locknut, 1/2–20
13. Rubber Bushing (brackets manufactured after 5/82)
14. Manual Secondary Lock Release Handle
15. Manual Secondary Lock
16. Torsion Spring
17. Kingpin Gauge
18. 2" Lock Gauge (Plug)
19. Kingpin Lock Tester
20. Cam Plate (right-hand)
21. Secondary Lock (right-hand)
22. Release Handle
23. Cotter Pin, 1/8 x 1–1/4
24. Washer, 1–3/8" o.d. x 9/16" i.d.
25. Compression Spring
26. Washer, 1–1/16" o.d. x 5/8" i.d.
27. Grease Zerk
28. Cotter Pin, 1/4 x 2
29. Lockpin
30. Lock Jaw Set
31. Extension Spring
32. Operation Tag
33. Secondary Lock (left-hand)
34. Roll Pin, 1/2 x 2–3/4
35. Torsion Spring
36. Yoke
37. Compression Spring
38. Yoke Shaft
39. Lock Adjustment Tag
40. Rubber Washer
41. Washer, 1–1/2" o.d. x 13/16" i.d.

Fig. 1, Holland 3500 Series XA-351 Fifth Wheel and Accessories (bottom view)

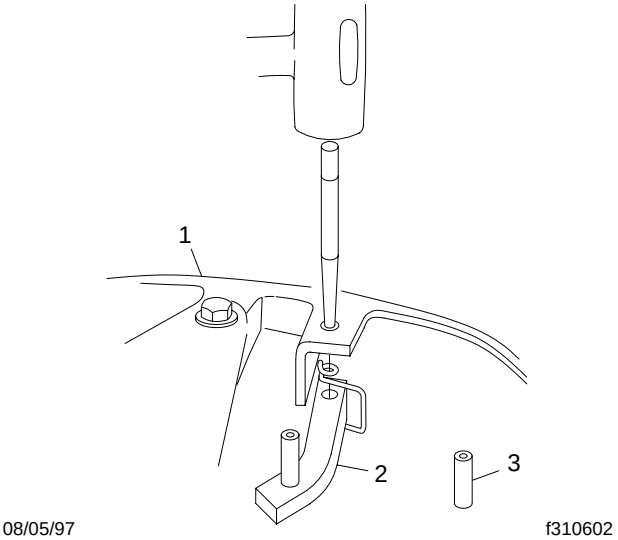
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Model XA–351 Top Plate Removal and Disassembly



1. Capscrew
2. Bushing Pin
3. Locknut
4. Top Plate

Fig. 2, Remove the Bushing Pin

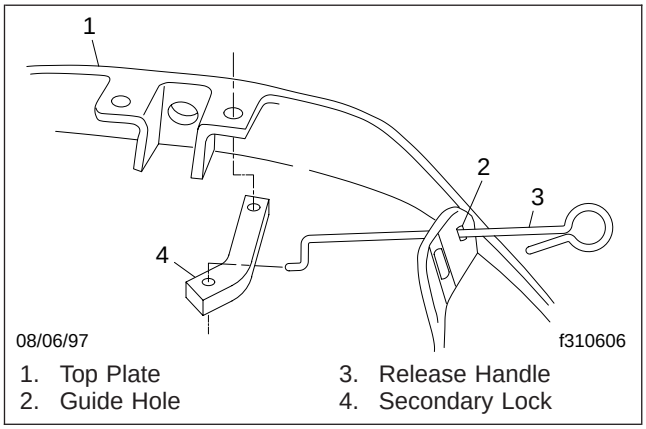


1. Top Plate
2. Secondary Lock
3. Roll Pin

Fig. 3, Disassemble the Secondary Lock

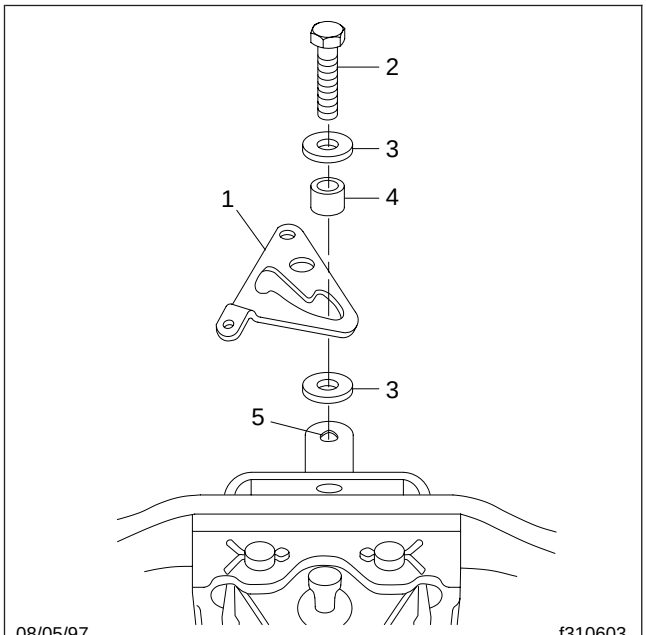
⚠ WARNING

Do not attempt to repair or rebuild the top plate if it is cracked or if the lockpin does not fit tightly. The top plate could fail or the locks could malfunction. This could result in loss of trailer connection during vehicle travel, possibly causing bodily injury and property damage.



1. Top Plate
2. Guide Hole
3. Release Handle
4. Secondary Lock

Fig. 4, Remove the Release Handle

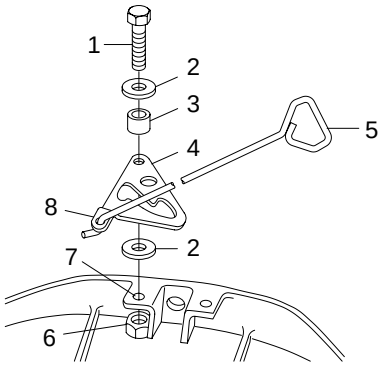


1. Cam Plate
2. Capscrew, 5/8–20
3. Washer
4. Roller
5. Threaded Hole In Yoke

Fig. 5, Remove the Capscrew From the Yoke

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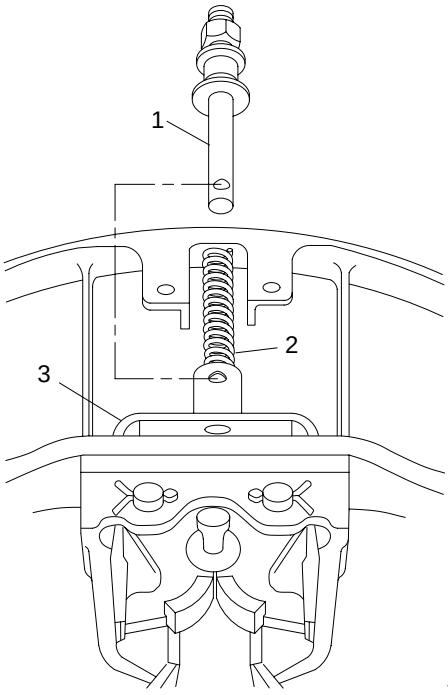
Model XA–351 Top Plate Removal and Disassembly



08/05/97 f310604

1. Capscrew, 1/2–20
2. Washer
3. Roller
4. Cam Plate
5. Release Handle
6. Nut, 1/2–20
7. Top Plate Lug
8. Raised Tab

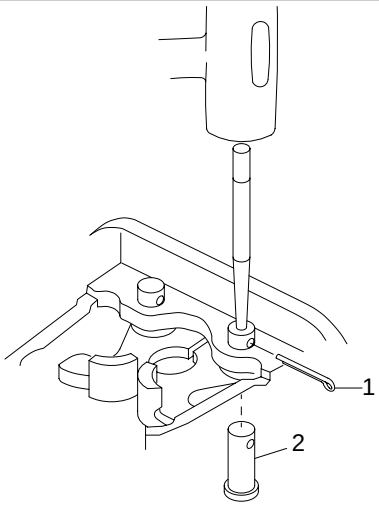
Fig. 6, Disassemble the Cam Plate



08/04/97 f310600

1. Yoke Shaft Assembly
2. Compression Spring
3. Yoke

Fig. 7, Remove the Yoke Shaft Assembly



08/06/97 f310608

1. Cotter Pin
2. Lockpin

Fig. 8, Remove the Lockpins

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Model XA–351 Top Plate Assembly and Installation

WARNING

All fifth wheel maintenance, adjustment and rebuilding must be done only by a qualified mechanic. Improper or incomplete procedures could result in loss of trailer connection during vehicle travel, possibly causing bodily injury and property damage.

Fifth wheel rebuild kits are available for servicing the 3500 series XA–351 fifth wheels. For the rebuild kits, the part numbers include:

- RK–351AL (left-side release with automatic secondary lock);
- RK–351A (right-side release with automatic secondary lock);
- RK–351A02L (left-side release with manual secondary lock);
- RK–351A02 (right-side release with manual secondary lock).

These fifth wheel rebuild kits contain all the replacement parts, except: the fifth wheel top plate, the bracket assembly rubber bushings, the bracket assembly bushing pins and the bracket assembly bushing pin capscrews and locknuts.

Review **Troubleshooting, 300** before rebuilding the fifth wheel. Rebuilding may be unnecessary.

IMPORTANT: Use only Holland rebuilding kits. Replace all roll pins, springs, capscrews, nuts and washers that are included in the kit. Do not reuse all parts.

WARNING

Use only genuine Holland parts and do not modify, change or add to the product. Any alterations to the fifth wheel assembly could compromise its performance. This could result in the loss of the trailer connection during vehicle travel, possibly causing bodily injury and property damage.

Assembly and Installation

WARNING

Do not attempt to repair or rebuild the top plate if it is cracked or distorted or if the lockpin does not fit tightly. The top plate could fail or the locks could malfunction. This could result in loss of trailer connection during vehicle travel, possibly causing bodily injury and property damage.

1. Inspect the top plate. See **Fig. 1**.
   - 1.1 If necessary, turn the fifth wheel upside down.
   - 1.2 Inspect the front lock surface for burrs or cracks. See **Fig. 2**. The front lock surface must be free of any burrs or cracks.
2. Install the lock.
   - 2.1 Lubricate the lockpin holes of the lock jaws with Never-Seez® (provided in the kit). See **Fig. 3**.

CAUTION

Use only Never-Seez®. Other lubricants can damage the lockpin holes.

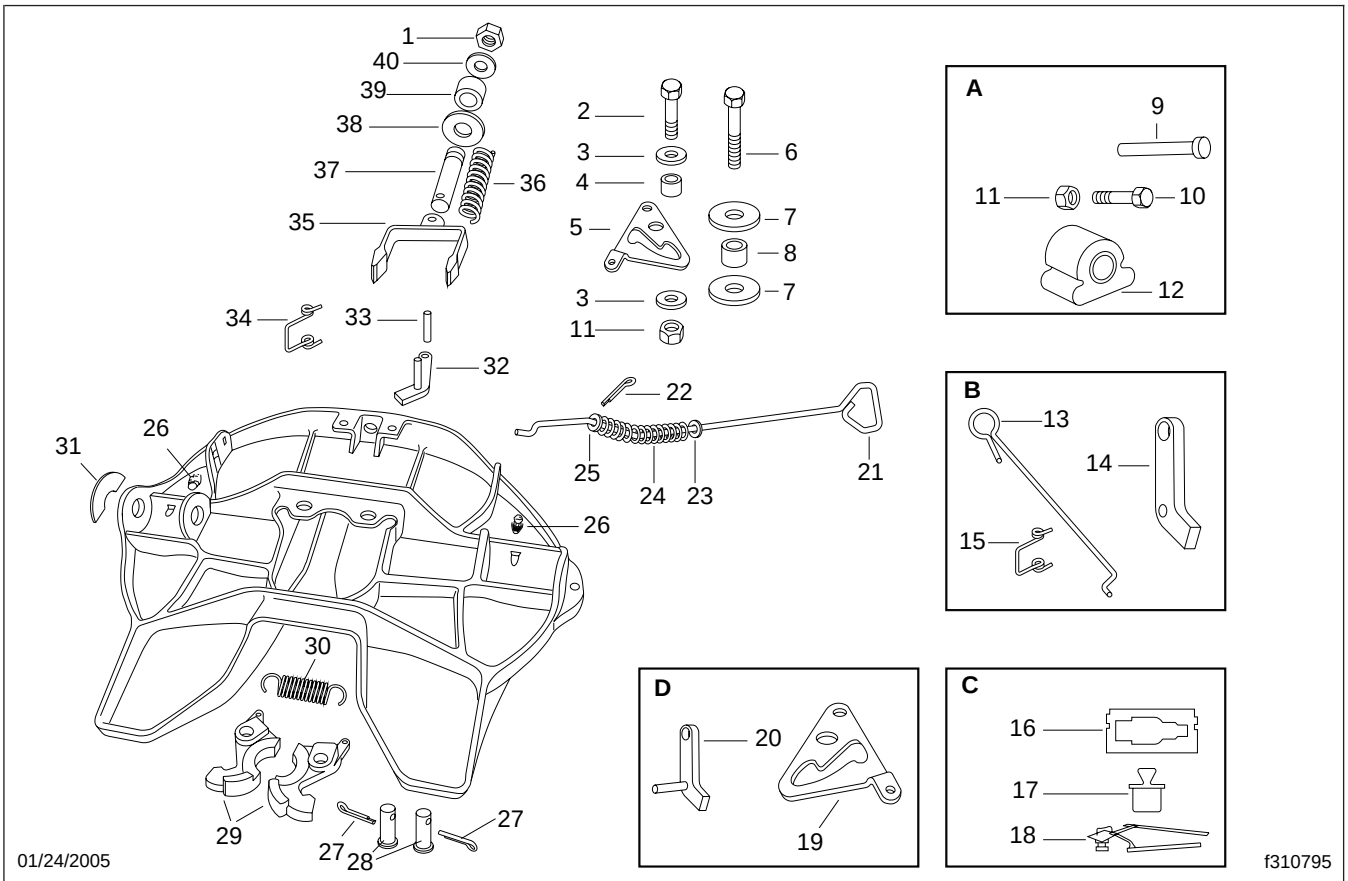
   - 2.2 Align the lock jaws in the casting and position the lock jaws so that the raised edge of the kingpin guides are facing up. See **Fig. 4**.
   - 2.3 Align the holes in the lockpins so that the cotter pins can be inserted. Insert the lockpins into the casting and through the lock jaws. Using a suitable hammer, drive the lockpins into the casting until the heads are flush with the casting. See **Fig. 5**.
   - 2.4 Insert the cotter pins and spread.
   - 2.5 Check that the lock jaws move freely.

WARNING

You must use a Holland lock gauge (TF–0237) or a precision plug that is 2.000 ± 0.005 inch (5.08 ± 0.0127 cm) for proper installation of the locking mechanism. If the proper plug is not used, the lock could malfunction or fail. This could result

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Model XA–351 Top Plate Assembly and Installation



A. Bushing Pin Assembly
B. Manual Secondary Lock Assembly
C. Fifth Wheel Accessories
D. Right-Side Secondary Lock Assembly

1. Locknut, 3/4–16
2. Capscrew, 1/2–20 x 1-3/4
3. Washer, 1-3/4 Inch o.d. x 9/16 Inch i.d.
4. Roller, 1/2 Inch i.d.
5. Cam Plate (left-side)
6. Capscrew, 5/8–18 x 3/4
7. Washer, 2-5/8 x 21/32
8. Roller, 5/8 Inch i.d.
9. Bracket Bushing Pin
10. Capscrew, 1/2–20 x 1-1/4
11. Locknut, 1/2–20
12. Rubber Bushing
13. Manual Secondary Lock Release Handle
14. Manual Secondary Lock
15. Torsion Spring
16. Kingpin Gauge
17. 2 Inch Lock Gauge (Plug)
18. Kingpin Lock Tester
19. Cam Plate (right-side)
20. Secondary Lock (right-side)
21. Release Handle
22. Cotter Pin, 1/8 x 1-1/4
23. Washer, 1-3/8 Inch o.d. x 9/16 Inch i.d.
24. Compression Spring
25. Washer, 1-1/16 Inch o.d. x 5/8 Inch i.d.
26. Grease Zerk
27. Cotter Pin, 1/4 x 2
28. Lockpin
29. Lock Jaw Set
30. Extension Spring
31. Operation Tag
32. Secondary Lock (left-side)
33. Roll Pin, 1/2 x 2-3/4
34. Torsion Spring
35. Yoke
36. Compression Spring
37. Yoke Shaft
38. Lock Adjustment Tag
39. Rubber Washer
40. Washer, 1-1/2 Inch o.d. x 13/16 Inch i.d.

Fig. 1, Holland 3500 Series XA-351 Fifth Wheel and Accessories (bottom view)

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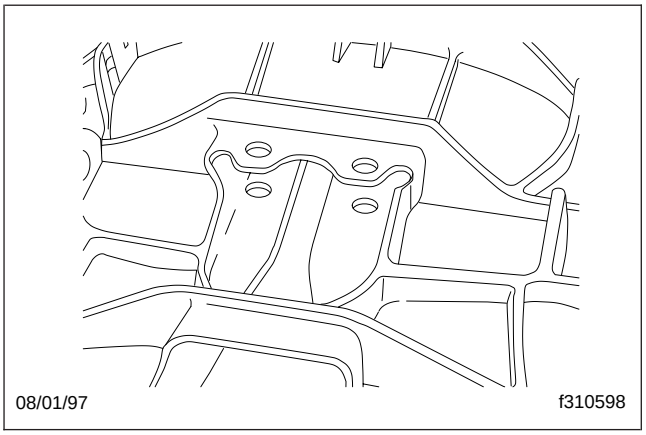
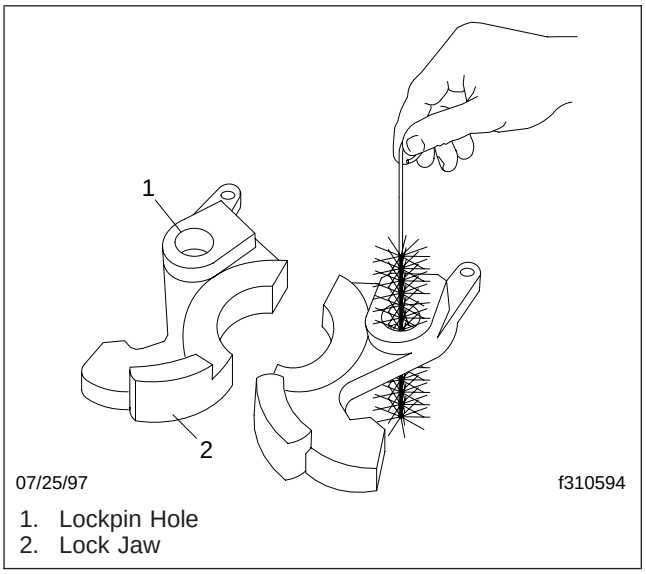


Fig. 2, Front Lock Surface Inspection



1. Lockpin Hole
2. Lock Jaw

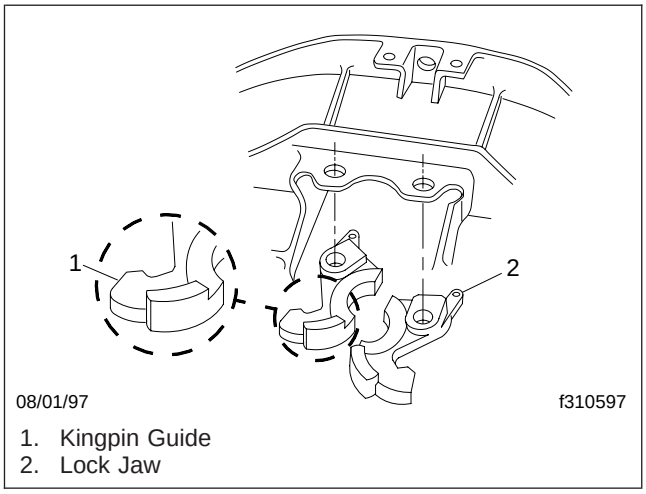
Fig. 3, Lubricate the Lockpin Holes

in the loss of the trailer connection during vehicle travel, possibly causing personal injury and property damage.

2.6 Position a 2-inch (5.08-cm) diameter "plug" into the lock jaws. See **Fig. 6**. A lock gauge, Holland part number TF–0237, is available at a Holland distributor.

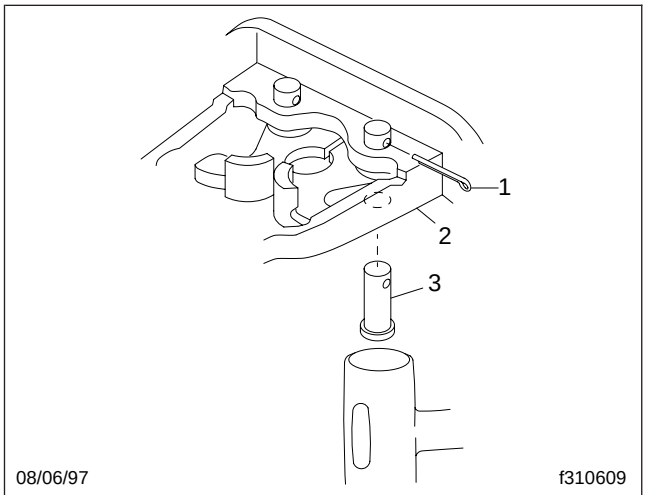
3. Install the yoke.

3.1 Lubricate the surface area of the yoke tips with light grease. With the threaded



1. Kingpin Guide
2. Lock Jaw

Fig. 4, Align the Lock Jaws



1. Cotter Pin, 1/4 x 2
2. Top Plate Casting
3. Lockpin

Fig. 5, Install the Lockpins

hole facing up, slide the yoke into the casting and seat it around the locks. See **Fig. 7**.

3.2 Inspect the amount of yoke tip engagement. Yoke tips must extend flush with the end of the locks and no more then 1/2 inch (12.7 mm) past the locks. See **Fig. 8**. If the new yoke extends more than 1/2 inch (12.7 mm) past the locks, *do not use it*. Discard it and order part number

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Model XA–351 Top Plate Assembly and Installation

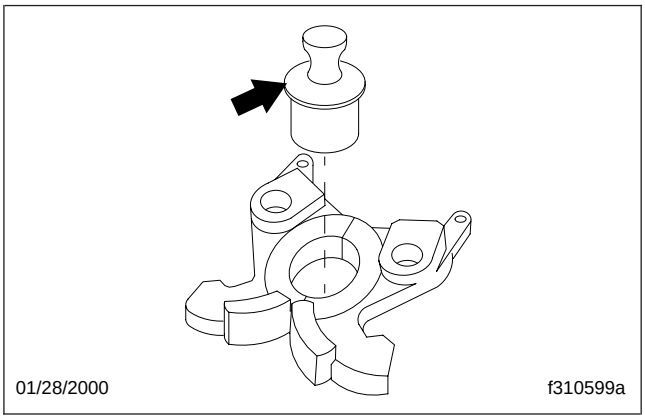
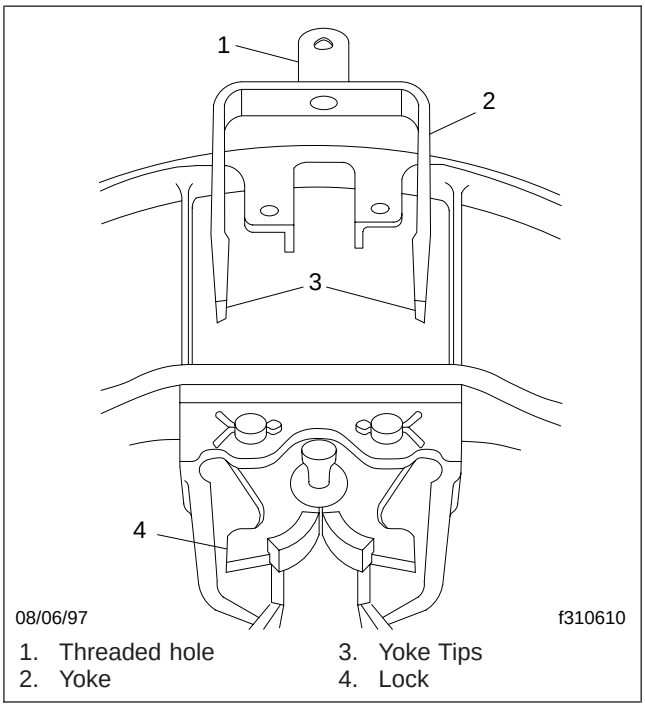


Fig. 6, Lock Gauge (Plug)



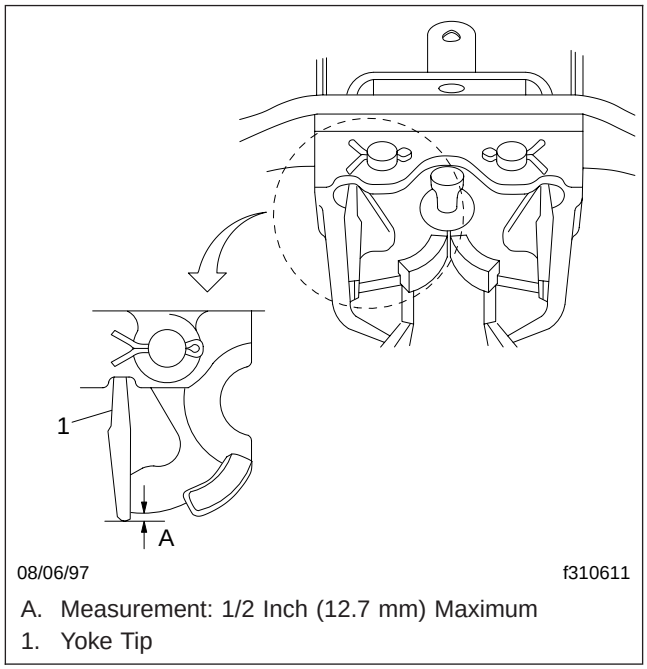
1. Threaded hole
2. Yoke
3. Yoke Tips
4. Lock

Fig. 7, Install the Yoke

XA–07295–THK from your nearest Holland distributor.

3.3 Install the lock spring. See **Fig. 9**.

3.4 Install the yoke spring. Slide the yoke shaft into the casting, through the yoke spring and into the yoke. Align the recessed hole in the yoke shaft with the threaded hole in the yoke. See **Fig. 10**.



A. Measurement: 1/2 Inch (12.7 mm) Maximum
1. Yoke Tip

Fig. 8, Measure the Yoke Tip Engagement

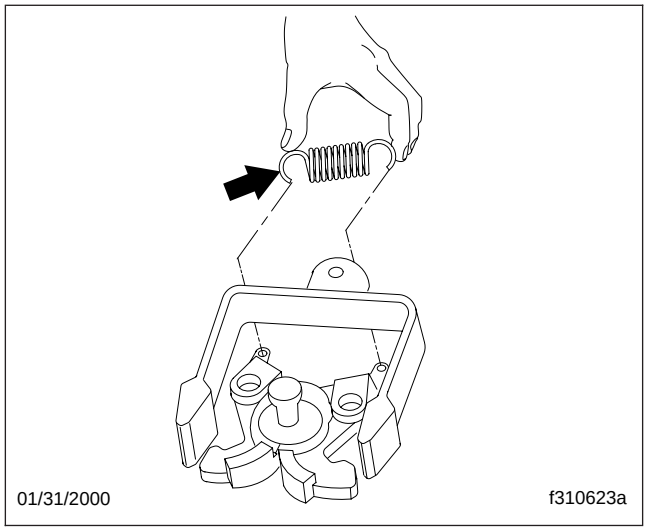


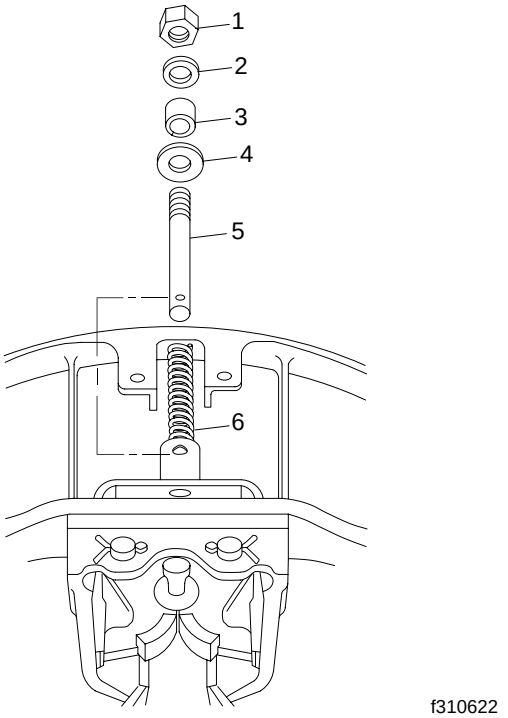
Fig. 9, Lock Spring

3.5 In this order, slide the lock adjustment tag, rubber washer and 1-1/2 inch washer onto the yoke shaft. Start the locknut and turn it finger tight. See **Fig. 10**.

4. Install the release handle.

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Model XA–351 Top Plate Assembly and Installation



1. Locknut, 3/4–16
2. Washer, 1-1/2 Inch o.d. x 13/16 Inch i.d.
3. Rubber Washer
4. Lock Adjustment Tag
5. Yoke Shaft
6. Yoke Spring

Fig. 10, Install and Assemble the Yoke Shaft

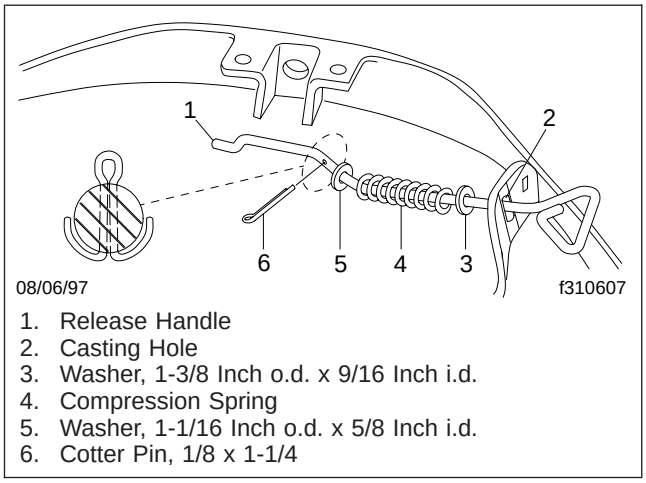
4.1 Slide the release handle through the hole in the casting (on the left-side for left-side release or on the right-side for right-side release). See **Fig. 11**.

4.2 In this order, slide the 1-3/4 inch washer, compression spring and 1-1/16 inch washer over the "S" bend of the release handle.

4.3 Compress the spring using the 1-1/16 inch washer until the cotter pin hole is exposed.

4.4 Insert the cotter pin. Spread it and wrap it completely around the release handle. See **Fig. 11**.

5. Install the cam plate.

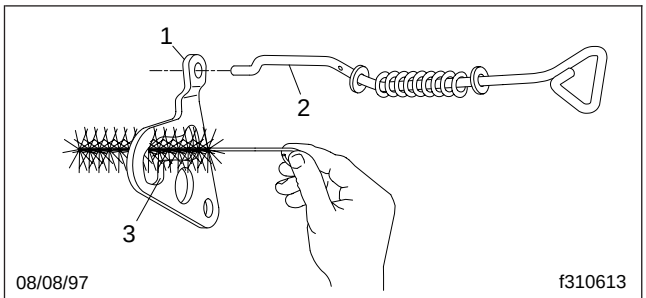


1. Release Handle
2. Casting Hole
3. Washer, 1-3/8 Inch o.d. x 9/16 Inch i.d.
4. Compression Spring
5. Washer, 1-1/16 Inch o.d. x 5/8 Inch i.d.
6. Cotter Pin, 1/8 x 1-1/4

Fig. 11, Install the Release Handle

5.1 Inspect the cam plate for burrs and remove as required.

5.2 Lubricate the cam plate track and pivot hole with light grease. Connect the raised tab in the cam plate to the "S" bend in the release handle. See **Fig. 12**.



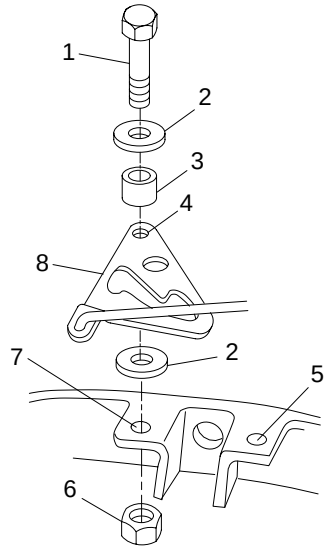
1. Cam Plate Raised Tab
2. Release Handle
3. Cam Plate Track

Fig. 12, Lubricate the Cam Plate

5.3 Position the cam plate attachment hole over the proper casting lug hole. Slide the 1-3/4 inch washer between the cam plate and casting lug hole with the rounded side of the washer facing the cam plate. Install the 1/2-inch roller into the cam plate and place the second 1-3/4 inch washer on top of the roller with the rounded side facing the cam plate. See **Fig. 13**.

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Model XA–351 Top Plate Assembly and Installation



1. Capscrew, 1/2–20 x 1-3/4
2. Washer, 1-3/4 Inch o.d. x 9/16 Inch i.d.
3. Roller, 1/2 Inch i.d.
4. Cam Plate Attachment Pivot Hole
5. Hole for Right Release
6. Locknut, 1/2–20
7. Hole for Left Release
8. Cam Plate

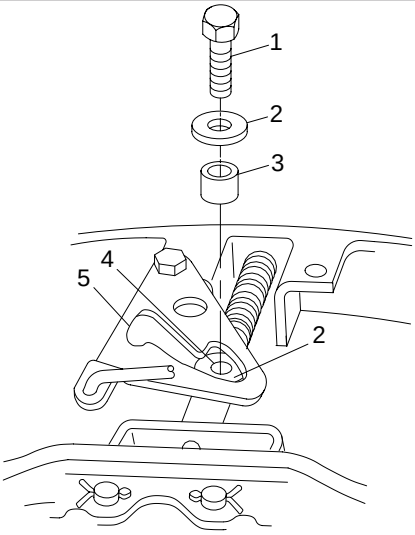
Fig. 13, Install the Cam Plate

5.4 Install the 1/2-inch capscrew through the washers, roller, and top plate lug. Secure the capscrew with the 1/2-inch locknut and tighten securely. See **Fig. 13**.

5.5 Check for free movement of the cam plate.

NOTE: When installing the washers, the rounded edge of the washers *must* always face the cam plate.

5.6 Align the cam plate track over the threaded hole in the yoke. Slide a 2-5/8 inch o.d. washer between the yoke and the cam plate with the rounded side of the washer facing the cam plate. Place the 5/8-inch roller into the cam plate track and place the second 2-5/8 inch o.d. washer over the roller with the rounded side of the washer facing the cam plate. See **Fig. 14**.



1. Capscrew (5/8–18 x 1-3/4 Inch)
2. Washer (2-5/8 x 21/32 Inch)
3. Roller (5/8 Inch i.d.)
4. Threaded Hole in Yoke
5. Cam Plate Track

Fig. 14, Install the Capscrew into the Yoke

5.7 Check the alignment of the recessed hole in the yoke shaft. Install the 5/8-inch capscrew through the washers, roller and cam plate and into the threaded hole in the yoke. Make sure the capscrew enters the recessed hole in the yoke shaft. Tighten the capscrew securely. See **Fig. 14**.

5.8 Check for free movement of the cam plate.

6. Install the secondary lock.

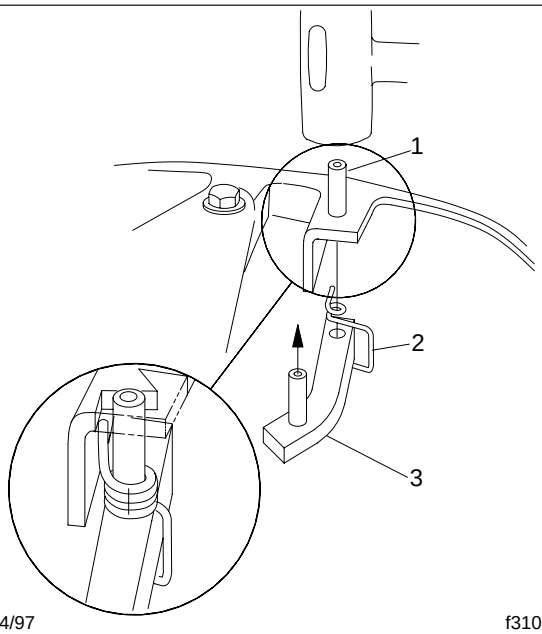
6.1 If equipped with the automatic version, start the roll pin into the hole in the top plate opposite the cam attachment capscrew. Assemble and install the secondary lock and torsion spring. Make sure the flats of the torsion spring are resting against the casting. See **Fig. 15**.

With a suitable hammer, drive the roll pin through the torsion spring and secondary lock until the roll pin is flush with the casting. See **Fig. 15**.

Check the lock spring for tension and lock for free movement.

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Model XA–351 Top Plate Assembly and Installation



1. Roll Pin, 1/2 x 2-3/4
2. Torsion Spring
3. Secondary Lock

Fig. 15, Install the Secondary Lock

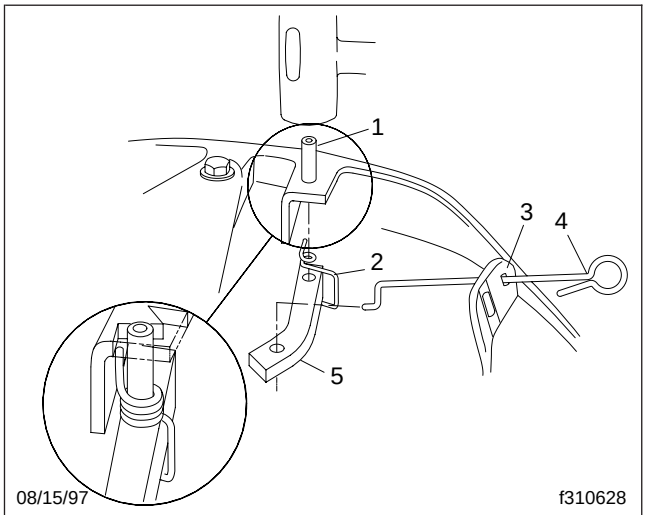
6.2 If equipped with the manual version, pass the "S" bend of the manual secondary release handle through the casting guide hole. Pass the "S" bend of the release handle through the large hole in the secondary lock. See **Fig. 16**.

6.3 If equipped with the manual version, start the roll pin into the hole in the top plate opposite the cam attachment capscrew. Assemble and install the secondary lock and torsion spring. Make sure the flats of the torsion spring are resting against the casting. See **Fig. 16**.

6.4 If equipped with the manual version, with a suitable hammer, drive the roll pin through the torsion spring and secondary lock until the roll pin is flush with the casting. See **Fig. 16**.

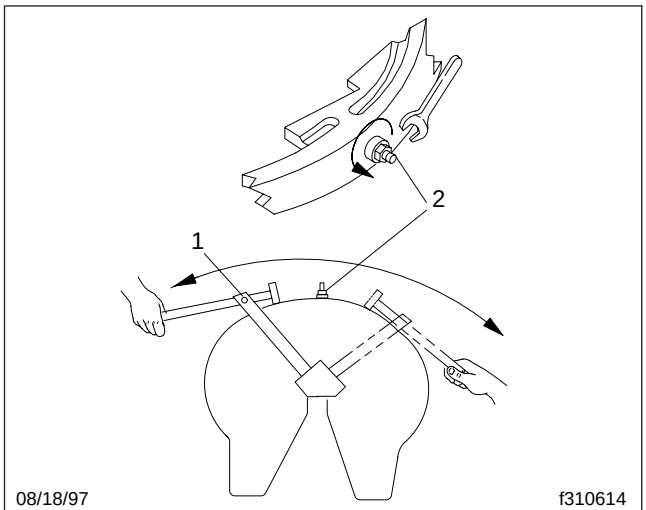
6.5 Check the lock spring for tension and lock for free movement.

7. Adjust the lock. See **Fig. 17**.



1. Roll Pin, 1/2 x 2-3/4
2. Torsion Spring
3. Guide Hole
4. Secondary Lock Release Handle
5. Secondary Lock

Fig. 16, Install the Secondary Lock



1. Lock Tester
2. Adjustment Nut

Fig. 17, Adjusting the Lock

7.1 If equipped, pull the secondary release handle and hook it on the casting. Pull the primary release handle to open the locks. Remove the 2-inch plug.

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Model XA–351 Top Plate Assembly and Installation

7.2 Turn the fifth wheel right side up and close the locks using a Holland Lock tester (see Holland publication FW130 for operating instructions for the lock tester).

7.3 Verify that the locks are completely closed around the kingpin. The lock halves should be seated against each other.

7.4 Alternately tighten the adjustment nut and turn the lock tester back and forth. Continue tightening the adjustment nut until there is some resistance felt in the lock tester (as it is turned back and forth).

The fifth wheel is properly adjusted when there is resistance between locks and the lock tester, but the lock tester can still be turned by hand.

7.5 Pull the release handle and remove the lock tester.

8. Check the fifth wheel for proper operation.

8.1 Using the Holland lock tester, open and close the fifth wheel at least three times.

Each time you close the locks, verify that the locks have closed completely around the kingpin and that the adjustment nut and rubber bushing are seated snug against the casting.

8.2 Check for resistance between the locks and the lock tester one final time and adjust as needed.

⚠ WARNING

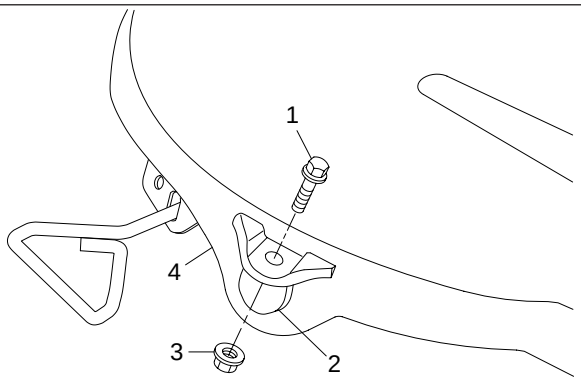
If the fifth wheel does not operate properly, do not use it. Either disassemble it and repeat the rebuilding procedure or contact your nearest Holland representative for assistance. Never use a fifth wheel that does not operate properly. The fifth wheel could malfunction, resulting in bodily injury or property damage due to a possible separation of the trailer from the tractor.

8.3 The fifth wheel is now ready for operation.

9. Install the top plate.

9.1 Using an overhead hoist, lift and position the fifth wheel over the bracket assembly.

9.2 Install the bushing pins through the fifth wheel and into the bracket assembly. Then, install and tighten securely the 1/2–20 bushing pin capscrews and locknuts. See **Fig. 18**. Remove the overhead hoist.



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1. Capscrew
2. Bushing Pin
3. Locknut
4. Top Plate

Fig. 18, Install the Bushing Pin

9.3 Lubricate the fifth wheel. For instructions, see Group 31 of the *Acterra® Maintenance Manual*.

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Troubleshooting Tables

Problem—The Fifth Wheel is Hard to Hook Up to the Trailer

Problem—The Fifth Wheel is Hard to Hook Up to the Trailer	
Possible Cause	**Remedy**
Trailer too high; kingpin not entering locks properly	Lower the trailer landing gear until the bolster plate contacts the fifth wheel.
Closed locks	Pull the release handle and pry open the locks.
Rust or grime interfering with lock operation	Spray a light lubricant or diesel fuel on all moving parts including the release handle. Operate the release mechanism several times.
Fifth wheel locks too tight	Check the lock adjustment. Correct as needed.
Bent release handle, bent kingpin, or damaged bolster plate interfering with lock movement	Check the release handle, kingpin, and bolster plate. Replace parts as required.
Damaged locks	Inspect the locks and replace parts as required.
Fifth wheel needs rebuilding	Rebuild the fifth wheel, using the parts in the appropriate rebuilding kit.

Problem—The Fifth Wheel is Hard to Unhook from the Trailer

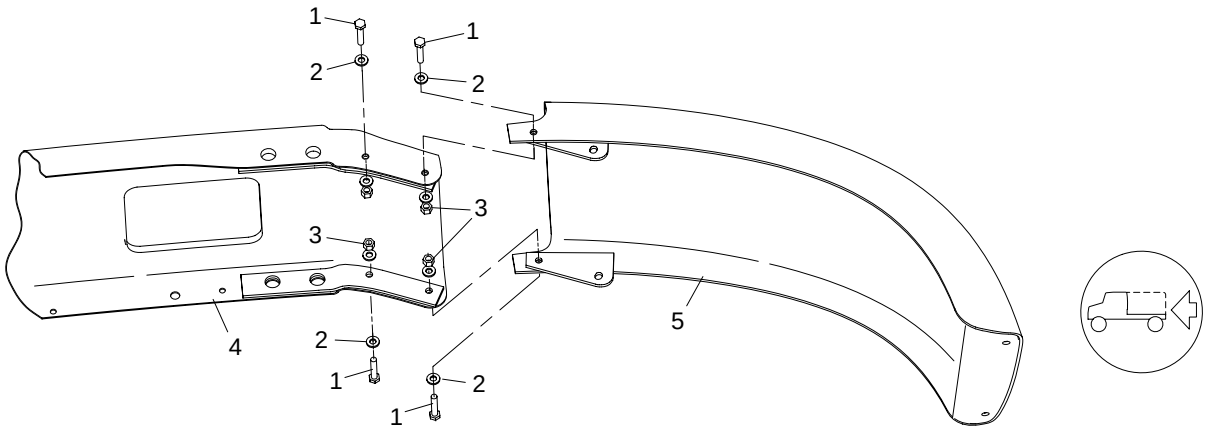
Problem—The Fifth Wheel is Hard to Unhook from the Trailer	
Possible Cause	**Remedy**
Secondary lock not released	If equipped with a manual secondary lock, pull the release handle and lock it open by resting it against the top plate. If equipped with an automatic secondary lock, inspect the lock for missing or broken parts, and repair or replace as required.
Tractor putting pressure against locks	Set the trailer brakes. Back the tractor into the trailer to relieve pressure and lock the tractor brakes before pulling the release handle.
Rust or grime on locking mechanism	Spray a light lubricant or diesel fuel on all moving parts including the release handle. Operate the release mechanism several times.
Bent kingpin or damaged bolster plate	Check the kingpin, using a Holland TF–0110 Kingpin Gauge. Check the bolster plate, using a 48-inch (122-cm) straight edge. Repair or replace parts as required.
Fifth wheel locks too tight	Check the lock adjustment. Correct as needed.
Release handle will not stay out or must be held out when unlocking	Replace the cam or release arm and the release handle spring.

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Bumper Removal and Installation

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Remove the four nuts, bolts and washers fastening the right-side bumper extension to the bumper. See **Fig. 1**.



1. Bolt
2. Washer
3. Nut
4. Bumper
5. Bumper Extension

Fig. 1, Bumper Extension, Right-Side Shown

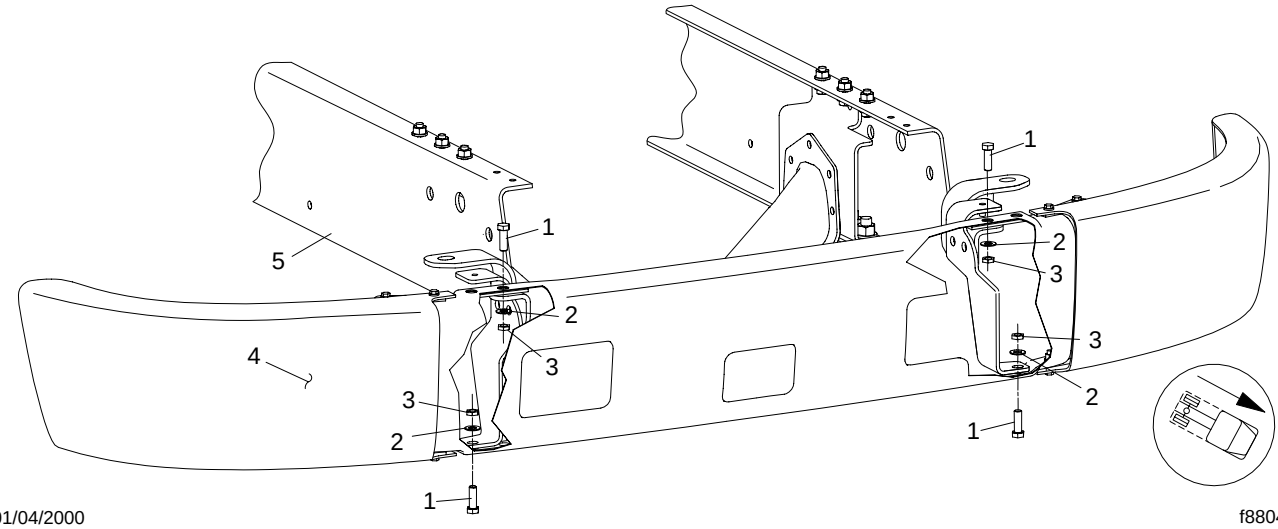
4. Remove the right-side bumper extension.
5. Remove the four nuts, bolts and washers fastening the left-side bumper extension to the bumper.
6. Remove the left-side bumper extension.
7. Remove the two nuts, bolts and washers fastening the bumper to the frame-mounted bracket. See **Fig. 2**.
8. Remove the bumper.

Installation

1. Position the bumper on the frame-mounted bracket.
2. Install the two nuts, bolts and washers fastening the bumper to the frame-mounted bracket. Tighten 64 lbf·ft (87 N·m).
3. Position the right-side bumper extension.
4. Install the four nuts, bolts and washers fastening the right-side bumper extension to the bumper. Tighten 9 to 13 lbf·ft (12 to 18 N·m).
5. Position the left-side bumper extension.
6. Install the four nuts, bolts and washers fastening the left-side bumper extension to the bumper. Tighten 9 to 13 lbf·ft (12 to 18 N·m).
7. Close and latch the hood.
8. Remove the chocks from the rear tires.

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Bumper Removal and Installation



1. Bolt
2. Washer
3. Nut
4. Bumper Extension
5. Frame Rail

Fig. 2, Bumper

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General Information

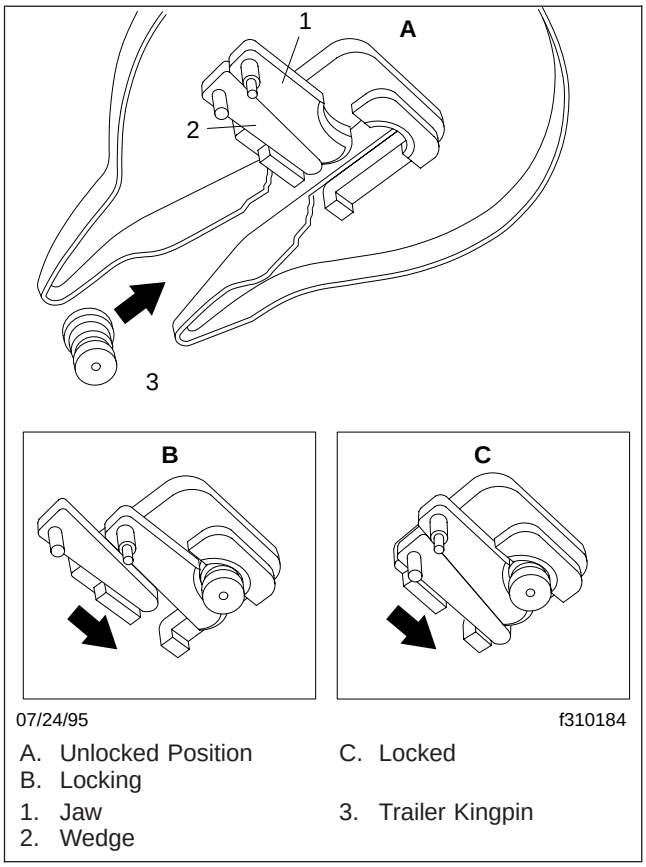
The Fontaine 6000 series fifth wheel couples to trailers having the standard kingpin. The fifth wheel is bracket-mounted to the tractor frame in a position that best distributes the trailer load over the tractor axles.

The Fontaine fifth wheel lock mechanism for the trailer kingpin consists of a spring-loaded jaw and a sliding wedge. Kingpin release is accomplished by pulling a manual lock control handle located on either the right side or the left side of the fifth wheel. Kingpin lockup occurs when the kingpin enters the throat of the fifth wheel, triggers the jaw and wedge to slide into place behind the kingpin, and moves the lock control handle into the locked position.

As the kingpin enters the lock mechanism, the jaw is moved first with the spring-loaded wedge sliding in place against the jaw. See **Fig. 1**. The jaw will move behind the kingpin, followed by the wedge. The wedge reinforces the jaw and automatically adjusts for slack around the kingpin.

Placing the lock control handle in the unlocked position moves the wedge and jaw out from behind the kingpin and unlocks the fifth wheel.

See Chapter 10 in the *Acterra Driver's Manual* for complete operating instructions.



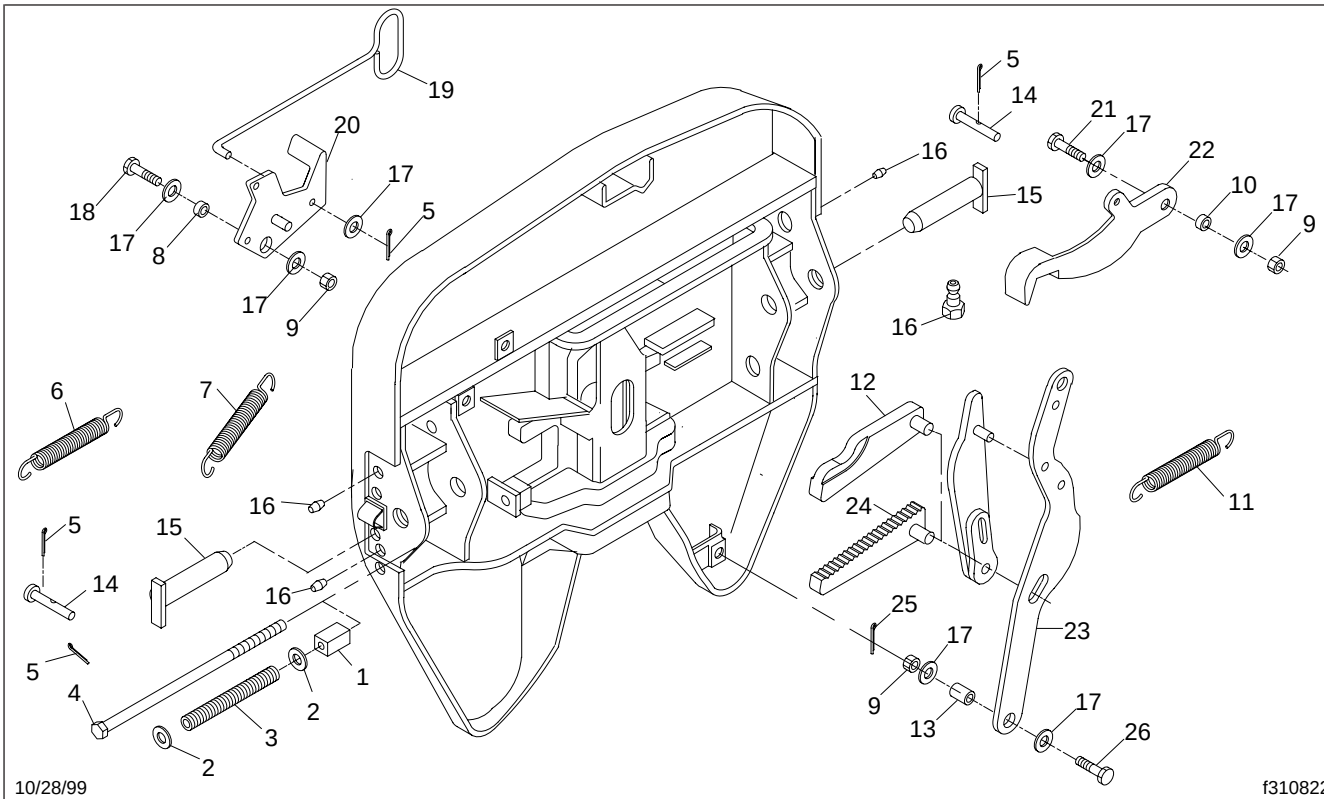
A. Unlocked Position
B. Locking
C. Locked
1. Jaw
2. Wedge
3. Trailer Kingpin

Fig. 1, Fontaine Kingpin Lock Mechanism

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Removal and Disassembly

(See Fig. 1)



1. Wedge Stop Rod Nut
2. Flat Washer, 5/8-Inch
3. Wedge Stop Rod Spring
4. Wedge Stop Rod
5. Cotter Pin, 3/16 x 1-Inch
6. Bumper Spring
7. Handle Spring
8. Bushing, 7/16-Inch
9. Hex Locknut, 1/2–13, Grade B
10. Bushing, 5/16-Inch
11. Timer Spring
12. Jaw
13. Bushing
14. Bracket Retainer Pin
15. Bracket Pin
16. Grease Fitting
17. Flat Washer, 1/2-Inch i.d., 1-3/8 Inch o.d.
18. Hexhead Bolt, 1/2–13 x 1-1/2 Inch, Grade 5
19. Pull Handle
20. Secondary Lock
21. Hexhead Bolt, 1/2–13 x 1-3/4 Inch, Grade 5
22. Bumper
23. Operating Handle
24. Wedge
25. Hair Pin Cotter
26. Hexhead Bolt, 1/2–13 x 2-1/4 Inch

Fig. 1, Fontaine 6000 Series Fifth Wheel (left-side release shown)

⚠ WARNING

All fifth wheel maintenance, adjustment and rebuilding must be done by a qualified mechanic. Improper or incomplete procedures could result in disengagement of the trailer from the tractor, leading to personal injury or property damage.

Parts are under spring compression. Wear safety goggles during disassembly and assembly. Failure to do so can result in personal injury, due to parts ejecting with force.

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Fifth Wheel Removal and Disassembly

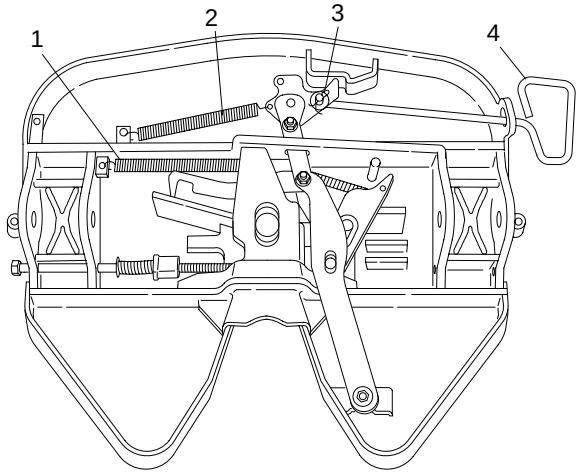
1. Steam clean the top plate. Remove it from the mount by removing the cotter pins from the retaining pins. Remove the retaining pins and bushing pins from both sides of the top plate.
2. Using an overhead hoist, lift the fifth wheel off the mount and tractor frame.
3. Turn the fifth wheel upside down.

NOTE: While disassembling the fifth wheel, check it for cracks and for missing or damaged parts.

⚠ WARNING

Do not attempt to repair or rebuild the top plate if it is cracked or if parts are damaged. The top plate or parts could malfunction. This could result in disengagement of the trailer during vehicle travel, possibly causing personal injury and property damage.

4. Remove the handle spring. See **Fig. 2**. Remove the cotter pin and flat washer holding the pull handle to the secondary lock and remove the pull handle. Remove the bumper spring.

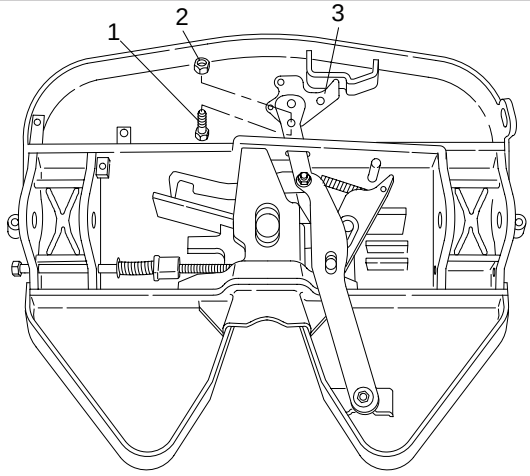


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1. Bumper Spring
2. Handle Spring
3. Secondary Lock
4. Pull Handle

Fig. 2, Pull Handle Removal

5. Unbolt and remove the secondary lock from the operating handle. See **Fig. 3**.

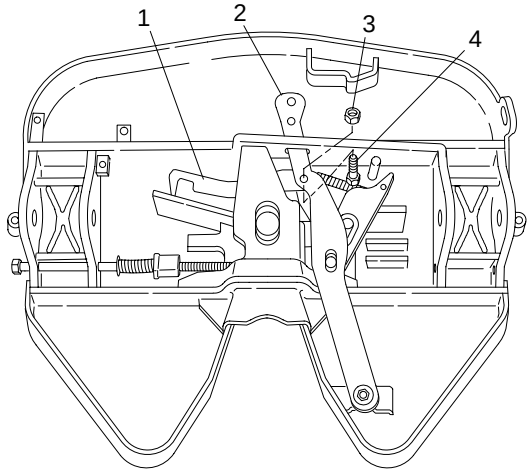


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1. Hexhead Bolt, 1/2–13, 1-1/2 Inch
2. Locknut, 1/2–13
3. Secondary Lock

Fig. 3, Secondary Lock Removal

6. Unbolt and remove the bumper from the operating handle. See **Fig. 4**.



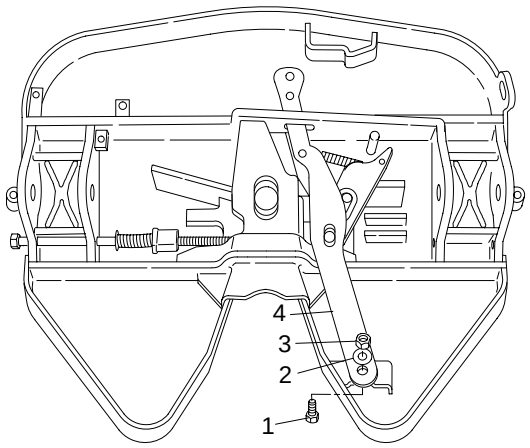
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1. Bumper
2. Operating Handle
3. Locknut, 1/2–13
4. Hexhead Bolt, 1/2–13, 1-3/4 Inch

Fig. 4, Bumper Removal

7. Unbolt the operating handle from the pivot mount and remove the operating handle. See **Fig. 5**.

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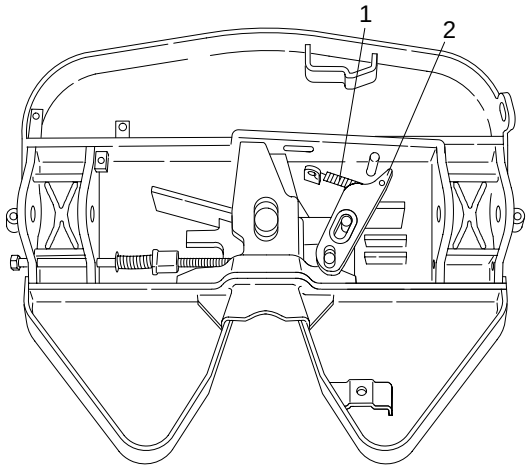


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1. Hexhead Bolt, 1/2–13, 2-1/4 Inch
2. Flat Washer
3. Locknut, 1/2–13
4. Operating Handle

Fig. 5, Operating Handle Removal

8. Remove the timer spring and timer. See **Fig. 6**.

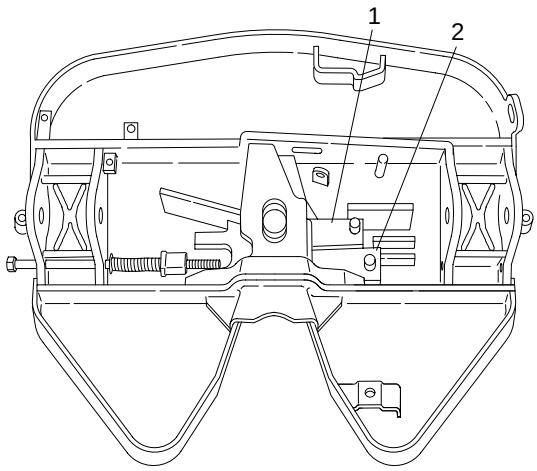


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1. Timer Spring
2. Timer

Fig. 6, Timer Spring and Timer Removal

9. Remove the jaw and wedge. See **Fig. 7**.



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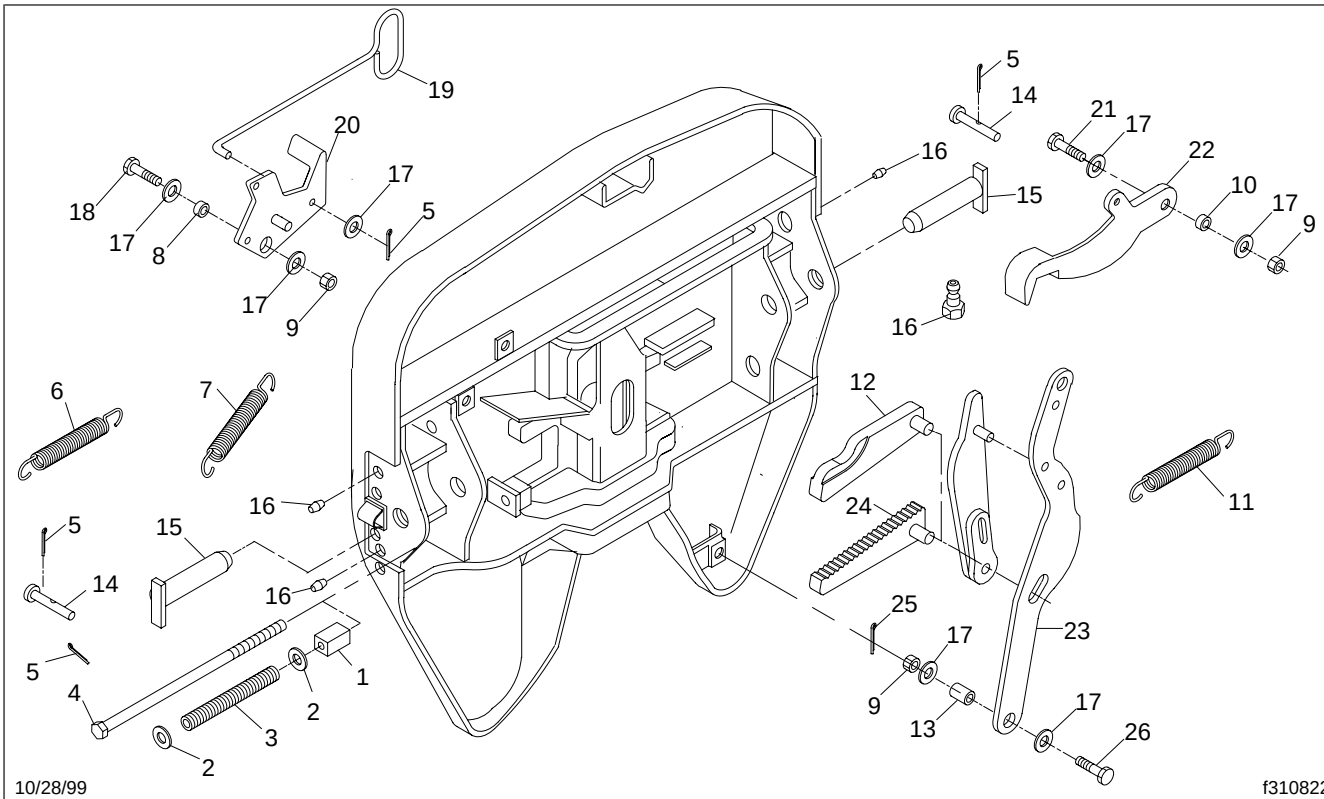
1. Jaw
2. Wedge

Fig. 7, Jaw and Wedge Removal

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Assembly and Installation

(See Fig. 1)



1. Wedge Stop Rod Nut
2. Flat Washer, 5/8-Inch
3. Wedge Stop Rod Spring
4. Wedge Stop Rod
5. Cotter Pin, 3/16 x 1-Inch
6. Bumper Spring
7. Handle Spring
8. Bushing, 7/16-Inch
9. Hex Locknut, 1/2–13, Grade B
10. Bushing, 5/16-Inch
11. Timer Spring
12. Jaw
13. Bushing
14. Bracket Retainer Pin
15. Bracket Pin
16. Grease Fitting
17. Flat Washer, 1/2-Inch i.d., 1-3/8 Inch o.d.
18. Hexhead Bolt, 1/2–13 x 1-1/2 Inch, Grade 5
19. Pull Handle
20. Secondary Lock
21. Hexhead Bolt, 1/2–13 x 1-3/4 Inch, Grade 5
22. Bumper
23. Operating Handle
24. Wedge
25. Hair Pin Cotter
26. Hexhead Bolt, 1/2–13 x 2-1/4 Inch

Fig. 1, Fontaine 6000 Series Fifth Wheel (left-side release shown)

⚠ WARNING

All fifth wheel maintenance, adjustment and rebuilding must be done by a qualified mechanic. Improper or incomplete procedures could result in possible disengagement of the trailer from the tractor, leading to personal injury and property damage.

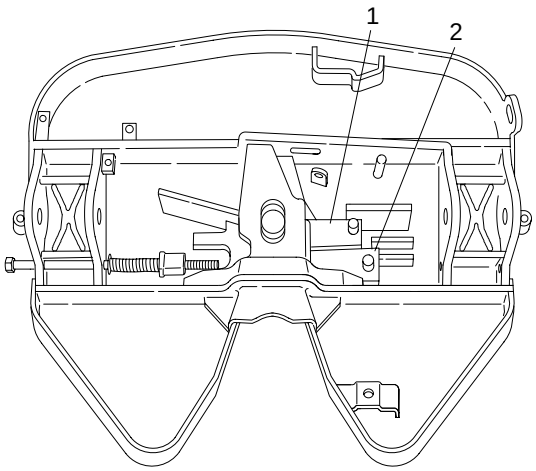
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Fifth Wheel Assembly and Installation

Parts are under spring compression. Wear safety goggles during disassembly and assembly. Failure to do so can result in personal injury, due to parts ejecting with force.

IMPORTANT: Replace any parts that show signs of wear, damage or deterioration.

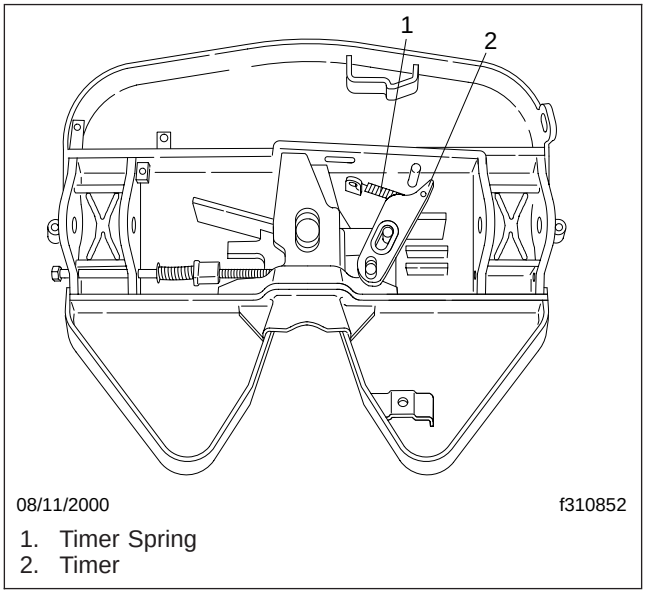
1. Clean all moving parts with No. 2 diesel fuel before assembly.
2. Insert the jaw and wedge. See **Fig. 2**.



1. Jaw
2. Wedge

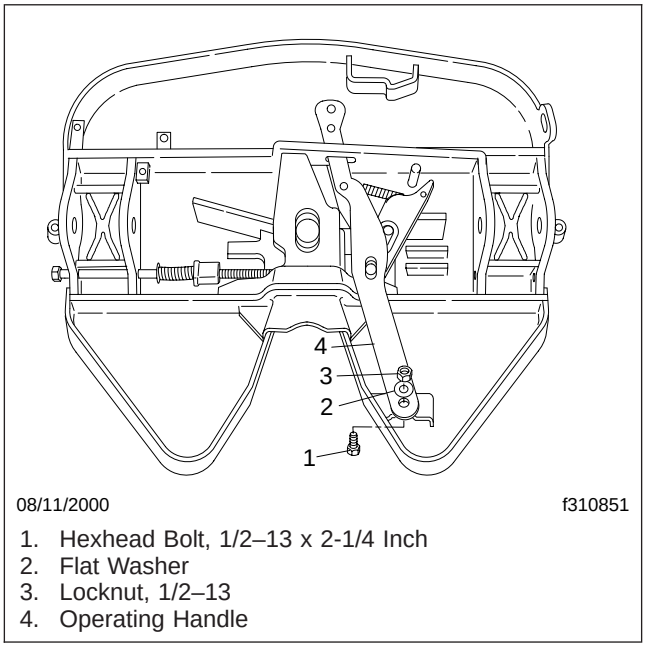
Fig. 2, Wedge and Jaw Installation

3. Insert the timer and timer spring. See **Fig. 3**.
4. Insert the operating handle and bolt it to the pivot mount. See **Fig. 4**.
5. Install the bumper and bolt it to the operating handle. See **Fig. 5**.
6. Insert the secondary lock and bolt it to the operating handle. See **Fig. 6**.
7. Position the pull handle and install the flat washer and cotter pin. Attach the handle spring and the bumper spring. See **Fig. 7**.



1. Timer Spring
2. Timer

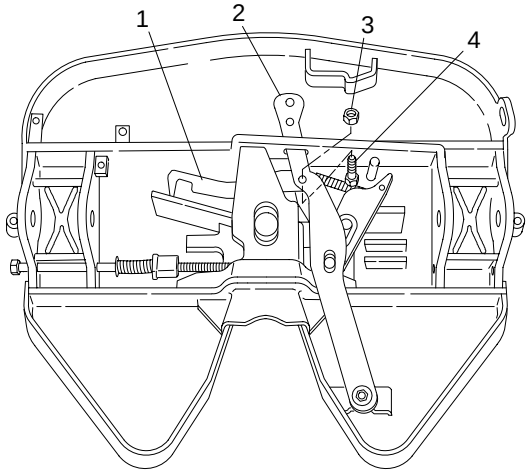
Fig. 3, Timer and Timer Spring Installation



1. Hexhead Bolt, 1/2–13 x 2-1/4 Inch
2. Flat Washer
3. Locknut, 1/2–13
4. Operating Handle

Fig. 4, Operating Handle Installation

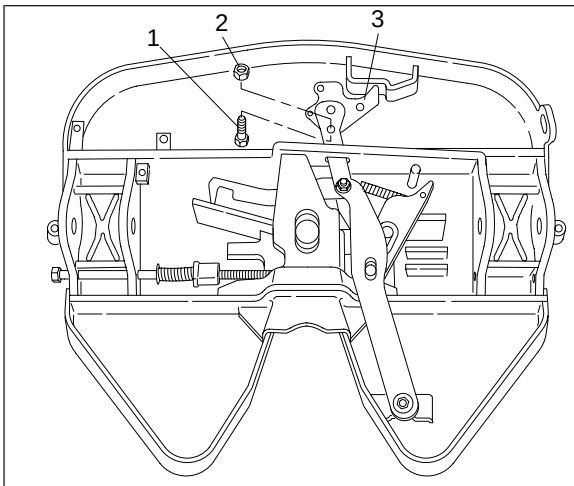
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1. Bumper
2. Operating Handle
3. Locknut, 1/2–13
4. Hexhead Bolt, 1/2–13 x 1-3/4 Inch

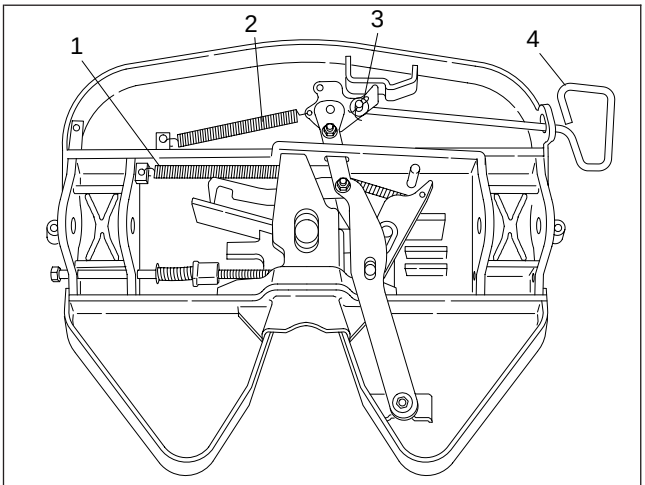
Fig. 5, Bumper Installation



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1. Hexhead Bolt, 1/2–13 x 1-1/2 Inch
2. Locknut, 1/2–13
3. Secondary Lock

Fig. 6, Secondary Lock Installation



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1. Bumper Spring
2. Handle Spring
3. Secondary Lock
4. Pull Handle

Fig. 7, Pull Handle Installation

⚠ WARNING

If the fifth wheel does not operate properly, do not use it. The fifth wheel could malfunction, resulting in personal injury or property damage due to possible disengagement of the trailer from the tractor.

8. Using an overhead hoist, position the fifth wheel on the mount assembly. Insert the bushing pins. Install the retaining pins and the 1-inch long cotter pins.
9. Close the fifth wheel several times with a standard 2-inch kingpin tool. With the lock closed, adjust the wedge stop rod so the end is 1/4-inch from the wedge. See **Troubleshooting, 300** for additional information.

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Troubleshooting Tables

Problem—Difficult Coupling

Problem—Difficult Coupling	
Possible Cause	**Remedy**
Kingpin too high to trip latch	Lower the landing gear.
Damaged trailer plate or kingpin	Check the trailer plate for flatness. Check the kingpin for squareness with the trailer plate.

Problem—Excessive Wear on the Fifth Wheel Top Plate

Problem—Excessive Wear on the Fifth Wheel Top Plate	
Possible Cause	**Remedy**
Damaged trailer plate	If the trailer plate is not flat, replace it.

Problem—Difficult Uncoupling

Problem—Difficult Uncoupling	
Possible Cause	**Remedy**
Pressure on locking mechanism caused by tractor drifting apart from trailer putting excess pressure on lock	Back up the tractor and set the brakes. Strike the wedge stop rod which protrudes through the side of the fifth wheel. This spring-loaded rod will release the pressure on the locking mechanism.

Problem—Slack

Problem—Slack	
Possible Cause	**Remedy**
Improperly adjusted wedge	Open the fifth wheel and insert a 2-inch kingpin or a shaft with a 2-inch diameter. Trip the lock and adjust the wedge stop rod so that it is 1/4-inch from the end of the wedge.
Undersized kingpin	Replace the kingpin if it is worn greater than 1/8-inch (3-mm) at the 2-inch (5-cm) diameter.
Worn jaw and wedge	The jaw and wedge could have excessive wear. Replace them.

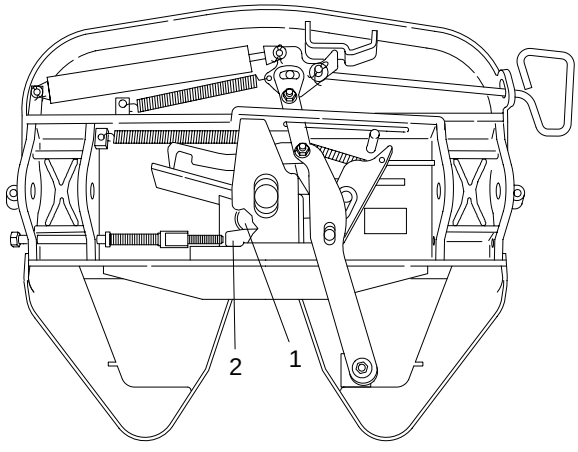
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General Information

Fontaine 6000 and 7000 series fifth wheels couple to trailers having a standard 2-inch kingpin. When installed as a stationary mount, the fifth wheel is bracket-mounted to the tractor frame in a position that best distributes the trailer load over the tractor axles. Sliding fifth wheels are mounted on the Fontaine AWB or MWS model slide mounts.

The Fontaine fifth wheel lock mechanism for the trailer kingpin consists of a spring-loaded jaw and sliding wedge. Kingpin release is accomplished by pulling a manual lock control handle located on either the right side (curbside) or left side (roadside) of the fifth wheel. Kingpin coupling occurs when the kingpin enters the throat of the fifth wheel, triggers the jaw and wedge to slide into place behind the kingpin, and moves the lock control handle into the locked position.

As the kingpin enters the lock mechanism, the jaw is moved first with the spring-loaded wedge sliding in place against the jaw. The jaw will move behind the kingpin, followed by the wedge. The wedge reinforces the jaw and automatically adjusts for slack around the kingpin. See **Fig. 1** for an illustration of the jaw and wedge in the locked position.

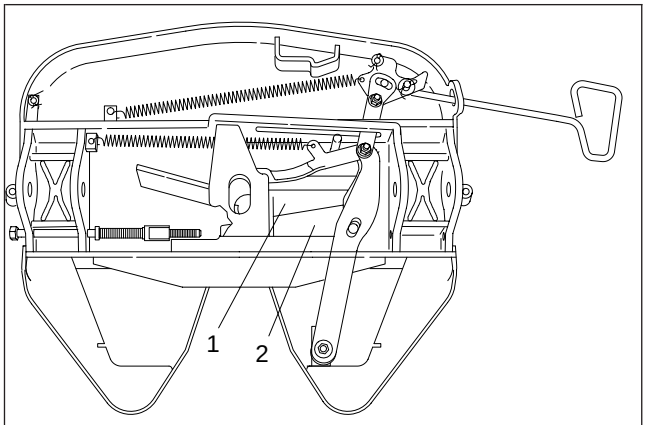


11/18/2002 f310931

1. Jaw
2. Wedge

Fig. 1, Locked Position

Placing the lock control handle in the unlocked position moves the wedge and jaw out from behind the kingpin and unlocks the fifth wheel. See **Fig. 2** for an illustration of the jaw and wedge in the unlocked position.



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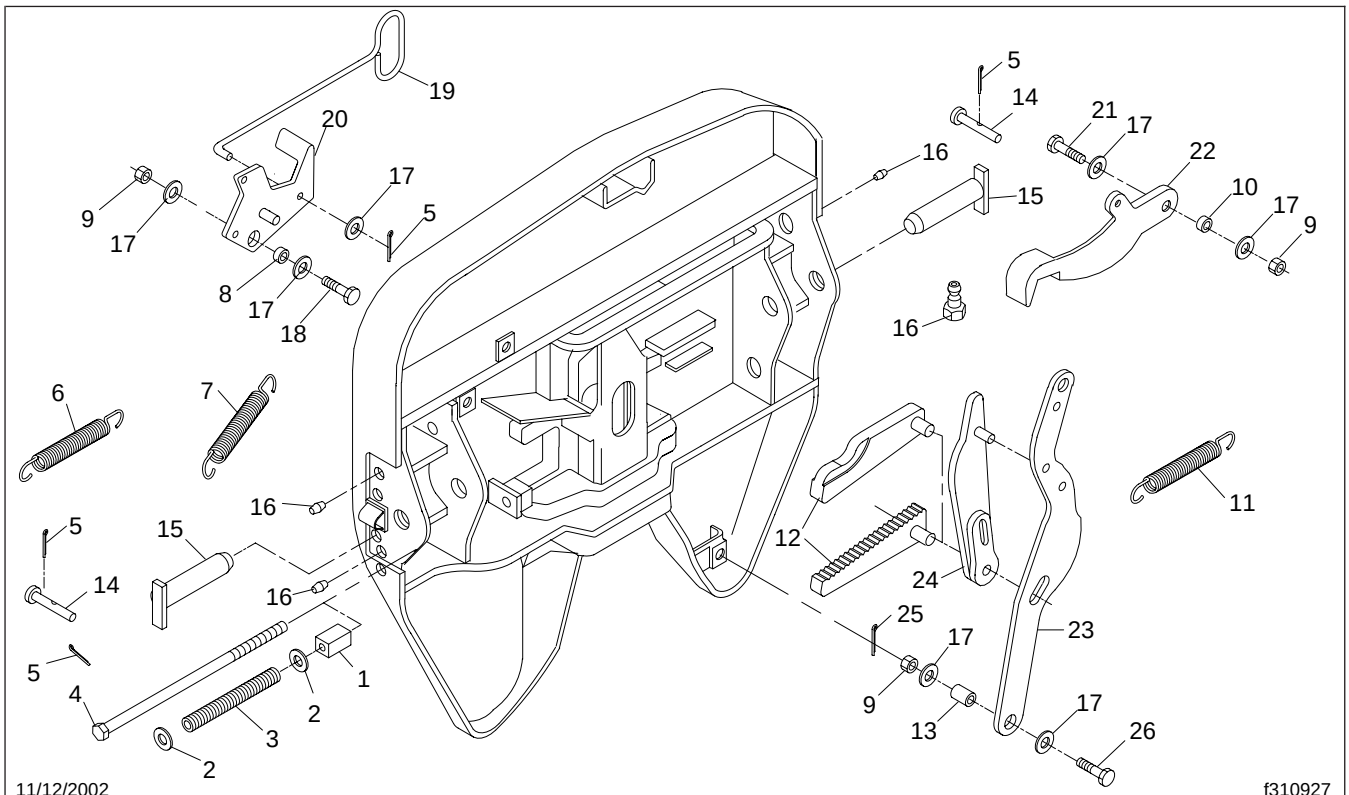
1. Jaw
2. Wedge

Fig. 2, Unlocked Position

https://truckmanualshub.com/

Fifth Wheel Removal and Disassembly

See **Fig. 1** for an exploded view of a Fontaine® 6000 or 7000 No-Slack II series fifth wheel.



1. Wedge Stop Rod Nut
2. Flatwasher, 5/8", Plain
3. Wedge Stop Rod Spring
4. Wedge Stop Rod
5. Cotter Pin, 3/16 x 1"
6. Bumper Spring
7. Handle Spring
8. Bushing, 7/16"
9. Hex Locknut, 1/2–13
10. Bushing, 5/16"
11. Timer Spring
12. Step Jaw and Wedge Set
13. Bushing
14. Bracket Retainer Pin
15. Bracket Pin
16. Grease Fitting
17. Flatwasher, 1/2" I.D. x 1-3/4" O.D., Plain
18. Hexhead Bolt, 1/2–13 x 1-1/2", Grade 5
19. Pull Handle
20. Secondary Lock
21. Hexhead Bolt, 1/2–13 x 1-3/4", Grade 5
22. Bumper
23. Operating Handle
24. Timer
25. Hair Pin Cotter
26. Hexhead Bolt, 1/2–13 x 2-3/4", Grade 5

Fig. 1, Fontaine 6000 and 7000 No-slack II Series Fifth Wheel (left side release shown)

⚠ WARNING

All fifth wheel maintenance, adjustment, and rebuilding must be done only by a qualified mechanic. Improper or incomplete procedures could result in disengagement of the trailer from the tractor, leading to personal injury or property damage.

Parts are under spring compression. Wear safety goggles during disassembly and assembly. Failure to do so can result in personal injury, due to parts ejecting with force.

1. Steam clean the top plate. Remove it from the sliding mount by removing the cotter pins from the retaining pins. Remove the retaining pins and bushing pins from both sides of the top plate.

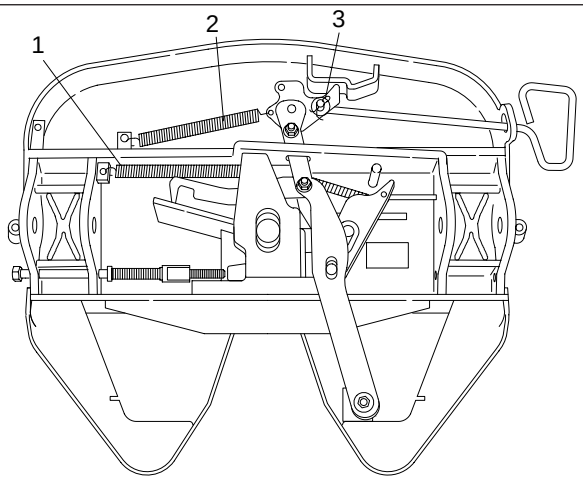
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Removal and Disassembly

2. Using an overhead hoist, lift the fifth wheel off the sliding mount and tractor frame.
3. Turn the fifth wheel upside down.

NOTE: While disassembling the fifth wheel, check it for cracks and for missing or damaged parts.

4. Remove the secondary lock spring and bumper spring. See **Fig. 2**. Remove the pull handle cotter pin and washer, then slide out the pull handle.

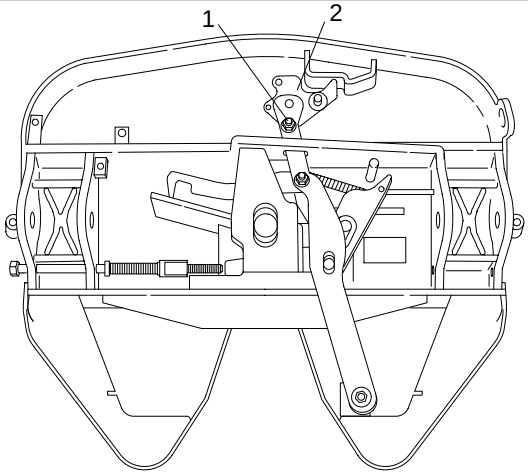


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1. Bumper Spring
2. Secondary Lock Spring
3. Pull Handle Cotter Pin

Fig. 2, Pull Handle

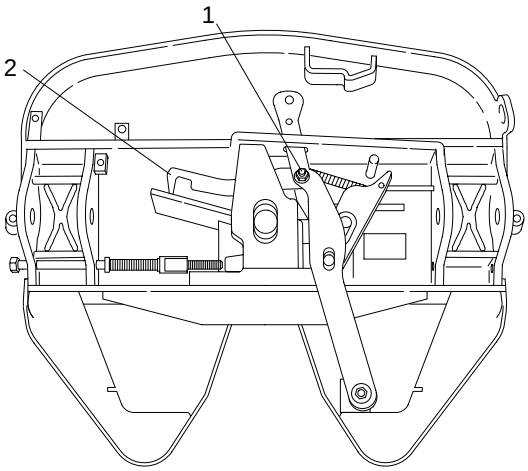
5. Unbolt and remove the secondary lock from the operating handle. Discard the locknut and bushing. See **Fig. 3**.
6. Unbolt and remove the bumper from the operating handle. Discard the locknut and bushing. See **Fig. 4**.
7. Unbolt the operating handle from the pivot mount and remove. Discard the locknut. See **Fig. 5**.
8. Remove the timer spring and timer. See **Fig. 6**.
9. Remove the jaw and wedge. See **Fig. 7**.



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1. Bolt
2. Secondary Lock

Fig. 3, Secondary Lock

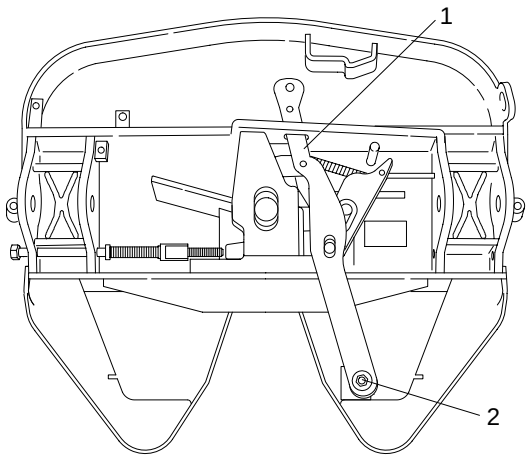


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1. Bolt
2. Bumper

Fig. 4, Bumper

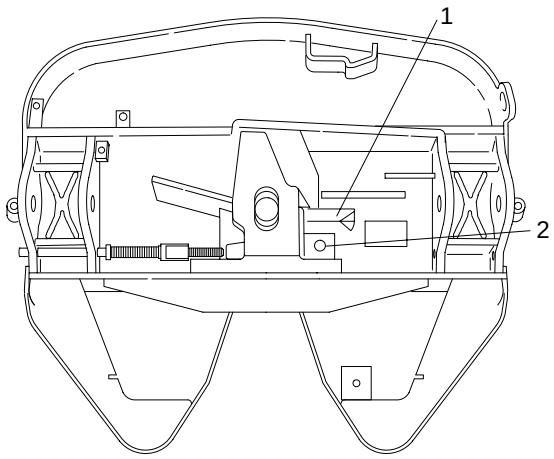
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1. Operating Handle
2. Bolt

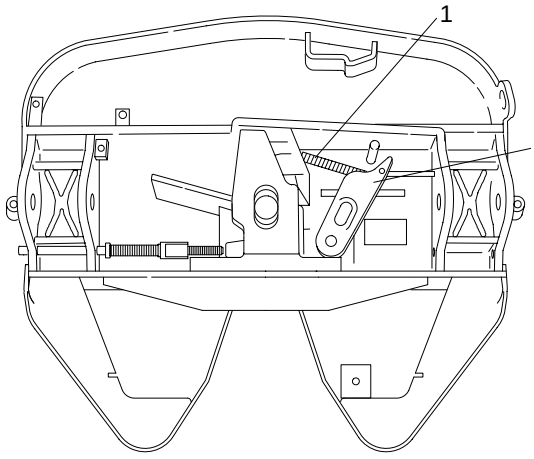
Fig. 5, Operating Handle



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1. Jaw
2. Wedge

Fig. 7, Jaw and Wedge



11/12/2002 f310924

1. Timer Spring
2. Timer

Fig. 6, Timer Spring and Timer

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Assembly and Installation

⚠ WARNING

Before rebuilding the assembly, check to make sure that there are no cracks in the crossmembers or other components. Also check the bracket pin holes to ensure they are not worn oversize (pins should fit snugly). Under no circumstances should a fifth wheel be repaired or used if any component (crossmember, saddle bearing, etc.) is cracked. Operating a fifth wheel with damaged components could result in disengagement of the trailer from the tractor, leading to personal injury or property damage.

Use a Moly-based lubricant such as Mobil grease Moly 50 or equivalent when applying lubricant to the locking jaw and wedge. Lightly oil other moving parts in the fifth wheel.

See **Fig. 1** for an exploded view of a Fontaine® 6000 or 7000 No-Slack II series fifth wheel.

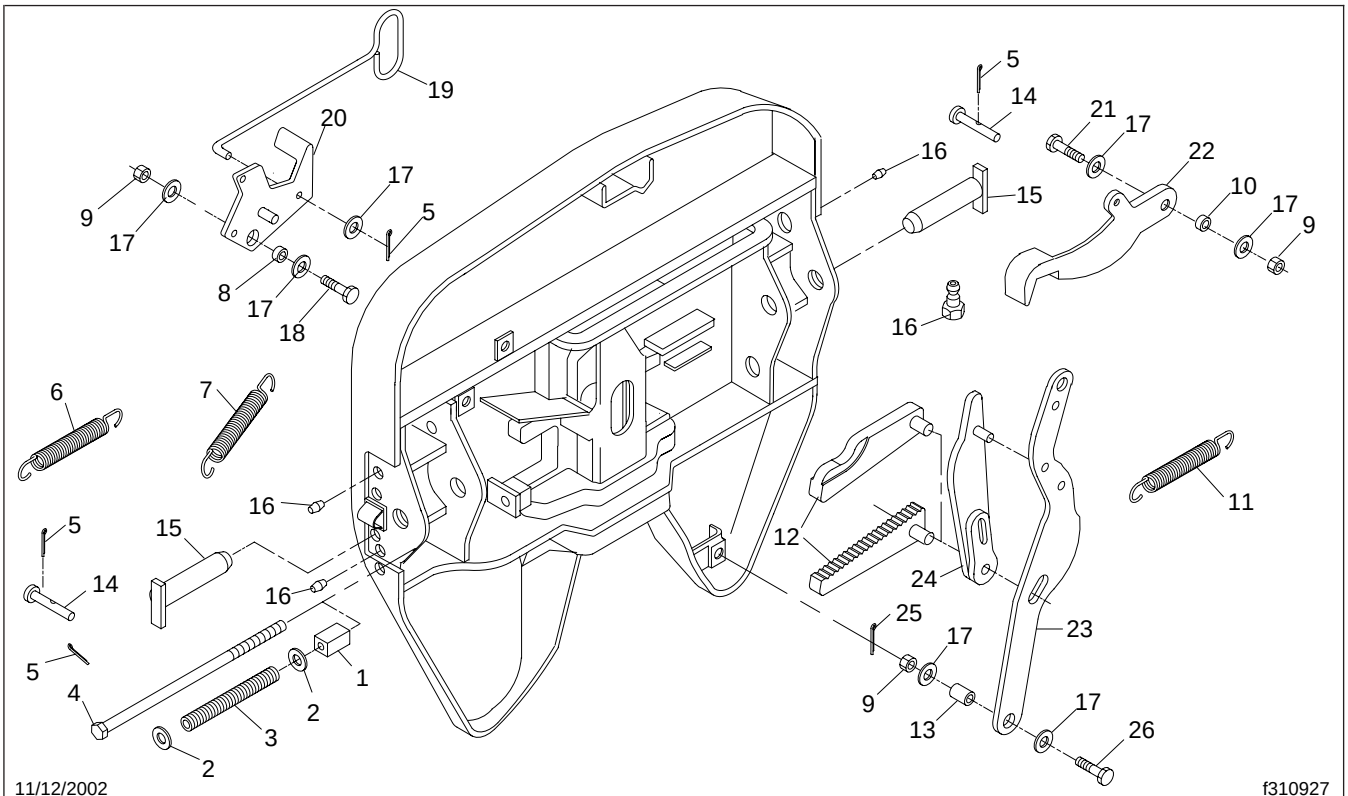
1. Always assemble parts around a 2-inch kingpin or a 2-inch-diameter shaft. Insert the jaw first, then the wedge below it. See **Fig. 2**. Grease the jaw and wedge on the top and bottom.
2. Install the timer and the timer spring. See **Fig. 3**.
3. Install the operating handle and bolt to the pivot mount. See **Fig. 4**. Use the existing bolt, washer, hairpin cotter pin and bushing. Inspect the bushing for wear before using it and replace it if necessary. Use the new locknut that is supplied in the repair kit. Note the orientation of the bolt (**Fig. 1**).
4. Install the bumper and bolt it to the operating handle. See **Fig. 5**. Use the existing bolt and washers (inspect for wear before using and replace if necessary). Use the new locknut and bushing that is supplied in the repair kit. Note the orientation of the bolt (**Fig. 1**). After installing the bumper, check to make sure that it can pivot freely.
5. Insert the secondary lock and bolt it to the operating handle. See **Fig. 6**. Use the existing bolt and washers (inspect for wear before using and replace if necessary). Use the new locknut and bushing that is supplied in the repair kit. Note the orientation of the bolt (**Fig. 1**).
6. Install the pull handle. See **Fig. 7**. Use the existing washer and cotter pin (inspect for wear before using, and replace if necessary). Attach the new secondary lock/bumper spring that is supplied in the repair kit. Open and close the fifth wheel to ensure that it works properly. The fifth wheel must be properly lubricated before opening and closing the wheel.

Use a Moly-based lubricant such as Mobil grease Moly 50 or equivalent when applying lubricant to the locking jaw and wedge. Lightly oil other moving parts in the fifth wheel.

7. Close the fifth wheel several times with a standard 2-inch kingpin tool. With the lock closed, adjust the wedge stop rod so that the end is 1/4-inch (6-mm) from the wedge. See **Fig. 8**.
8. Using an overhead hoist, position the fifth wheel on the sliding mount assembly. Insert the bushing pins. Install the retaining pins and the 1-inch-long cotter pins.

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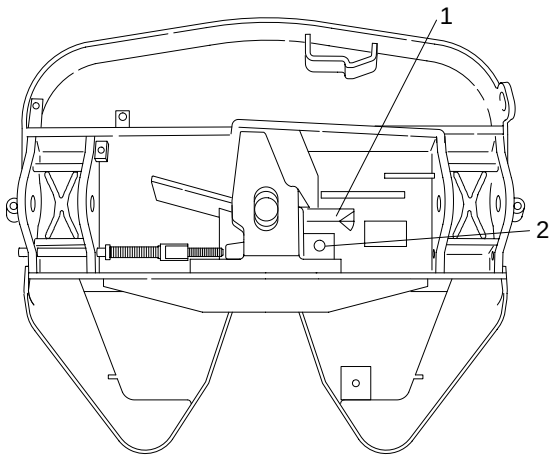
Assembly and Installation



1. Wedge Stop Rod Nut
2. Flatwasher, 5/8", Plain
3. Wedge Stop Rod Spring
4. Wedge Stop Rod
5. Cotter Pin, 3/16 x 1"
6. Bumper Spring
7. Handle Spring
8. Bushing, 7/16"
9. Hex Locknut, 1/2–13
10. Bushing, 5/16"
11. Timer Spring
12. Step Jaw and Wedge Set
13. Bushing
14. Bracket Retainer Pin
15. Bracket Pin
16. Grease Fitting
17. Flatwasher, 1/2" I.D. x 1-3/4" O.D., Plain
18. Hexhead Bolt, 1/2–13 x 1-1/2", Grade 5
19. Pull Handle
20. Secondary Lock
21. Hexhead Bolt, 1/2–13 x 1-3/4", Grade 5
22. Bumper
23. Operating Handle
24. Timer
25. Hairpin Cotter Pin
26. Hexhead Bolt, 1/2–13 x 2-3/4", Grade 5

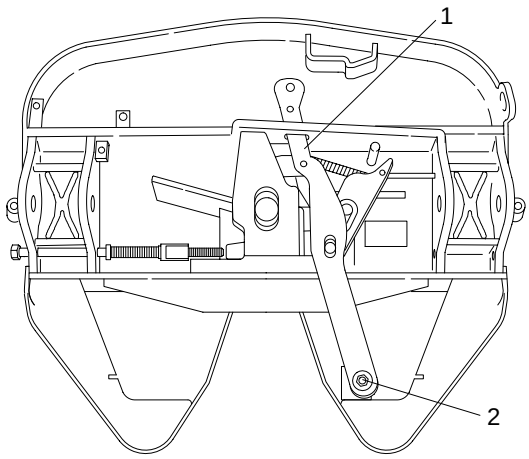
Fig. 1, Fontaine 6000 and 7000 No-slack II Series (left-side release shown)

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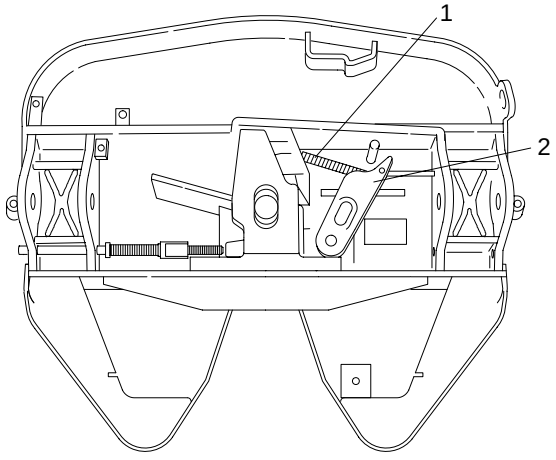
1. Jaw
2. Wedge

Fig. 2, Jaw and Wedge



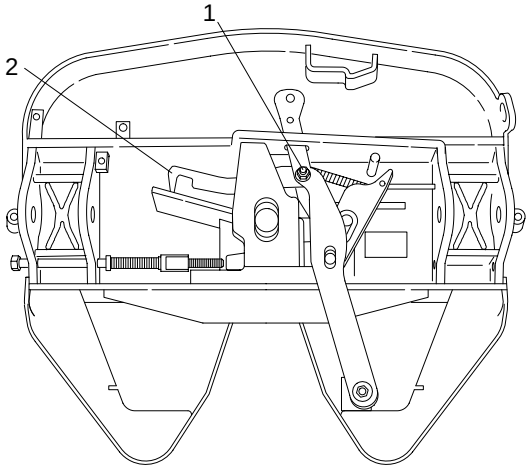
1. Operating Handle
2. Bolt

Fig. 4, Operating Handle



1. Timer Spring
2. Timer

Fig. 3, Timer Spring and Timer

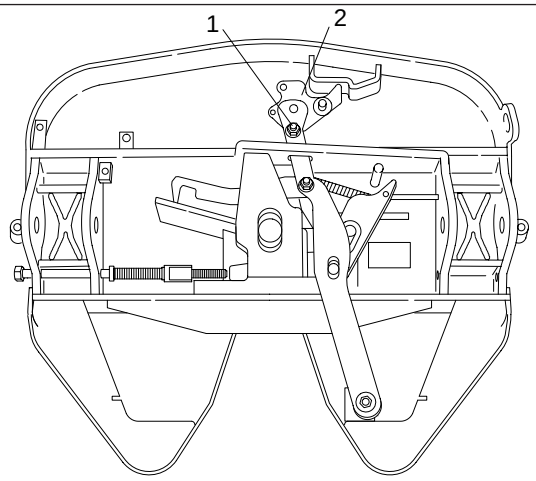


1. Bolt
2. Bumper

Fig. 5, Bumper

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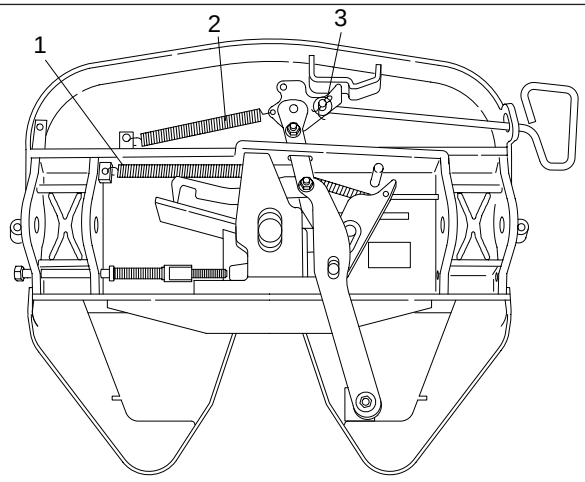
Assembly and Installation



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1. Bolt
2. Secondary Lock

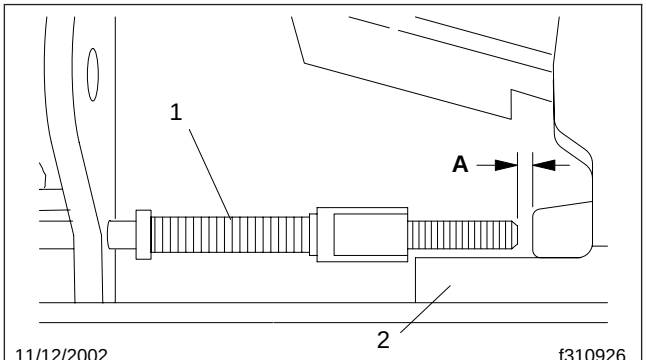
Fig. 6, Secondary Lock



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1. Bumper Spring
2. Secondary Lock Spring
3. Pull Handle Cotter Pin

Fig. 7, Pull Handle



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A. 1/4 inch (6 mm)

1. Stop Rod
2. Wedge

Fig. 8, Wedge Stop Rod Adjustment

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Troubleshooting Tables

Problem—Difficulty Coupling

Possible Cause	Remedy
The kingpin is too high to trip the latch	Lower the landing gear.
The trailer plate or kingpin is damaged	Check the trailer plate for flatness. Check the kingpin for squareness with the trailer plate.

Problem—Excessive Wear on the Fifth Wheel Top Plate

Possible Cause	Remedy
Damaged trailer plate	If the trailer plate is not flat, replace it.

Problem—Difficulty Uncoupling

Possible Cause	Remedy
Pressure on the locking mechanism caused by truck drifting apart from the trailer putting excess pressure on the lock	Back up the trailer and set the brakes. Strike the wedge stop rod which protrudes through the side of the fifth wheel. This spring-loaded rod will release the pressure on the locking mechanism.
Oval-shaped kingpin	Lower the landing gear.
Debris build-up in the grease	

Problem—Slack

Possible Cause	Remedy
Undersized kingpin	Replace the kingpin if worn greater than 1/8 inch (3 mm) at the 2-inch (5-cm) diameter.
Worn jaw and wedge	Jaw and wedge could have excessive wear. Replace them.

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General Information

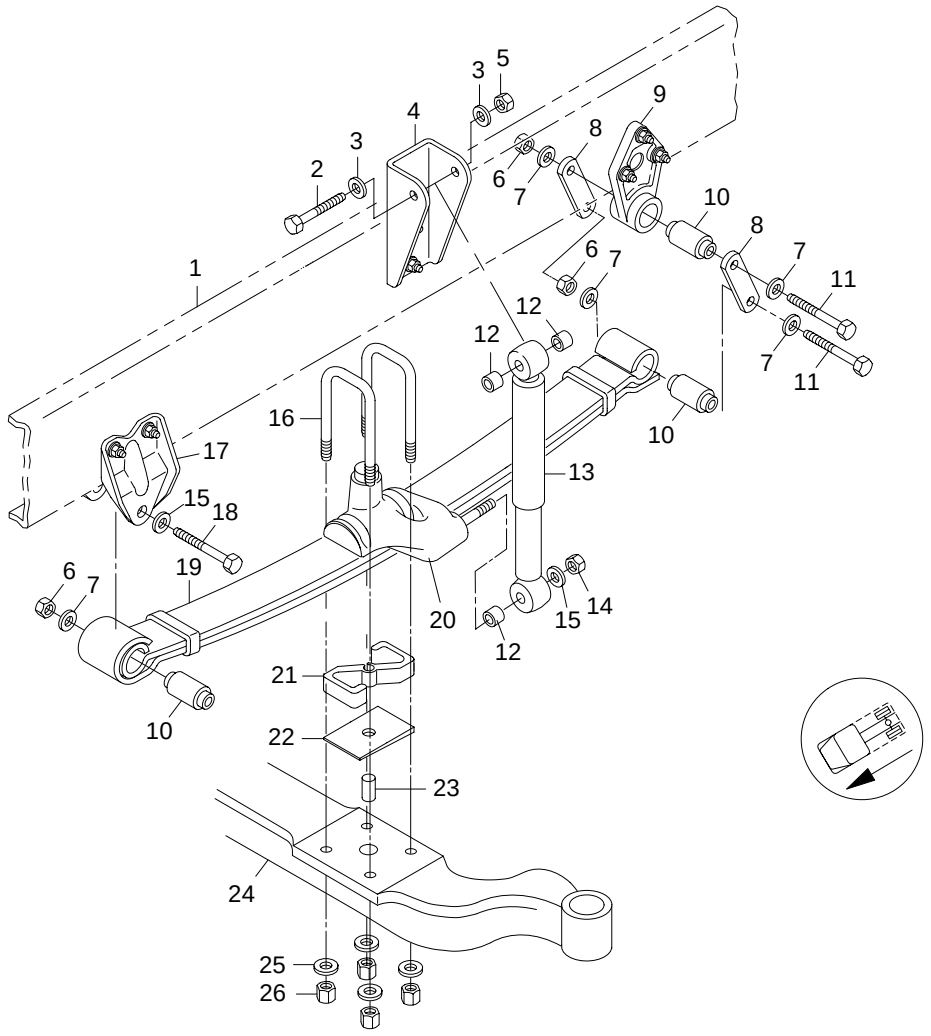
Acterra® front suspensions use either taper-leaf or multi-leaf springs with varying capacities. See **Fig. 1**, **Fig. 2**, and **Fig. 3**. Shock absorbers are standard on taper-leaf springs and optional on multi-leaf springs.

The spring assemblies are attached to the axle with U-bolts, hardened washers and high nuts. The forward end of each spring mounts to a stationary front spring bracket. The rear of each spring mounts to either a spring shackle suspended from a frame-mounted bracket, or fits straight into the frame-mounted bracket, and is locked in place by the deflection pad tooth. The shackle or deflection pad allows for variations in spring length as the spring flexes.

The leaf spring assembly absorbs and stores energy over bumps, releasing it at a controlled rate to smooth the ride. Individual spring leaves are held together by a center bolt. Alignment clips limit the sideways spread and vertical separation of the individual leaves.

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General Information

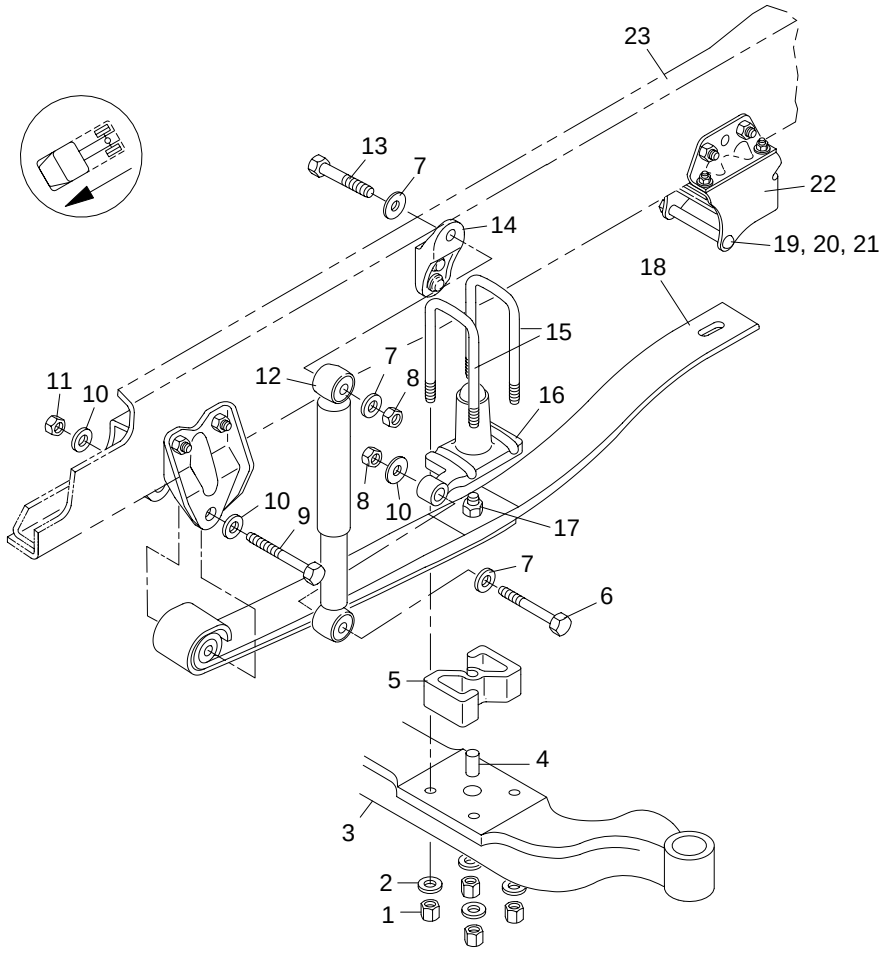


11/09/2001 f320839

1. Frame Rail
2. Shock Absorber Upper-Mounting Bolt
3. Hardened Washer
4. Shock Absorber Upper-Mounting Bracket
5. Hexnut
6. Hexnut, 3/4–10, Grade C
7. Hardened Washer
8. Spring Shackle
9. Shackle Bracket
10. Bushing
11. Spring Shackle Bolt, 3/4–10 x 6.5
12. Spacer
13. Shock Absorber
14. Hexnut
15. Hardened Washer
16. U-Bolt, 5/8–18 (3/4–16 for 12,000-lb capacity)
17. Front Spring Bracket
18. Front Spring Mounting Eye Bolt, 3/4–10 x 6
19. Spring Assembly
20. Shock Absorber Lower-Mounting Bracket
21. Spacer
22. Caster Adjustment Shim
23. Dowel Pin
24. Axle
25. Hardened Washer
26. High Hexnut, 5/8–18 (3/4–16, Grade C for 12,000-lb capacity)

Fig. 1, Taper-Leaf Front Suspension (vehicles built before September 15, 2002)

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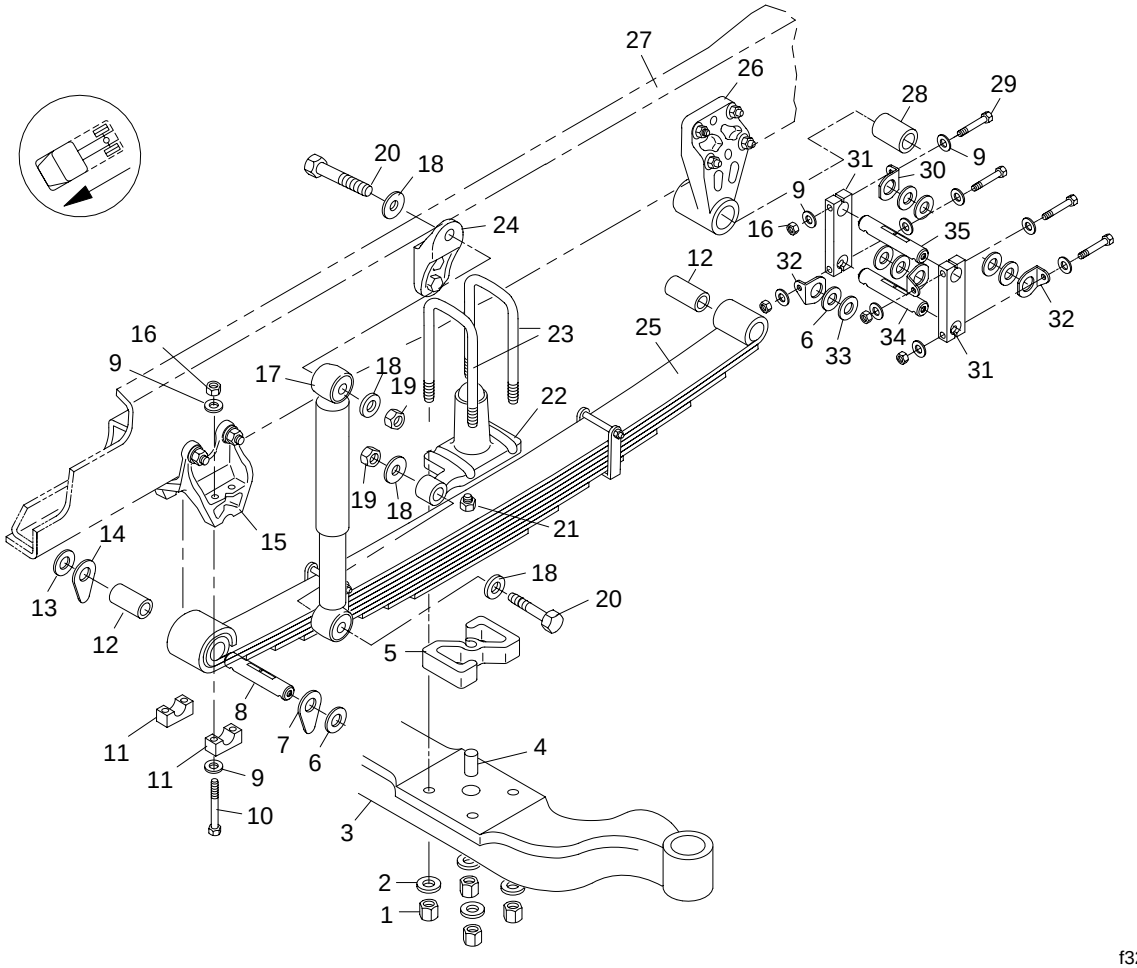
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1. U-Bolt High Nut
2. Bearing Washer
3. Axle
4. Dowel
5. Spacer
6. Hexbolt, 3/4–10
7. Flatwasher
8. Hexnut, 3/4–10
9. Hexbolt, 3/4–10
10. Flatwasher
11. Hexnut, 3/4–10
12. Shock Absorber
13. Hexbolt, 3/4–10
14. Shock Absorber Upper Mounting Bracket
15. U-Bolts
16. Axle Stop and Shock Absorber Lower Mounting Bracket
17. Spring Center-Bolt and Nut
18. Leaf Spring (leaf-and-a-half)
19. Carriage Bolt, 1/2–13
20. Washer
21. Hexnut, 1/2–13
22. Rear Spring Hanger
23. Left Frame Rail

Fig. 2, Taper-Leaf Front Suspension (vehicles built from September 15, 2002)

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General Information



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1. U-Bolt High Nut
2. Bearing Washer
3. Axle
4. Dowel
5. Spacer
6. Outboard Spacing Washer(s)
7. Outboard Spring Spacer
8. Spring Pin, Forward Spring Eye
9. Hardened Washer, 1/2–13
10. Hexbolt, 1/2–13 x 5"
11. Spring Pin Retainer
12. Spring-Eye Bushing
13. Hardened Washer
14. Inboard Spring Spacer
15. Front Suspension Bracket
16. Locknut, 3/4–10
17. Shock Absorber
18. Hardened Washer
19. Locknut, 3/4–10
20. Hexbolt, 3/4–10
21. Spring Center-Bolt and Nut
22. Axle Stop and Shock Absorber Lower Mounting Bracket
23. U-Bolt
24. Shock Absorber Upper Mounting Bracket
25. Leaf Spring
26. Shackle Bracket
27. Frame Rail
28. Shackle Bracket Bushing
29. Pinch Bolt, 1/2–13 x 4"
30. Inboard Wear Plate
31. Shackle
32. Outboard Wear Plate
33. Hardened Washer, 2-1/4" o.d.
34. Spring Pin, Rear Spring Eye
35. Shackle Bracket Pin

Fig. 3, Multi-Leaf Front Suspension (vehicles built from September 15, 2002)

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Leaf Spring and Components Removal and Installation

Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Remove the front bumper. For instructions, see **Group 31**.
4. Support the frame and axle with safety stands.

⚠ WARNING

Use safety stands to securely support all axle and frame weight during suspension repairs. Unsecured components may drop when fasteners are loosened or removed, causing component damage and serious personal injury.

5. Raise the front of the vehicle until both wheels are off the ground and the frame is supported with safety stands. The axle and leaf springs can then be manipulated with the floor jack.
6. Remove the wheel and tire for access to the leaf spring. For instructions, see **Group 40**.
7. Remove the leaf spring assembly.

   NOTE: Leaf spring assemblies on vehicles with suspensions manufactured at 14,000-pound (6 350 kg) and 18,000-pound (8 165 kg) weight ratings have multiple leaf springs, heavy duty brackets, U-bolts and other components.

   7.1 Verify that the axle is supported by the floor jack. Remove the U-bolt high nuts and washers. Remove the U-bolts. See **Fig. 1**.

   7.2 Loosen the shock absorber upper mounting bolt. Swing the shock absorber and attached lower mounting bracket out of the way. See **Fig. 2** and **Fig. 3**.

   7.3 Remove the spring shackle lower bolt. See **Fig. 4**.

   NOTE: If removing the left side spring, the steering wheel must be at right full-lock so the bolt can clear the drag link.

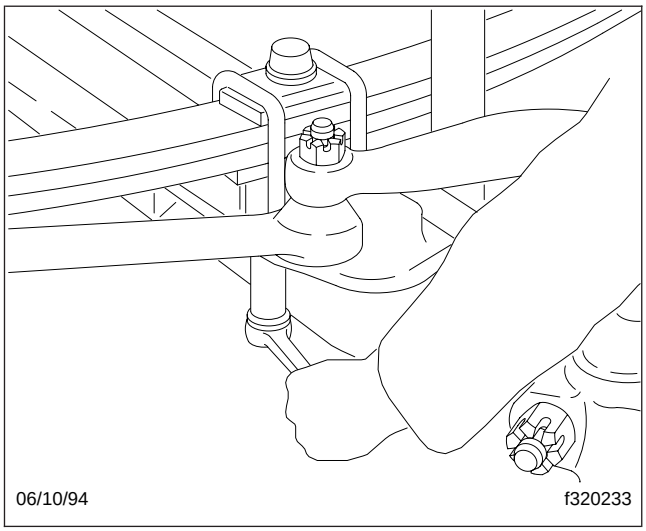
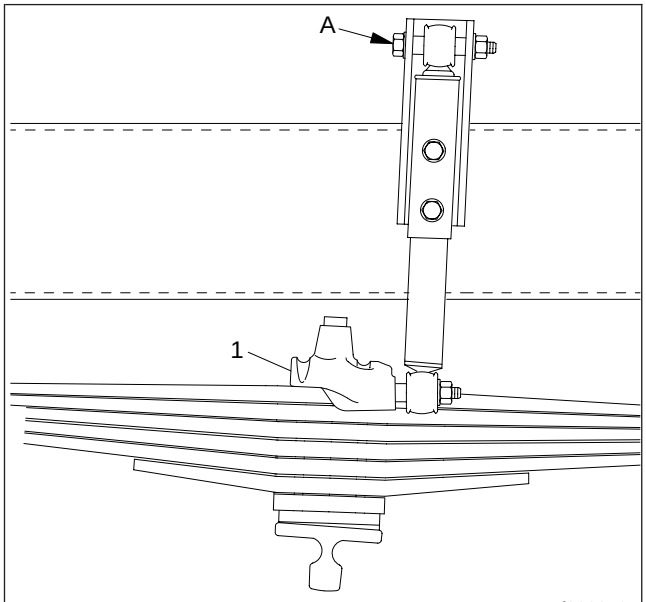


Fig. 1, U-Bolt Removal



A. Loosen the shock absorber upper mounting bolt.
1. Shock Absorber Lower Mounting Bracket

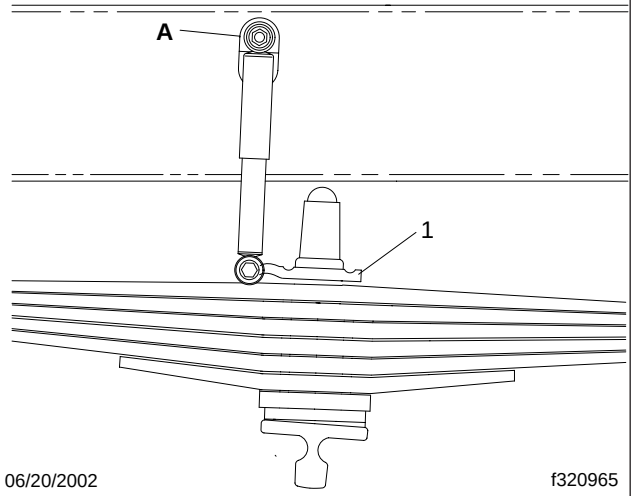
Fig. 2, Shock Absorber Lower Mounting Bracket Removal (vehicles built before September 15, 2002)

   7.4 Remove the front spring mounting eye bolt. See **Fig. 5**.

   7.5 Support the front axle with a jack. Remove the safety stand. Lower the front axle enough to allow removal of the spring.

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Leaf Spring and Components Removal and Installation



A. Loosen the shock absorber upper mounting bolt.
1. Shock Absorber Lower Mounting Bracket

Fig. 3, Shock Absorber Lower Mounting Bracket Removal (left-side shown; vehicles built from September 15, 2002)

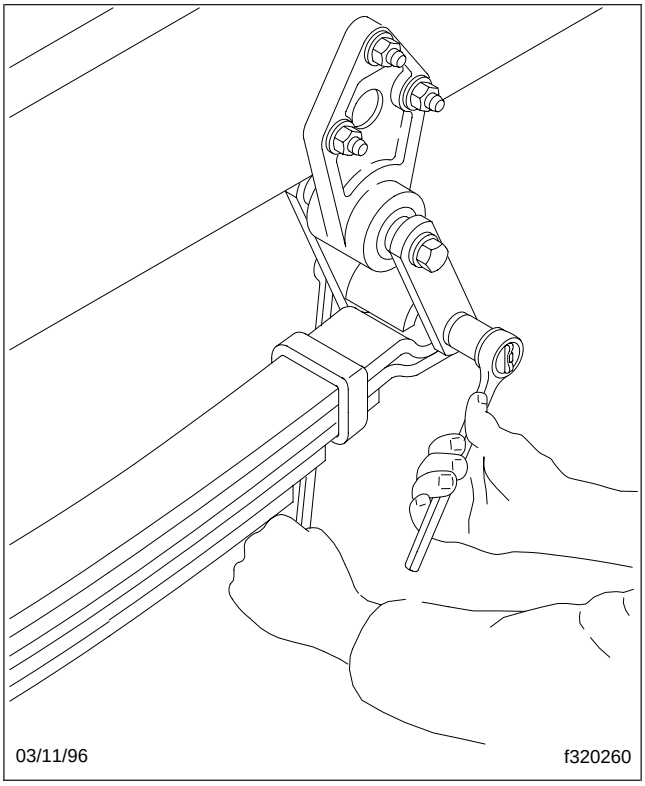


Fig. 4, Spring Shackle Lower Bolt Removal/Installation

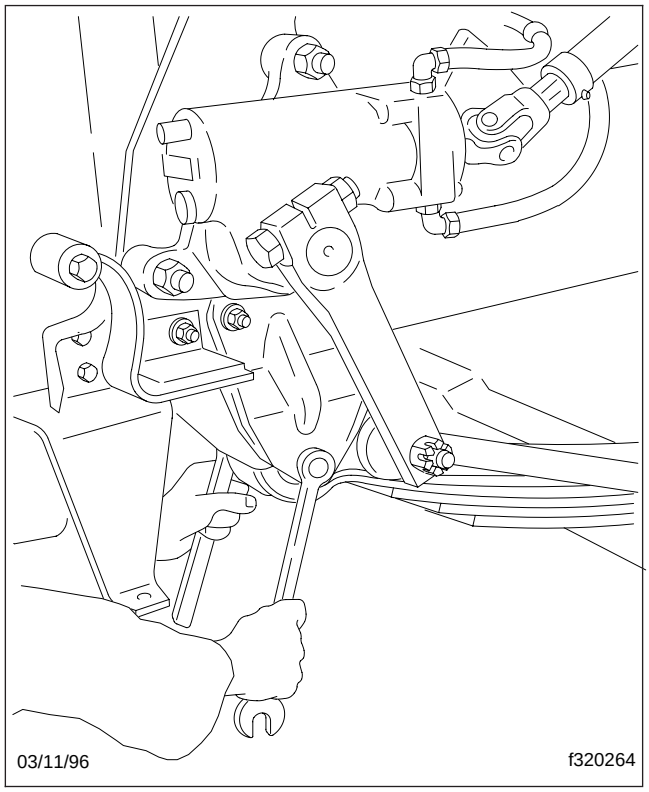


Fig. 5, Spring Eye Bolt Removal/Installation

Note the location of the spring spacer and any caster adjustment shims.

WARNING

The spring assembly is heavy. To prevent bodily injury, always use two people to remove it.

7.6 Remove the spring by sliding it toward the front of the vehicle. See **Fig. 6**.

8. Remove the shackle upper bolt and nut. See **Fig. 7**. Press out the bushing. Remove the fasteners that hold the shackle bracket to the frame. See **Fig. 8**. Remove the bracket.

Installation

IMPORTANT: For normal highway operation do not install springs of two different designs or load capacities on the front axle. In order to maintain a balanced front suspension system, install identical spring assemblies.

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Leaf Spring and Components Removal and Installation

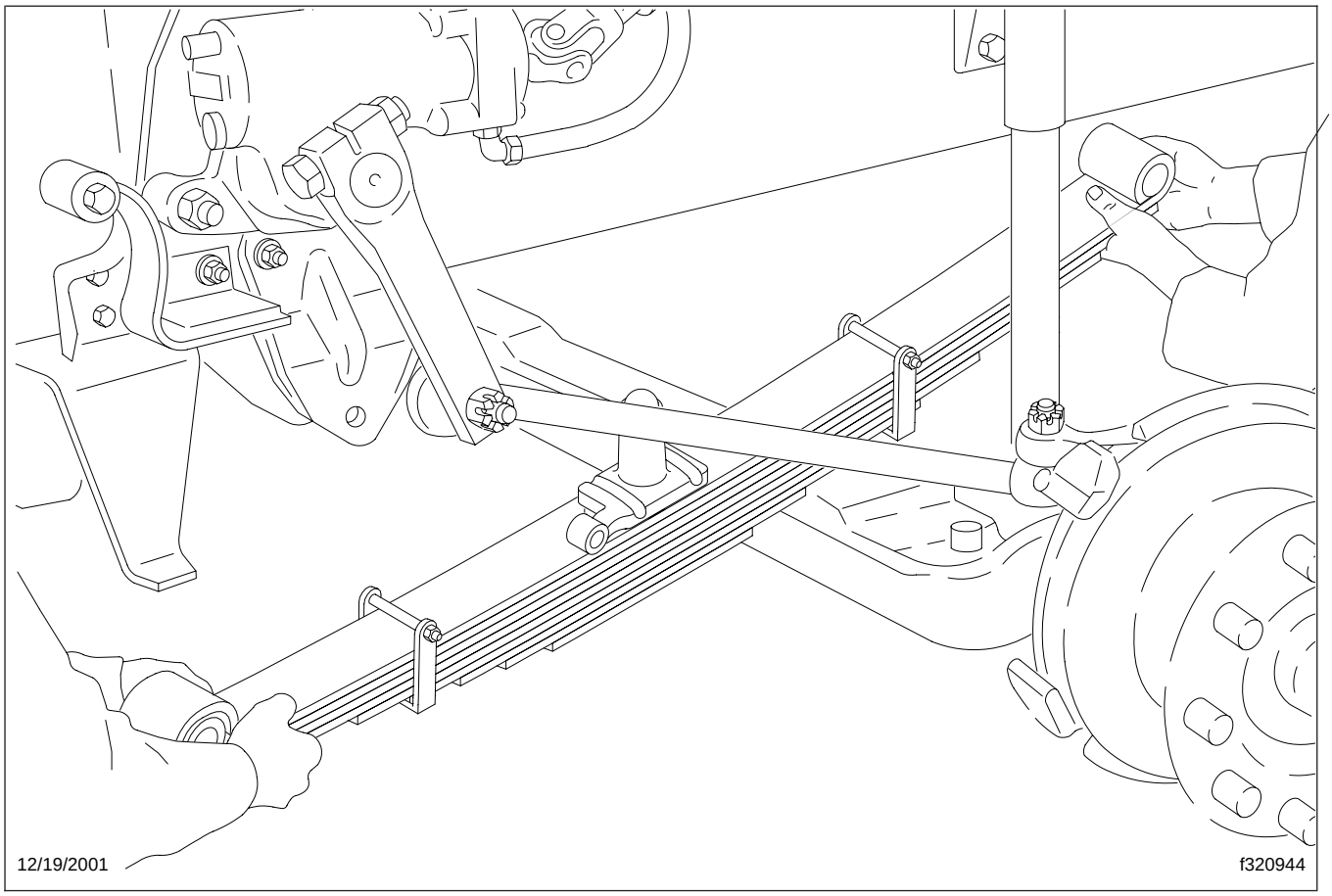


Fig. 6, Spring Removal/Installation

1. If the shackle bracket was removed, install it. See **Fig. 8**. Tighten the mounting bolts 135 lbf·ft (183 N·m).

NOTE: All suspension bracket (frame) fasteners require periodic retightening. See Group 32 in the *Acterra® Maintenance Manual* for the recommended intervals.

2. If the spring shackle was removed, install it. Do not tighten the upper bolt in the shackle at this time.

⚠ WARNING

The spring assembly is heavy. To prevent bodily injury, always use two people to install it.

3. Install the spring assembly.

NOTE: Leaf spring assemblies on vehicles with suspensions manufactured at 14,000-pound (6 350 kg) and 18,000-pound (8 165 kg) weight ratings have multiple leaf springs, heavy duty brackets, U-bolts and other components.

3.1 Lift the spring into position. See **Fig. 6**. Install the spring to the axle by tightening the spring eye bolt at the front of the spring and the lower bolt in the shackle at the rear of the spring just enough to secure the spring to the axle. Make sure the spring is secured to the axle before torquing the bolts. See **Fig. 4** and **Fig. 5**.

3.2 Tighten the spring eye bolt and the bolts at the top and bottom of the shackle 240 lbf·ft (325 N·m).

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Leaf Spring and Components Removal and Installation

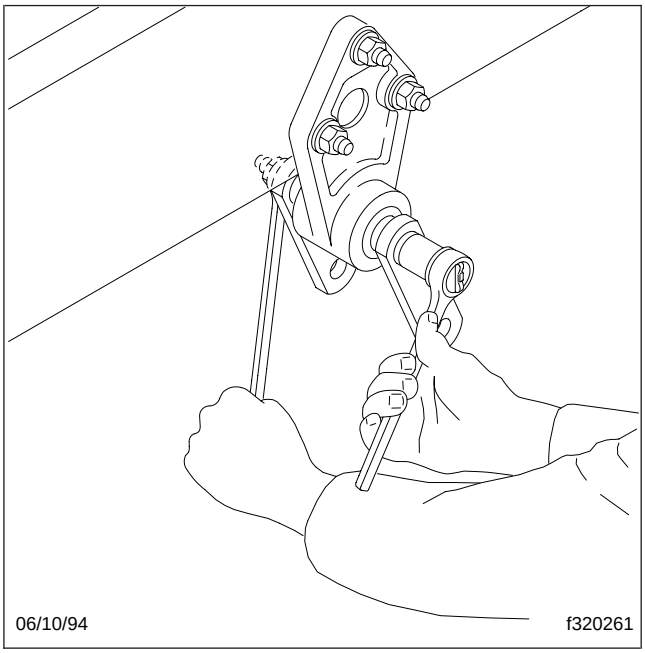


Fig. 7, Spring Shackle Bushing Removal

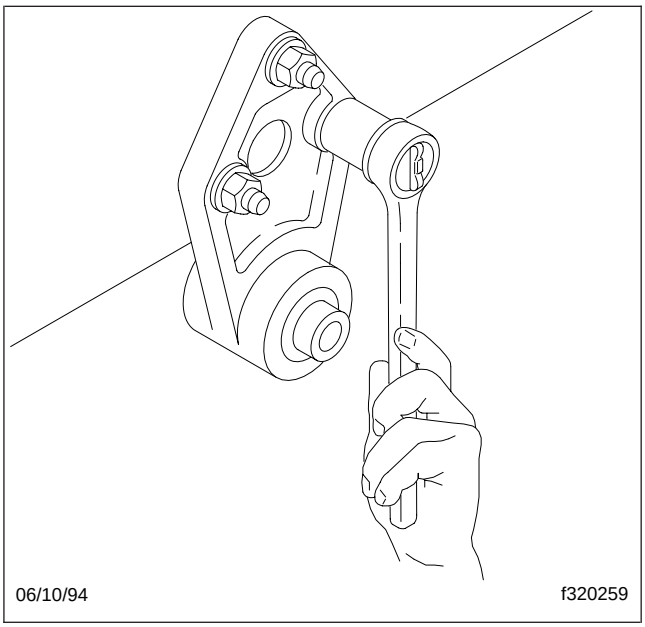


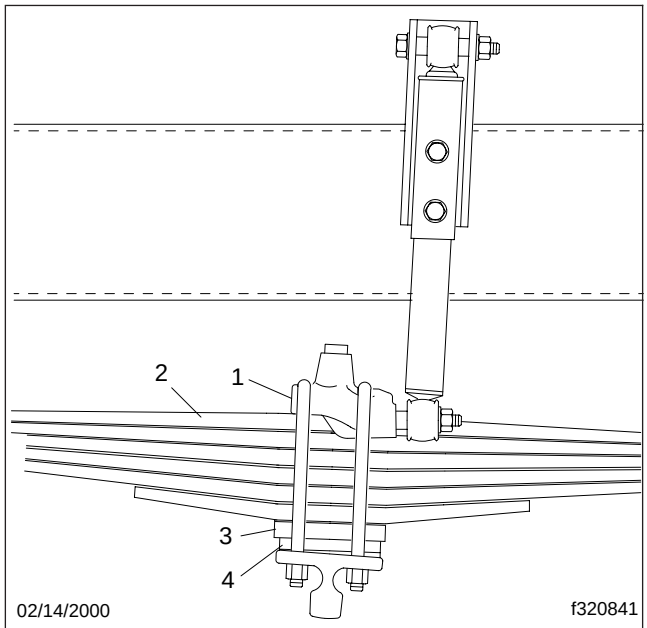
Fig. 8, Shackle Bracket Installation

3.3 Apply Alumilastic® or a similar compound to the top and bottom of the spring spacer and any caster adjustment shims.

CAUTION

Failure to apply Alumilastic compound or an equivalent to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to suspension parts.

3.4 Place the caster adjustment shim and spring spacer on the axle. See **Fig. 9** and **Fig. 10**.



1. U-Bolt Pad and Shock Absorber Lower Mounting Bracket
2. Leaf Spring
3. Spring Spacer
4. Caster Adjustment Shim

Fig. 9, Caster Adjustment Shim Location (vehicles built before September 15, 2002)

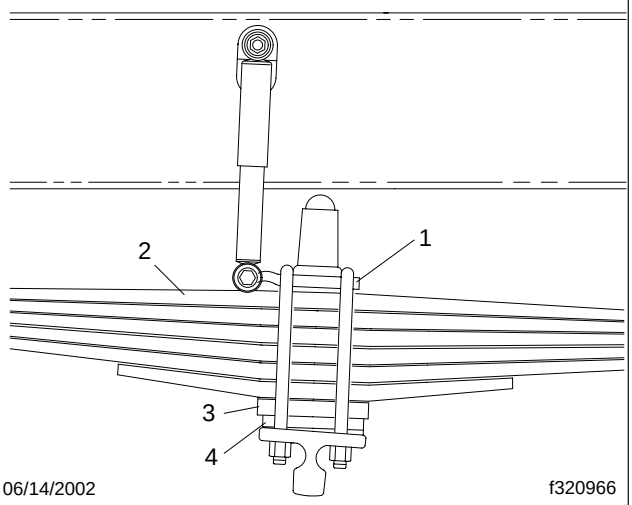
3.5 Place the U-bolt pad and shock absorber lower mounting bracket in position on the leaf spring.

3.6 Using a jack, lift the axle into position.

3.7 Install the U-bolts over the U-bolt pad, spring leaves, spring spacer, caster adjustment shims and through the front axle.

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Leaf Spring and Components Removal and Installation



1. U-Bolt Pad and Shock Absorber Lower Mounting Bracket
2. Leaf Spring
3. Spring Spacer
4. Caster Adjustment Shim

Fig. 10, Caster Adjustment Shim Location (vehicles built after September 15, 2002)

3.8 Install the high nuts on the U-bolts and tighten them as described in **Specifications 400**.

4. Install the front bumper. See **Group 31** for instructions.
5. Install the wheel and tire. See **Group 40** for instructions.
6. Remove the floor jack and safety stands.
7. Close and latch the hood.
8. Remove the chocks from the tires.

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Cleaning and Inspection

1. Using a wire brush and solvent or steam cleaning equipment, wash all parts to remove dirt, grease, and scale.
2. Inspect all components for damage.
   - 2.1 Inspect the spring shackles and the shackle bracket for cracks, wear, and other damage. Replace any damaged parts.
   - 2.2 Inspect the leaf spring assembly for cracks or corrosion. If any leaves are cracked or broken, replace the *entire spring assembly.*

⚠ WARNING

Do not replace individual leaves of a leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. On front spring assemblies, if cracks or breaks exist in the two top leaves, a loss of vehicle control could occur. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

   - 2.3 If the protective coating is gone from some areas of the spring, the cleaned areas can be painted with a rust-inhibiting paint. If rusting or corrosion is severe, replace the spring assembly.

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Shackle Bracket Bushing Replacement

NOTE: See **Fig. 1** or **Fig. 2** for this procedure.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Remove the front bumper. For instructions, see **Group 31**.
4. Remove the wheel and tire for access to the leaf spring. For instructions, see **Group 40**.
5. Remove the half-fender.
6. Remove the shackle bracket from the vehicle.
   - 6.1 Jack up the frame until the shackle lower bolt can be removed. Remove the bolt.
   - 6.2 Remove the shackle upper bolt and the spring shackle.
   - 6.3 Remove the shackle bracket from the frame.
7. Using a press, remove the bushing from the shackle bracket.
8. Inspect the shackle bracket and new bushing.
   - 8.1 With an inside micrometer or bore gauge, check whether the bracket bore is out-of-round. Replace the bracket if the bushing bore is out-of-round.
   - 8.2 Before installing the new bushing, check the shackle bracket bolt for ease of fit in the bushing. There should be an easy slip fit without wobble between the bolt and the bushing.
9. Using a press, insert the new bushing into the bracket until the bushing is centered in the bracket.

IMPORTANT: Do not press in the bushing by the center sleeve. This could damage the bushing.

10. Check the shackle bracket bolt again for ease of fit in the bushing. It should still fit easily without wobble between the bolt and the bushing. If it binds, the bushing may have been distorted during installation. Replace the bushing and check again for proper fit.
11. Install the shackle bracket. Install the fasteners and tighten them 135 lbf·ft (183 N·m).
12. Connect the leaf spring.
    - 12.1 Install the spring shackle and the shackle upper bolt.
    - 12.2 Adjust the height of the jack supporting the frame until the bushing at the rear of the leaf spring lines up with the hole for the shackle lower bolt.
    - 12.3 Install the shackle lower bolt. Tighten it 240 lbf·ft (325 N·m).
13. Install the half-fender.
14. Install the wheel and tire. For instructions, see **Group 40**.
15. Install the front bumper. For instructions, see **Group 31**.
16. Close and latch the hood.
17. Remove the chocks from the rear tires.

Spring Bushing Replacement

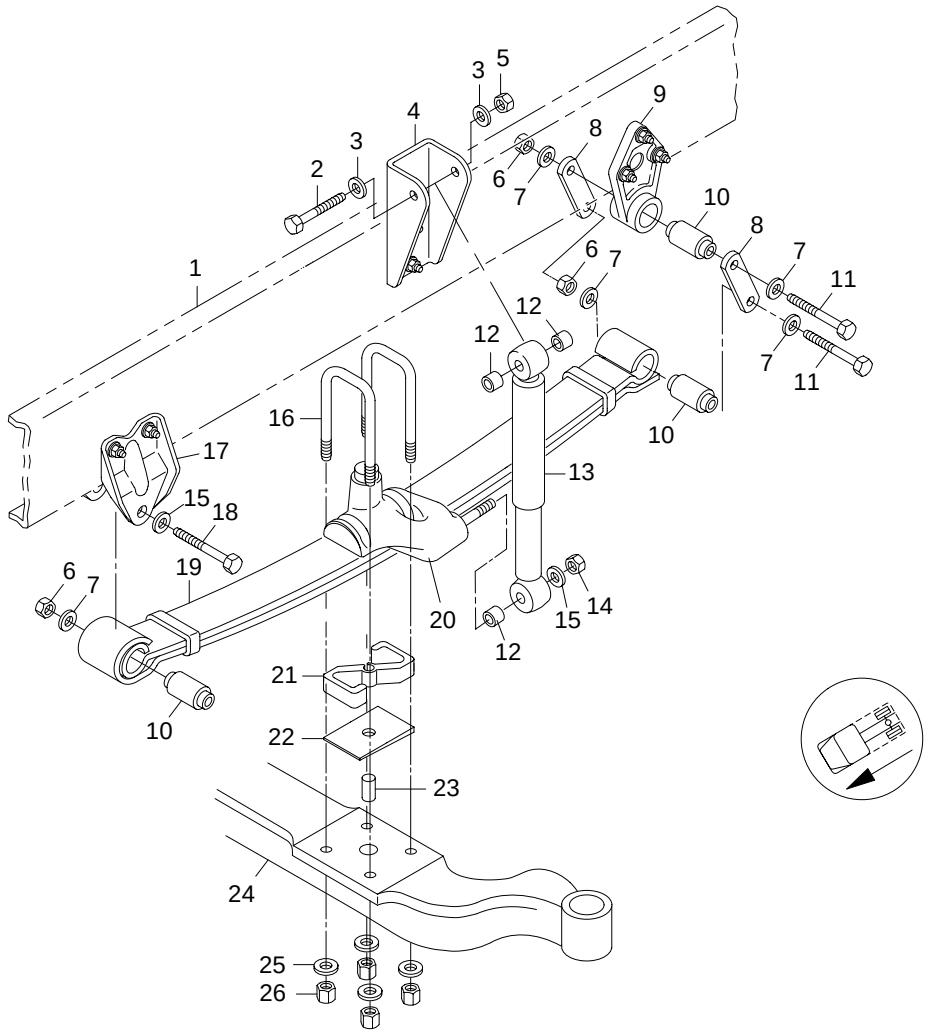
1. Remove the leaf spring from the vehicle. See **Subject 100** for instructions.
2. Using a press, remove the worn or damaged bushing.
3. Using a press, insert the new bushing into the spring eye until the bushing is flush with the edges of the spring eye.

IMPORTANT: Do not press in the bushing by the center sleeve. This could damage the bushing.

4. Install the leaf spring. See **Subject 100** for instructions.

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Bushing Replacement

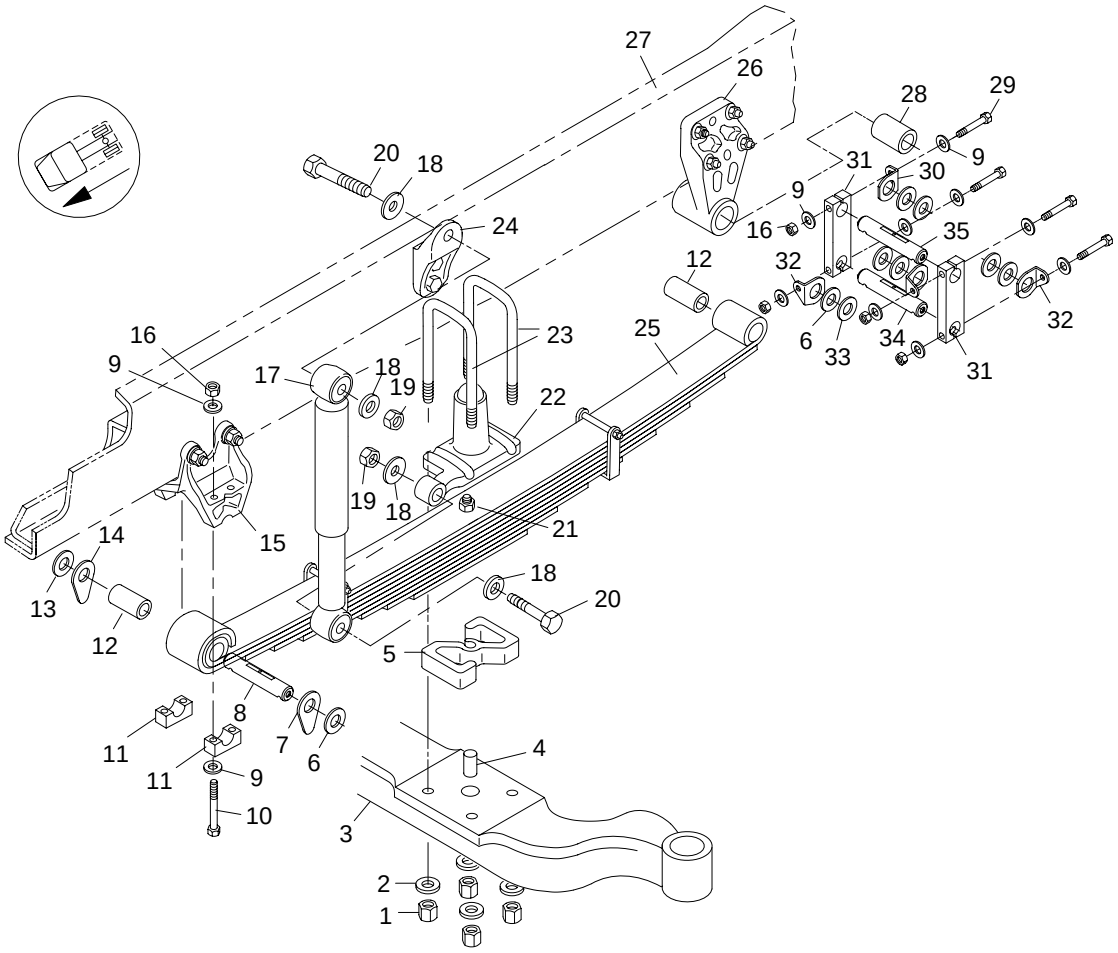


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1. Frame Rail
2. Shock Absorber Upper-Mounting Bolt
3. Hardened Washer
4. Shock Absorber Upper-Mounting Bracket
5. Hexnut
6. Hexnut, 3/4–10, Grade C
7. Hardened Washer
8. Spring Shackle
9. Shackle Bracket
10. Bushing
11. Spring Shackle Bolt, 3/4–10 x 6.5
12. Spacer
13. Shock Absorber
14. Hexnut
15. Hardened Washer
16. U-Bolt, 5/8–18 (3/4–16 for 12,000-lb capacity)
17. Front Spring Bracket
18. Front Spring Mounting Eye Bolt, 3/4–10 x 6
19. Spring Assembly
20. Shock Absorber Lower-Mounting Bracket
21. Spacer
22. Caster Adjustment Shim
23. Dowel Pin
24. Axle
25. Hardened Washer
26. High Hexnut, 5/8–18 (3/4–16, Grade C for 12,000-lb capacity)

Fig. 1, Front Suspension (vehicles built before September 15, 2002)

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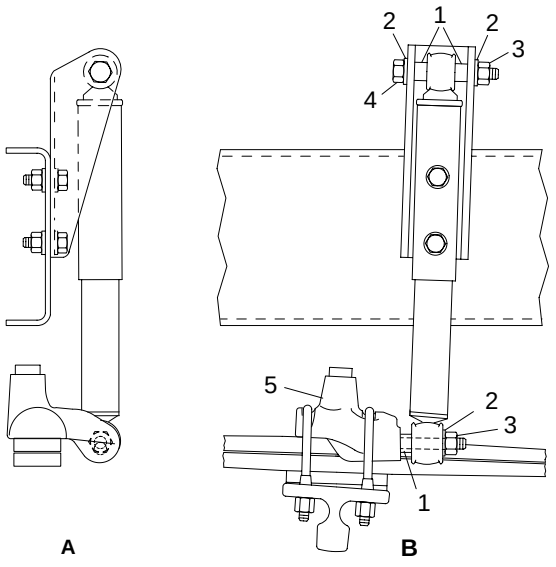
1. U-Bolt High Nut
2. Bearing Washer
3. Axle
4. Dowel
5. Spacer
6. Outboard Spacing Washer(s)
7. Outboard Spring Spacer
8. Spring Pin, Forward Spring Eye
9. Hardened Washer, 1/2–13
10. Hexbolt, 1/2–13 x 5"
11. Spring Pin Retainer
12. Spring-Eye Bushing
13. Hardened Washer
14. Inboard Spring Spacer
15. Front Suspension Bracket
16. Locknut, 3/4–10
17. Shock Absorber
18. Hardened Washer
19. Locknut, 3/4–10
20. Hexbolt, 3/4–10
21. Spring Center-Bolt and Nut
22. Axle Stop and Shock Absorber Lower Mounting Bracket
23. U-Bolt
24. Shock Absorber Upper Mounting Bracket
25. Leaf Spring
26. Shackle Bracket
27. Frame Rail
28. Shackle Bracket Bushing
29. Pinch Bolt, 1/2–13 x 4"
30. Inboard Wear Plate
31. Shackle
32. Outboard Wear Plate
33. Hardened Washer, 2-1/4" o.d.
34. Spring Pin, Rear Spring Eye
35. Shackle Bracket Pin

Fig. 2, Front Suspension (vehicles built from September 15, 2002)

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Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Remove the shock absorber.
   - 3.1 Remove the locknut from the shock absorber upper mount. Remove the capscrew, washers, and spacers.
   - 3.2 Remove the locknut from the shock absorber lower mount. Remove the washers and spacers.
   - 3.3 Remove the shock absorber.
4. Install the new shock absorber as shown in **Fig. 1** and **Fig. 2**. Tighten the locknuts 110 lbf·ft (149 N·m).



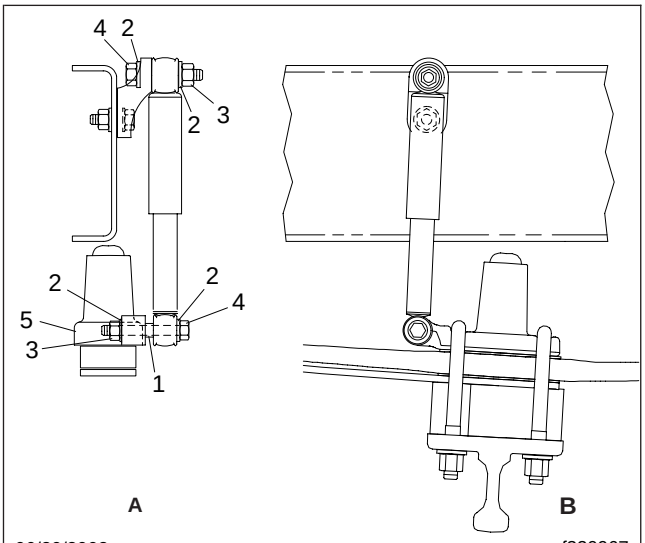
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A. Front View B. Side View

1. Spacer
2. Washer, 3/4-Inch
3. Locknut, 3/4-Inch
4. Capscrew, 3/4–10 x 5.5
5. Lower Shock Absorber Mounting Bracket

Fig. 1, Shock Absorber Mounting (vehicles built before September 15, 2002)

5. Close the hood and remove the chocks from the tires.



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A. Front View B. Left Side View

1. Spacer
2. Washer, 3/4-Inch
3. Locknut, 3/4-Inch
4. Capscrew, 3/4–10
5. Lower Shock Absorber Mounting Bracket

Fig. 2, Shock Absorber Mounting (vehicles built from September 15, 2002)

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Troubleshooting Tables

Problem—Vehicle Leans to One Side

Problem—Vehicle Leans to One Side	
Possible Cause	**Remedy**
One or more spring leaves broken	Replace the spring assembly.
Weak or fatigued spring assembly	Replace the spring assembly.
Unmatched spring-design/load-capacity spring assemblies installed	Install the correct spring assemblies as originally specified for the vehicle.
Bent or twisted frame rail	Check the frame rails for bends and twists. Correct as needed.

Problem—Vehicle Wanders

Problem—Vehicle Wanders	
Possible Cause	**Remedy**
One or more spring leaves broken	Replace the spring assembly.
Wheels out of alignment	Adjust the wheel alignment using the instructions in **Group 33**.
Caster is incorrect	Install correct caster shims. See **Group 33** for specifications.
Steering gear not centered	Adjust steering using the instructions in **Group 46**.
Drive axle out of alignment	Align the drive axle using the instructions in **Group 35**.

Problem—Vehicle Bottoms Out

Problem—Vehicle Bottoms Out	
Possible Cause	**Remedy**
Excessive weight on vehicle causing an overload	Reduce the loaded vehicle weight to the maximum spring capacities.
One or more spring leaves broken	Replace the spring assembly.
Weak or fatigued spring assembly	Replace the spring assembly.

Problem—Frequent Spring Breakage

Problem—Frequent Spring Breakage	
Possible Cause	**Remedy**
Overloaded vehicle or operated under severe conditions	Reduce the loaded vehicle weight to the maximum spring capacities. Caution the driver on improper vehicle handling.
Insufficient torque on the U-bolt high nuts	Torque the U-bolt high nuts to the value listed in the torque table in **Specifications, 400**.
Loose center bolt allowing spring leaves to slip	Check the spring leaves for damage. If damaged, replace the spring assembly. If not, tighten the center-bolt nut to the value listed in the torque table in **Specifications, 400**.
Worn or damaged spring bushings allowing spring end-play	Replace the spring bolt and bushing.

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Troubleshooting

Problem—Frequent Spring Breakage	
Possible Cause	**Remedy**
Loose spring bolt allowing spring end-play	Replace the spring bolt and bushing.

Problem—Noisy Spring

Problem—Noisy Spring	
Possible Cause	**Remedy**
Loose U-bolt nut or center bolt allowing spring leaf slippage	Inspect the components for damage. Replace damaged components as necessary. Torque all fasteners to the values listed in the torque table in **Specifications, 400**.
Loose, bent, or broken spring shackle or front suspension bracket impairing spring flex	Inspect the shackles and brackets for damage. Replace damaged components as necessary. Torque the fasteners to the values listed in the torque table in **Specifications, 400**.
Worn or damaged spring bolts allowing spring end-play	Replace any worn or damaged spring bolts.
Worn or damaged spring bushings allowing spring end-play	Replace the spring bolt and bushing.

Problem—Rough Ride

Problem—Rough Ride	
Possible Cause	**Remedy**
See **Section 32.03**.	

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Specifications

Front Suspension Fastener Torques		
Description	**Size**	**Torque: lbf·ft (N·m)**
Upper and Lower Spring Shackle Bolt	3/4–10	135 (183)
Shackle Bracket Mounting Bolt	5/8–11	135 (180)
	3/4–10	240 (325
Spring Shackle Pinch-Bolt Locknuts	1/2–13	Aluminum Shackles: 45 (61)
		Steel Shackles: 70 (95)
Spring Eye Bolt	3/4–10	240 (325)
Shock Absorber Mounting Capscrews	3/4–10	120 (163)
U-Bolt High Nut (Tighten in a diagonal pattern as shown in **Fig. 1**.)	5/8–18	Stage 1: Hand-Tighten Stage 2: 60 (80) Stage 3: 200 (271) Stage 4: 180–230 (245–313)
	3/4–16	Stage 1: Hand-Tighten Stage 2: 60 (80) Stage 3: 200 (271) Stage 4: 270–330 (367–449)
	7/8–14	Stage 1: Hand-Tighten Stage 2: 60 (80) Stage 3: 200 (271) Stage 4: 420–500 (571–680)

Table 1, Front Suspension Fastener Torques

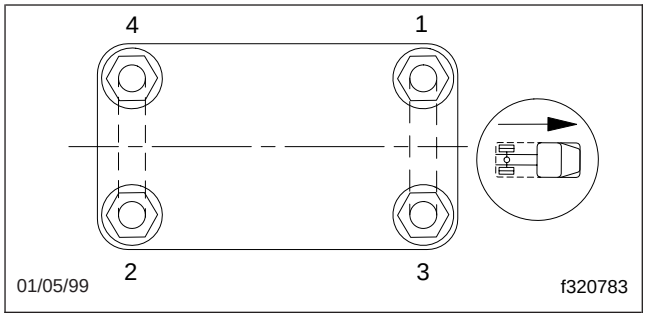


Fig. 1, Tightening Pattern for U-Bolt High Nuts

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General Information

The rear leaf spring suspension uses a radius leaf/slipper spring design with varying capacities. See **Fig. 1**. Optional helper leaves provide a progressive spring rate and additional roll stability. The spring ends ride in cast iron slipper brackets mounted on the frame rails. Each spring bracket holds a replaceable wear pad. The spring assemblies are attached to the axle with U-bolt assemblies. A radius leaf attaches each spring assembly to its forward spring bracket and holds the axle in alignment.

Shock absorbers are optional with all suspension capacities.

Vehicles built after September 15, 2002, use either 60-inch taper-leaf or 52-inch multi-leaf springs with varying capacities. See **Fig. 2**, **Fig. 3**, **Fig. 4**, and **Fig. 5**.

Taper-leaf springs have shackles and pins to secure the rear spring end, while multi-leaf spring applications use a slip spring design in which the rear spring end rides in a cast iron bracket mounted on the frame rail.

The 52-inch multi-leaf spring suspension is available with a rubber or leaf-spring helper. A rubber helper is standard with the 60-inch taper-leaf spring suspension.

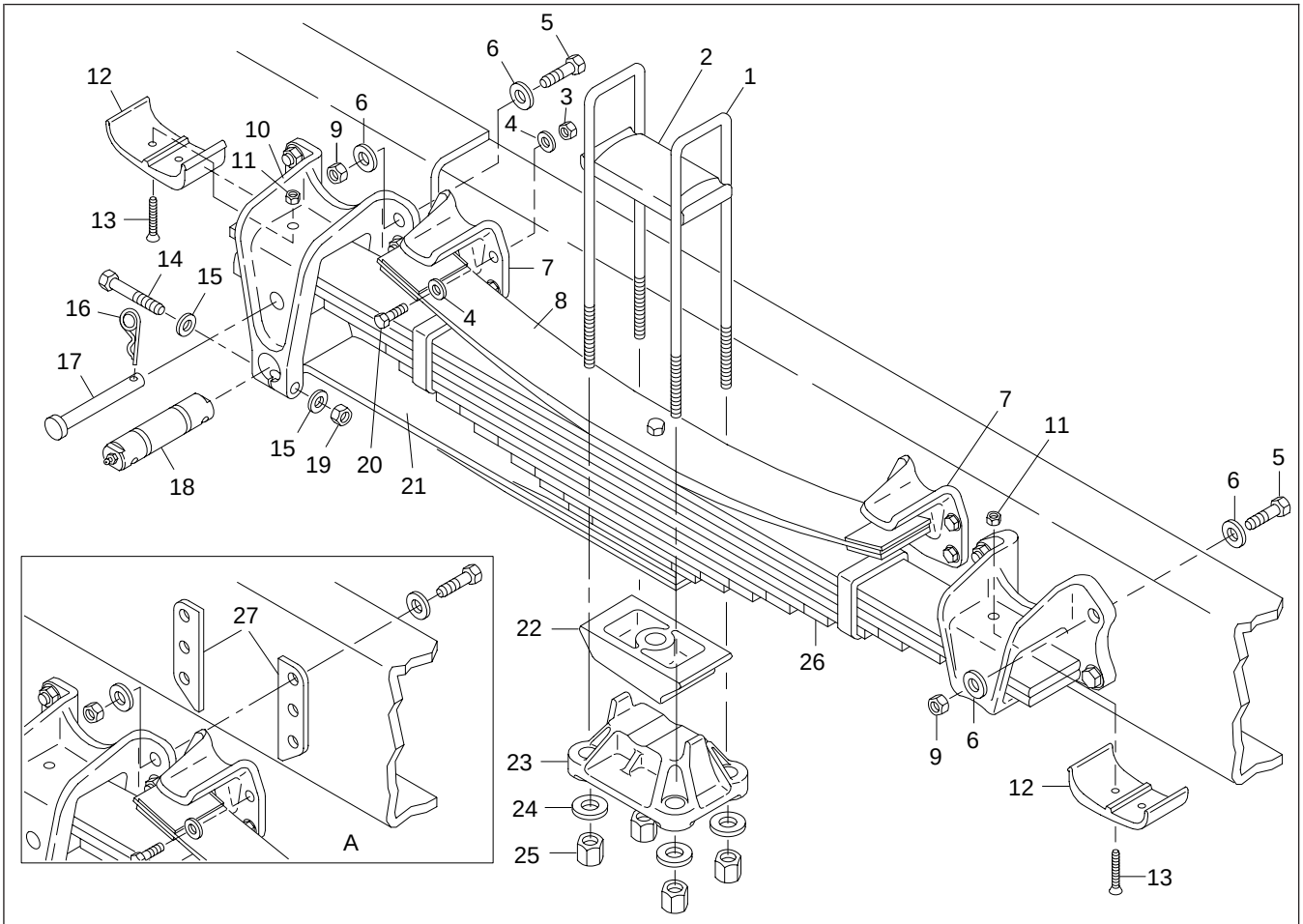
Both types of helper provide additional spring rate for extra load-carrying capacity and increased roll stability.

Both types of spring assemblies are attached to the axle with U-bolt assemblies. Shock absorbers are optional with the 52-inch multi-leaf suspension, and are standard with the 60-inch taper-leaf suspension.

Stabilizer bars are optional on both types of spring assemblies.

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General Information

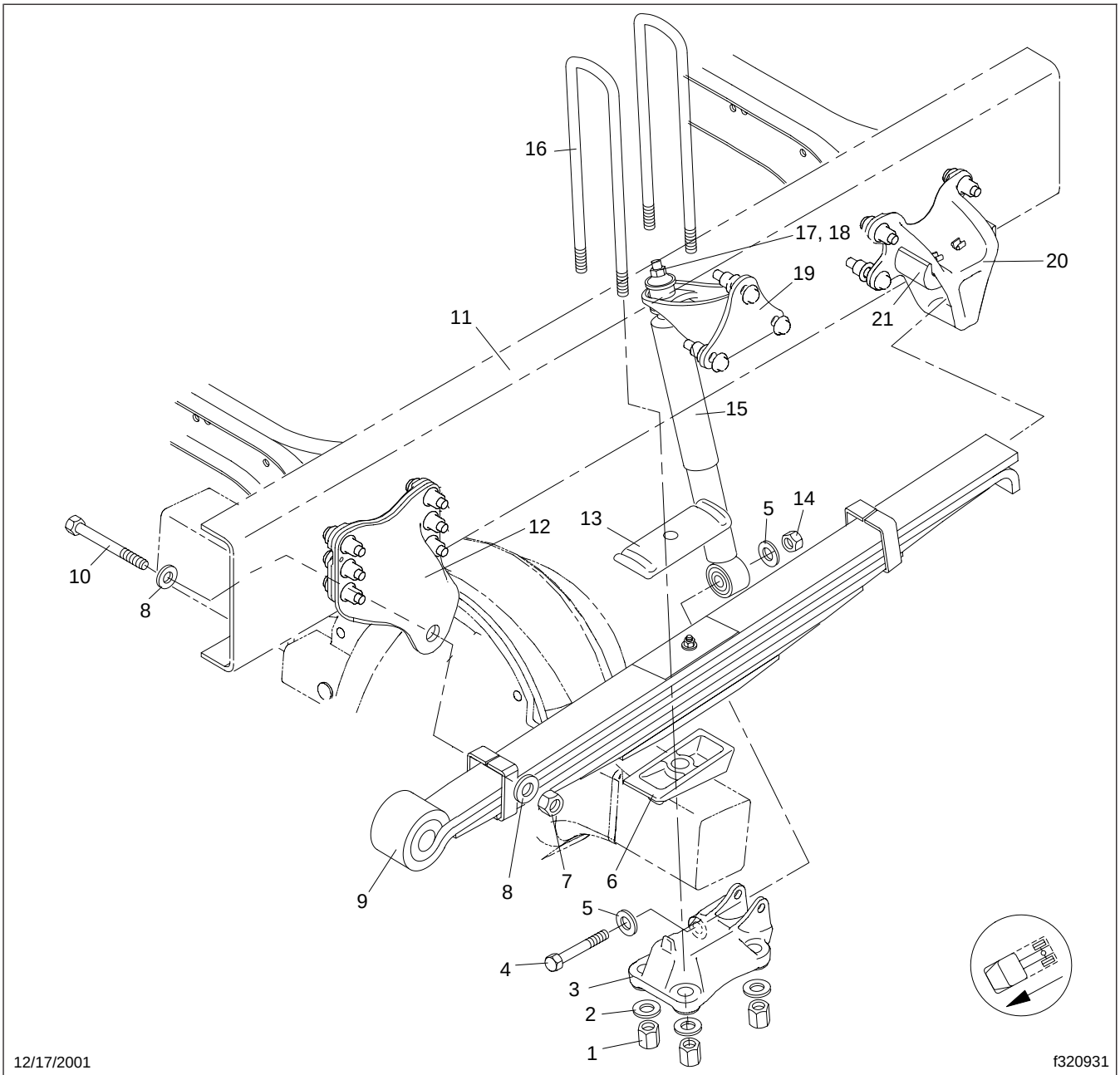


A. Spacers are used when there is no frame rail reinforcement.

1. U-Bolt
2. U-Bolt Pad
3. Helper Spring Bracket Locknut
4. Washer
5. Spring Bracket Mounting Capscrew
6. Washer
7. Helper Spring Bracket
8. Helper Spring
9. Spring Bracket Mounting Locknut
10. Front Spring Bracket
11. Wear Pad Mounting Screw Locknut
12. Wear Pad
13. Allen-Head Screw
14. Spring Eye Pin Pinch Bolt
15. Pinch Bolt Washer
16. Spring Retainer Pin Clip
17. Spring Retainer Clip
18. Spring Eye Pin
19. Pinch Bolt Locknut
20. Helper Spring Bracket Mounting Capscrew
21. Radius Leaf
22. Spring Seat
23. U-Bolt Retainer
24. Hardened Washer
25. U-Bolt High Nut
26. Leaf Spring
27. Spacers

Fig. 1, Leaf Spring Suspension (vehicles built before September 15, 2002)

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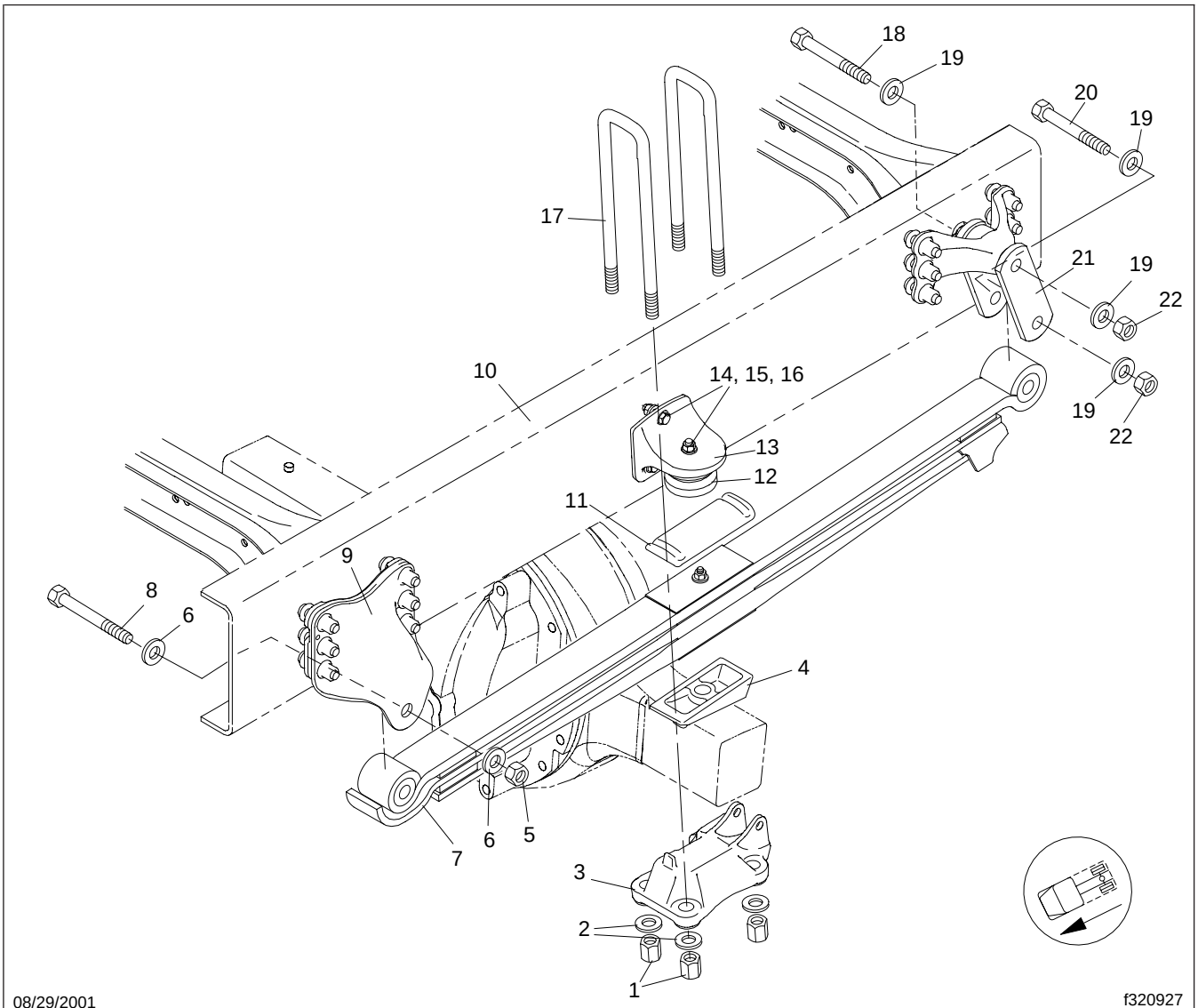


1. U-Bolt High Nut (4 qty.)
2. Flatwashers
3. U-Bolt Retainer
4. Lower Shock Absorber Bolt
5. Flatwasher
6. Axle Seat
7. Hexnut, 3/4–10
8. Flatwasher
9. Leaf Spring Assembly
10. Forward Spring-Eye Bolt
11. Left Frame Rail
12. Forward Spring Hanger
13. U-Bolt Pad
14. Hexnut, 3/4–10
15. Shock Absorber
16. U-Bolt
17. Hexnut, 5/8–18
18. Flatwasher
19. Upper Shock Absorber Bracket
20. Rear Spring Hanger
21. Wear Pad

Fig. 2, 52-Inch Multi-Leaf Spring Suspension (vehicles built after September 15, 2002)

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General Information

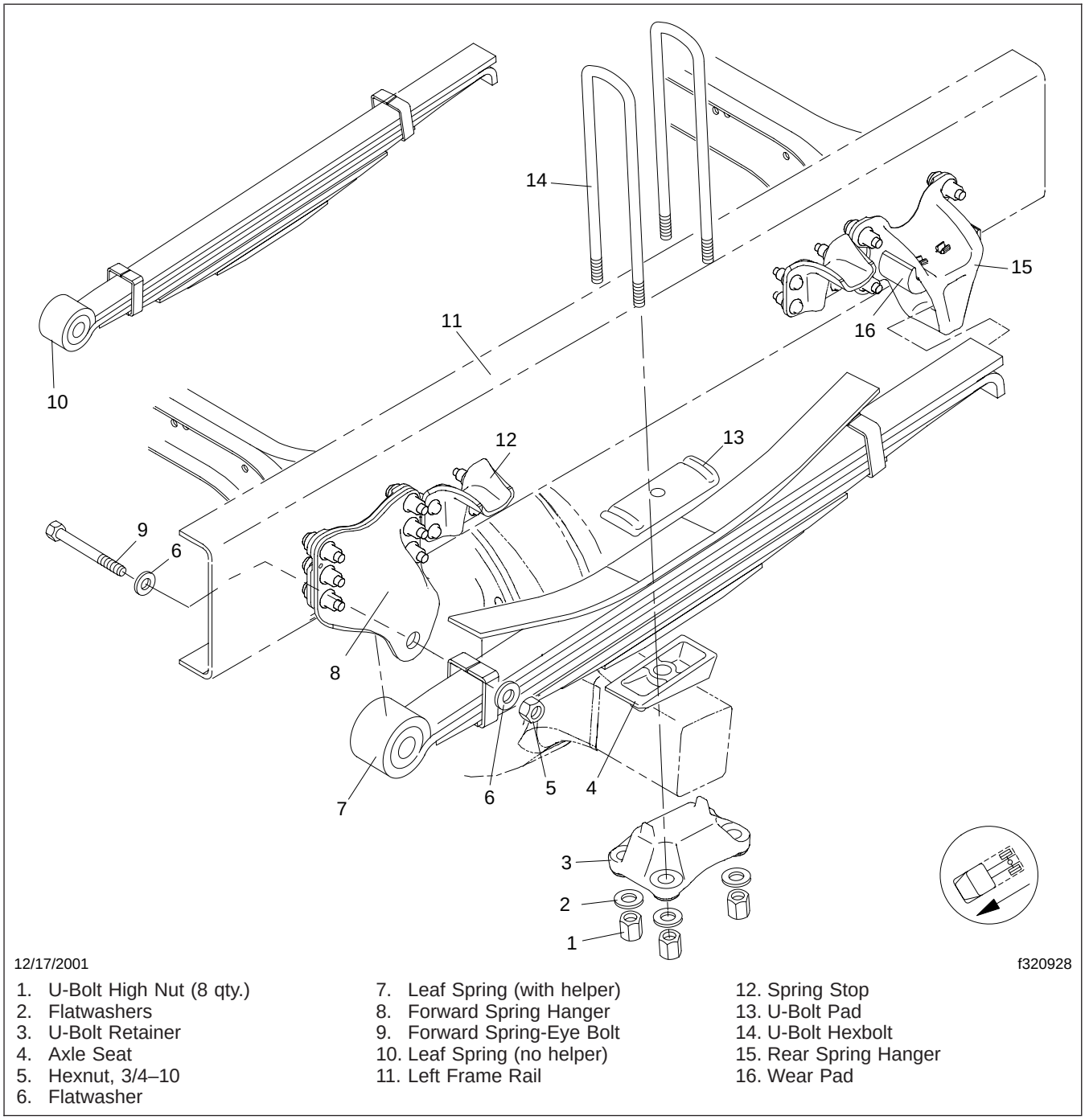


NOTE: Shock absorbers (standard with this suspension) not shown.

1. U-Bolt High Nuts
2. Flatwashers
3. U-Bolt Retainer
4. Axle Seat
5. Hexnut, 3/4–10
6. Flatwasher
7. Leaf Spring Assembly
8. Forward Spring-Eye Bolt
9. Forward Spring Hanger
10. Left Frame Rail
11. U-Bolt Pad
12. Rubber Helper
13. Helper Bracket
14. Hexbolt, 1/2–13
15. Hexnut, 1/2–13
16. Flatwasher
17. U-Bolts
18. Upper Shackle Bolt
19. Flatwasher
20. Lower Shackle Bolt
21. Rear Spring Shackle
22. Hexnut, 3/4–10

Fig. 3, 60-Inch Taper-Leaf Spring Suspension (vehicles built after September 15, 2002)

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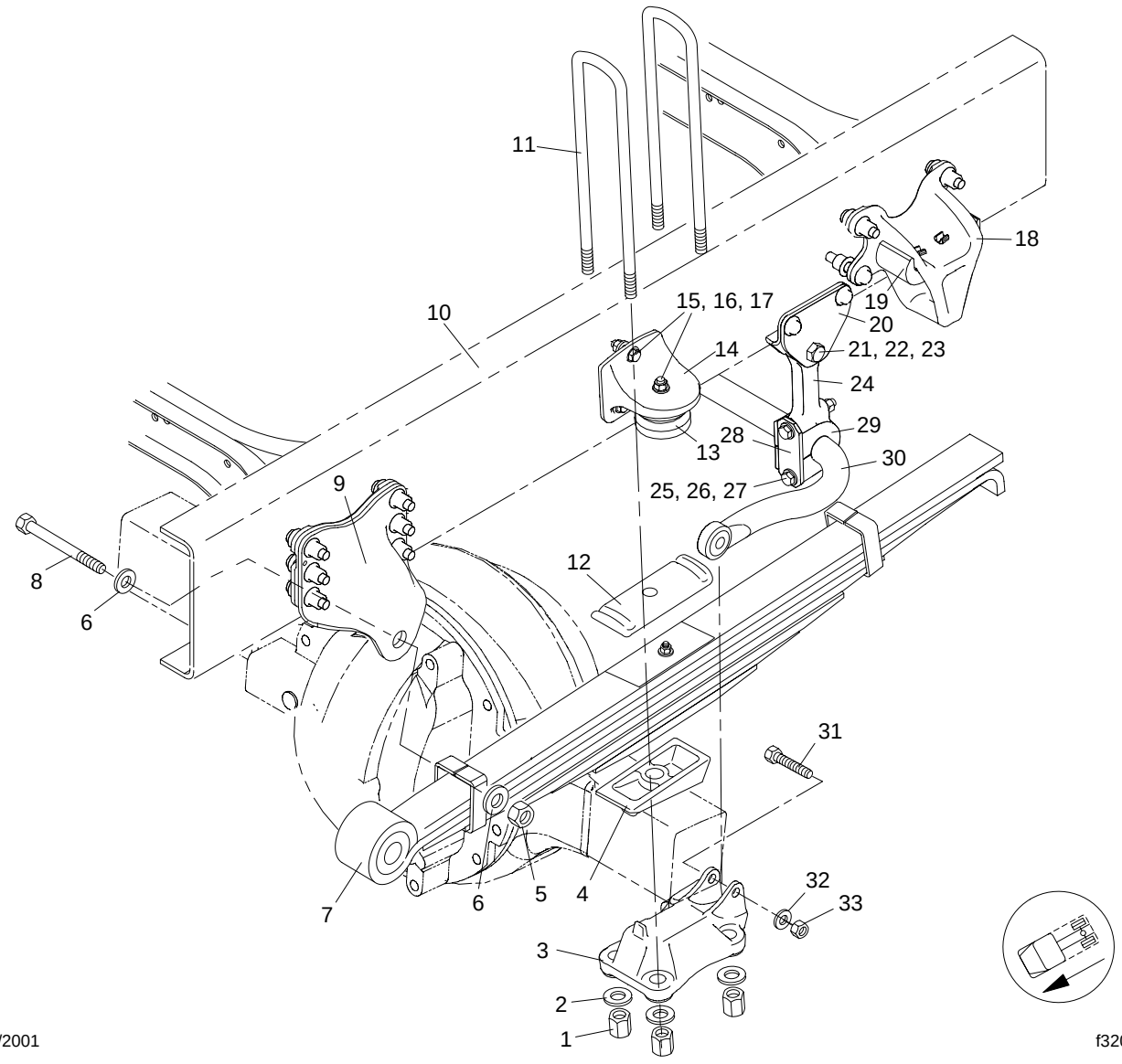


1. U-Bolt High Nut (8 qty.)
2. Flatwashers
3. U-Bolt Retainer
4. Axle Seat
5. Hexnut, 3/4–10
6. Flatwasher
7. Leaf Spring (with helper)
8. Forward Spring Hanger
9. Forward Spring-Eye Bolt
10. Leaf Spring (no helper)
11. Left Frame Rail
12. Spring Stop
13. U-Bolt Pad
14. U-Bolt Hexbolt
15. Rear Spring Hanger
16. Wear Pad

Fig. 4, 52-Inch Multi-Leaf Spring Suspension (vehicles built after September 15, 2002)

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General Information



1. U-Bolt High Nuts
2. Flatwashers
3. U-Bolt Retainer
4. Axle Seat
5. Hexnut, 3/4–10
6. Flatwasher
7. Leaf Spring Assembly
8. Forward Spring-Eye Bolt
9. Forward Spring Hanger
10. Left Frame Rail
11. U-Bolt
12. U-Bolt Pad
13. Rubber Helper
14. Helper Bracket
15. Hexnut, 1/2–13
16. Hexbolt, 1/2–13
17. Flatwasher
18. Rear Spring Hanger
19. Wear Pad
20. Stabilizer Link Bracket
21. Hexbolt, 5/8–11
22. Hexnut, 5/8–11
23. Flatwasher
24. Stabilizer Bar Link
25. Hexbolt, 1/2–13
26. Hexnut, 1/2–13
27. Flatwasher
28. Strap
29. Stabilizer Bar Bushing
30. Stabilizer Bar
31. Hexbolt, 5/8–11
32. Flatwasher
33. Hexnut, 5/8–11

Fig. 5, 52-Inch Multi-Leaf Spring Suspension (vehicles built after September 15, 2002)

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Replacement

1. Park the vehicle on a level surface and set the parking brakes, shut down the engine, and chock the front tires.
2. If needed, remove the rear tires. For instructions, see **Group 40**.

⚠ WARNING

Use safety stands to securely support all axle and frame weight during suspension repairs. Unsecured components may drop when fasteners are loosened or removed, causing component damage and serious personal injury.

3. Lift the rear axle and support it with safety stands. Lift the vehicle frame to take weight off the rear springs.
4. Remove the U-bolt high nuts. Remove the U-bolts. See **Fig. 1**.

NOTE: The remainder of this procedure is divided into instructions for vehicles built before September 15, 2002 and vehicles built from September 15, 2002. Use the applicable instructions for your vehicle.

Vehicles Built Before September 15, 2002

⚠ WARNING

Failure to use a C-clamp may cause components to be forcibly ejected, possibly causing serious personal injury.

1. Remove the spring eye pin that attaches the radius leaf to the front spring bracket.

   For other vehicles, go to the step for removing the spring assembly.

   1.1 Using a C-clamp, take the load off the radius leaf. See **Fig. 2**.

   1.2 Remove the pinch bolts. See **Fig. 3**.

   1.3 Using a brass hammer and drift, tap the eye pin out. See **Fig. 4**.

2. Remove the clip (**Fig. 5**) and the spring retainer pin (**Fig. 6**).

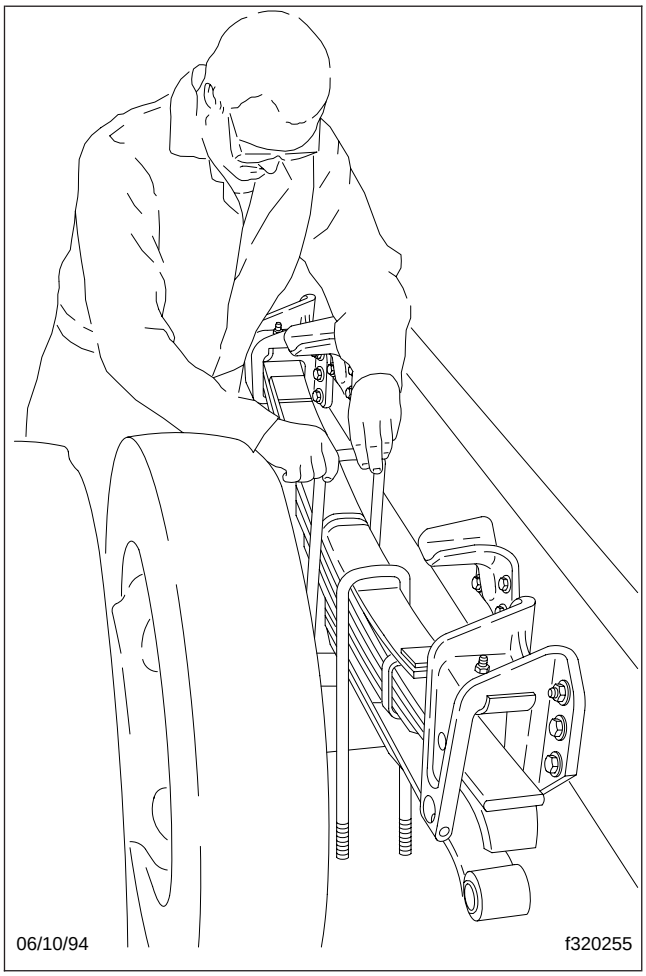


Fig. 1, Removing the U-Bolts (vehicles built before September 15, 2002 shown)

⚠ WARNING

The leaf spring assembly is heavy. Always use two people when moving it, to avoid personal injury.

3. Remove the spring assembly.

   3.1 If the vehicle is equipped with the optional helper spring, lift it off. See **Fig. 7**.

   3.2 If equipped with rear shackles, remove the lower shackle bolt.

   3.3 If applicable, remove the front spring-eye bolt.

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Spring Assembly Replacement

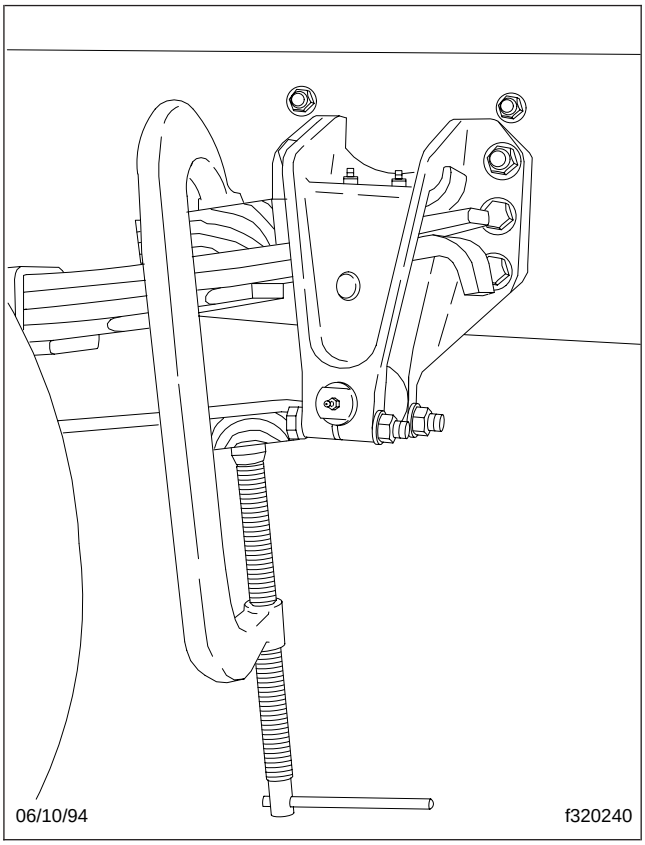


Fig. 2, Compress Springs to Remove Eye Pin

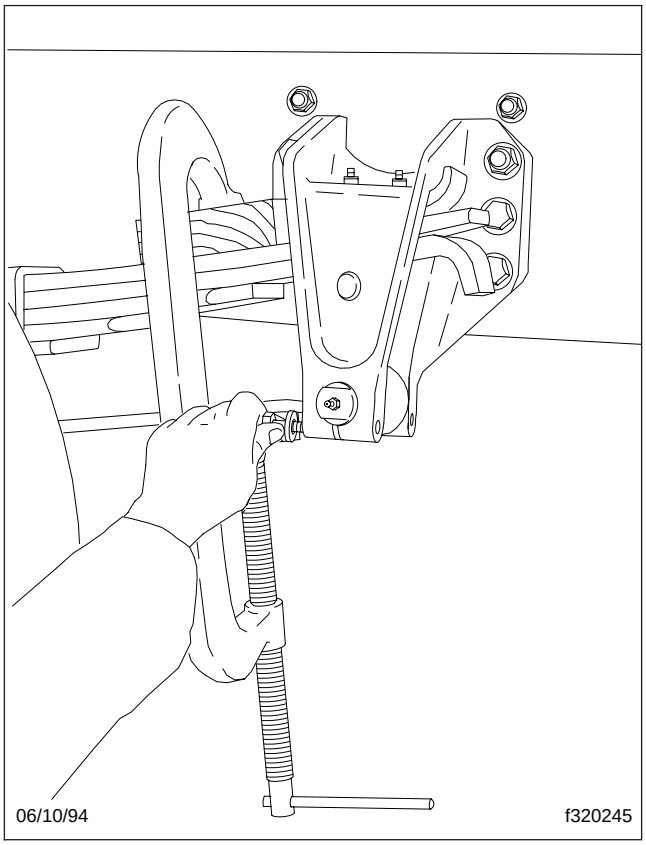


Fig. 3, Removing/Installing the Pinch Bolts

3.4 Slide the leaf spring assembly forward and remove it from the vehicle. See **Fig. 8**.

4. Inspect the wear pads for wear. Replace them if needed. For instructions, see **Subject 130**.
5. Install the new spring assembly.

   5.1 Position the new spring on the axle seat.

   NOTE: It may be necessary to raise the frame slightly.

   5.2 Lower the frame until the spring is correctly located between the spring brackets.

   5.3 If equipped with the optional auxiliary spring, place it on the main spring.
6. Install the leaf spring.

   6.1 *For 52-inch multi-leaf springs only,* slide the rear end of the spring into the rear spring hanger.

   6.2 Position the new spring on the axle seat.

   NOTE: It may be necessary to raise the frame slightly.

   6.3 Lower the frame or raise the axle until the front spring eye lines up with the hole in the forward spring bracket.

   6.4 Install the forward spring-eye bolt, nut and washers. Make sure the bolt is inboard. Tighten 240 lbf·ft (325 N·m).

   6.5 If equipped with the optional helper leaf spring, place it on the main spring.
7. Install the U-bolts and the U-bolt retainer. The taller end of the retainer must be towards the front of the vehicle. See **Fig. 9**.
8. Install the U-bolt high nuts (**Fig. 10**), but do not tighten them now.

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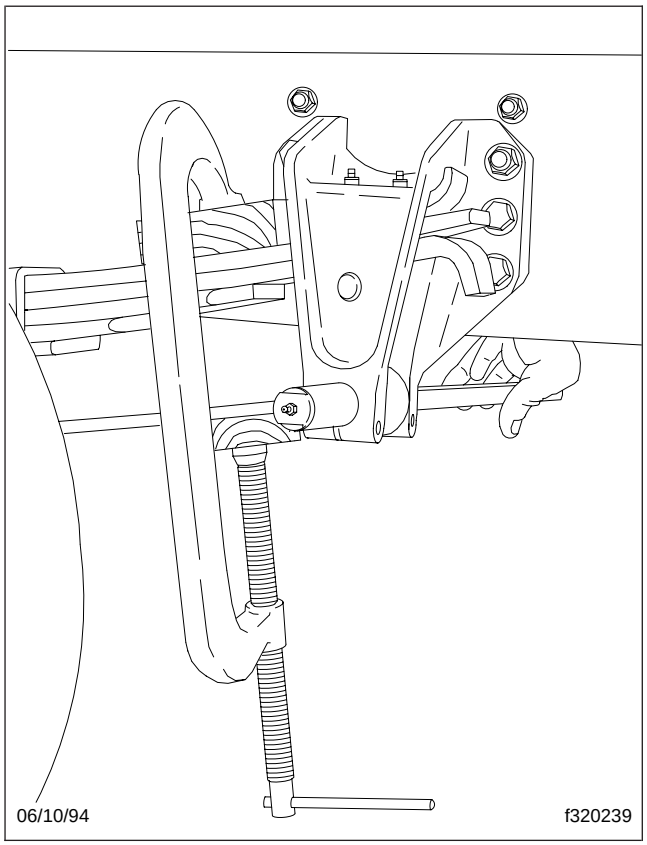


Fig. 4, Removing Eye Pin from Radius Leaf

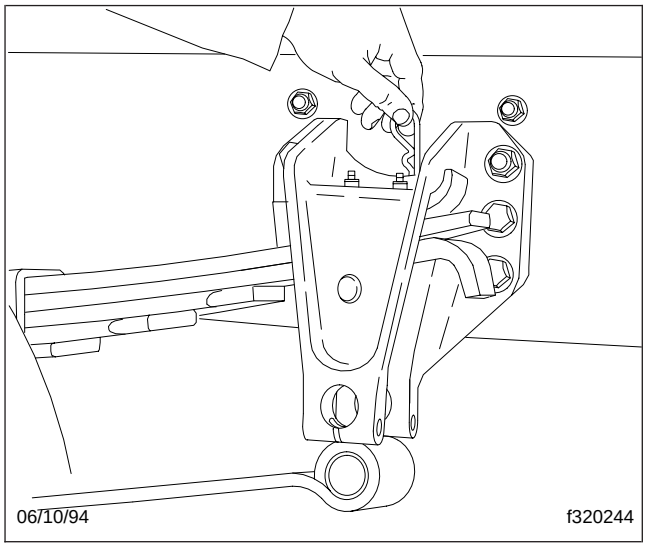


Fig. 5, Removing/Installing Retainer Pin Clip

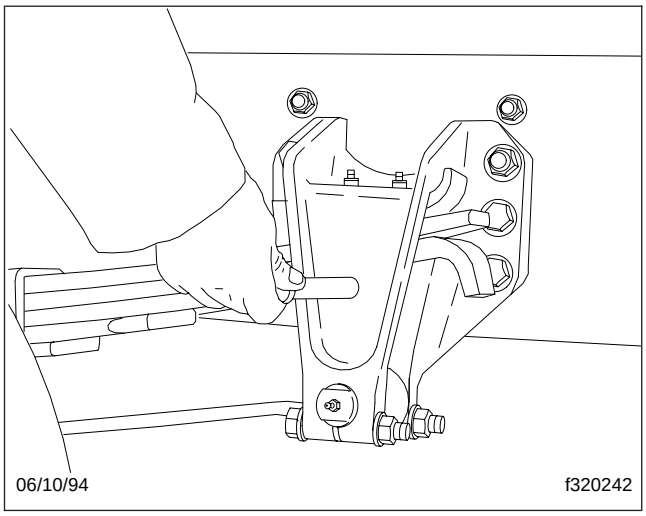


Fig. 6, Removing the Retainer Pin

9. Lift the spring above the hole for the spring retainer pin in the front spring bracket. Insert the retainer pin. See **Fig. 11**.
10. Install the clip on the pin. See **Fig. 5**.
11. Install the spring eye pin.
    - 11.1 Using a C-clamp, compress the spring until the front spring eye pin can be installed. See **Fig. 2**.
    - 11.2 Inspect the pin for wear or damage. Replace it with a new pin if necessary.
    - 11.3 Using a brass hammer, tap the pin into position. See **Fig. 12**.
    - 11.4 Install the pinch bolts and nuts. See **Fig. 3**. Tighten the nuts to 32 lbf·ft (43 N·m).
    - 11.5 Remove the C-clamp.
12. Tighten the U-bolt high nuts as described in **Specifications 400**.
13. If they were removed, install the rear tires. For instructions, see **Group 40**.
14. Remove the jack or safety stands from the rear axle and the frame.
15. Remove the chocks from the front tires.

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Spring Assembly Replacement

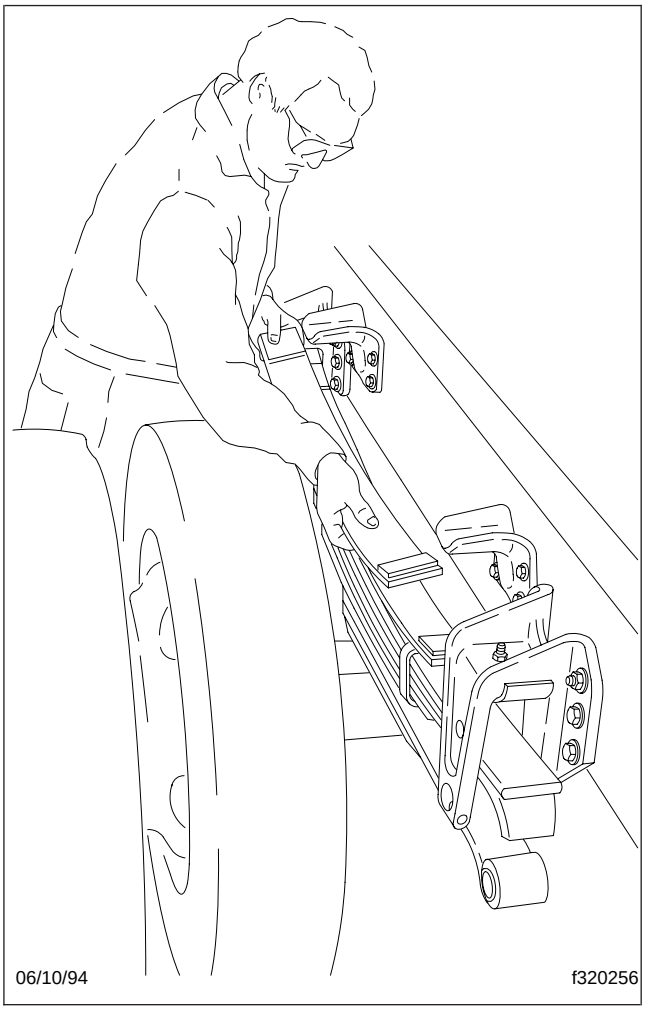


Fig. 7, Removing the Optional Helper Spring (vehicles built before September 15, 2002)

Vehicles Built From September 15, 2002

1. Remove the spring assembly.
   - 1.1 If the vehicle is equipped with the optional helper spring, lift it off. See **Fig. 13**.
   - 1.2 If equipped with rear shackles, remove the lower shackle bolt.
   - 1.3 If applicable, remove the front spring-eye bolt.
   - 1.4 Slide the leaf spring assembly forward and remove it from the vehicle. See **Fig. 14**.

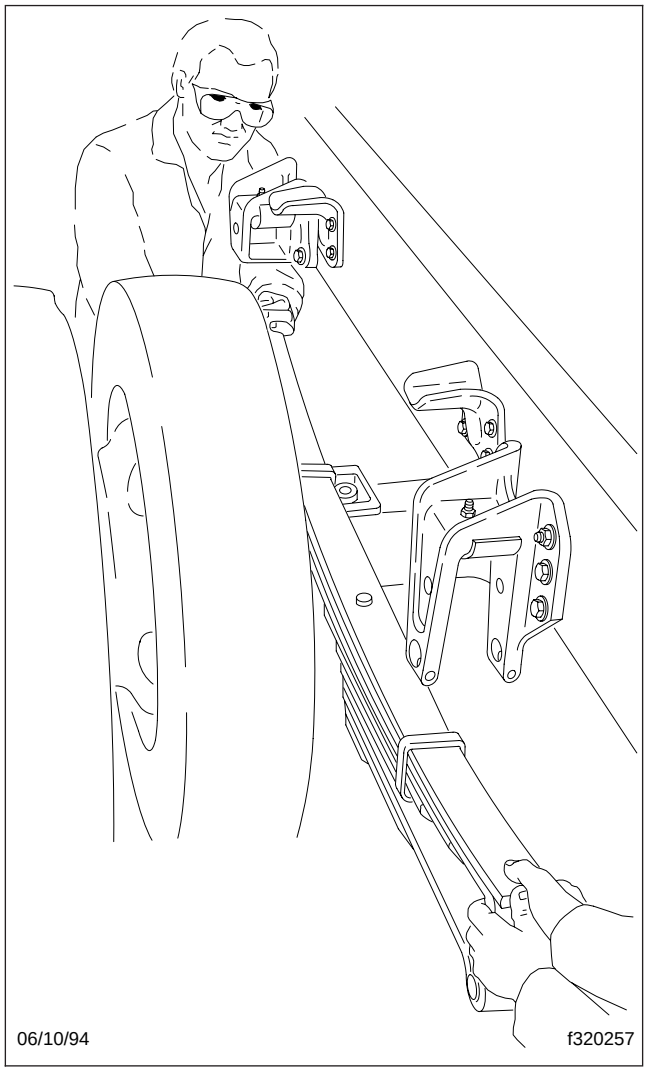
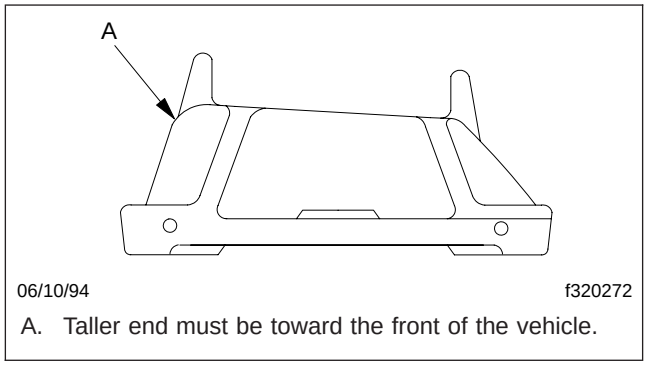


Fig. 8, Removing the Leaf Spring Assembly



A. Taller end must be toward the front of the vehicle.

Fig. 9, Alignment of the U-Bolt Retainer

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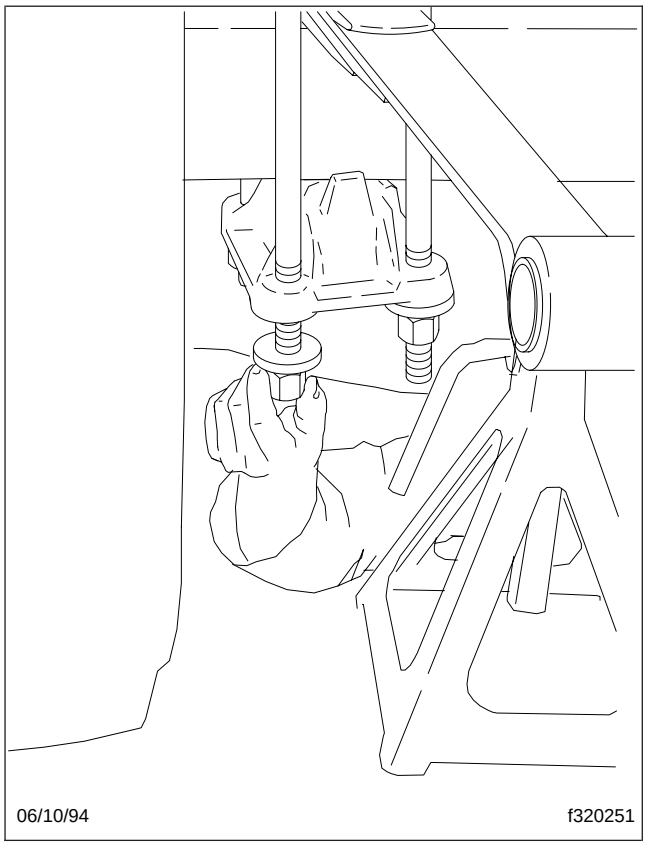


Fig. 10, Installing the U-Bolt High Nuts

2. Install the leaf spring.

   2.1 *For 52-inch multi-leaf springs only,* slide the rear end of the spring into the rear spring hanger.

   2.2 Position the new spring on the axle seat.

   NOTE: It may be necessary to raise the frame slightly.

   2.3 Lower the frame or raise the axle until the front spring eye lines up with the hole in the forward spring bracket.

   2.4 Install the forward spring-eye bolt, nut and washers. Make sure the bolt is inboard. Tighten 240 lbf·ft (325 N·m).

   2.5 If equipped with the optional helper leaf spring, place it on the main spring.

   2.6 For 60-inch taper-leaf springs, raise the spring assembly until the rear spring eye is lined up with the lower shackle holes.

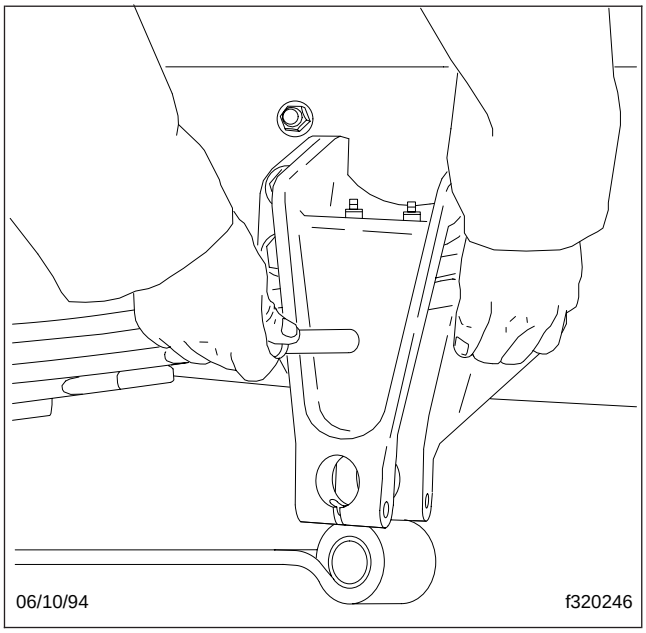


Fig. 11, Installing the Retainer Pin

   Install the shackle fasteners, making sure the bolt head is inboard. Tighten 240 lbf·ft (325 N·m).

3. Install the U-bolts and the U-bolt retainer. The taller end of the retainer must be towards the front of the vehicle. See **Fig. 15**.
4. Tighten the U-bolt high nuts as described in **Specifications 400**.
5. If they were removed, install the rear tires. For instructions, see **Group 40**.
6. Remove the jack or safety stands from the rear axle and the frame.
7. Remove the chocks from the front tires.

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Spring Assembly Replacement

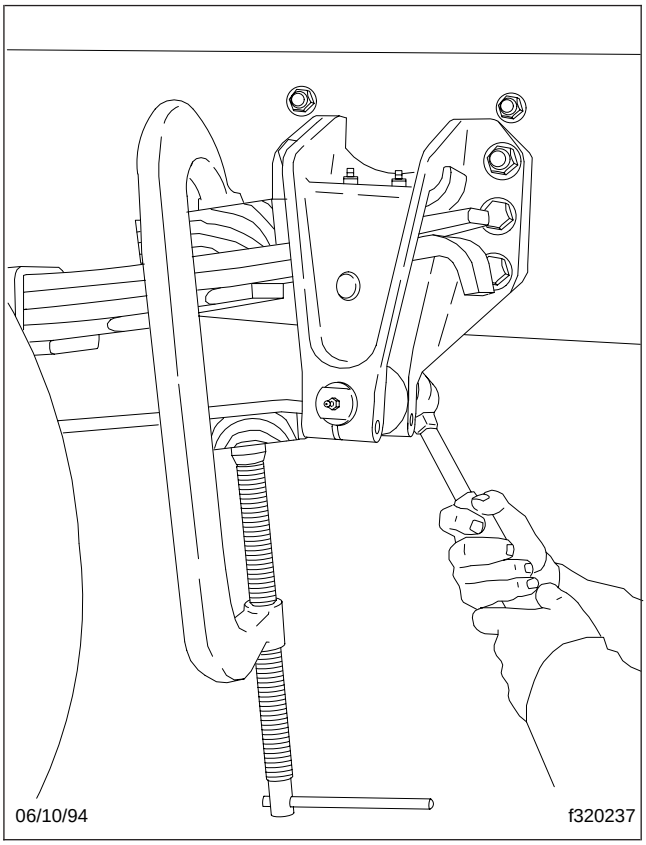


Fig. 12, Installing the Spring Eye Pin

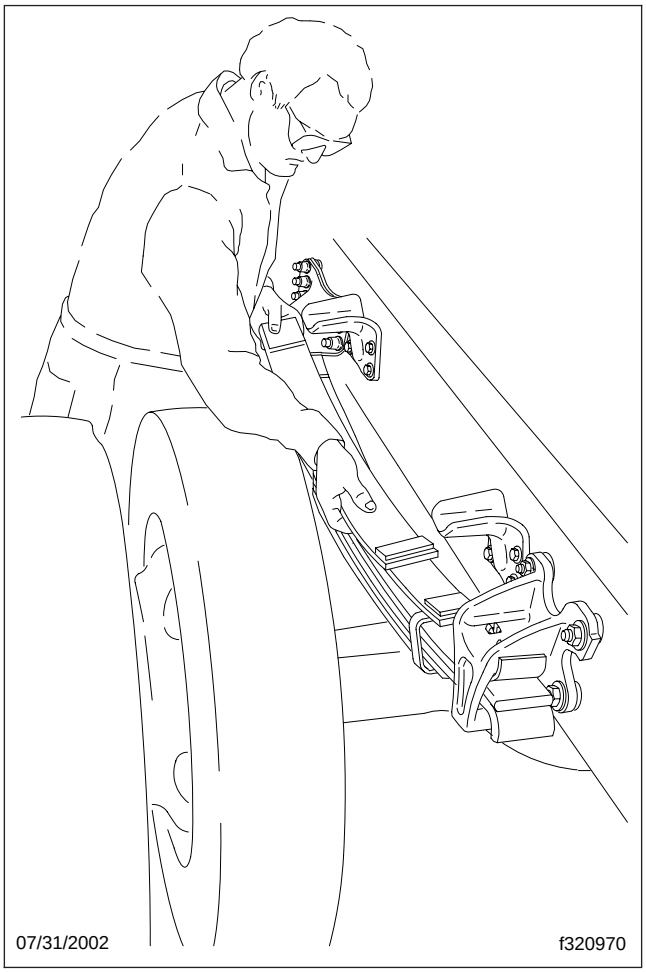


Fig. 13, Removing the Optional Helper Spring (vehicles built from September 15, 2002)

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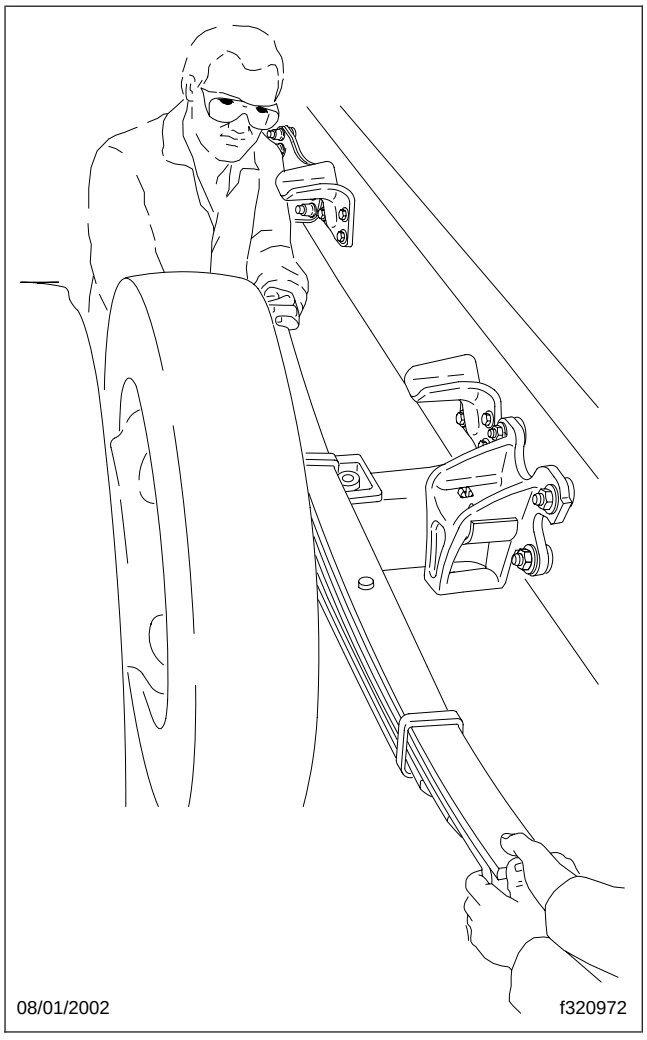


Fig. 14, Removing the Leaf Spring (vehicles built from September 15, 2002)

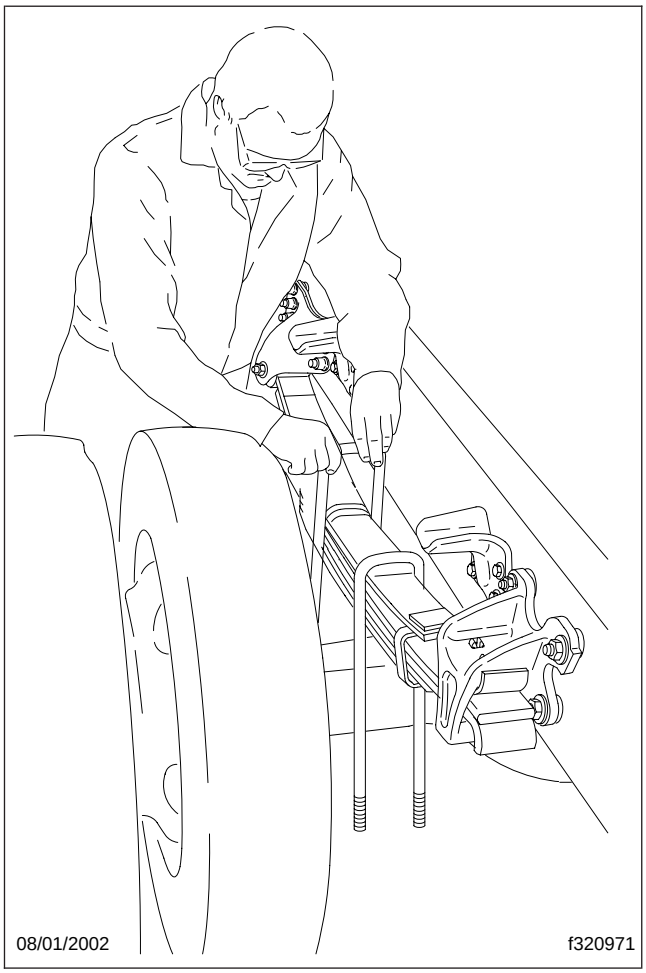


Fig. 15, Installing the U-Bolts (vehicles built from September 15, 2002)

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Rear Spring Bracket Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Jack up the frame rail at the rear of the vehicle until the leaf spring is floating free in the rear spring bracket.
3. Remove the fasteners holding the rear spring bracket to the frame rail. See **Fig. 1**.

   On vehicles built from September 15, 2002, cut off to the Huck fasteners.

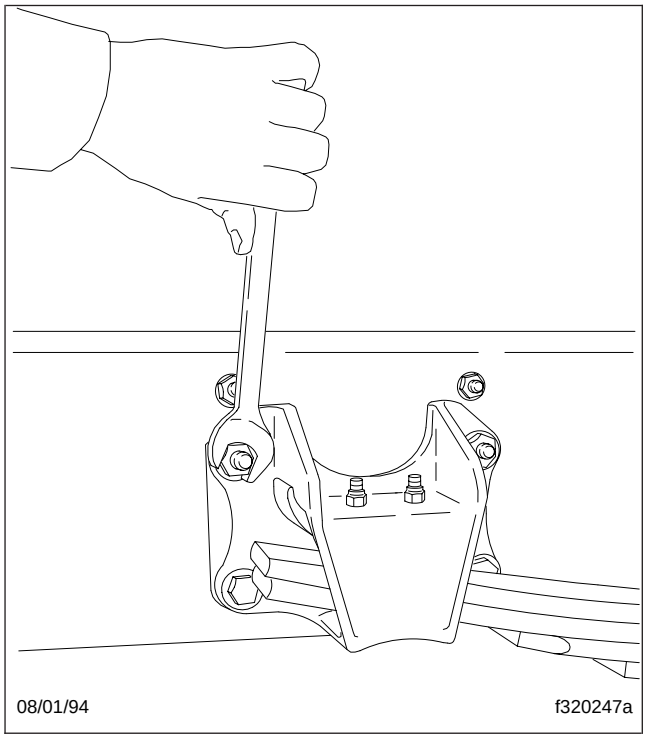


Fig. 1, Rear Spring Bracket Fastener Removal (vehicles built before September 15, 2002)

4. Slide the spring bracket off the end of the leaf spring assembly. See **Fig. 2**.
5. Check the wear pad for wear. Replace it if needed. For instructions, see **Subject 130**.
6. Slide the new spring bracket into position.

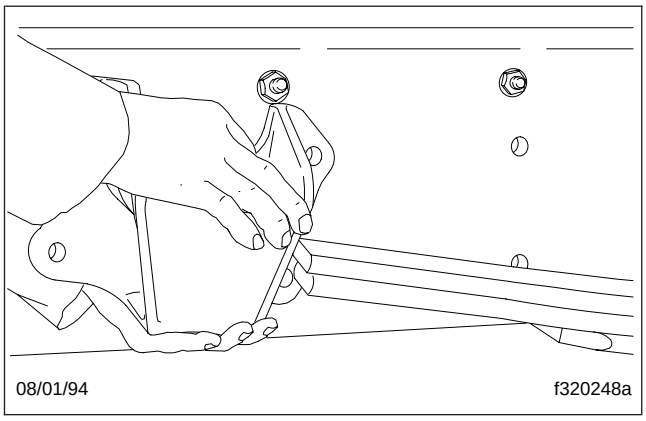


Fig. 2, Sliding Bracket from Leaf Spring Assembly (vehicles built before September 15, 2002)

7. Install the fasteners and tighten 135 lbf·ft (184 N·m). If applicable, replace the Huck fasteners with hexbolts, hardened washers, and hexnuts. Tighten 135 lbf·ft (184 N·m).
8. Lower the frame rail and remove the chocks from the tires.

Forward Spring Bracket Replacement

NOTE: This procedure applies to vehicles built before September 15, 2002.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Jack up the frame rail at the rear of the vehicle until the weight is removed from the leaf spring.
3. Remove the spring bracket.
   - 3.1 Using a C-clamp, take the load off the radius leaf. See **Fig. 3**.
   - 3.2 Remove the pinch bolts holding the spring eye pin. See **Fig. 4**.
   - 3.3 Using a brass hammer, tap out the spring eye pin. See **Fig. 5**.
   - 3.4 If applicable, remove the clip and the spring retainer pin. See **Fig. 6** and **Fig. 7**.
   - 3.5 Remove the fasteners holding the front spring bracket to the frame rail.

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Spring Bracket Replacement

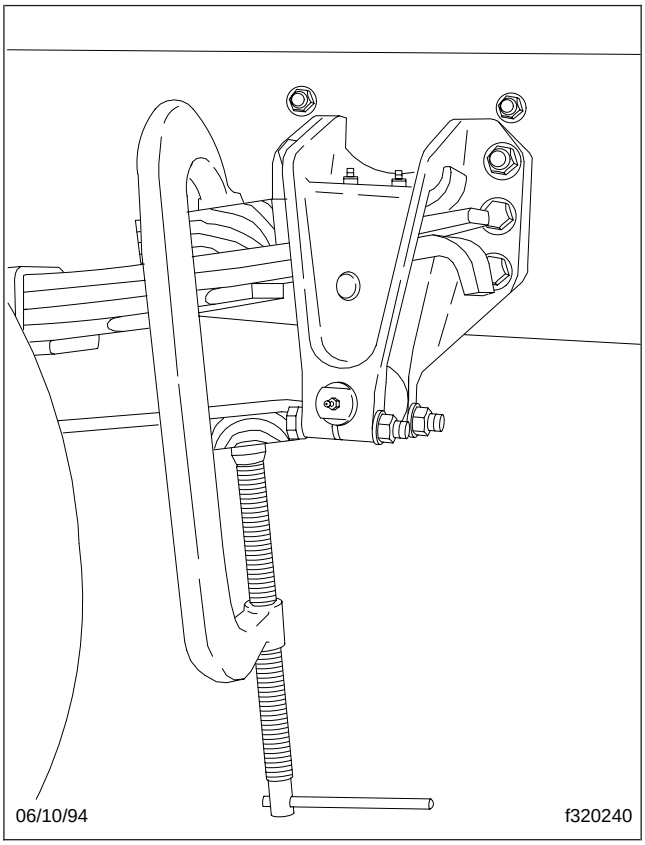


Fig. 3, C-Clamping Radius Leaf

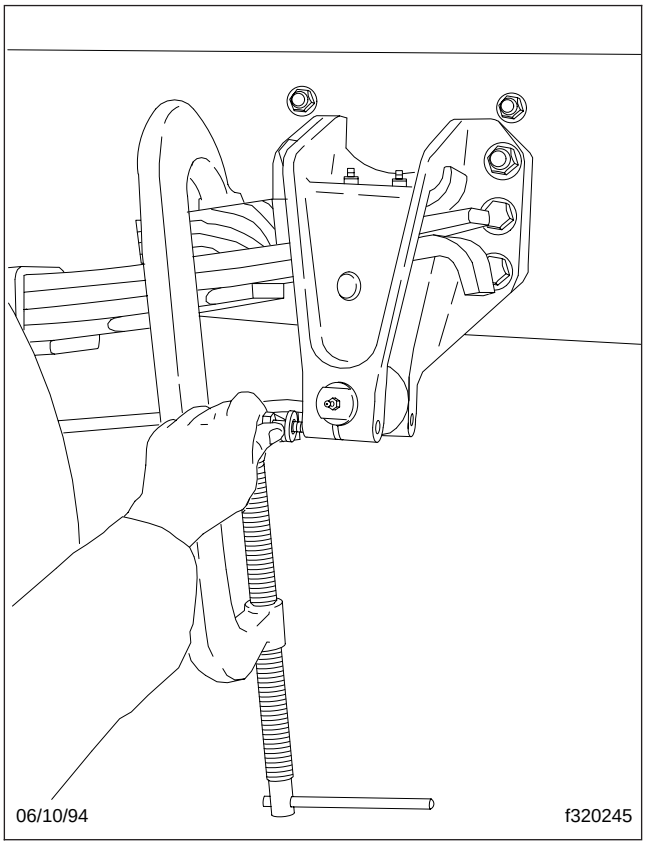


Fig. 4, Removing Pinch Bolts

3.6 Slide the spring bracket off the front of the leaf spring assembly.

4. Install a new spring bracket.

4.1 Slide a new spring bracket into position.

4.2 Install the fasteners and tighten 240 lbf·ft (325 N·m). If Huck fasteners were removed, replace them with hexbolts, hardened washers, and hexnuts. Tighten 240 lbf·ft (325 N·m).

4.3 While lifting the spring, install the spring retainer pin and clip. See **Fig. 7**.

4.4 Using a hammer, drive in the spring eye pin. See **Fig. 8**.

4.5 Install the pinch bolts and nuts. Tighten the nuts 32 lbf·ft (43 N·m).

5. Remove the jack stands and lower the frame rail.

6. Remove the chocks from the tires.

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Spring Bracket Replacement

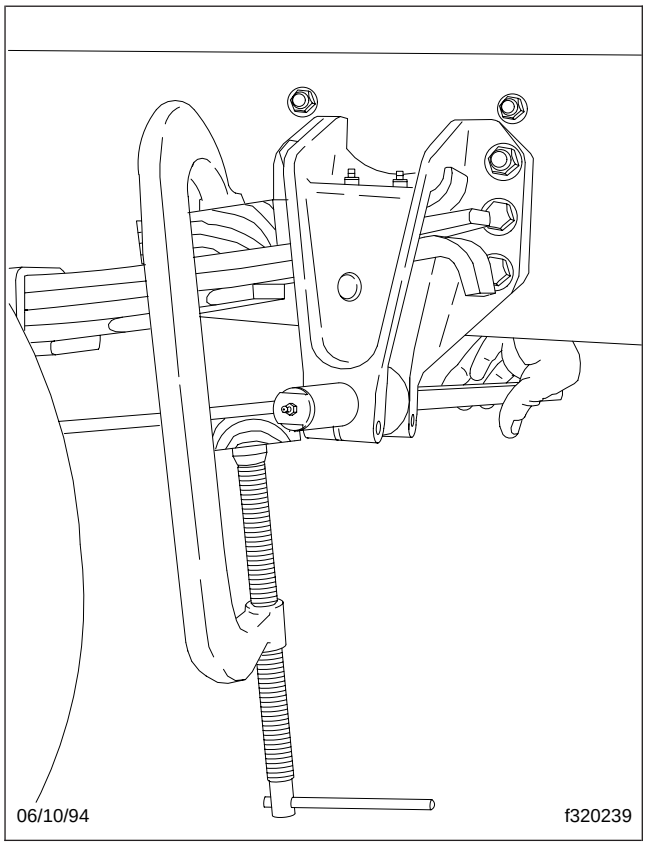


Fig. 5, Tap Out Spring Eye Pin

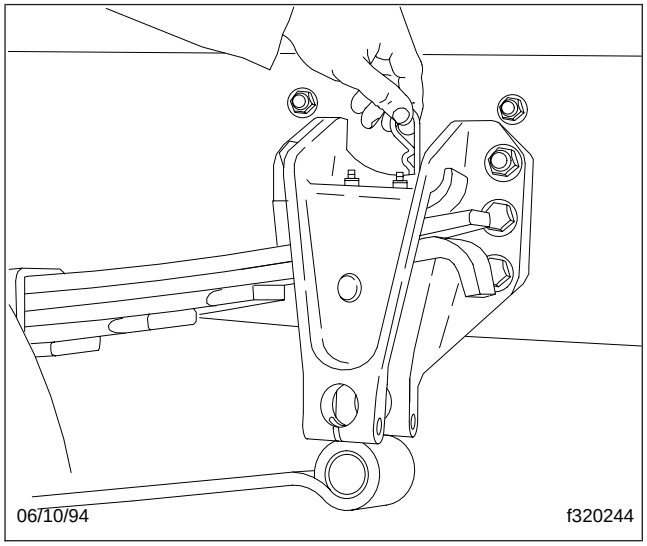


Fig. 6, Clip Removal

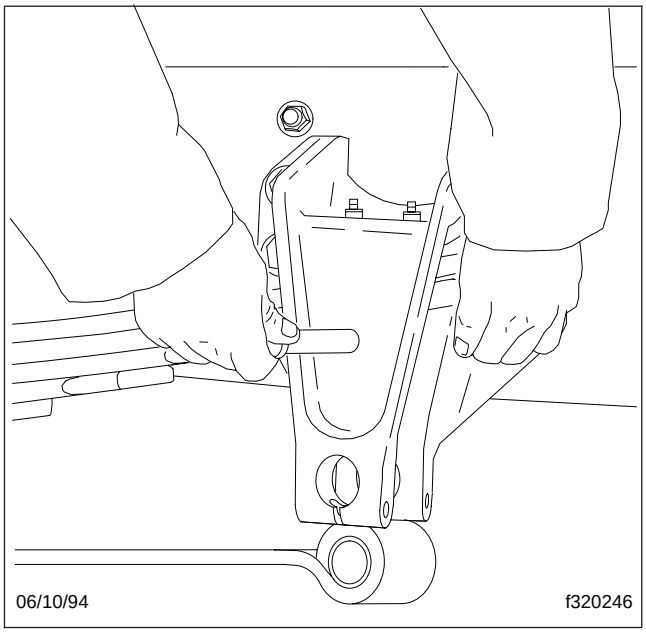


Fig. 7, Spring Retainer Pin Removal

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Spring Bracket Replacement

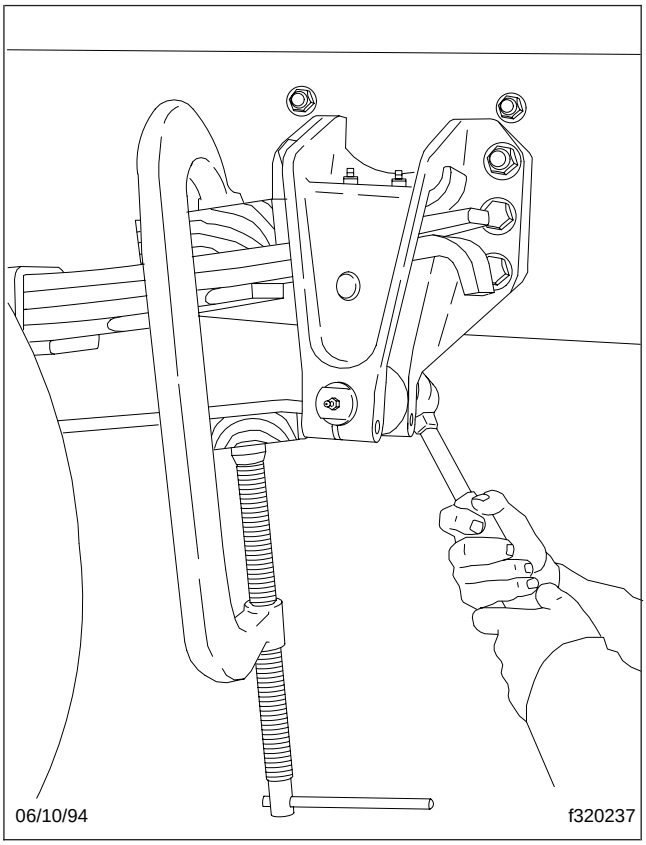


Fig. 8, Spring Eye Pin Installation

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Replacement

NOTE: This procedure applies to vehicles built before September 15, 2002.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine.
2. Using a floor jack, lift the frame rail to take weight off the spring.
3. Using a C-clamp, take the load off the radius leaf. See **Fig. 1**.

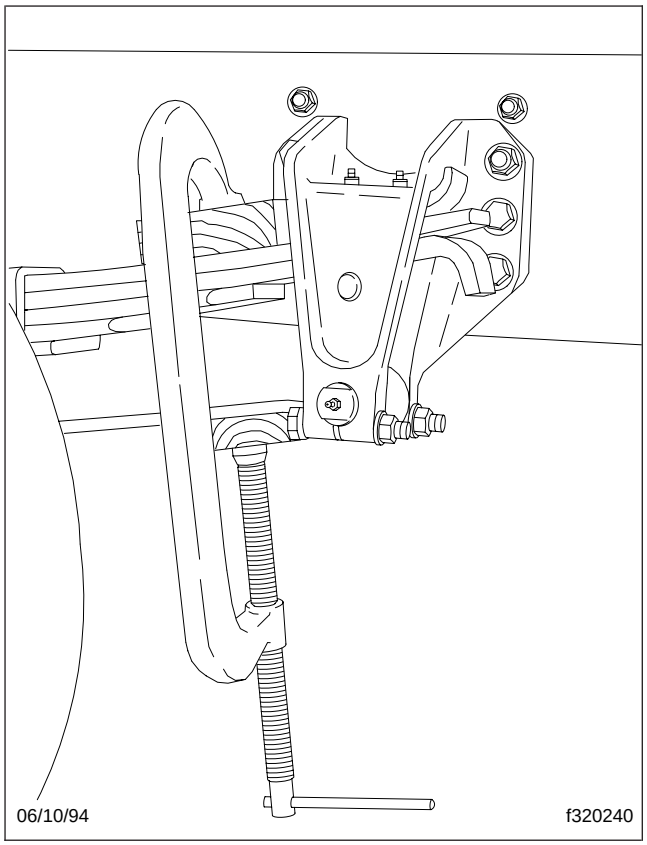


Fig. 1, Position of C-Clamp on Radius Leaf

4. Loosen and remove the pinch bolts. See **Fig. 2**.
5. Using a brass hammer and a drift, tap the pin out. See **Fig. 3**.
6. Grease the outer surface of a new pin and insert it (**Fig. 4**). Drive it in using a hammer. See **Fig. 5**.

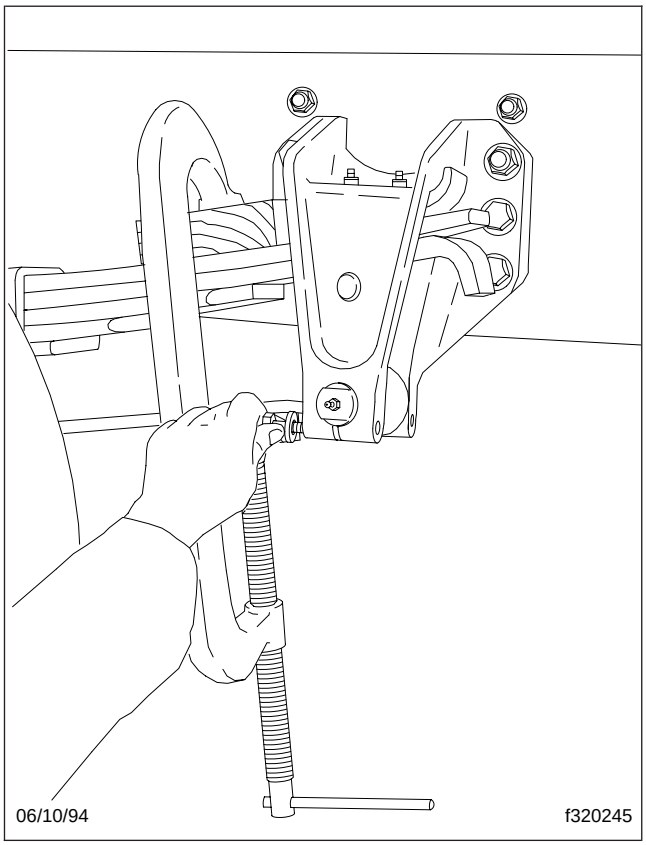


Fig. 2, Pinch Bolt Removal/Installation

7. Install the pinch bolts (**Fig. 2**) and nuts. Tighten the nuts 32 lbf·ft (43 N·m).
8. Install a new zerk fitting and the spring eye pin.
9. Remove the C-clamp and lower the jack.

NOTE: When replacing the pin, if the spring has shifted, loosen the U-bolt nuts so the spring can be shifted fore and aft.

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Spring Eye Pin Replacement

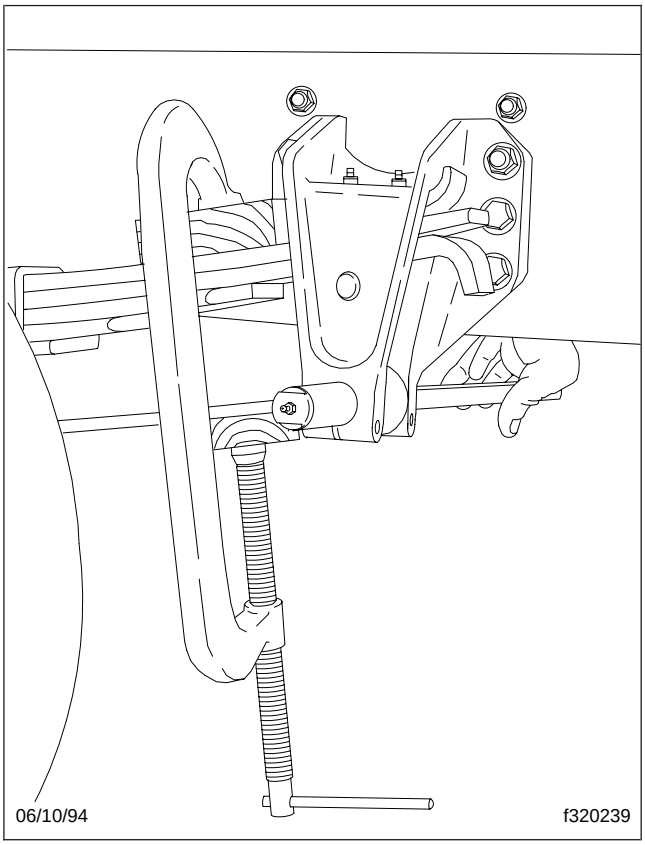


Fig. 3, Tapping Out the Pin

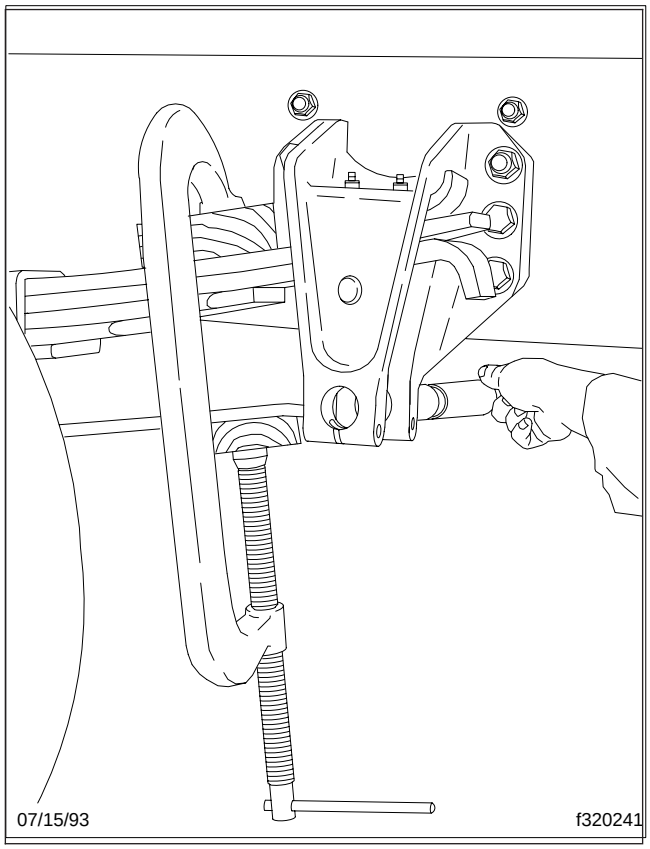


Fig. 4, Inserting New Pin

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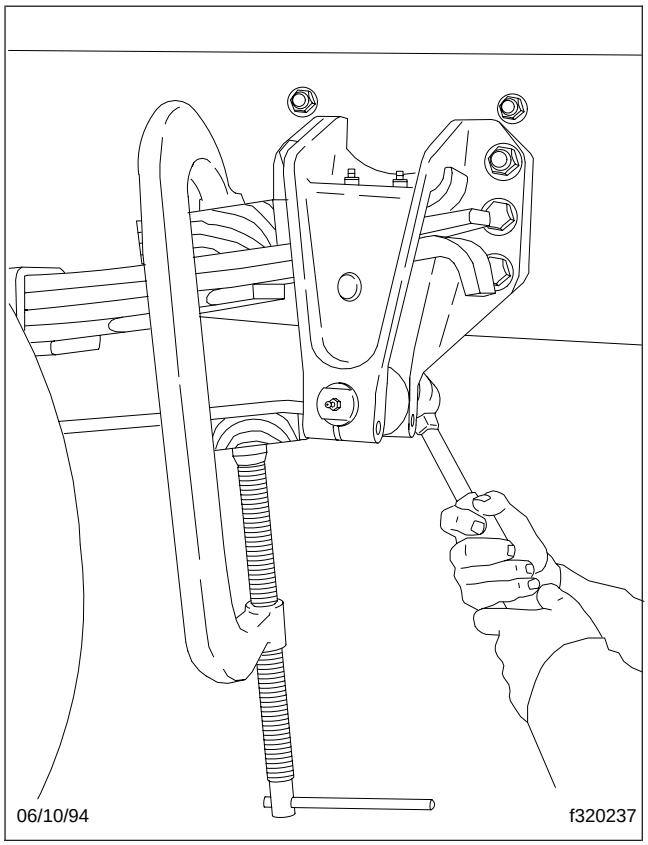


Fig. 5, Driving in New Pin With Hammer

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Replacement

NOTE: Wear pads can be replaced without removing the leaf spring assemblies.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Using a floor jack or a crane, take the weight off the frame rail so there is no contact between the spring and the wear pad.

Vehicles Built Before September 15, 2002

1. For front wear pad replacement, remove the clip and the spring retainer pin. See **Fig. 1** and **Fig. 2**.

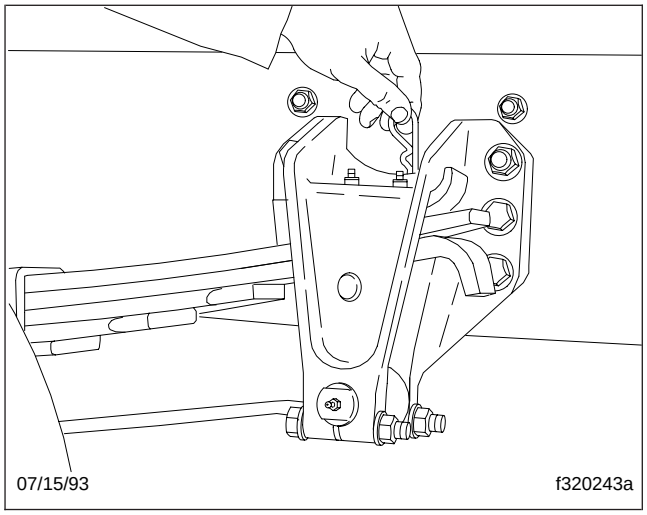


Fig. 1, Clip Removal

2. Remove the hexbolts and nuts attaching the wear pad to the spring bracket. See **Fig. 3** for the front wear pad, and **Fig. 4** for the rear wear pad. Remove and discard the wear pad.
3. Install the new wear pad so that the thicker portion of the pad is toward the axle. See **Fig. 5** for the front wear pad. While holding it in place, install and tighten the fasteners until snug.
4. If removed, install the spring retainer pin and its clip.
5. Lower the frame rail.

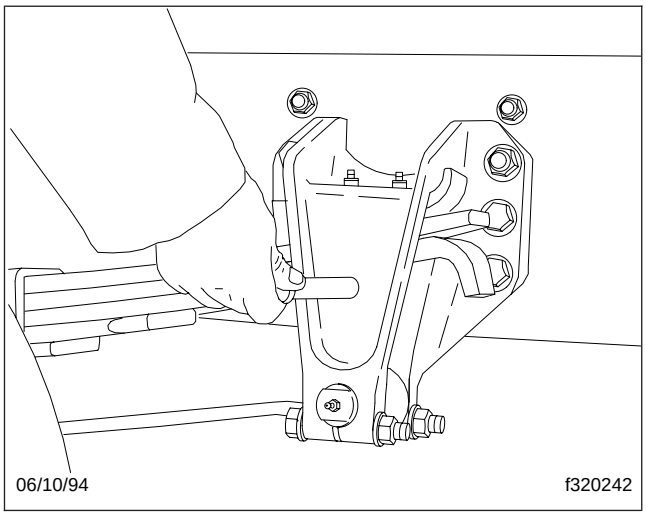


Fig. 2, Spring Retainer Pin Removal

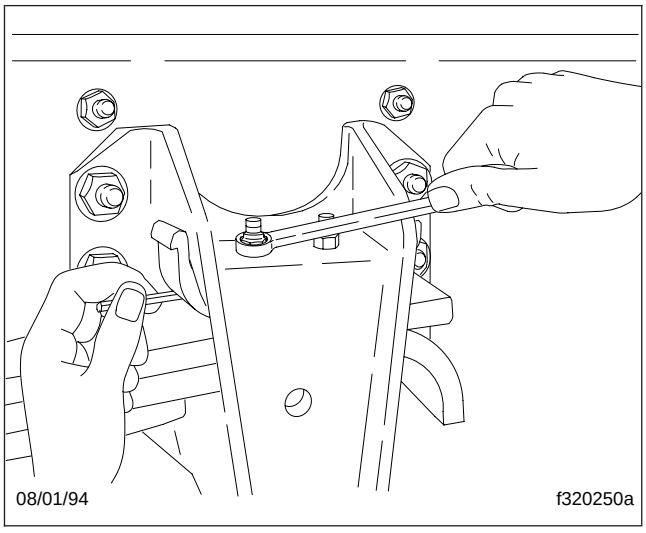


Fig. 3, Removal of Wear Pad Fasteners (vehicles built before September 15, 2002)

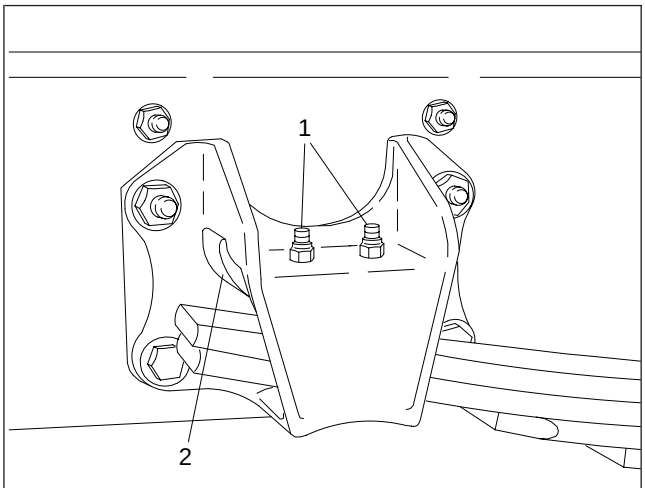
6. Remove the chocks from the front tires.

Vehicles Built From September 15, 2002

1. Using a suitable pair of pliers, pinch the tabs of the wear pad together and push them out of the slot in the upper part of the rear spring hanger. See **Fig. 6**.
2. Remove and discard the wear pad.

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Wear Pad Replacement



1. Fasteners
2. Wear Pad

Fig. 4, Rear Wear Pad Fasteners (vehicles built before September 15, 2002)

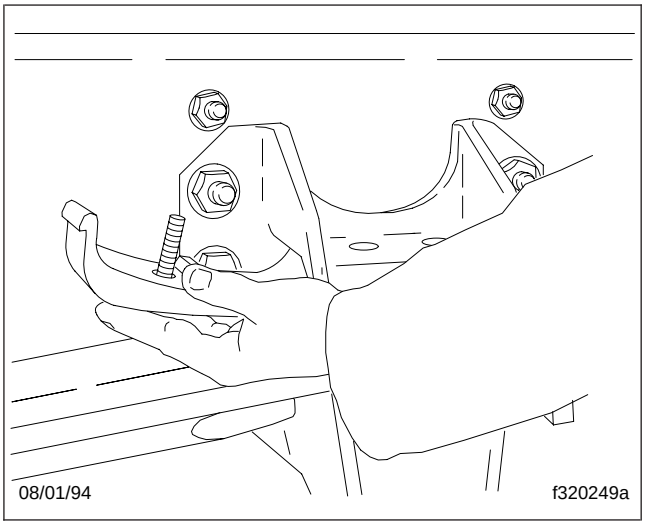


Fig. 5, Wear Pad Installation (vehicles built before September 15, 2002)

3. Install the new wear pad so that the thicker portion of the pad is toward the axle.
4. Push the wear pad up into place.
5. Lower the frame rail.
6. Remove the chocks from the tires.

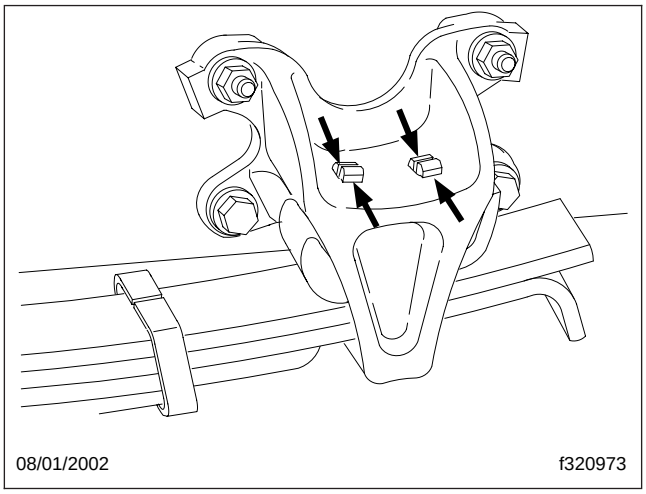


Fig. 6, Wear Pad Removal and Installation (vehicles built from September 15, 2002)

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Replacement

NOTE: See **Fig. 1** and **Fig. 2** for this procedure.

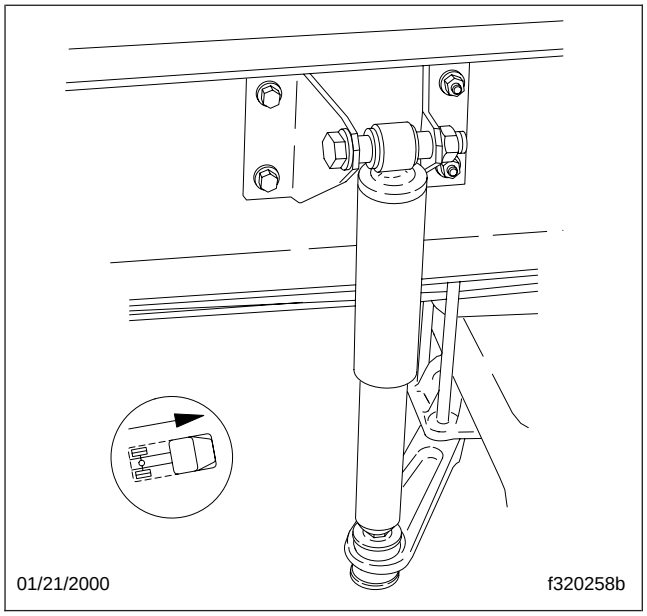
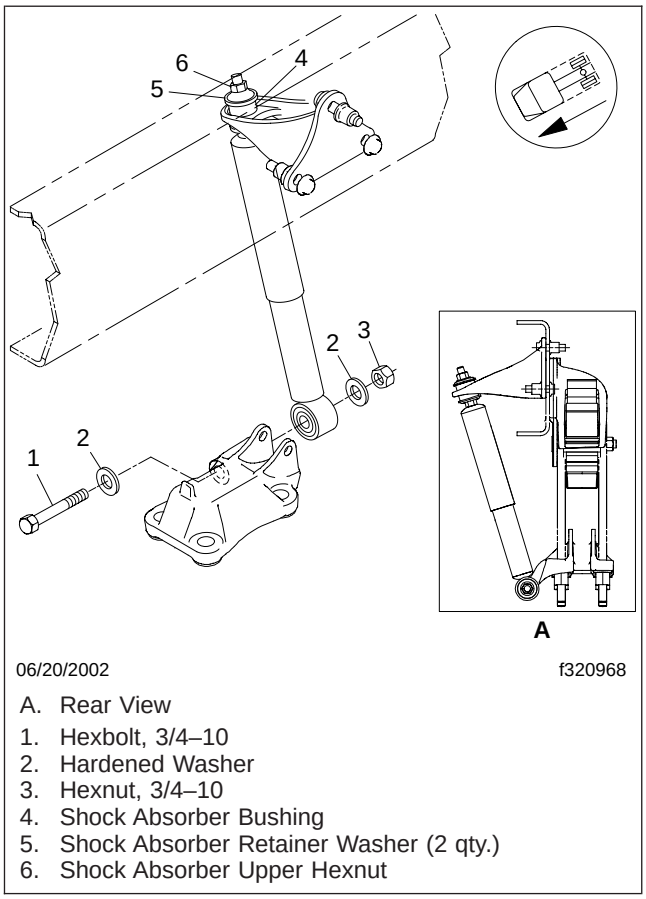


Fig. 1, Shock Absorber and Mounting Brackets (vehicles built before September 15, 2002)

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the locknut, retainers, and bushings from the shock absorber lower mount.
3. Remove the locknut, capscrew, and washers from the shock absorber upper mount.
4. Remove the shock absorber.
5. Install the replacement shock absorber.
6. Install the capscrew and locknut in the upper mount. Hand tighten them at this time.
7. Install the replacement bushings, retainers, and locknut. For vehicles built before September 15, 2002, see **Fig. 3**.

⚠ WARNING

Use only the retainers included with the replacement shock absorber. Do not use washers. They can be pushed over the nut and be ejected violently, possibly causing personal injury and property damage.



A. Rear View
1. Hexbolt, 3/4–10
2. Hardened Washer
3. Hexnut, 3/4–10
4. Shock Absorber Bushing
5. Shock Absorber Retainer Washer (2 qty.)
6. Shock Absorber Upper Hexnut

Fig. 2, Shock Absorber and Mounting Brackets (vehicles built from September 15, 2002)

8. *For vehicles built before September 15, 2002:* Tighten the shock absorber upper mounting locknut 167 lbf·ft (226 N·m).

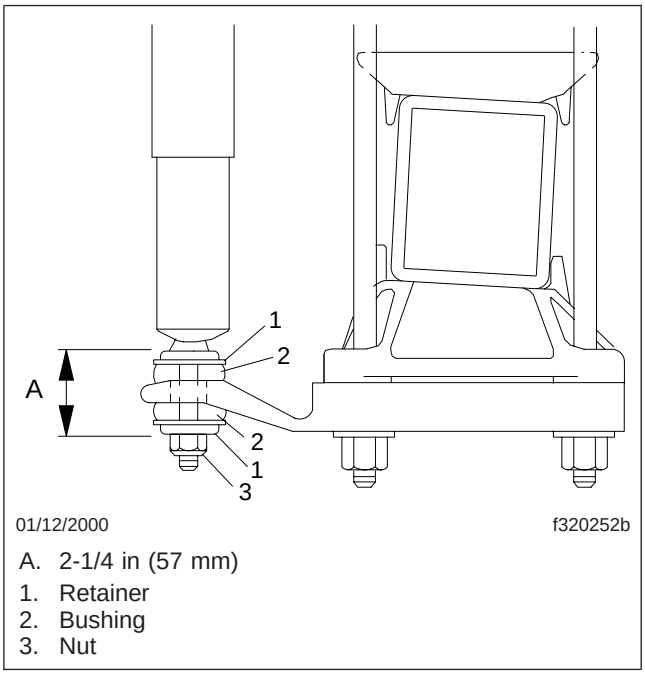
   For vehicles built from September 15, 2002: Tighten the shock absorber upper mounting locknut until the rubber bushings expand to the same size as the retainer washer.

9. *For vehicles built before September 15, 2002:* Tighten the shock absorber lower mounting nut to compress the bushings to the dimension shown in **Fig. 3**.

   For vehicles built from September 15, 2002: Tighten the shock absorber lower mounting fasteners to 240 lbf·ft (325 N·m).

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Shock Absorber Replacement



A. 2-1/4 in (57 mm)
1. Retainer
2. Bushing
3. Nut

Fig. 3, Compressed Shock Absorber Bushings (vehicles built before September 15, 2002)

10. Remove the chocks from the tires.

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Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Remove the fasteners holding the ends of the stabilizer bar to the lower U-bolt brackets. See **Fig. 1**.
3. Remove the fasteners from the stabilizer-bar link straps. See **Fig. 1**. Set the stabilizer-bar link straps and the fasteners aside.
4. Remove the stabilizer bar and rubber bushings from each stabilizer-bar link by pulling the link rearward and pushing the bar and the bushing forward and out of the link. It may be necessary to use a dead-blow mallet.
5. Remove the rubber bushings from the stabilizer bar by pushing the bushings inboard, then prying each one apart to remove it.
6. Remove the stabilizer bar from the vehicle.
7. If it is necessary to replace a stabilizer-bar link, remove the fasteners attaching the link to the inner and outer mounting brackets.

   If the fasteners are not accessible, remove the inner and outer mounting brackets and the link as a unit as follows:

⚠ WARNING

Never work under a vehicle that is supported only by a jack. Jacks can slip, causing the vehicle to fall, which could result in severe injury or death. Always support the vehicle with safety stands.

   7.1 Raise the vehicle and support the frame rails to take the weight off the leaf springs.

   7.2 Remove the fasteners holding the inner and outer mounting brackets to the frame rail. See **Fig. 1**.

   NOTE: If the inner and outer mounting brackets are attached to the frame rails with Huck® fasteners, cut off the fasteners.

   7.3 Remove the stabilizer-bar link and the inner and outer mounting brackets as a unit.

   7.4 Remove and save the fasteners holding the stabilizer-bar link to the inner and outer mounting brackets.

8. If removed, install the stabilizer-bar link to the inner and outer mounting brackets on the frame rail. Make sure the hexbolt head is installed outboard. Tighten the 5/8 –11 hexnut 136 lbf·ft (184 N·m).

   If it was necessary to remove the link and the mounting brackets as a unit, do the following:

   8.1 Attach the new stabilizer-bar link to the inner and outer mounting brackets. Make sure the hexbolt head will be facing outboard when the assembly is installed on the frame rail. Tighten enough to hold the link to the brackets.

   8.2 Attach the stabilizer-bar link and the mounting bracket assembly to the frame rail. If Huck fasteners were used to attach the mounting brackets to the frame rail, replace them with 5/8–11 fasteners.

   Make sure the all the hexbolt heads are facing outboard. Tighten all the fasteners 136 lbf·ft (184 N·m).

   8.3 Raise the vehicle, remove the jack stands, then lower the vehicle.

9. Install the stabilizer bar.

   9.1 Install the rubber bushings onto the stabilizer bar, making sure the split ends of the bushings will be facing forward when the bar is installed.

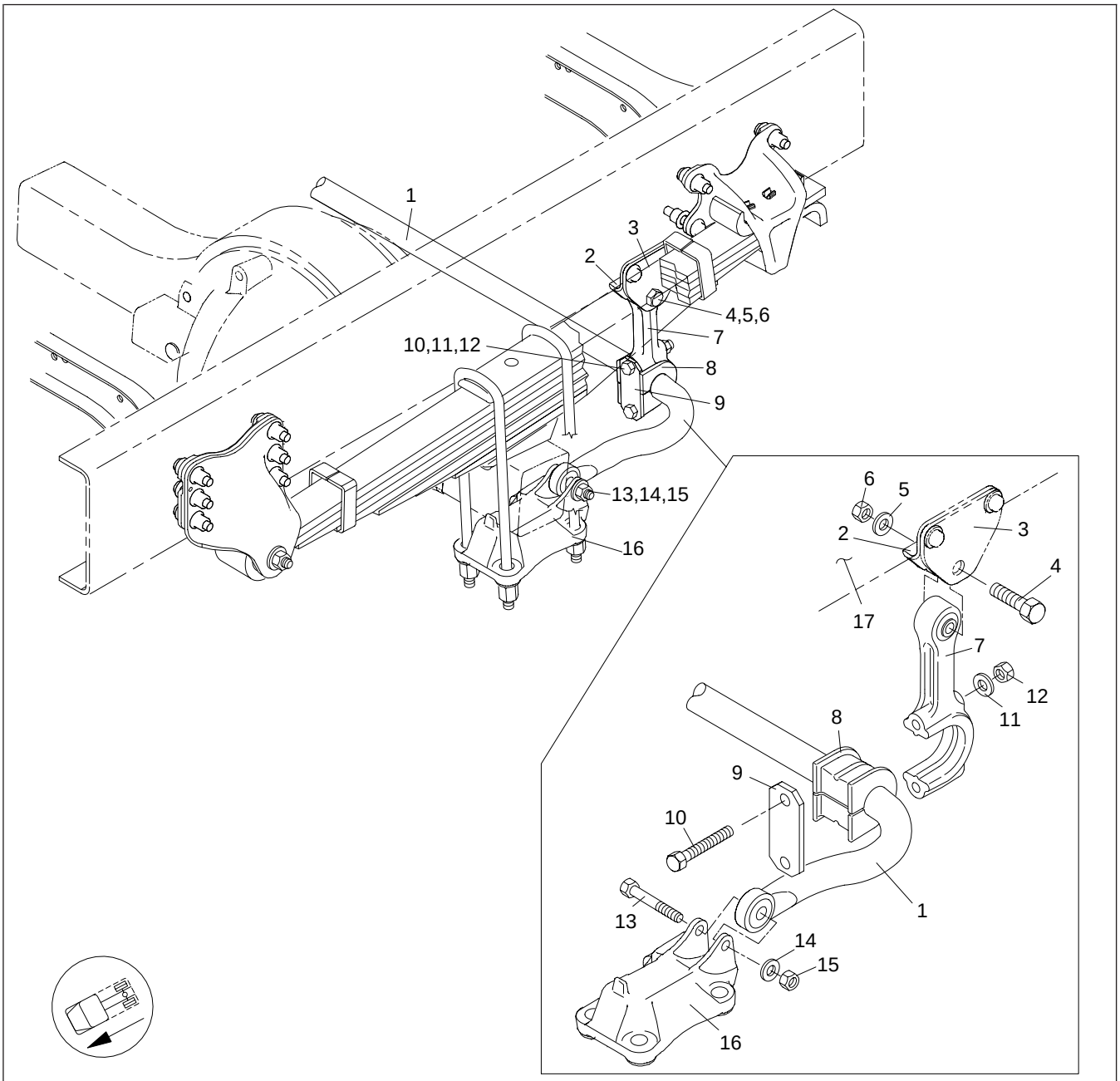
   9.2 Slide the rubber bushings along the stabilizer bar so they will line up with the stabilizer-bar links.

   9.3 Using a deadblow mallet, install the sway bar and the rubber bushings into the stabilizer-bar links.

   9.4 Install the stabilizer-bar link straps onto the front of the links. Don’t tighten the fasteners completely.

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Stabilizer Bar Replacement



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1. Stabilizer Bar
2. Inner Mounting Bracket
3. Outer Mounting Bracket
4. Hexbolt, 5/8–11 x 1-1/4-inch
5. Hardened Washer
6. Hexnut, 5/8–11
7. Stabilizer-Bar Link
8. Rubber Bushing
9. Stabilizer-Bar Link Strap
10. Hexbolt, 1/2–13
11. Flatwasher
12. Hexnut, 1/2–13
13. Hexbolt, 5/8–11 x 1-1/2 inch
14. Hardened Washer
15. Hexnut, 5/8–11
16. Lower U-Bolt Bracket
17. Left Frame Rail

Fig. 1, Stabilizer Bar Installation/Removal

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9.5 Align the holes in the forward ends of the sway bar with the slots in the lower U-bolt brackets. Use a deadblow mallet, if necessary.

9.6 Using the 5/8–11 fasteners previously removed, attach the ends of the stabilizer bar to the lower U-bolt brackets. Make sure the bolt heads are inboard. Tighten 136 lbf·ft (184 N·m).

10. Tighten the 1/2–13 stabilizer-bar link strap fasteners 68 lbf·ft (92 N·m).

11. Remove the chocks from the tires.

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Specifications

Torque Values			
Description	**Size**	**IFI Grade**	**Torque lbf·ft (N·m)**
Forward Spring Bracket-to-Frame Rail Locknut *	3/4–10	C	240 (325)
Rear Spring Bracket-to-Frame Rail Locknut *	5/8–11	C	135 (184)
Axle U-Bolt High Nuts Tighten in a diagonal pattern as shown in **Fig. 1**.	5/8–18	C	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 180 to 230 (245 to 313)
	3/4–16	C	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 270 to 330 (367 to 449)
	7/8–14	C	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420 to 500 (570 to 678)
Spring Eye Pin Pinch Bolts	7/16–14	C	37 (50)
Shock Absorber Upper Locknut †	—	C	167 (226)
Forward Spring Bolt *	3/4–10	—	240 (325)
Rear Spring Shackle Bolts *	3/4–10	—	240 (325)
	1/2–13	—	68 (92)
Helper Bracket Hexbolts	1/2–13	—	68 (92)
Shock Absorber Lower Locknuts	—	C	240 (325)
Stabilizer Bar Fasteners *	5/8–11	—	136 (184)
Stabilizer-Bar Link Strap Fasteners *	1/2–13	—	68 (92)

* Cadmium-plated, wax-coated nuts, and grade 8 hexbolts with phosphate- and oil-coated threads; both used with hardened washers.
† For vehicles built from September 15, 2002, see **Subject 140** for shock absorber upper locknut tightening sequence.

Table 1, Torque Values

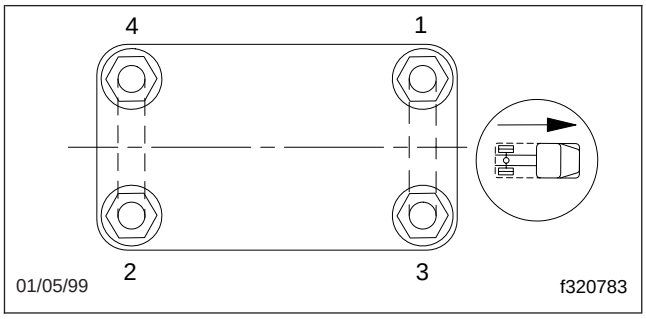


Fig. 1, Tightening Pattern for U-Bolt High Nuts

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General Information

The Freightliner AirLiner Suspension is a single axle or tandem axle suspension that uses a combination of air and leaf springs. The suspension is manufactured at numerous weight ratings up to 46,000 pounds (20 865 kg). The top of the air spring is bolted to a bracket on the frame rail or through the bottom flange of the frame rail; the bottom is bolted to the rear end of the tapered leaf spring assembly or, for the 23,000-pound (10 433 kg) and 46,000-pound suspensions, to a cross bar. The axle housing is fastened to the leaf spring assembly by U-bolts. A control rod, mounted between the axle housing and the frame rail, can be used to help locate the assembly laterally.

The air springs compensate for changes in road conditions and vehicle load, maintaining vehicle height. The air springs also absorb road shock.

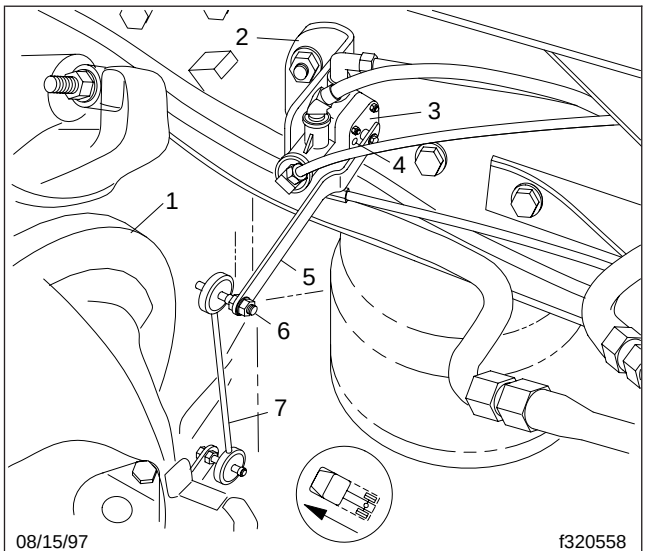
A height-control valve regulates the air flow into or out of all the air springs; see **Fig. 1**. As the air spring compresses or expands, changes in the clearance between the vehicle frame and the differential housing activate the height-control valve.

The height-control valve is mounted on the frame rail; see **Fig. 1** and **Fig. 2**. A horizontal control lever extends from the end of the valve control shaft to a vertical linkage that connects to the height-control valve linkage bracket welded to the differential housing.

When the load changes, the horizontal control lever turns the height-control valve control shaft, activating either the intake or exhaust function of the height-control valve. This adjusts the volume of air in the air springs, until the frame returns to the normal ride height, and the horizontal control lever returns to the horizontal (neutral) position.

A side-to-side restriction valve inside the height-control valve maintains vehicle roll stability by preventing inflation of the air spring on one side and deflation on the other side during curves.

A pressure holding valve, located in the air line to the height-control valve, is preset to maintain a minimum pressure of 65 psi (448 kPa) in the vehicle secondary air system if a leak should occur in the air suspension system.

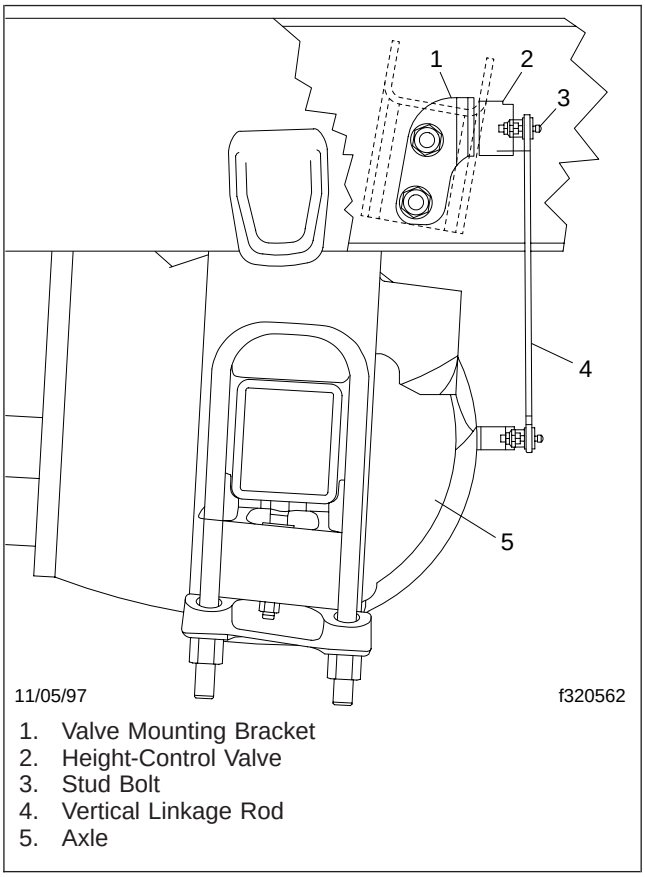


1. Forward Drive Axle
2. Valve Mounting Bracket
3. Height-Control Valve
4. Neutral-Position Hole
5. Horizontal Control Lever
6. Stud Bolt
7. Vertical Linkage

Fig. 1, Barksdale Height-Control Valve Installation

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General Information



1. Valve Mounting Bracket
2. Height-Control Valve
3. Stud Bolt
4. Vertical Linkage Rod
5. Axle

Fig. 2, Barksdale Height-Control Valve Installation, Side View

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General Guidelines

1. To keep the air suspension system operating reliably, the air system must be kept free of any oil, moisture or foreign material. Inspect and maintain the air system components regularly. See Group 32 in the *Acterra Maintenance Manual* for maintenance operations.

⚠ CAUTION

Failure to take precautions against the entry of moisture, oil or other foreign material into the air suspension system could eventually lead to sludge forming in the air system. Sludge could adversely affect the operation of the air suspension system and other air system components.

2. Use only SAE grade 8 bolts, grade C prevailing torque locknuts, and hardened washers to attach spring hangers and brackets to the frame.
3. For suspension component inspection, lubrication and fastener torque check intervals and instructions, see Group 32 in the *Acterra Maintenance Manual*.

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Ride Height Adjustment, Vehicle with a Barksdale Valve

NOTICE

Failure to adjust the suspension ride height could adversely affect driveline angles. Also, if the air springs are set too high, the driver may have difficulty (or be prevented from) backing the vehicle under a trailer. If the air springs are set too low, rapid wear of suspension parts will result.

IMPORTANT: Before checking the suspension height, make sure there is no load on the chassis. For tractors, unhitch the trailer. Trucks must be empty.

1. Park the vehicle on a level surface, using a light application of the brakes. Do not apply the parking brakes. Put the transmission in neutral. Build the secondary air pressure to at least 100 psi (690 kPa). Shut down the engine.
2. Mark the location of the front and rear tires on the floor, then chock the tires on one axle only.

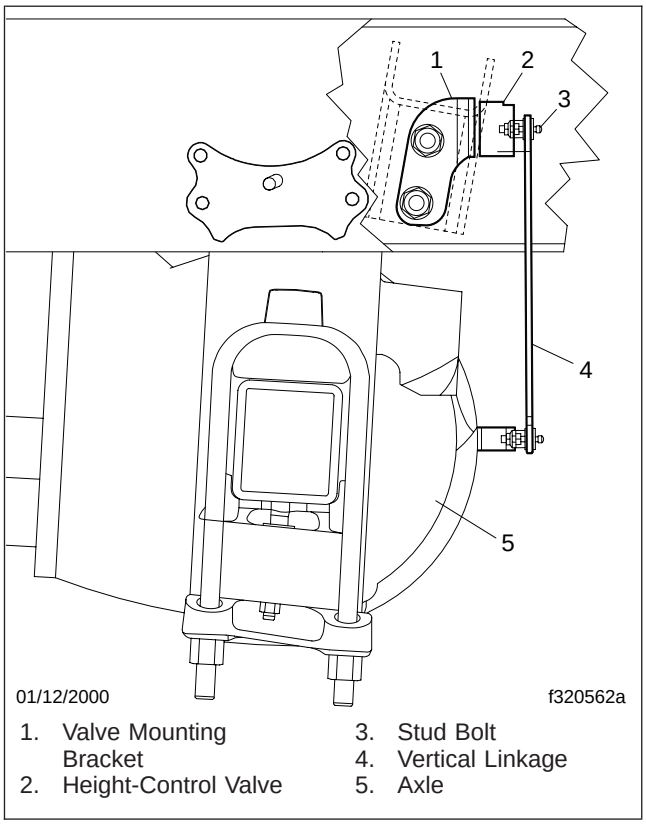
NOTE: The stud bolt that fastens the horizontal control lever to the vertical linkage is oriented correctly when the linkage rod is vertical as viewed from the side of the vehicle; see **Fig. 1**.

3. Measure the distance between the left forward-most axle stop and the suspension as indicated; see **Table 1**, **Table 2**, **Table 3**, **Table 4**, and **Table 5** for an acceptable range of heights for each suspension.

IMPORTANT: **Suspensions with Dual-Leaf Springs, and all Vehicles built before August 24, 2001:** Measure between the top of the U-bolt and the bottom of the axle stop (distance A).

Suspensions with Single-Leaf Springs, built after August 24, 2001: Measure between the top of the U-bolt **pad** and the bottom of the axle stop (distance B).

4. If the distance is within the acceptable range, ride height is adjusted correctly. Apply the parking brakes.



1. Valve Mounting Bracket
2. Height-Control Valve
3. Stud Bolt
4. Vertical Linkage
5. Axle

Fig. 1, Barksdale Height-Control Valve Installation (side view)

If the measurement is not within the acceptable range, go to the next step.

NOTICE

When loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

5. While holding the height-control valve mounting studs in place with an Allen wrench, loosen the nuts that attach the valve to the mounting bracket.

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Suspension Ride Height Adjustment

6. Adjust the position of the valve body, until the distance from the bottom of the left axle stop to the top of the U-bolt or U-bolt pad is the target measurement from the applicable *Suspension Ride Height Measurement* table.
7. Center the horizontal control lever on the valve by inserting a 5/32-inch (4-mm) pin or drill bit into the neutral-position hole in the height-control valve and the horizontal control lever.
8. While holding the height-control valve mounting studs in place with an Allen wrench, tighten the nuts 95 lbf·in (1100 N·cm). Do not overtighten.
9. Remove the pin or drill bit previously inserted in the height-control valve.
10. Drive the vehicle unloaded for about 1/4 mile (1/2 km), then stop the vehicle in the exact location (as previously marked) of the original measurement.

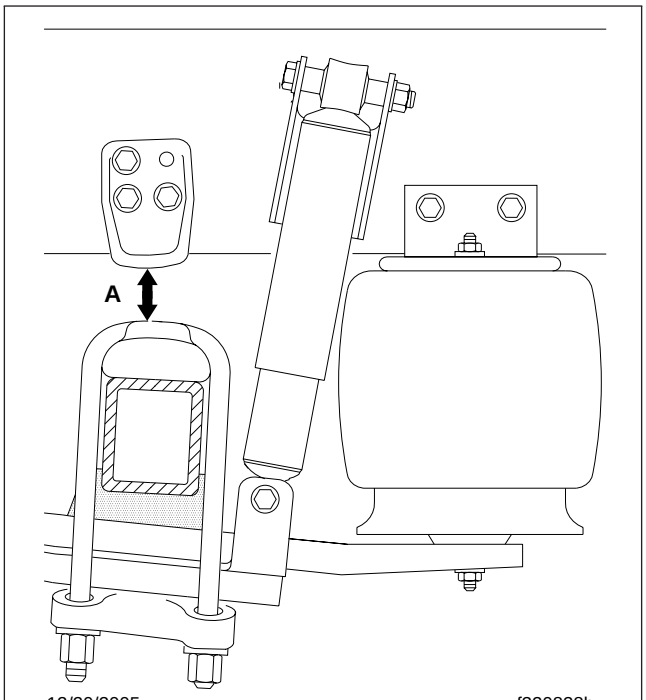
    Park the vehicle using a light brake application. Chock the tires on one axle only, and put the transmission in neutral. Do not apply the parking brakes.
11. Check the distance between the bottom of the left axle stop and the top of the axle U-bolt or U-bolt pad.

IMPORTANT: **Suspensions with Dual-Leaf Springs, and all Vehicles built before August 24, 2001:** Measure between the top of the U-bolt and the bottom of the axle stop (distance A).

Suspensions with Single-Leaf Springs, built after August 24, 2001: Measure between the top of the U-bolt *pad* and the bottom of the axle stop (distance B).

12. If the distance is within the acceptable range, the ride height is adjusted correctly. Apply the parking brakes.

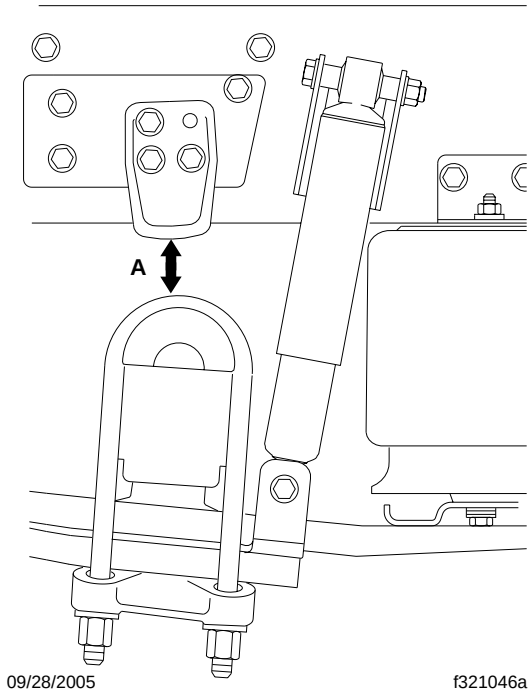
    If the distance is not within the acceptable range, repeat the adjustment procedure.



Measure Point	Suspension Height Measurement (A)		
	Min	Target	Max
A = Measure Here	2-3/8 inch (60 mm)	2-5/8 inch (67 mm)	2-7/8 inch (73 mm)

Table 1, Suspension Ride Height Measurement, Dual-Leaf Spring, 20k/40k High Ride

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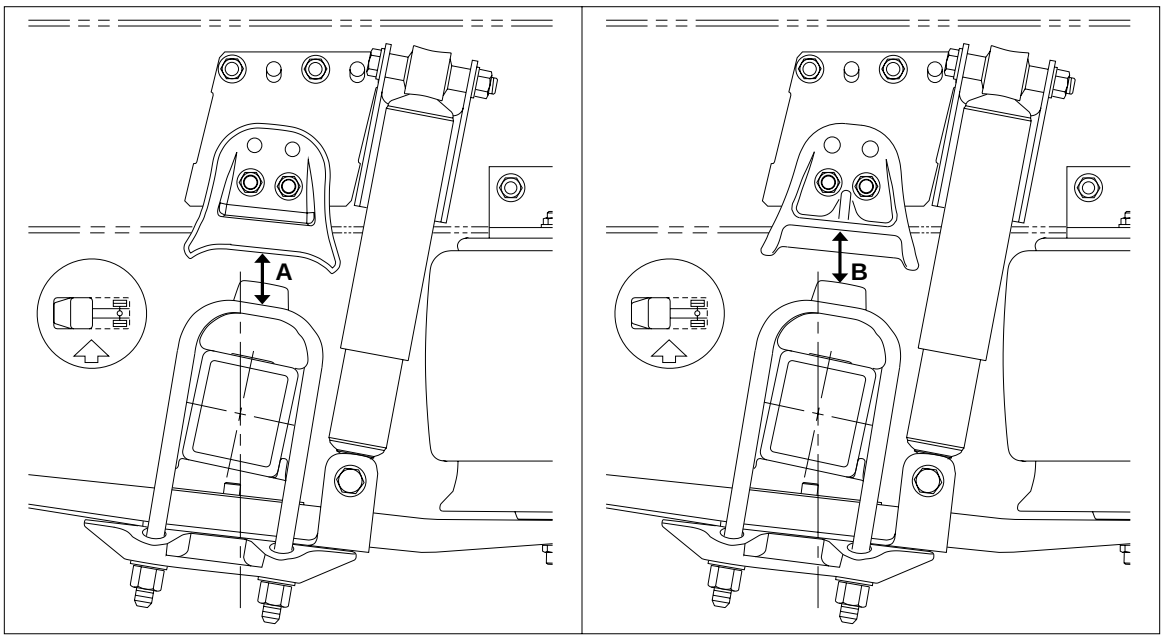


Measure Point	Suspension Height Measurement (A)		
	Min	Target	Max
A = Measure Here	2-3/4 inch (70 mm)	3 inch (76 mm)	3-1/4 inch (83 mm)

Table 2, Suspension Ride Height Measurement, Dual-Leaf Spring, 23k/46k/69k High Ride

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Suspension Ride Height Adjustment

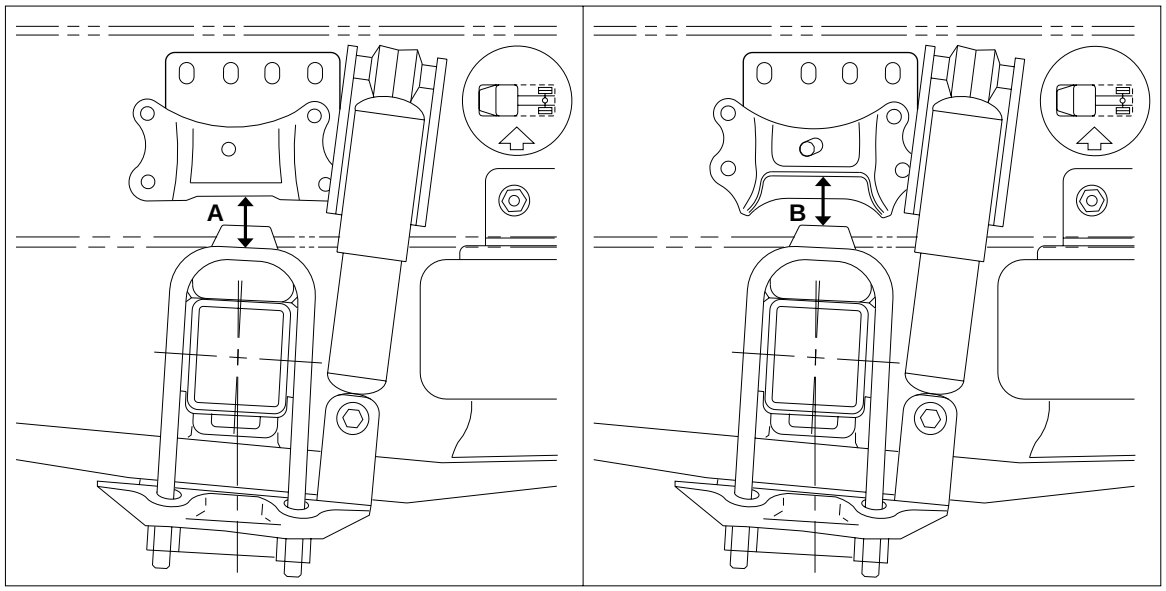


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Measure Point	Suspension Height Measurement (A or B)		
	Min	Target	Max
A = Measure Here if Built Before August 24, 2001 B = Measure Here if Built After August 24, 2001	2-3/8 inch (60 mm)	2-5/8 inch (67 mm)	2-7/8 inch (73 mm)

Table 3, Suspension Ride Height Measurement, Single-Leaf Spring, 20k/40k, High Ride Height

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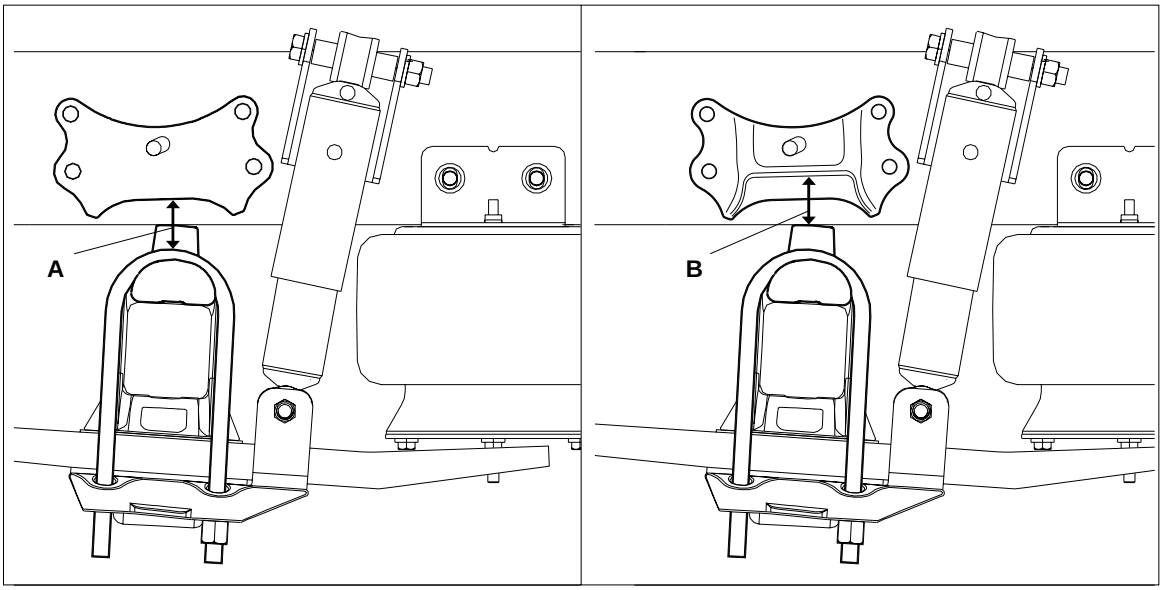


Measure Point	Suspension Height Measurement (A or B)		
	Min	Target	Max
A = Measure Here if Built Before August 24, 2001 B = Measure Here if Built After August 24, 2001	2-3/8 inch (60 mm)	2-1/2 inch (64 mm)	2-7/8 inch (73 mm)

Table 4, Suspension Ride Height Measurement, Single-Leaf Spring, 10k/12k/15k/18k Mid Ride Height and 40k Low and Mid Ride Height

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Suspension Ride Height Adjustment



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Measure Point	Suspension Height Measurement (A or B)		
	Min	Target	Max
A = Measure Here if Built Before August 24, 2001 B = Measure Here if Built After August 24, 2001	2-1/8 inch (54 mm)	2-9/32 inch (58 mm)	2-5/8 inch (67 mm)

Table 5, Suspension Ride Height Measurement, Single-Leaf Spring, 10k/12k/15k Low or Extra Low Ride Height

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Height-Control Valve Checking

It is normal to hear air escaping from the height-control valve for as much as 10 minutes after getting out of the vehicle when it is in an unladen condition. This air "leaking" is just the height-control valve exhausting air from the suspension air springs in order to return to the neutral mode.

The height-control valves used on the Acterra are Barksdale valves. Two methods are available to check the operation of the Barksdale height-control valves. A leak in the valve may be discovered without using a test kit, but a test kit is necessary to determine if the valve has an unacceptable rate of leakage.

Some Barksdale height-control valves have been returned for warranty because the four bolts in the valve housing were overtightened, often, enough to crack the valve housing. These bolts should not be loose, and should not normally require tightening, as there are no serviceable parts in the valve.

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing if you detect leaks in the housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

NOTICE

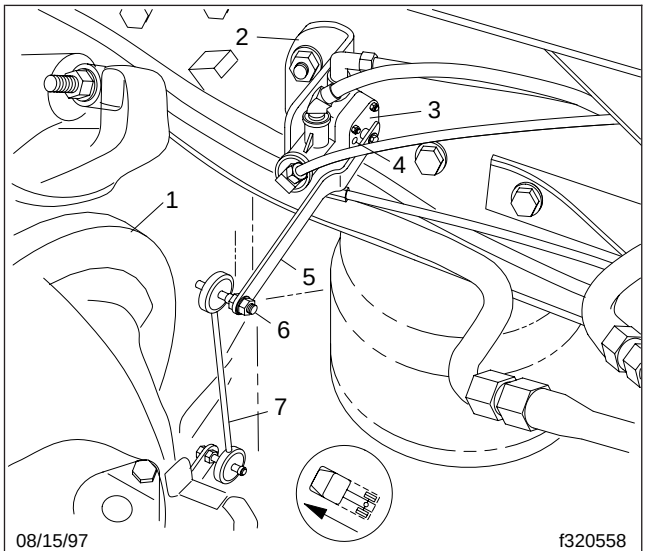
When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

Checking the Height-Control Valve Without Using a Test Kit

1. Apply the parking brakes and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa).
3. Shut off the engine and wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve.

4. Disconnect the vertical linkage from the control lever; see **Fig. 1**.



1. Forward Drive Axle
2. Valve Mounting Bracket
3. Height-Control Valve
4. Neutral-Position Hole
5. Horizontal Control Lever
6. Stud Bolt
7. Vertical Linkage

Fig. 1, Barksdale Height-Control Valve Assembly

5. Pull the control lever up about 45 degrees for 6 to 8 seconds. If air passes through the valve, that section of the valve is working.

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6. Return the control lever to the neutral position. Air should stop flowing. If so, that section of the valve is working.
7. Push the control lever down about 45 degrees for 6 to 8 seconds. If air exhausts from the valve, that section of the valve is working.
8. Return the control lever to the neutral position. If the air stops again in the neutral position, the valve is working correctly.
9. If the valve works as stated in all of the above steps, then no further checking is necessary. Connect the vertical linkage to the control lever, then tighten the linkage nut.

   If needed, adjust the ride height or replace the height-control valve. For adjustment of the ride height, see **Subject 110**. For replacement of the height-control valve, see **Subject 130**.

NOTE: If a leak is detected on a Barksdale height-control valve, go to "Checking the Height-Control Valve Using a Test Kit". Barksdale valves have an acceptable leak rate of 3 cubic inches (50 cc) per minute. You can determine if a leak is acceptable only by using the Barksdale test kit.

Checking the Height-Control Valve Using a Test Kit

IMPORTANT: The procedure described below is for use on Barksdale height-control valves only.

NOTE: The Barksdale field test kit is designed to be used with the height-control valve installed on the vehicle. Refer to **Specifications 400** for information on ordering the Barksdale height-control valve test kit KD2264.

1. If not already done, park the vehicle on a level surface, apply the parking brakes, and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa).
3. Shut off the engine and wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve.

4. For valves without an integral dump port, go to the next step.

   For valves with an integral dump port, check the rubber exhaust flapper at the back of the valve housing for leaks; see **Fig. 2**. Use a soapy solution.

   If a leak is found, there may be contaminants blocking the piston. Cycle the height-control valve switch inside the cab for two-second bursts, four or five times, to clear away any contaminants.

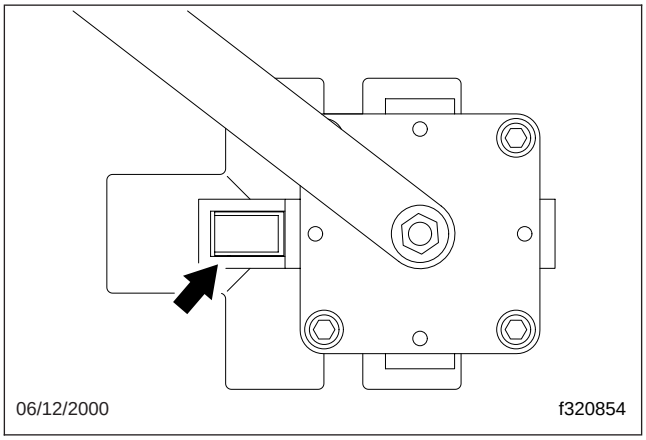
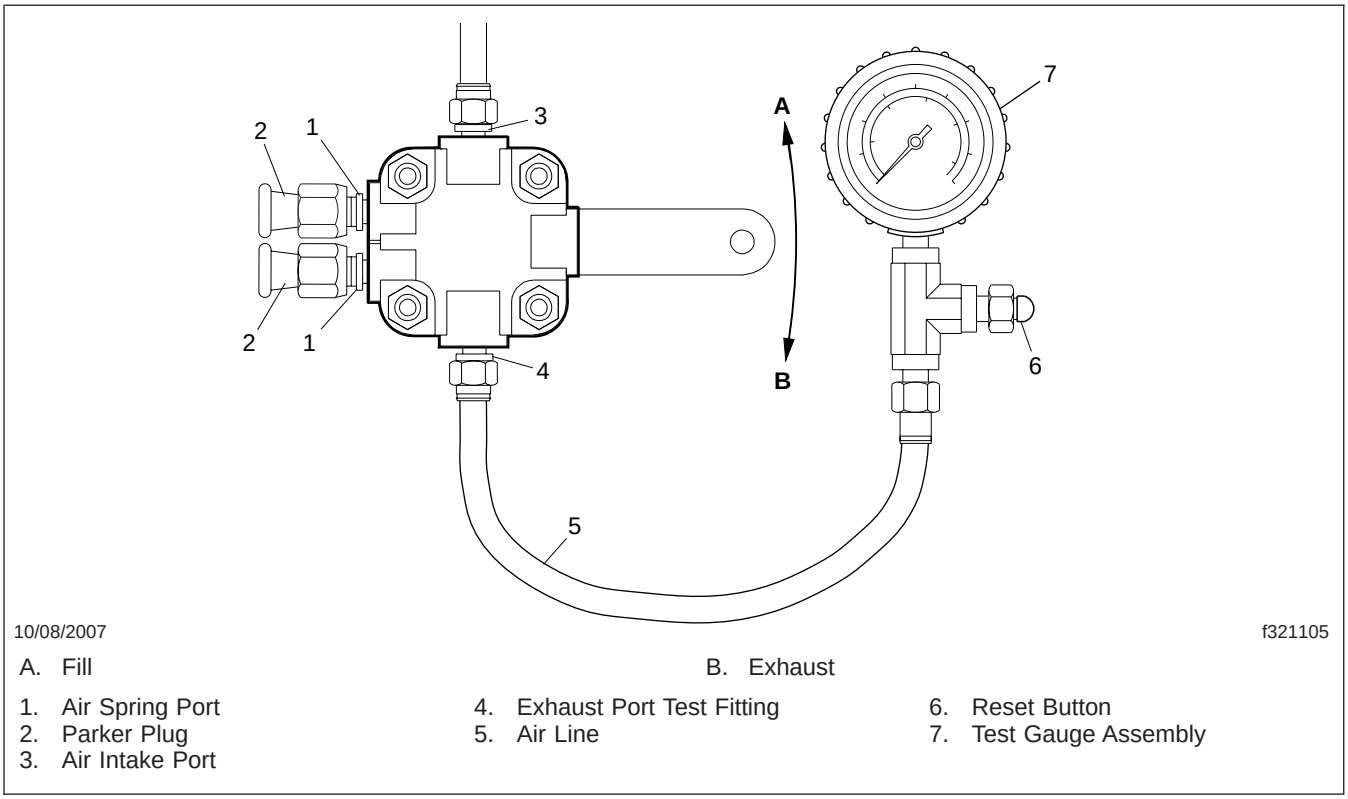


Fig. 2, Exhaust Flap Location (height-control valve with integral dump port)

5. Disconnect the vertical linkage from the horizontal control lever.
6. Rotate and hold the horizontal control lever down at about 45 degrees to exhaust air from the air springs.
7. *If equipped with an integral dump port,* turn on the quick dump switch on the dash. Leave the switch on until testing is complete.

   If not equipped with an integral dump port, disconnect the air lines from the air spring ports on the height-control valve. Leave the elbow fittings (if equipped) in place. Install a Parker plug into each air spring port (or elbow fitting); see **Fig. 3**.
8. If a flapper is present on the exhaust port of the height-control valve, remove it using needlenose pliers.

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A. Fill
B. Exhaust

1. Air Spring Port
2. Parker Plug
3. Air Intake Port
4. Exhaust Port Test Fitting
5. Air Line
6. Reset Button
7. Test Gauge Assembly

Fig. 3, Test Connections

9. Clean the surface around the exhaust port, then install the test fitting into the exhaust port. The centering pin on the fitting must align with the slot on the exhaust port. Rotate the test fitting 45 degrees clockwise to lock it in place; see **Fig. 3**.

NOTE: It may be necessary to cut the tie straps that hold the chassis wiring running below the height-control valve, in order to access the exhaust port.

10. Connect one end of the air hose from the kit to the test connector on the exhaust port, and the other end to the test gauge.
11. Check the height-control valve in the fill mode, as follows.
    - 11.1 Rotate the valve control lever up 45 degrees from the horizontal to the fill position.
    - 11.2 Press the reset button on the test gauge.
    - 11.3 Observe the test gauge for 30 seconds. Refer to **Fig. 4** for the maximum allowable exhaust pressure change versus inlet pressure.

      The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.

      If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

12. Check the height-control valve in the exhaust mode, as follows.
    - 12.1 Rotate the valve control lever down 45 degrees from the horizontal to the exhaust position.
    - 12.2 Press the reset button on the test gauge.
    - 12.3 Observe the test gauge for 30 seconds. Refer to **Fig. 4** for the maximum allowable

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Height-Control Valve Checking

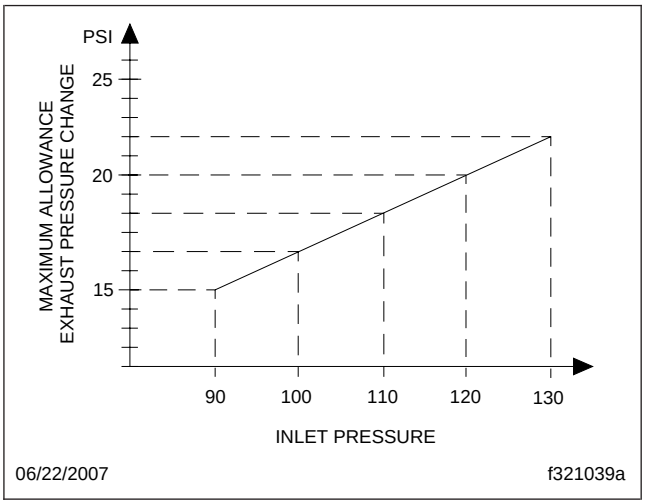


Fig. 4, Inlet Pressure vs. Exhaust Pressure Change in 30 Seconds

exhaust pressure change versus inlet pressure.

The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.

If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

13. Disconnect the test gauge and connector from the valve exhaust port.
14. If the height-control valve is defective, replace it; see **Subject 130**.
15. Install the flapper on the exhaust port by pressing it into place.
16. *For height-control valves with an integral dump port,* connect the vertical linkage to the height-control valve control lever. Turn off the quick dump switch on the dash. The ride height will automatically return to the correct position.

    For height-control valves without an integral dump port, remove the two Parker plugs from the air spring ports, and connect the air lines to the air spring ports (or elbow fittings). Connect the vertical linkage to the height-control valve control lever. The ride height will automatically return to the correct position.

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Barksdale Height-Control Valve Replacement

The Barksdale valve does not use an adjustable linkage rod. To adjust the Barksdale valve, see **Subject 110**.

1. Apply the parking brakes and chock the tires.

⚠ WARNING

Keep your hands and all objects away from the area under and around the slack adjusters and suspension components when removing the pressure from the air system. These parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

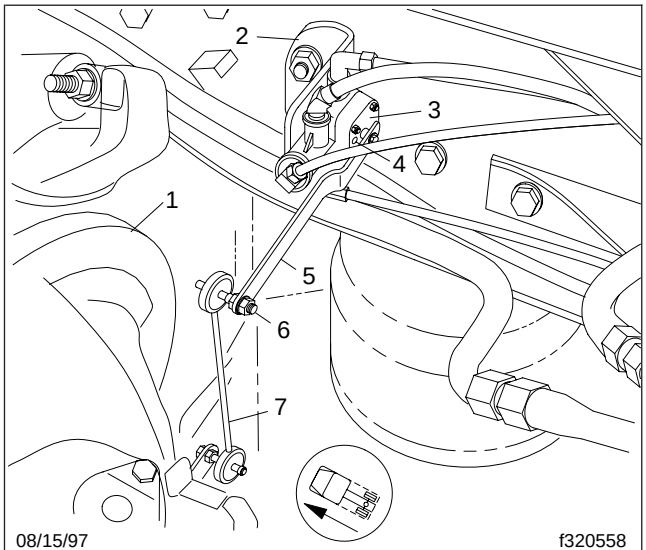
2. Drain all air from the air tanks.

⚠ WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

3. Remove the nut and washer that attaches the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever; see **Fig. 1**.
4. Rotate and hold the horizontal control lever down until all air is exhausted from the air springs.
5. Disconnect the air lines at the height-control valve, and mark the lines for later reference. Using tape, cover the open ends of the air lines and fittings to prevent dirt or foreign material from entering.

IMPORTANT: For quick-connect tube fittings, do not remove the tube by cutting it close to the fitting. If the remaining part of the tube cannot be pulled from the fitting, the fitting will not be reusable and the warranty on that unit will be void.



1. Forward Drive Axle
2. Valve Mounting Bracket
3. Height-Control Valve
4. Neutral-Position Hole
5. Horizontal Control Lever
6. Stud Bolt
7. Vertical Linkage

Fig. 1, Barksdale Height-Control Valve

NOTICE

When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

6. While holding the height-control valve mounting studs in place with an Allen wrench, remove the nuts and washers that attach the valve to the mounting bracket. Remove the height-control valve.
7. Position the new height-control valve on the height-control bracket. While holding the height-control valve mounting studs in place with an Allen wrench, install the nuts and washers, and

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Height-Control Valve Replacement

tighten the nuts 95 lbf·in (1100 N·cm). Do not overtighten.

8. Remove the tape from the air lines and fittings, and connect the air lines to the height-control valve as marked earlier. Tighten nylon tube air fittings until only two threads show on the fitting. On wire-braid hose fittings, tighten the nut with a wrench until there is firm resistance, then tighten one-sixth turn more.
9. Close the drain cocks on all reservoirs.
10. Build up normal operating pressure in the air system. Check all air lines and connections for leaks. Eliminate all leaks.
11. Adjust the height-control valve; see **Subject 110**.

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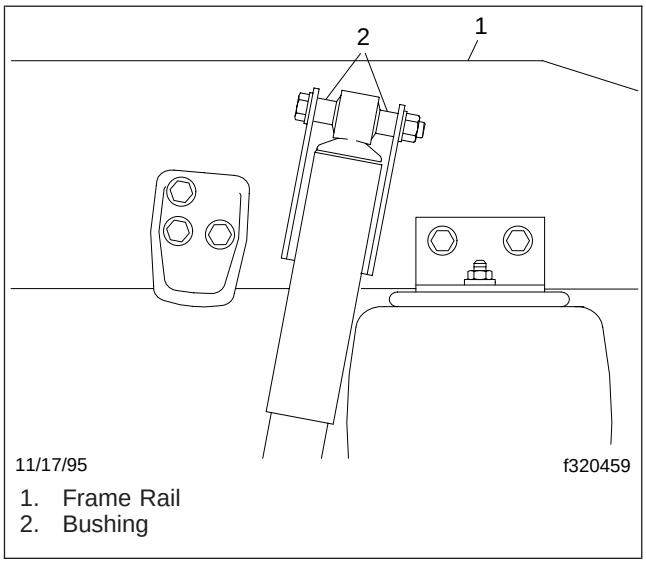
Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the locknut, bolt and spacer from the shock absorber lower mounting bracket.
3. Remove the nut, upper retainer and upper bushing from the top of the shock absorber.
4. Pull the shock absorber out of the upper mounting bracket, and remove the retainer and bushing.
5. Install the replacement shock absorber, making sure the new bushings and retainers are positioned as shown in **Fig. 1**.

⚠ WARNING

Use only the retainers included with the replacement shock absorber. Do not use washers. They can be pushed over the nut and be ejected violently, possibly causing personal injury and property damage.

6. Tighten the shock absorber lower mounting locknut 170 lbf·ft (230 N·m).
7. Tighten the shock absorber upper mounting nut to compress the bushings as shown in **Fig. 1**.
8. Remove the chocks from the tires.



1. Frame Rail
2. Bushing

Fig. 1, Shock Absorber Mounting

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Air Spring Bag Replacement

Replacement

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front tires. Raise the vehicle frame and support it with safety stands to remove all weight from the air springs.
2. Disconnect the leveling valve and exhaust all air from the air springs.
3. Using a dull instrument, pry the air spring bead off the piston lip. Be careful not to damage the piston.
4. Disconnect the air supply line, including the brass tee, from the air spring. Using tape, cover the ends of the air supply line and the fitting to prevent dirt or foreign material from entering.
5. Remove the locknuts and washers that connect the air spring bag to the upper mounting bracket.
6. Remove the air spring bag.
7. Check the piston for residue, and remove any, if found.

NOTE: When space is limited (such as at the forward axle of tandem axles), it may be easier to remove the piston from the leaf spring and assemble the bag and piston on a workbench. Secure the air spring mounting bracket, which is attached to the bag, in a vise. Fully extend the air bag and plug the air supply port. Apply a soap-and-water solution to the piston lip and air bag bead, and, using a twisting motion, push the piston onto the airbag until the piston is fully seated. Inspect the circumference of the bag-to-piston connection to make sure there is less than 1/8 inch (3.2 mm) of clearance between the air bag and the piston shoulder. The gap should be uniform around the assembly. After inspecting, remove the plug in the air supply port and push the piston into the air bag so that it rolls over the piston. Install on the vehicle.

⚠ WARNING

Do not add air pressure to the air spring assembly when it is not mounted on a vehicle. Doing so could cause components to eject from the assembly, which could cause serious personal injury or property damage.

8. Attach the new air spring bag to the upper mounting bracket, using the 1/2–13 locknut on the outside of the frame rail and the 3/4–16 locknut on the inside. Tighten 3/4–16 locknuts 45 lbf·ft (61 N·m); tighten 1/2–13 locknuts 23 lbf·ft (31 N·m).
9. Remove the tape from the ends of the air supply line, the fitting, and the brass tee. Connect the air supply line to the air spring. Tighten nylon tube air fittings until only two threads show on the fitting. Onwire-braid hose fittings, tighten the nut with a wrench until there is firm resistance. Tighten one-sixth turn more.
10. Make sure the air spring bag is fully extended alongside the piston so there are no folds in the bag near the bead. See **Fig. 1**.
11. Fold the air spring bag so the bead is fully parallel with the piston lip. See **Fig. 2**.
12. Apply a soap-and-water solution to the bead and piston lip.
13. Pull the rear of the air spring bag over the piston lip making sure the bead is the lowest part of thebag— none of the bag should droop over the piston. Work the front of the bag over the piston lip like a button in a button hole. See **Fig. 3**.
14. Feeling the bead through the folds of the air spring bag, snap the bead over the piston lip so it seats fully. A snapping sound confirms correct seating of the bead.
15. Inspect the circumference of the bag-to-piston connection to make sure there is less than 1/8 inch (3.2 mm) of clearance between the air bag and the piston shoulder. The gap should be uniform around the assembly.
16. Connect the leveling valve and inflate the air spring bag. As it's inflating, the bag should roll into position over the piston. See **Fig. 4**.
17. Remove the safety stands, and lower the vehicle.
18. Remove the chocks from the tires.

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Air Spring Bag Replacement

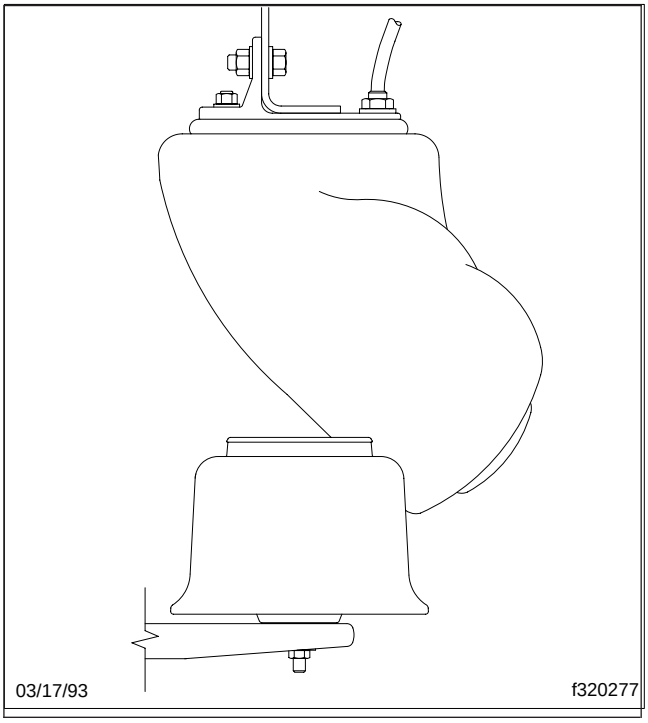


Fig. 1, Air Spring Bag Extended

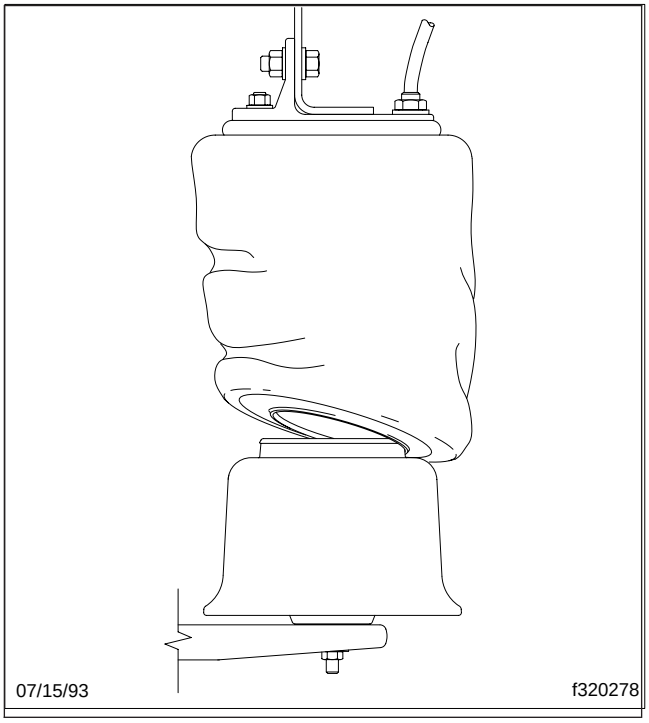


Fig. 3, Air Spring Bag Aligned with Piston

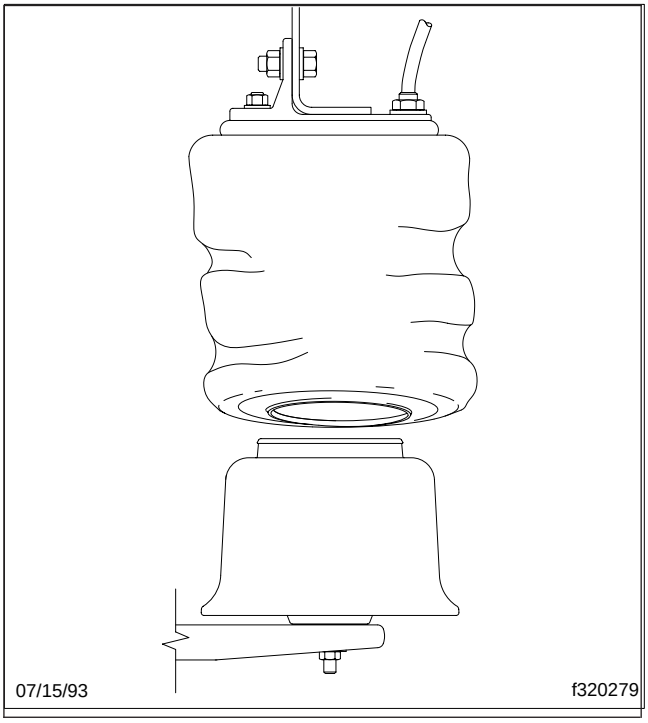


Fig. 2, Air Spring Bag Folded

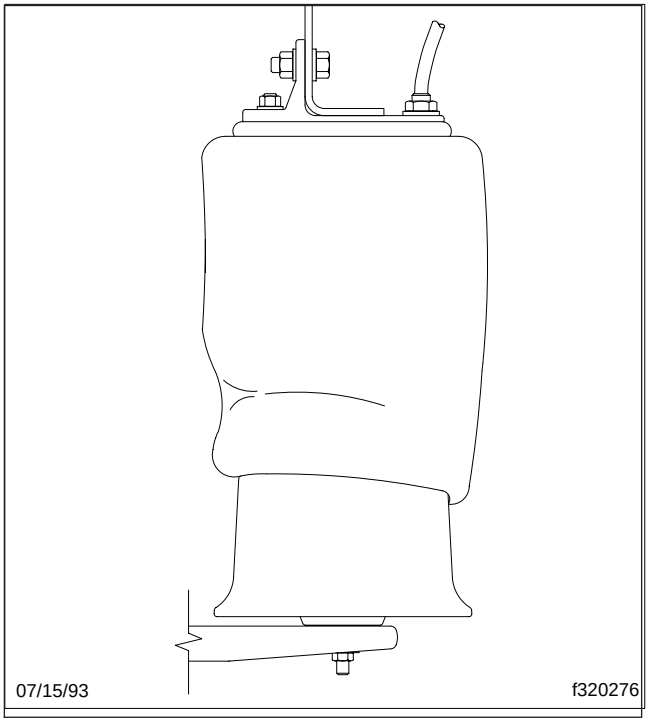
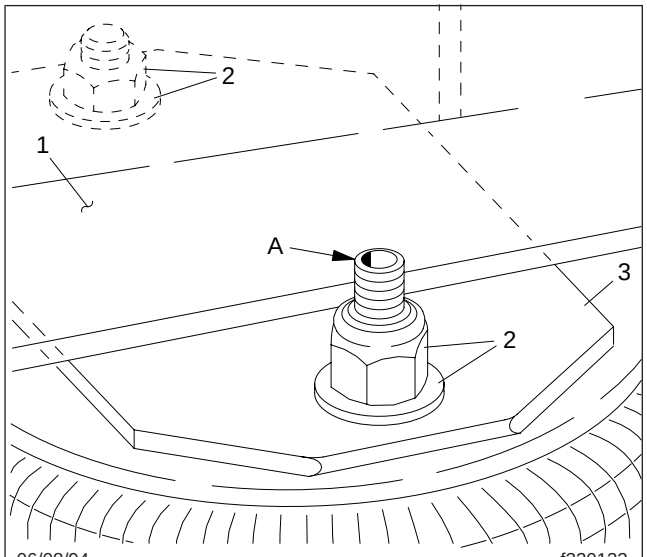


Fig. 4, Air Spring Bag Rolling Onto Piston

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Air Spring Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Raise the vehicle frame and support it with safety stands to remove all weight from the air springs. The leveling valve automatically releases air from the air springs when all weight is removed from the suspension.
3. Disconnect the air supply line, including the brass tee, from the air spring. Using tape, cover the ends of the air supply line and the fitting to prevent dirt or foreign material from entering.
4. Remove the locknuts and washers that connect the air spring to the upper mounting bracket, or to the frame rail flange. See **Fig. 1** and **Fig. 2**.

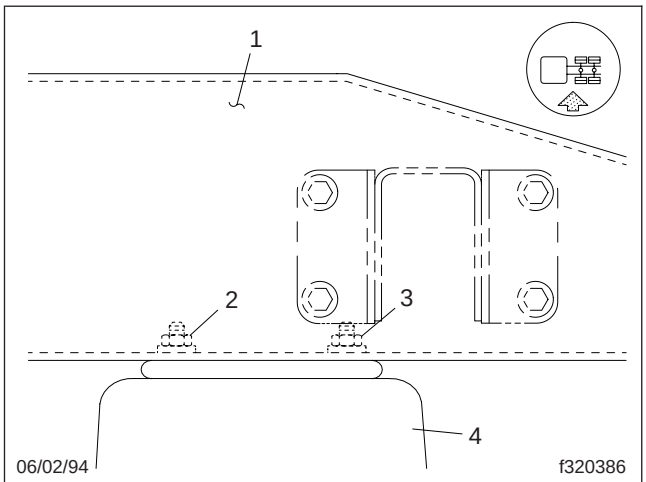


A. Air line connects here.
1. Right Frame Rail Flange
2. Locknut and Washer
3. Upper Mounting Bracket

Fig. 1, Bracket-Mounted Air Spring

5. Remove the capscrews and lockwashers that connect the air spring to the rear of the leaf spring. Remove the air spring.

NOTE: Suspensions manufactured to a 46,000-pound (20 865 kg) or 23,000-pound (10 433 kg) weight rating have a different leaf spring, and an additional cross bar attached between the air spring and rear of the leaf spring.



1. Frame Rail (left)
2. 3/4–16 Locknut and Washer
3. 1/2–13 Locknut and Washer
4. Air Spring

Fig. 2, Flange-Mounted Air Spring

6. Place the new air spring on the rear of the leaf spring (or the cross bar on the 23,000- and 46,000-pound suspensions), and install the washer and locknut that hold the air spring (and cross bar) in place. Tighten the locknut 55 lbf·ft (75 N·m).
7. *For bracket-mounted air springs:* Attach the air spring to the upper mounting bracket, using the 1/2–13 locknut on the outside of the frame rail and the 3/4–16 locknut on the inside. See **Fig. 1**. Tighten the 3/4–16 locknut 45 lbf·ft (61 N·m); tighten the 1/2–13 locknut 23 lbf·ft (31 N·m).

   For flange-mounted air springs: Attach the air spring to the frame rail flange, using the 3/4–16 locknut on the forward stud of the air spring, and the 1/2–13 locknut on the rear stud. See **Fig. 2**. Tighten the 3/4–16 locknut 45 lbf·ft (61 N·m); tighten the 1/2–13 locknut 23 lbf·ft (31 N·m).
8. Remove the tape from the ends of the air supply line, the fitting, and the brass tee. Connect the air supply line to the air spring. Tighten nylon tube air fittings until only two threads show on the fitting. On wire-braid hose fittings, tighten the nut with a wrench until there is firm resistance. Tighten one-sixth turn more.

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Air Spring Replacement

9. Remove the safety stands and lower the vehicle.
10. Remove the chocks from the tires.

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Leaf Spring Replacement

(See Fig. 1)

⚠ WARNING

Do not replace individual leaves of a damaged leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Raise the rear of the vehicle, and support the rear axle(s) with safety stands. Raise the vehicle so that all weight is removed from the leaf springs, then securely support the frame with safety stands. Remove the wheel and tire assembly to easily access the suspension. See **Group 40** in this manual for instructions.
3. Remove the nut, bolt, and washers from the shock absorber lower mounting bracket. Remove the high nuts, flatwashers, and axle clamp from each U-bolt. Support the leaf spring assembly with a jack.
4. If the air spring mounts to the leaf spring, disconnect the bottom of the air spring from the leaf spring.

   If the air spring mounts to a cross bar, disconnect the cross bar from the leaf spring by removing the capscrews, nuts, and washers.
5. Note the number and position of the alignment shims on the spring mounting bolt. See **Fig. 1**.
6. Remove the hexnut, washers, alignment shim(s), spring mounting bolt, and wear shoe clip from the spring hanger. See **Fig. 1**.

⚠ WARNING

The leaf spring assembly is heavy. Use care when handling it to prevent injury.

7. Remove and discard the leaf spring assembly.
8. While supporting a new leaf spring assembly with a jack, position the assembly on the spring hanger. Install the bolts, wear shoe clips, washers, alignment shims, and hexnuts. Tighten the bolts just enough to hold the leaf spring assembly in place.
9. If the air spring mounts to the leaf spring, attach the air spring to the leaf spring assembly. Install the washer and locknut. Tighten the locknut 55 lbf·ft (75 N·m).

   If the air spring mounts to a cross bar, attach the cross bar to the leaf spring assembly. The longer capscrews attach in the forwardmost holes; the shorter capscrews attach in the aft holes.
10. Making sure that the U-bolt pads are in place on the top of the axle, fasten the leaf spring assembly to the axle using the U-bolts, axle clamp, washers, and high nuts making sure the U-bolt pads and axle clamps are positioned correctly.

NOTE: On single-drive axles angled 5 degrees, the arrow on the U-bolt pads must point to the front of the axle housing. See **Fig. 2**. On single-drive axles angled 3 degrees, there is no arrow. Make sure that the axle bump stop on the U-bolt pad is positioned toward the vehicle centerline. See **Fig. 3**.

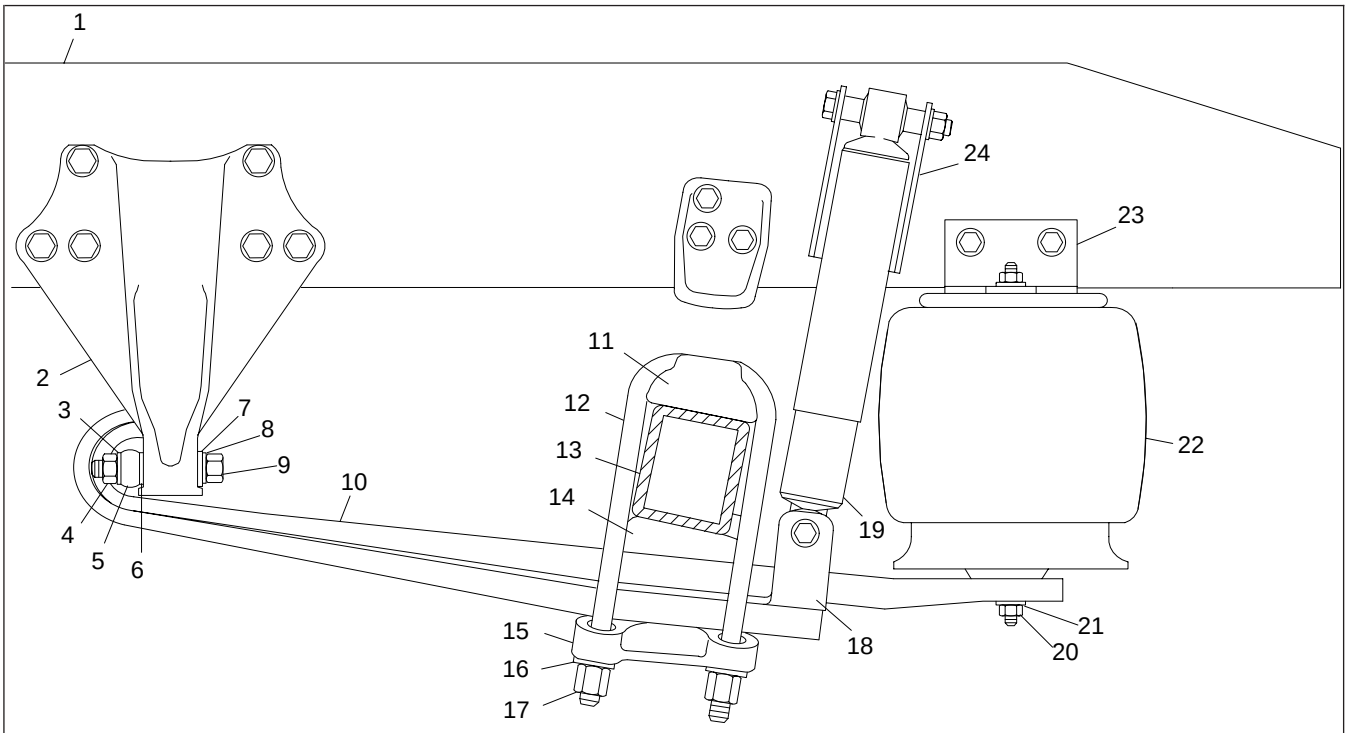
With both 3- and 5-degree single-drive axle angles, the arrow on the bottom of the axle clamp must point toward the rear of the vehicle. See **Fig. 1**.

On tandem axle suspensions, the arrow on the bottom of the axle clamp must point toward the rear of the vehicle on the forward rear axle and toward the front of the vehicle on the rearmost axle. If there is no arrow, make sure that the axle bump stop on the U-bolt pad is positioned toward the vehicle centerline.

11. Tighten the U-bolt high nuts as described in **Specifications, 400**.
12. Install the bolt, washers, and hexnut to connect the shock absorber to its lower mounting bracket. Tighten the hexnut 170 lbf·ft (230 N·m).
13. Tighten the locknut on the bottom of the air spring 55 lbf·ft (75 N·m).

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Leaf Spring Replacement



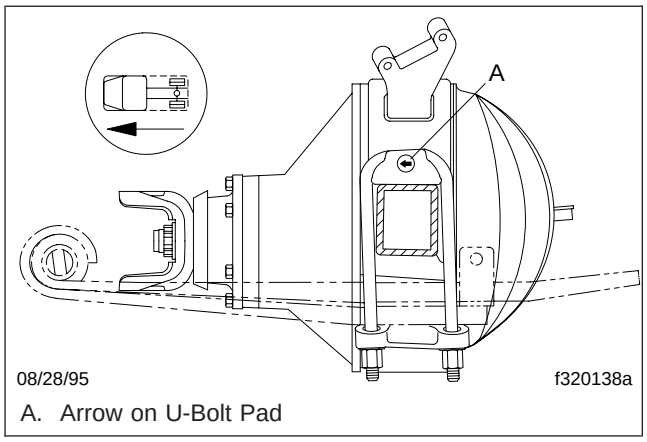
1. Frame Rail
2. Spring Hanger
3. Washer
4. Hexnut
5. Spring Mounting Eye Pin
6. Alignment Shim
7. Wear Shoe Clip
8. Washer
9. Spring Mounting Bolt
10. Leaf Spring Assembly
11. U-Bolt Pad
12. U-Bolt
13. Axle
14. Axle Seat
15. Axle Clamp
16. Flatwasher
17. High Nut
18. Shock Absorber Lower Mounting Bracket
19. Shock Absorber
20. Nylon Locknut
21. Washer
22. Air Spring
23. Air Spring Mounting Bracket
24. Shock Absorber Upper Mounting Bracket

Fig. 1, AirLiner Leaf Spring Assembly (40,000-lb 2-leaf shown)

On 23,000-pound and 46,000-pound suspensions, tighten the locknuts on the bottom of the cross bar 241 lbf·ft (327 N·m).

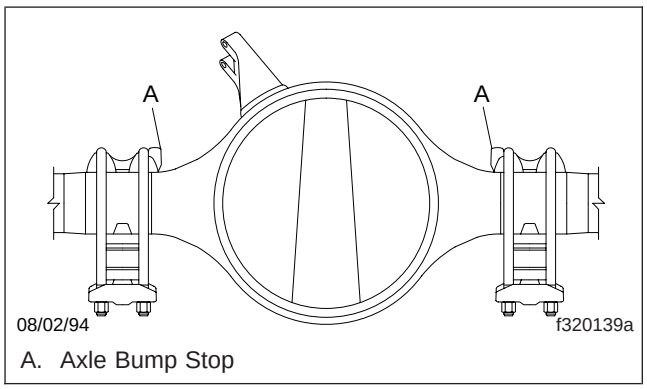
14. Tighten the hexnuts at the front of the leaf spring 170 lbf·ft (230 N·m).
15. Install the wheel and tire assembly. For instructions, see **Group 40**. Remove the safety stand, and lower the vehicle.
16. Check the rear axle alignment. For instructions, see **Group 35** in this manual. If necessary, adjust the rear axle alignment using the instructions in **Subject 190**.
17. Remove the chocks from the tires.

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A. Arrow on U-Bolt Pad

Fig. 2, U-Bolt Pad Arrow Positioning



A. Axle Bump Stop

Fig. 3, Axle Bump Stop Positioning

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Replacement

WARNING

Do not replace individual leaves of a damaged leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front tires.
2. Raise the rear of the vehicle, and support the rear axle(s) with safety stands. Raise the vehicle so that all weight is removed from the leaf springs. Securely support the frame with safety stands.
3. Remove the wheel and tire assembly to easily access the suspension. For instructions, see the information in **Group 40**.
4. Remove the leaf spring assembly. See removal information in **Subject 170**.

WARNING

The leaf spring assembly is heavy. Use care when handling it to prevent injury.

5. Remove the bushing from the leaf spring eye.

WARNING

Do not use a cutting torch to remove the outer metal of the bushing from the spring eye. Welding, torching or cutting the leaf spring assembly can damage the leaf spring material, which may result in the failure of the components and cause serious personal injury, death, or property damage.

   5.1 Using a shop press with a capacity of at least 10 tons (9 072 kg), place the spring assembly in the shop press with the spring assembly squarely supported on the press bed for safety and to avoid bending the spring assembly.

   5.2 Center the bushing tool on the outer metal of the bushing and push the bushing from the spring eye.

   5.3 Remove any burrs or material left behind by the old bushing.

6. Install the new bushing in the leaf spring eye.

   6.1 Position the bushing on the shop press.

   6.2 Apply a bonding agent, either Permabond HM–160 or Loctite® RC–609 or 680, liberally around the outside surface of the bushing.

   6.3 Press the bushing into place.

   6.4 Allow the bonding agent to cure for 24 hours.

   NOTE: After the curing time, the bushing must resist a minimum 7,700 lb (3 490 kg) pushout force.

7. Install the leaf spring assembly. See the information in **Subject 170**.
8. Install the wheel and tire assembly. For instructions, see **Group 40**. Remove the safety stands, and lower the vehicle.
9. Check the rear axle alignment. For instructions, see **Group 35** in this manual. If necessary, adjust the rear axle alignment using the instructions in **Subject 190**.
10. Remove the chocks from the tires.

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Adjustment

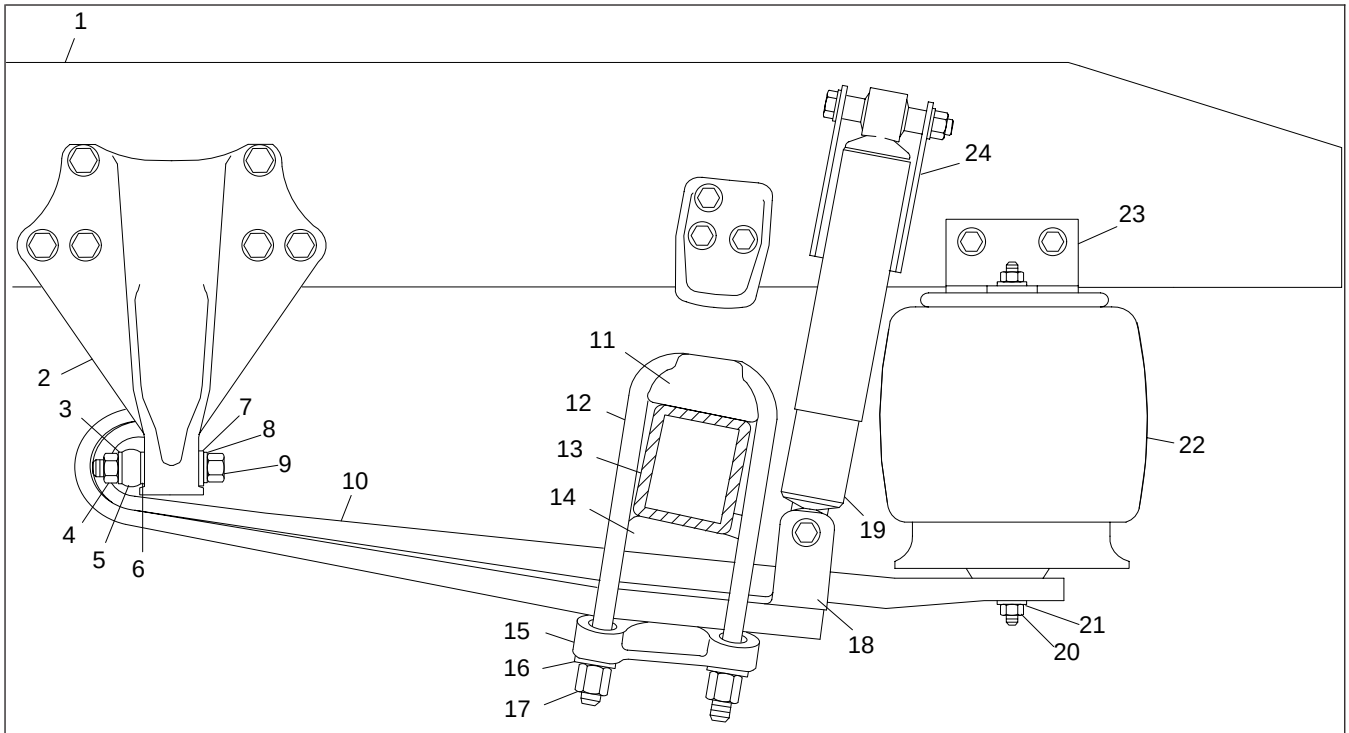
See **Fig. 1**.

Follow the instructions in **Group 35** to determine if rear axle alignment adjustment is needed. If it is needed, proceed as follows:

1. Loosen the spring mounting eye bolts so that the forward end of the leaf spring can slide fore and aft in the spring hanger.
2. Move the axle forward or backward until it is aligned within the tolerances listed in **Group 35**.
3. When the axle is in alignment, install an alignment shim(s) to take up the slack between the spring hanger and the spring mounting eye pin.

IMPORTANT: Make sure the same number of shims is installed on both ends of the spring mounting eye pin.

4. Tighten the spring mounting eye bolts 170 lbf·ft (230 N·m).
5. Check the axle alignment again. If necessary, repeat the above procedure until the alignment is within tolerances.



11/17/95 f320462

1. Frame Rail
2. Spring Hanger
3. Washer
4. Hexnut
5. Spring Mounting Eye Pin
6. Alignment Shim
7. Wear Shoe Clip
8. Washer
9. Spring Mounting Bolt
10. Leaf Spring Assembly
11. U-Bolt Pad
12. U-Bolt
13. Axle
14. Axle Seat
15. Axle Clamp
16. Flatwasher
17. High Nut
18. Shock Absorber Lower Mounting Bracket
19. Shock Absorber
20. Nylon Locknut
21. Washer
22. Air Spring
23. Air Spring Mounting Bracket
24. Shock Absorber Upper Mounting Bracket

Fig. 1, AirLiner Leaf Spring Assembly

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Rear Axle Alignment Adjustment

Rear Axle Tracking Adjustment

Single Axle

1. At the forward edge of the right rear tire, measure the distance from the inner side of the tire to the outer side of the right frame rail. See **Fig. 2**.

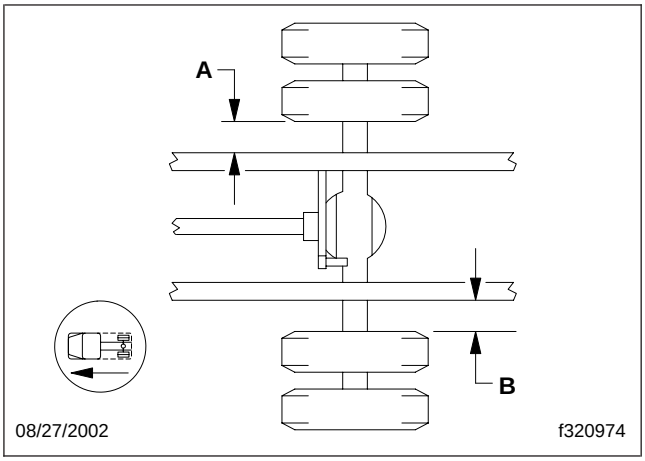


Fig. 2, Rear Axle Tracking Measurements (single axle)

2. At the rear edge of the left rear tire, measure the distance from the inner side of the tire to the outer side of the left frame rail. See **Fig. 2**.

IMPORTANT: Measurement "A" should not vary by more than 1/4-inch (6 mm) from measurement "B."

3. If measurements "A" and "B" vary by more than 1/4-inch (6 mm), loosen the fasteners holding the lateral torque rod to the frame rail. Add or remove torque-rod shims as needed.
4. For bar-pin style torque rods, tighten the fasteners 136 lbf·ft (184 N·m).

   For taper-pin style torque rods, tighten the fasteners 165 lbf·ft (224 N·m). See **Fig. 3**.

Tandem Axles

1. Check the tracking of the forward-rear axle. For instructions, see "Single Axle" in this subject. Adjust the tracking if needed.
2. At the forward-rear drive axle, measure the distance from the inner side of the right rear tire to the outer side of the right frame rail. Measure at the forward edge of the tire. See **Fig. 4**.

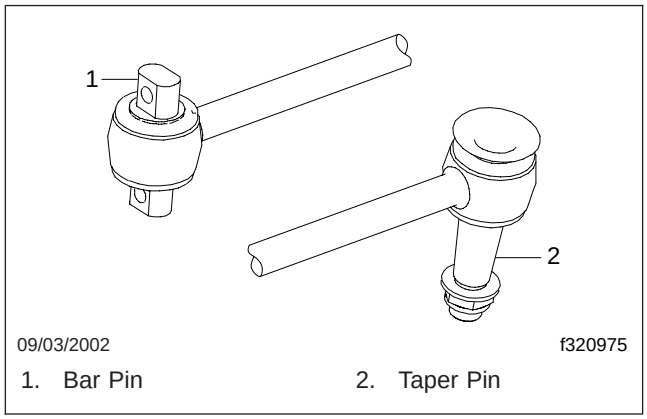


Fig. 3, Torque Rod Types

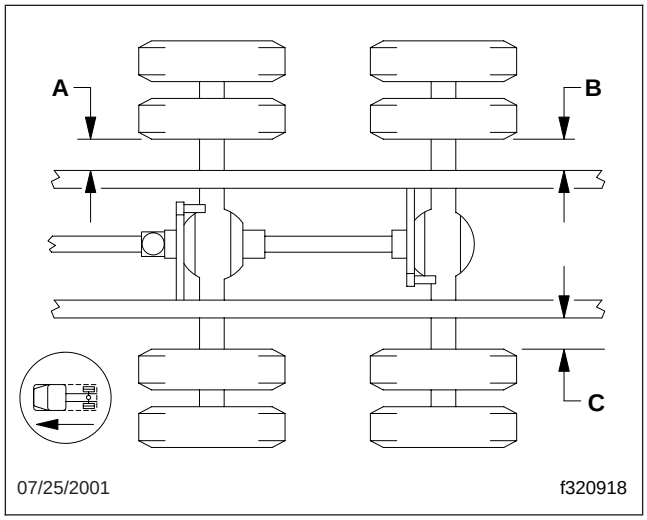


Fig. 4, Rear Axle Tracking Measurements (tandem axles)

3. At both sides of the rear-rear drive axle, measure the distance from the inner side of the rear tires to the outer side of each frame rail. Measure at the rear edge of each tire. See **Fig. 4**.

IMPORTANT: Measurements "B" and "C" should not vary by more than 1/4-inch (6 mm) from measurement "A."

4. If measurements "B" and "C" vary by more than 1/4-inch (6 mm) from measurement "A," loosen the fasteners holding the axle lateral torque rod at the rear-rear drive axle to the frame rail. Add or remove torque-rod shims as needed.

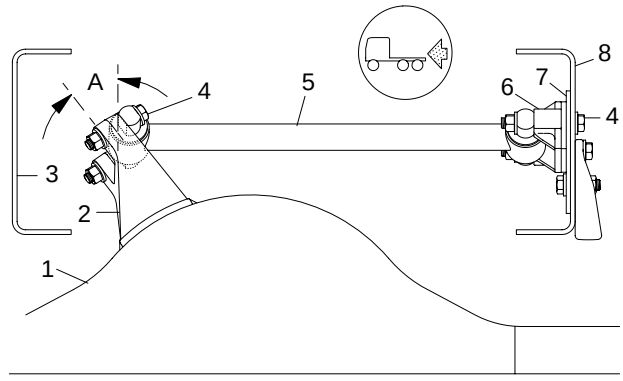
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5. For bar-pin style torque rods, tighten the fasteners 136 lbf·ft (184 N·m). For taper-pin style torque rods, tighten the fasteners 165 lbf·ft (224 N·m). See **Fig. 3**.

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Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Raise the vehicle. Support the frame rails with jack stands.
3. Remove the fasteners holding the control rod to the frame rail bracket. Remove the shims, and set the shims aside.
4. Remove the control rod.
5. Position the new control rod so that the end with the fasteners angled up at 35 degrees is installed in the axle housing bracket. See **Fig. 1**.



A. Angle: 35 degrees

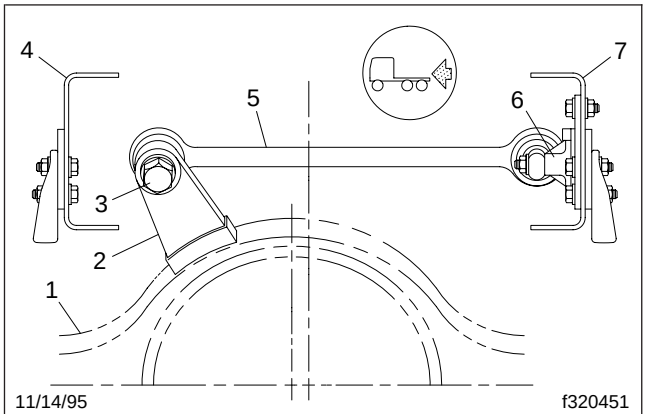
1. Axle Housing
2. Control Rod Axle Bracket
3. Left Frame Rail
4. Bolt
5. Control Rod
6. Control Rod Frame Bracket
7. Shim
8. Right Frame Rail

Fig. 1, AirLiner Control Rod Installation

6. Install the fasteners with the bolt heads facing up. Tighten the fasteners enough to hold the control rod in place.
7. Install the shims that were previously removed.
8. Install the other end of the control rod in the frame rail bracket. Install the fasteners. Tighten the fasteners enough to hold the control rod in place.
9. Tighten all the fasteners 136 lbf·ft (184 N·m).
10. Remove the jack stands and lower the vehicle.

NOTE: Control rods on suspensions manufactured to a 23,000-pound (10 433 kg) and 46,000-pound (20 865 kg) weight rating are larger and are attached to the axle bracket with a single bolt. Tighten the fasteners attaching the control rod frame bracket to the frame rail 160 to 170 lbf·ft (217 to 230 N·m), and the bolt connecting the control rod to the axle housing 175 to 225 lbf·ft (237 to 305 N·m). See **Fig. 2**.

11. Remove the chocks from the tires.



1. Axle Housing
2. Control Rod Axle Bracket
3. Bolt
4. Left Frame Rail
5. Control Rod
6. Control Rod Frame Bracket
7. Right Frame Rail

Fig. 2, Control Rod Installation on 23,000- and 46,000-lb AirLiner Suspensions

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Torque Specifications

For fastener torque values, see **Table 1**.

Torque Values			
Description	**Size**	**Torque**	
		lbf·ft (N·m)	**lbf·in (N·cm)**
Height-Control Valve Housing Bolts*	1/4–20	—	45 (500)
Height-Control Valve Mounting Locknuts*	1/4–20	—	95 (1100)
Air Spring Lower Mounting Locknuts	1/2–13	55 (75)	—
Air Spring Upper Mounting Bracket	5/8–11	125 (170)	—
Air Spring Upper Mounting Locknuts	3/4–16	45 (61)	—
	1/2–13	23 (31)	—
Axle U-Bolt High Nuts Tighten in a diagonal pattern as shown in **Fig. 1**.	7/8–14	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420 to 500 (571 to 680)	—
Lateral Control Rod Mounting Bolt Nuts	5/8–11	136 (184)	—
Leaf Spring Mounting Eye Bolt Locknuts	5/8–11	170 (230)	—
Shock Absorber Lower Mounting Nuts	3/4–10	170 (230)	—
Shock Absorber Upper Bracket Mounting Locknuts	5/8–11	125 (170)	—
Shock Absorber Upper Mounting Nuts	3/4–10	170 (230)	—
Spring Hanger Mounting Locknuts	3/4–10	210 (285)	—

* See the cautionary statements below.

Table 1, Torque Values

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

NOTICE

When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

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Specifications

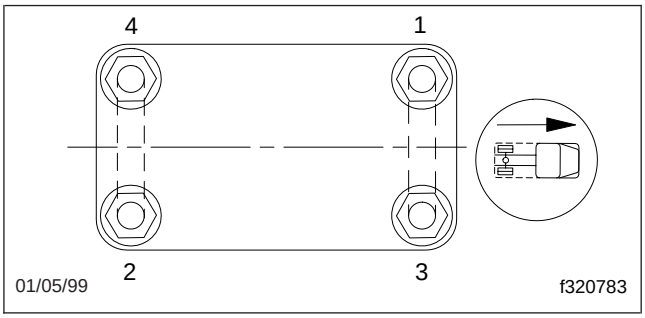


Fig. 1, Tightening Pattern for U-Bolt High Nuts

Wiring Diagram

See **Fig. 2** for a full view of the air suspension dump wiring.

Special Tools

Use the kit shown in **Fig. 3** to test a Barksdale height-control valve. Test kit BKS KD2264 is available via the Direct Ship program in Paragon.

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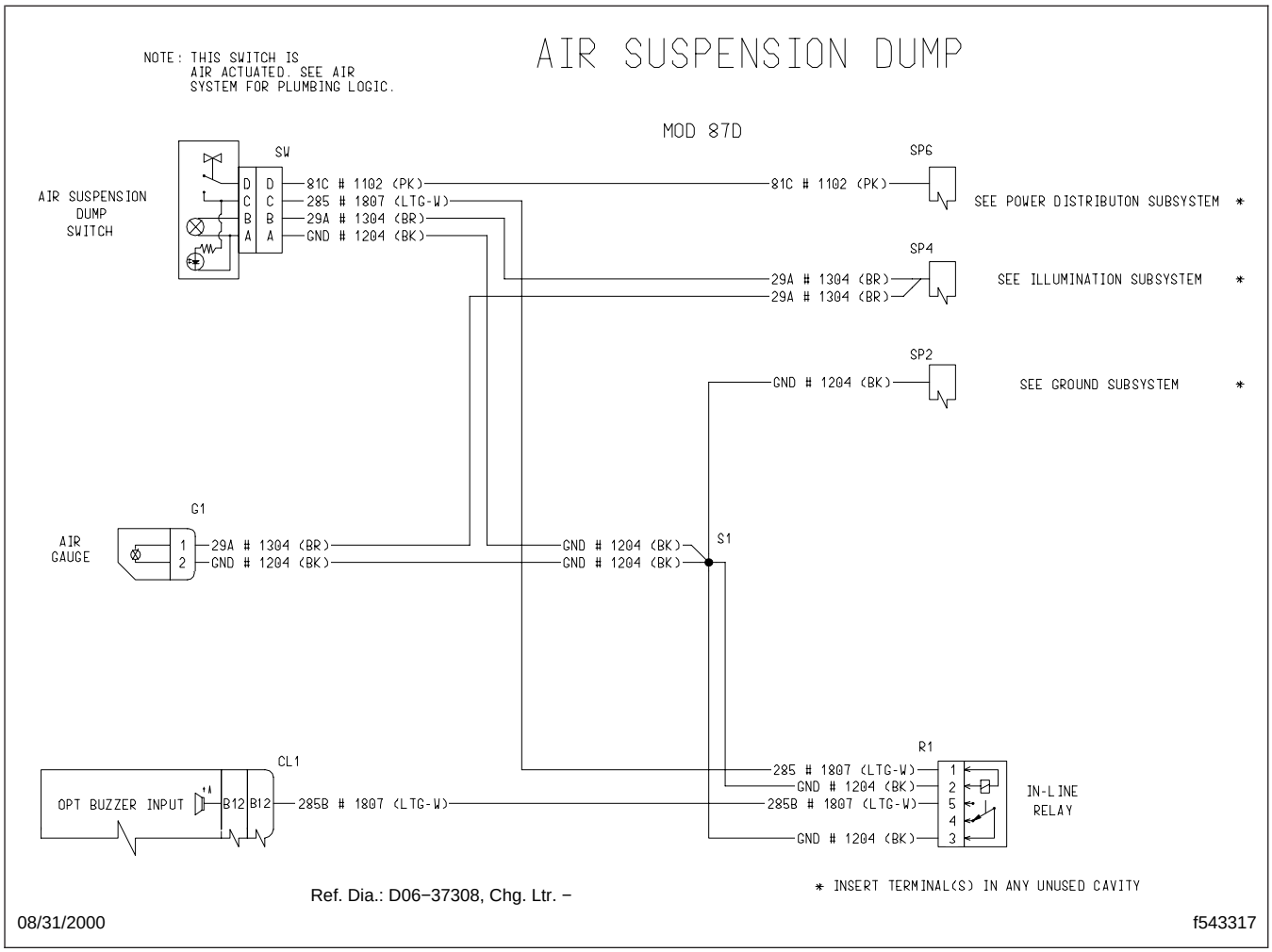
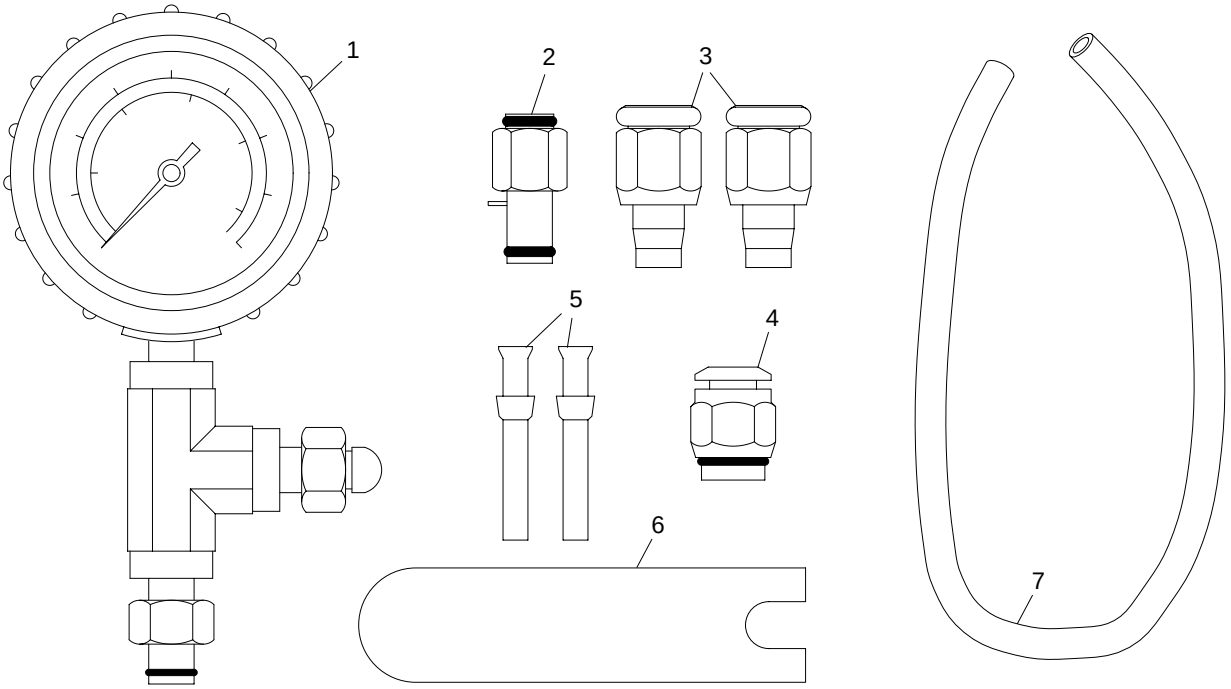


Fig. 2, Air Suspension Dump Wiring

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Specifications



NOTE: Parts for cab suspension valve testing included.

1. Test Gauge Assembly with Reset Button
2. Exhaust Port Test Connector for Cab Suspension Valve (used for cab suspension valve testing)
3. Parker Plugs
4. Exhaust Port Test Connector for Chassis Suspension Valve
5. Test Plugs for Cab Suspension Valve (used for cab suspension valve testing)
6. Special Tool for Disconnecting Air Line
7. Air Line

Fig. 3, Barksdale Height-Control Valve Test Kit BKS KD2264

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General Information

Ride quality is determined by a complex interaction of several factors including the vehicle specifications, installed equipment, vehicle speed, suspension loading, and the roughness of the road. An unusual combination of these factors may result in a rough ride.

There are two terms used to describe rough ride conditions: harmonic and harsh. Harmonic ride problems are those in which the once-per-revolution energy input from such things as bent or imbalanced wheels matches the natural frequency of the frame flexing. This produces a fore-and-aft motion in the cab, which continues as long as the critical road speed is maintained. Harmonic ride problems can occur on smooth roads.

Harsh ride problems are those in which the suspension transfers, rather than absorbs, the momentary energy inputs produced when the tires hit bumps or holes in the road. Wavy asphalt, or a series of bumps, may cause repetition of the harsh, jarring motion in the cab, but the motion stops after the tires pass over the bumps. Harsh ride problems occur on rough roads.

This section is designed for use as an aid in locating and correcting rough ride problems. It is not intended for use as a replacement for the detailed service information located in the applicable sections in this manual, or in the component manufacturer's service manuals.

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Harmonic Ride Checks

1. Visually check the vehicle for signs of damaged or missing suspension components. Repair or replace the components using the instructions in **Group 32**, **Group 33** or **Group 35**.
2. Test drive the vehicle.

NOTE: When test driving the vehicle, duplicate as closely as possible the conditions under which the problem occurs. Note the area of the vehicle where the problem seems to be occurring. Pay special attention to this area during the service operations.

3. Raise the vehicle until the tires are off the ground, and all of the weight is removed from the leaf springs. Block the axle and frame with safety stands. Perform the remedies under "Problem—Harmonic Ride, Tires Off the Ground" in **Troubleshooting, 300**.

⚠ WARNING

Always make sure that fasteners are properly tightened. Serious personal injury, property damage or component damage may occur when fasteners are loosened or removed causing unsecured components to drop.

4. Remove the safety stands from under the frame and axle, then lower the vehicle. Perform the remedies under "Problem—Harmonic Ride, Tires On the Ground" in **Troubleshooting, 300**.

Harsh Ride Checks

1. Visually check the vehicle for signs of damaged or missing suspension components. Repair or replace the components using the instructions in **Group 32**, **Group 33** or **Group 35**.
2. Test drive the vehicle.

NOTE: When test driving the vehicle, duplicate as closely as possible the conditions under which the problem occurs. Note the area of the vehicle where the problem seems to be coming from. Pay special attention to this area during the service operations.

3. Perform the corrections under "Problem—Harsh Ride, Tires On the Ground" in **Troubleshooting, 300**.
4. If the problem persists, perform the harmonic ride checks in this subject. Occasionally, ride problems associated with rough roads are harmonic ride problems masked by the road conditions.

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Troubleshooting Tables

Problem—Harmonic Ride, Tires Off the Ground

Problem—Harmonic Ride, Tires Off the Ground	
Possible Cause	**Remedy**
Bent, distorted, or out-of-round wheels or rims causing a rough ride	Inspect and repair the assemblies using the instructions in **Group 40**.
Bent, distorted, or out-of-round brake drums or hubs causing a rough ride	Replace damaged components using the instructions in **Group 33** or **Group 35**.
Improperly seated tire-to-rim bead causing an out-of-round assembly	Inspect the tires and rims for proper bead seating. Correct the problem using the instructions in **Group 40**.
Improperly installed tire and rim assembly on spoke wheels causing an out-of-round assembly	Remove and install the tire and rim assembly using the instructions in **Group 40**.
Worn or distorted rim spacers causing an out-of-round assembly	Replace damaged spacers using the instructions in **Group 40**.
Out of balance wheels, brake drums, or hub assemblies	Inspect the components for missing balance weights. Balance, as necessary.
Radial force variations in the tires causing a rough ride	Exchange the tires and wheels with a set that is known to cause no ride problems. If this corrects the problem, discard the old tires. For instructions, see **Group 40**.

Problem—Harmonic Ride, Tires On the Ground

Problem—Harmonic Ride, Tires On the Ground	
Possible Cause	**Remedy**
Worn or loose cab mounts allow cab to bounce	With a long bar, lever the cab legs up and down. If there is looseness, replace or tighten the mounts, as necessary.
Forces from the trailer suspension pushing on the tractor fifth wheel	Review the ride problems in this subject that apply to the trailer suspension. Perform the corrections, as necessary.

Problem—Harsh Ride, Tires Off the Ground

Problem—Harsh Ride, Tires Off the Ground	
Possible Cause	**Remedy**
Seized front spring shackle pins not allowing springs to flex	Replace the seized shackle pins. For instructions, see the applicable front suspension section in **Group 32**.

Problem—Harsh Ride, Tires On the Ground

Problem—Harsh Ride, Tires On the Ground	
Possible Cause	**Remedy**
Improperly inflated tires	Adjust the tire pressure using the instructions in the wheels and tires group of the maintenance manual.

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Troubleshooting

Problem—Harsh Ride, Tires On the Ground	
Possible Cause	**Remedy**
Frame bottoming out against suspension	Check the suspension for weak or damaged springs or components. Inspect the springs for "gull-winging" when the vehicle is loaded. Replace the spring assembly, as necessary, using the instructions in **Group 32**.
	Reduce the overall loaded weight on each axle to conform with the maximum spring load capacities on the vehicle specification sheet. Do not exceed the maximum spring load capacities.
	Adjust the air spring height using the instructions in **Section 32.02**.
Vehicle normal loaded weight is markedly below the spring load capacity	Customers should contact an Acterra dealer for the correct application of a lower rated spring. Replace the spring assembly using the instructions in **Group 32**.
Front axle spring shackle angle not within rearward 3 to 18 degree angle when vehicle is loaded	Customers should contact an Acterra dealer for shackle angle corrective measures. See **Group 32** for service instructions.
Weight on tractor fifth wheel causing overloading on front axle springs	Change the loading pattern on the trailer.
Forces trailer suspension are pushing on tractor fifth wheel causing a rough ride condition	Review the ride problems in this subject that apply to the trailer suspension. Perform the corrections, as necessary.

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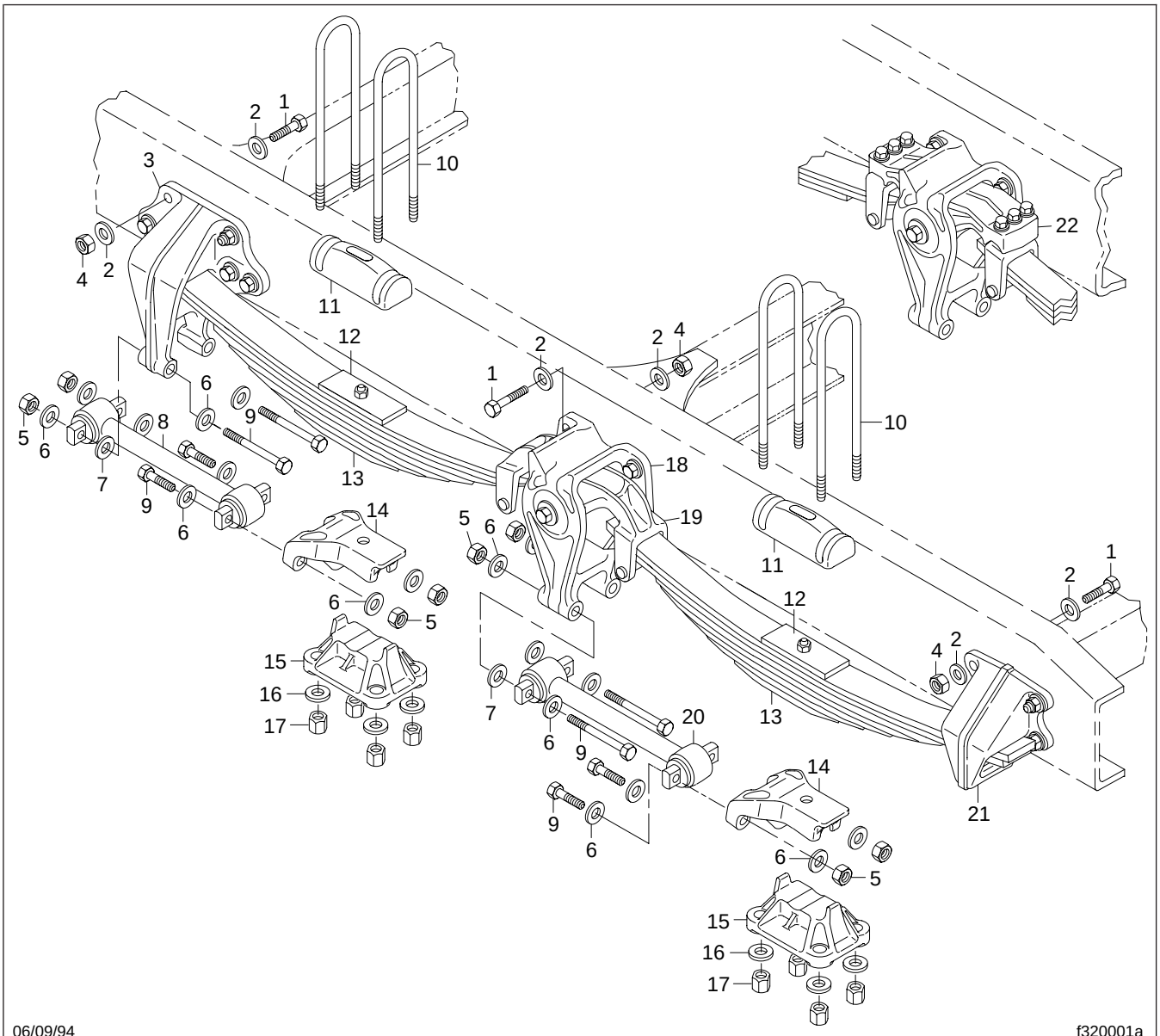
General Information

The tandem-axle rear spring suspension uses a six-point equalizing leaf spring design, which compensates for axle articulation, from side-to-side, and front-to-rear. See **Fig. 1**. Four semi-elliptical spring assemblies are attached to the axles with U-bolts. On both sides of the vehicle, the forward end of the forward spring and the rear end of the rear spring ride in aluminum brackets that are mounted on the frame rails. Steel wear shoes are cast into each bracket.

At the center, between the forward and rear springs, the springs ride on an equalizer, which pivots on a sleeve in the equalizer bracket. Equalizer travel is stopped when the top of the equalizer and the equalizer bracket make contact. Each axle is held in alignment by a pair of radius rods that extend forward from the axle seats to the forward spring brackets for the forward-rear axle, and to the equalizer brackets for the rearmost axle.

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General Information



NOTE: Huck fasteners may be used to attach brackets to frame rails.

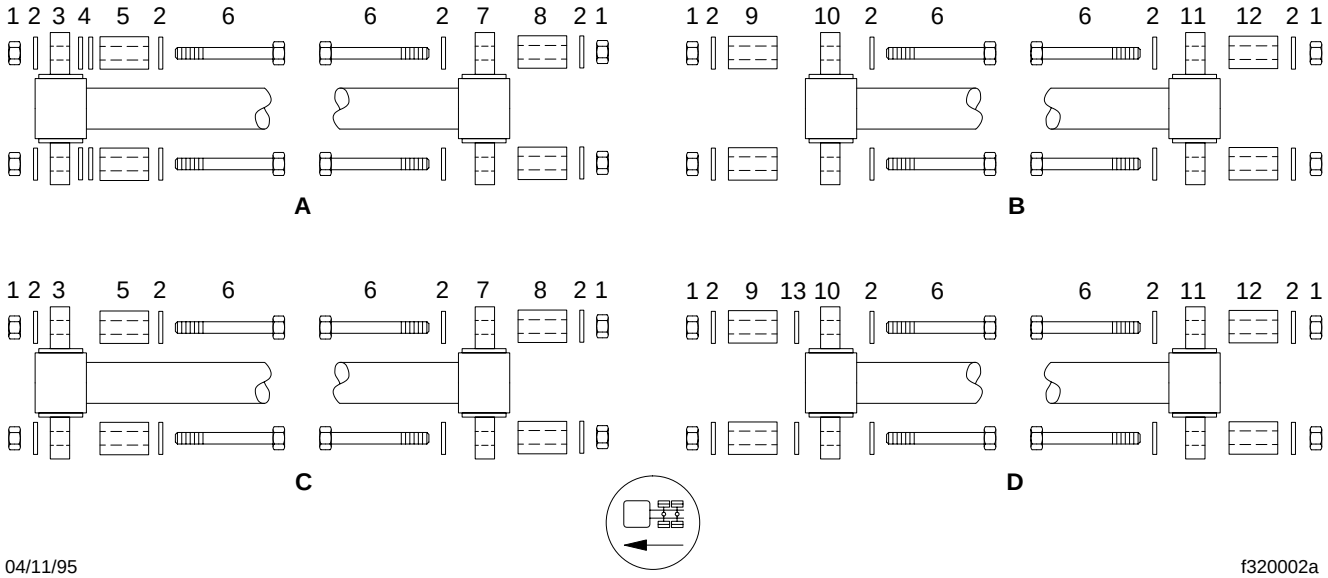
1. Suspension Bracket Hexbolt
2. Hardened Washer
3. Forward Spring Bracket
4. Suspension Bracket Hex Locknut
5. Radius Rod Hex Locknut
6. Hardened Washer
7. Axle Alignment Washer
8. Forward Radius Rod
9. Radius Rod Hexbolt
10. U-Bolt
11. U-Bolt Pad
12. Spring Liner
13. Leaf Spring Assembly
14. Spring Seat
15. U-Bolt Retainer
16. Hardened Washer
17. U-Bolt High Nut
18. Equalizer Bracket
19. Equalizer, One-Piece (tandem drive axles)
20. Rear Radius Rod
21. Rear Spring Bracket
22. Equalizer, Three-Piece (tag or pusher axle)

Fig. 1, Tandem-Axle Spring Suspension

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Radius Rod Removal and Installation

Removal (See Fig. 1)



A. Forward Right-Side Radius Rod
B. Rear Right-Side Radius Rod
C. Forward Left-Side Radius Rod
D. Rear Left-Side Radius Rod

1. Hex Locknut
2. Hardened Washer
3. Forward Radius Rod Front Pin
4. Alignment Washers (install only on one side of front axle; right-side installation shown)
5. Forward Spring Bracket
6. Hexhead Bolt
7. Forward Radius Rod Rear Pin
8. Forward Axle Seat
9. Equalizer Bracket
10. Rear Radius Rod Front Pin
11. Rear Radius Rod Rear Pin
12. Rear Axle Seat
13. Alignment Washer (install only on one side of rear axle; left-side installation shown)

Fig. 1, Radius Rod Attachment (top view)

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Note the number of axle alignment washers at the forward end of each radius rod that is being removed.
3. Remove the fasteners that attach the radius rod to the forward spring bracket or equalizer bracket, and to the axle seat.
4. Remove the radius rod and any axle alignment washers.

Installation (See Fig. 1)

IMPORTANT: At all points where steel parts (including bolts, washers, and nuts) contact aluminum brackets, apply Alumilastic® compound, or an equivalent, on the mating surfaces.

⚠ CAUTION

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to the suspension.

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Radius Rod Removal and Installation

If installing forward and rear radius rods, install the forward radius rod before installing the rear radius rod.

1. If installing a forward radius rod, place the radius rod front pin on the front side of the forward spring bracket, and place the radius rod rear pin in front of the axle seat.

   If installing a rear radius rod, place the radius rod pins between the rear side of the equalizer bracket and the front side of the axle seat.

2. Install a hexhead bolt with a hardened washer through each end of the radius rod rear pin and the axle seat ears. Install the hardened washers and locknuts.

3. If installing a forward radius rod, install any previously removed axle alignment washers between the radius rod front pin and the forward spring bracket. Install the hexhead bolts, hardened washers, and locknuts.

   If installing a rear radius rod, install any previously removed axle alignment washers between the radius rod front pin and the equalizer bracket. Install the hexhead bolts, hardened washers, and locknuts.

4. Tighten the radius rod locknuts to the torque value in **Specifications, 400**.

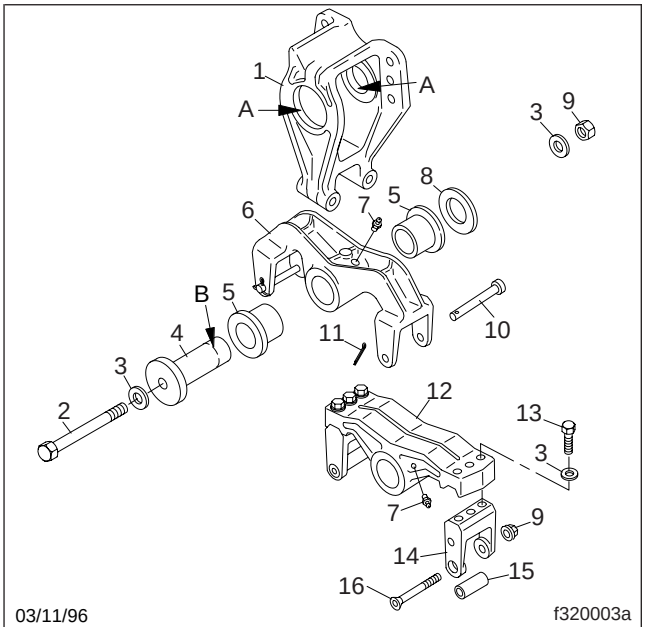
5. After all of the radius rods are installed, check the rear axle alignment. For instructions, refer to **Group 35**. If necessary, adjust the axle alignment, using the instructions in **Subject 140**.

6. Remove the chocks from the tires.

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Equalizer Removal, Inspection, and Installation

Removal (See Fig. 1)



A. Apply Loctite here.
B. No grease here.
1. Equalizer Bracket
2. Hexbolt
3. Bearing Washer
4. Cap and Tube Assembly
5. Equalizer Assembly Bushing
6. Equalizer, One-Piece (tandem drive axles)
7. Grease Fitting
8. Wear Washer(s)
9. Locknut
10. Spring Retainer Pin
11. Cotter Pin
12. Equalizer, Three-Piece (tag or pusher axle)
13. Capscrew
14. Wear-Shoe Side-Restraint
15. Side-Restraint Sleeve
16. Flathead Bolt

Fig. 1, Equalizer Assembly

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Raise the rear of the vehicle, and block the axles with safety stands. Raise the vehicle frame so that all weight is removed from the leaf springs. Block the frame with safety stands. Make sure the stands will securely support the weight of the axles and frame. To allow access to the equalizer, remove the wheel assemblies on that side, using the instructions found in **Group 40**.
3. If removing an equalizer from a vehicle with two drive axles, remove the cotter pin from the outboard end of each spring retainer pin. Remove the retainer pins.

   If removing an equalizer from a vehicle with a pusher or tag axle, remove the nuts from the flathead bolts in the wear-shoe side-restraints, on each end of the equalizer. Remove the flathead bolts and side-restraint sleeves. Remove the six capscrews and washers, and remove both wear-shoe side-restraints from the equalizer.
4. Remove the cap and tube assembly locknut, inboard bearing washer, bolt, and outboard bearing washer.
5. Insert a bar between the bottom of the equalizer and the equalizer bracket. Gently lever the weight of the equalizer off the cap and tube assembly. Insert a piece of barstock through the inboard cap and tube assembly bolt hole, and lightly tap the cap and tube assembly out of the equalizer.
6. Remove the equalizer from the equalizer bracket. Remove the wear washer(s) and equalizer bushings from the equalizer.

Inspection

1. Thoroughly clean the equalizer with steam or a hot soap solution. Inspect it for wear, cracks, or other damage. Replace the equalizer if any of these conditions are present.

⚠ WARNING

Replace a worn or damaged equalizer. A broken equalizer could cause a loss of vehicle control, resulting in personal injury or property damage.

2. Inspect the equalizer bushings, cap and tube assembly, and the equalizer bracket. If wear, cracks, or other damage are present, replace the bushings, cap and tube assembly, or bracket.

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Equalizer Removal, Inspection, and Installation

Installation (See Fig. 1)

1. Apply a thin film of multipurpose chassis grease to the outside of the equalizer bushings. Install the bushings in the equalizer.

NOTE: The equalizer is *not* symmetrical. To ensure that the equalizer is installed in the proper direction, an arrow is cast into its top surface.

2. Install the equalizer in the equalizer bracket. Make sure that the arrow cast into the top of the equalizer is pointing toward the frame rail. See **Fig. 2**.

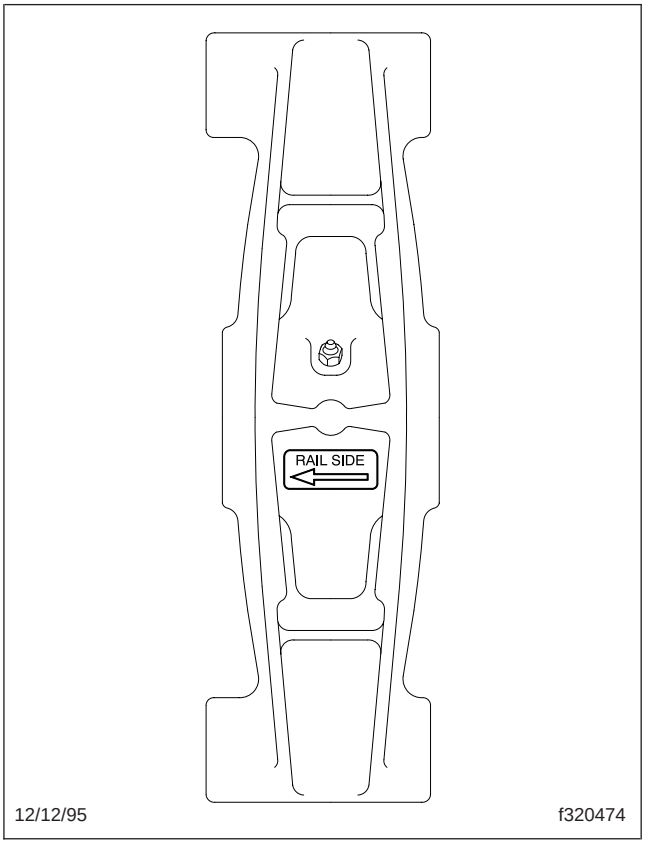


Fig. 2, Equalizer Marking

NOTE: The next four steps must be completed before the Loctite® begins to cure (approximately 5 to 10 minutes).

IMPORTANT: Be careful to prevent grease from contacting the inboard surface of the cap and tube assembly, where the Loctite is applied.

3. Apply Loctite 680 to both interior surfaces of the equalizer bracket, where the cap and tube assembly is inserted. Apply multipurpose chassis grease to the cap and tube assembly, except the last inch which connects to the equalizer bracket. See **Fig. 1** . Start the cap and tube assembly into the equalizer, through the equalizer bracket.
4. Push the cap and tube assembly part way through the equalizer. Place the wear washer(s) between the inboard equalizer bushing and the equalizer bracket. Push the cap and tube assembly the rest of the way into the equalizer bracket.
5. Place the outboard bearing washer on the equalizer cap and tube assembly bolt, and install the bolt in the cap and tube assembly.
6. Install the inboard bearing washer and locknut on the cap and tube assembly bolt. Tighten the locknut to the torque value in **Specifications, 400**.
7. Lubricate the equalizer assembly by applying multipurpose chassis grease at the grease fitting. Lubricate with a hand gun or pressure gun until grease is forced past the bushing seals, or if equipped with a pressure-relief grease fitting, until grease is forced out from the base of the pressure relief fitting.
8. If installing an equalizer on a vehicle with two drive axles, apply Alumilastic® compound, or an equivalent, to the spring retainer pins. Install them from the inboard side. Be sure the hooked ends of the spring leaves are above the retainer pins. Install a cotter pin in the outboard end of each retainer pin, and lock it in place.

   If installing an equalizer on a vehicle with a pusher or tag axle, apply Alumilastic compound, or an equivalent, to the surfaces where the wear-shoe side-restraints contact the equalizer. Attach the side-restraints to the equalizer, offsetting them toward the inboard side of the equalizer. Tighten the equalizer wear-shoe capscrews to the torque value in **Specifications, 400**. Install the side-restraint sleeves and flathead bolts in the wear-shoe side-restraints. Be sure the hooked ends of the spring leaves are above the side-restraint sleeves. Install the nuts, and tighten them to the applicable torque value in **Specifications, 400**.

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Equalizer Removal, Inspection, and Installation

⚠ CAUTION

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel contact each other, could lead to corrosion of the metals, resulting in suspension damage.

9. Install the wheel assemblies, using the instructions found in **Group 40**. Remove the safety stands from under the frame and axle, and lower the vehicle.
10. If the radius rods have been loosened, or the equalizer bracket has been removed, check the rear axle alignment. For instructions, refer to **Group 35**. If necessary, adjust the axle alignment using the instructions in **Subject 140**.
11. Remove the chocks from the front tires.

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Replacement (See Fig. 1)

⚠ WARNING

Do not replace individual leaves of a damaged leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Raise the frame so that all weight is removed from the leaf springs. Block the frame with safety stands. Raise the rear axle until the spring no longer contacts the spring bracket wear shoes and the spring retainer pin (or side-restraint sleeve). Block the axle. Make sure the stands will securely support the weight of the axles and frame. To access the spring assembly, remove the wheel assembly. See **Group 40** for instructions.
3. If equipped with two drive axles, remove the cotter pin from the spring retainer pin on the end of the equalizer where the spring is being replaced. Drive the spring retainer pin out of the equalizer.

   If equipped with a pusher or tag axle, remove the nut from the flathead bolt on the end of the equalizer where the spring is being replaced. Remove the bolt and the side-restraint sleeve from the wear-shoe side-restraint.
4. Remove the U-bolt high nuts, hardened washers, U-bolt retainer, U-bolts, and upper U-bolt pad.
5. Remove the spring assembly by lifting it off the axle seat, then moving it toward the equalizer, out of the forward or rear spring bracket.
6. Using chassis grease, lubricate the new spring assembly where the ends will contact the stationary wear shoes in the spring bracket and equalizer.
7. Place the new spring assembly in the spring bracket and on the axle seat. Make sure the spring center-bolt head seats in the axle seat hole.
8. If the upper U-bolt pad is aluminum, apply Alumilastic® compound, or an equivalent, to those areas of the pad that will come in contact with the U-bolts and with the upper spring leaf.

⚠ CAUTION

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel contact each other, could lead to corrosion of the metals, resulting in suspension damage.

9. Place the upper U-bolt pad on the spring assembly. Place the U-bolts over the upper U-bolt pad and the spring assembly.
10. Install the U-bolt retainer, hardened washers, and U-bolt high nuts. Tighten the high nuts until snug.
11. If installing a spring assembly on a vehicle with two drive axles, apply Alumilastic compound, or an equivalent, to the spring retainer pins. Install them from the inboard side. Be sure the hooked ends of the spring leaves are above the retainer pins. Install a cotter pin in the outboard end of each retainer pin, and lock it in place.

    If installing a spring assembly on a vehicle with a pusher or tag axle, install the side-restraint sleeves and flathead bolts in the wear-shoe side-restraints. Be sure the hooked ends of the spring leaves are above the side-restraint sleeves. Install the nuts, and tighten them to the applicable torque value in **Specifications, 400**.
12. Tighten the axle U-bolt high nuts as described in **Specifications, 400**.

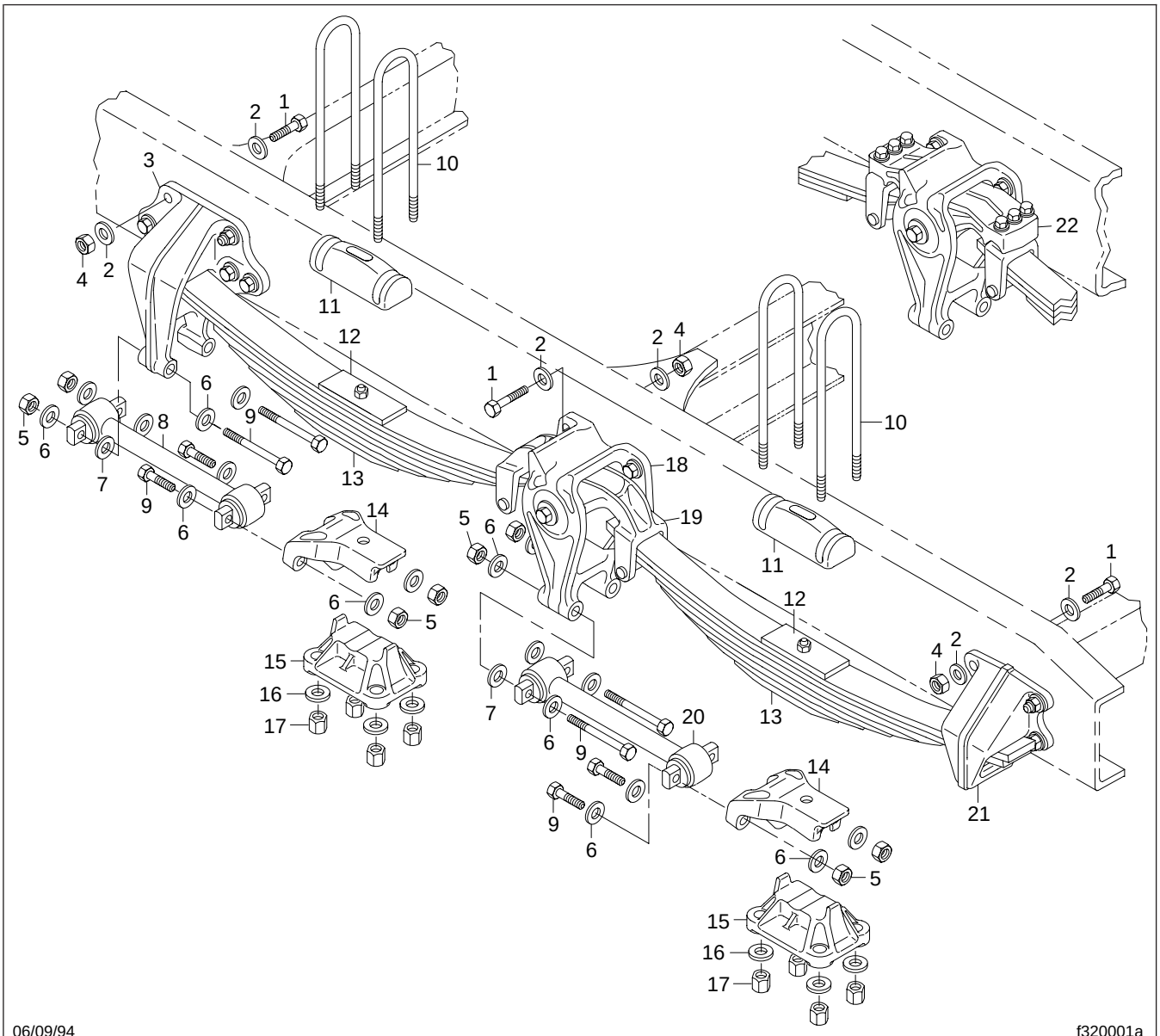
⚠ CAUTION

Failure to torque the suspension fasteners periodically can result in abnormal tire wear, and damage to the springs, spring brackets, and frame rail.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 of the *Acterra Maintenance Manual*.

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Spring Assembly Replacement



NOTE: Huck fasteners may be used to attach brackets to frame rails.

1. Suspension Bracket Hexbolt
2. Hardened Washer
3. Forward Spring Bracket
4. Suspension Bracket Hex Locknut
5. Torque Arm Hex Locknut
6. Hardened Washer
7. Axle Alignment Washer
8. Forward Torque Arm
9. Torque Arm Hexbolt
10. U-Bolt
11. U-Bolt Pad
12. Spring Liner
13. Leaf Spring Assembly
14. Spring Seat
15. U-Bolt Retainer
16. Hardened Washer
17. U-Bolt High Nut
18. Equalizer Bracket
19. Equalizer, One-Piece (tandem drive axles)
20. Rear Torque Arm
21. Rear Spring Bracket
22. Equalizer, Three-Piece (tag or pusher axle)

Fig. 1, Tandem-Axle Spring Suspension

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13. Install the wheel assembly, using the instructions found in **Group 40**. Remove the safety stands from under the frame and axle, and lower the vehicle.
14. Check the rear axle alignment. For instructions, see **Group 35.** If necessary, adjust the axle alignment, using the instructions in **Subject 140**.
15. Remove the chocks from the tires.

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Spring Bracket and Equalizer Bracket Replacement

Replacement (See Fig. 1)

WARNING

Failure to replace worn, cracked, or damaged spring brackets or equalizer brackets could result in breakage of the bracket, which could cause a loss of vehicle control, resulting in personal injury or property damage.

IMPORTANT: At all points where steel parts (including bolts, washers, and nuts) contact the aluminum spring brackets, apply Alumilastic® compound, or an equivalent, on the mating surfaces.

CAUTION

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to the suspension.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Raise the rear of the vehicle, and block the axles with safety stands. Raise the vehicle frame so that all weight is removed from the leaf springs. Block the frame with safety stands. Make sure the stands will securely support the weight of the axles and frame.
3. If removing the forward spring bracket or the equalizer bracket, note the number of any axle alignment washers. Remove the fasteners that attach the radius rod to the forward spring bracket or equalizer bracket. Remove any axle alignment washers.
4. If removing an equalizer bracket, remove the equalizer. For instructions, see **Subject 110**.
5. Remove the fasteners that attach the forward or rear spring bracket, or equalizer bracket, to the frame rail. Remove the bracket.
6. Place the new spring bracket or equalizer bracket on the frame rail. Align the mounting holes, and install the fasteners.

NOTE: If installing the forward spring bracket, install the nuts for the top two bolts on the outboard side of the frame rail, and install the nuts for the bottom four bolts on the inboard side of the frame rail. See **Fig. 2**.

NOTE: If installing the equalizer bracket, for clearance, install all of the nuts on the inboard side of the frame rail. See **Fig. 2**.

NOTE: If installing the rear spring bracket, install the nuts for the top two bolts on the outboard side of the frame rail, and install the nuts for the bottom two bolts on the inboard side of the frame rail. See **Fig. 2**.

7. Tighten the bracket mounting locknuts to the applicable torque value in **Specifications, 400**.

CAUTION

Failure to torque the suspension fasteners periodically can result in abnormal tire wear, and damage to the springs, spring brackets, and frame rail.

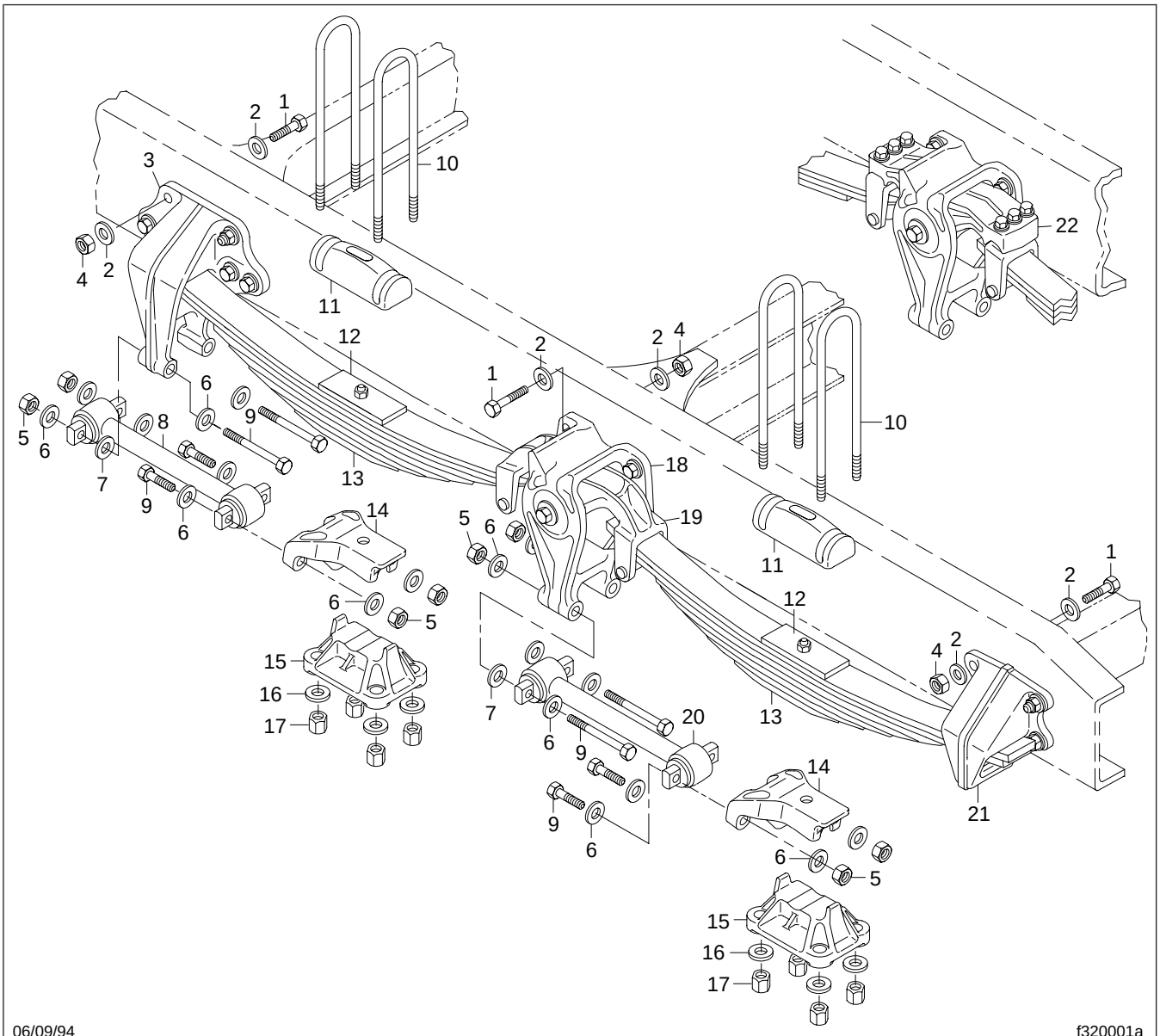
IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 of the *Acterra Maintenance Manual*.

8. When replacing the forward spring bracket or equalizer bracket, install any previously removed axle alignment washers between the forward radius rod front pin and the forward spring bracket, or between the rear radius rod front pin and the equalizer bracket, as applicable. See **Fig. 3**.

   Install bolts with hardened washers in the radius rod front pin, and the forward spring bracket or equalizer bracket. Install the hardened washers and locknuts, and tighten the locknuts to the torque value in **Specifications, 400**.
9. If replacing an equalizer bracket, install the equalizer. For instructions, see **Subject 110**.
10. Remove the safety stands from under the frame and axle, and lower the vehicle.
11. Remove the chocks from the tires.

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Spring Bracket and Equalizer Bracket Replacement



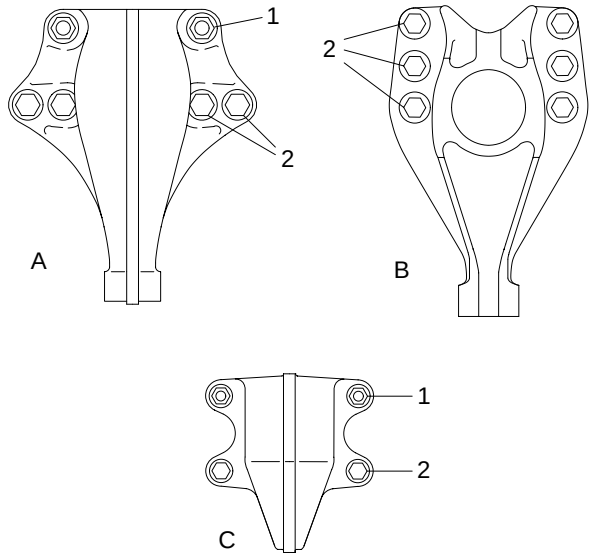
NOTE: Huck fasteners may be used to attach brackets to frame rails.

1. Suspension Bracket Hexbolt
2. Hardened Washer
3. Forward Spring Bracket
4. Suspension Bracket Hex Locknut
5. Radius Rod Hex Locknut
6. Hardened Washer
7. Axle Alignment Washer
8. Forward Radius Rod
9. Radius Rod Hexbolt
10. U-Bolt
11. U-Bolt Pad
12. Spring Liner
13. Leaf Spring Assembly
14. Spring Seat
15. U-Bolt Retainer
16. Hardened Washer
17. U-Bolt High Nut
18. Equalizer Bracket
19. Equalizer, One-Piece (tandem drive axles)
20. Rear Radius Rod
21. Rear Spring Bracket
22. Equalizer, Three-Piece (tag or pusher axle)

Fig. 1, Tandem-Axle Spring Suspension

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Spring Bracket and Equalizer Bracket Replacement



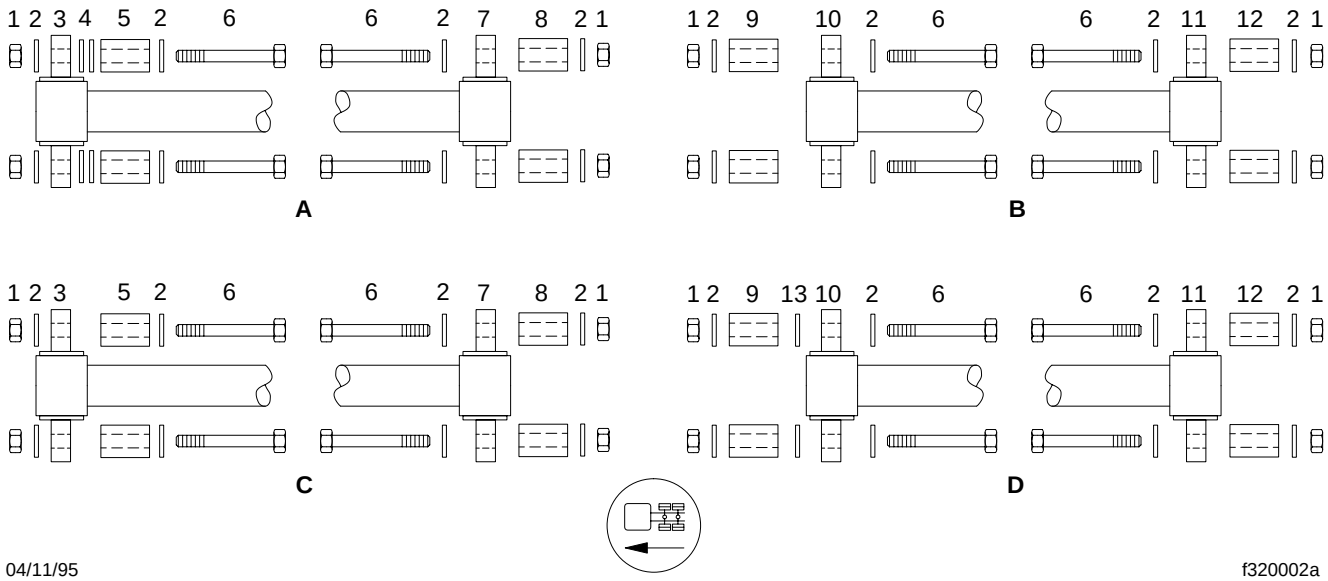
A. Forward Spring Bracket
B. Equalizer Bracket
C. Rear Spring Bracket
1. Nut (outboard)
2. Bolt Heads (outboard)

Fig. 2, Frame Brackets

12. Check the rear axle alignment. For instructions, see **Group 35**. If necessary, adjust the axle alignment, using the instructions in **Subject 140**.

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Spring Bracket and Equalizer Bracket Replacement



A. Forward Right-Side Radius Rod
B. Rear Right-Side Radius Rod
C. Forward Left-Side Radius Rod
D. Rear Left-Side Radius Rod

1. Hex Locknut
2. Hardened Washer
3. Forward Radius Rod Front Pin
4. Alignment Washers (install only on one side of front axle; right-side installation shown)
5. Forward Spring Bracket
6. Hexhead Bolt
7. Forward Radius Rod Rear Pin
8. Forward Axle Seat
9. Equalizer Bracket
10. Rear Radius Rod Front Pin
11. Rear Radius Rod Rear Pin
12. Rear Axle Seat
13. Alignment Washer (install only on one side of rear axle; left-side installation shown)

Fig. 3, Radius Rod Attachment (top view)

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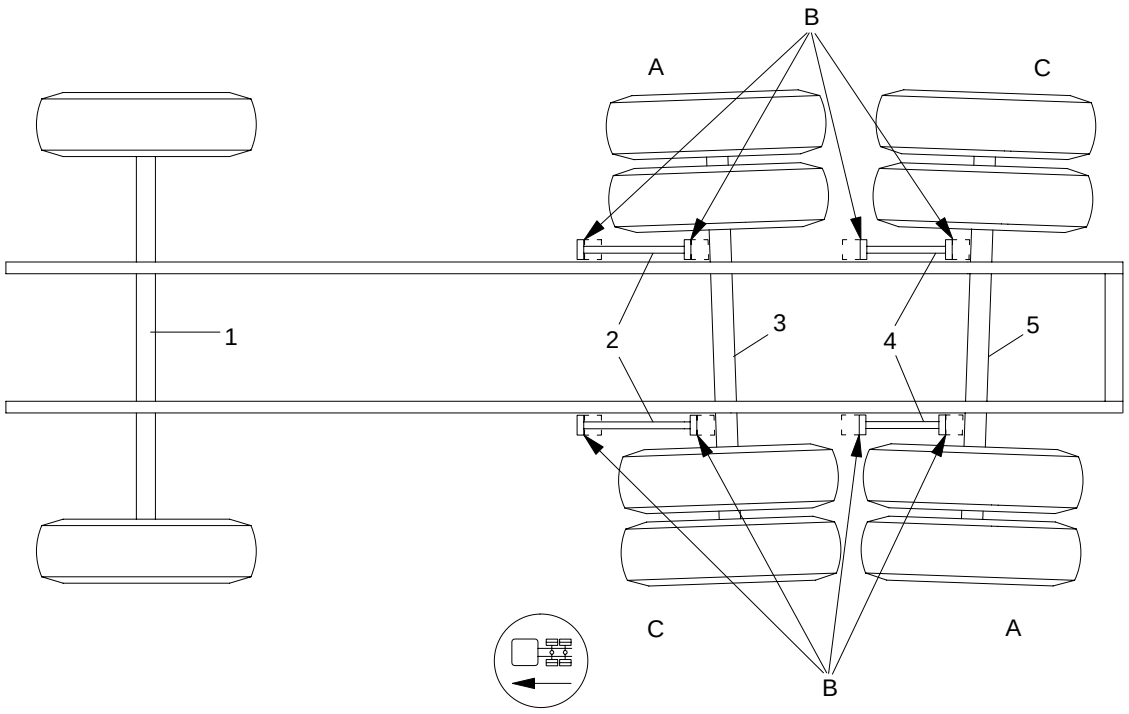
Adjustment

1. Using a straightedge and a tape measure, determine the amount of adjustment needed to align the forward-rear axle at a right angle to the frame. For instructions, see **Group 35**. The difference in measurements between the sides of the vehicle is the approximate amount that the trailing end of the forward-rear axle will have to be brought forward, or the leading end will have to be moved back to align it at a right angle to the frame. See **Fig. 1**.

   If the forward-rear axle alignment is within specifications, go to step 12.

3. On both sides of the forward-rear axle, loosen the axle U-bolts enough to allow the springs to shift on the axle seats.
4. On the side of the vehicle that is to be adjusted, remove the fasteners that attach the forward radius rod to the forward spring bracket. Remove any axle alignment washers.

NOTE: To move the leading end of the forward-rear axle rearward, *remove* alignment washers from between the radius rod and the leading end of the forward spring bracket or *add* alignment washers between the radius rod and the forward-rear axle seat.



A. Leading End
B. Possible Adjustment Points
C. Trailing End
1. Front Axle
2. Forward-Rear Axle Radius Rod
3. Forward-Rear Axle
4. Rearmost Axle Radius Rod
5. Rearmost Axle

Fig. 1, Tandem Axle, Shown Out of Alignment

2. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.

NOTE: To move the trailing end of the forward-rear axle forward, *remove* alignment washers from between the radius rod and the forward-rear axle seat on the trailing end.

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Rear Axle Alignment Adjustment

NOTE: Whenever possible, alignment washers should be *removed* instead of added.

5. Raise the frame just enough to relieve the weight from the springs. Place safety stands under the frame. Make sure the stands will securely support the weight of the frame.
6. Rolling the wheels, move the loosened end of the axle forward or backward as needed.
7. Insert or remove axle alignment washers at the appropriate location (front or rear of the left-hand or right-hand radius rod) to bring the forward-rear axle into alignment. Install the hexhead bolt, hardened washers, and locknut in the radius rod pin and forward spring bracket or axle seat.
8. Place an equal thickness of washers on the other end of the radius rod pin, and install the fasteners.
9. Tighten the radius rod locknuts to the torque value in **Specifications, 400**.
10. Remove the safety stands, and lower the vehicle.
11. Check the forward-rear axle alignment with the straightedge and the tape measure. If alignment is within specifications, center the spring in the forward spring bracket, if needed. Tighten the axle U-bolt nuts to the torque value in **Specifications, 400**.

    If not in alignment, repeat all of the steps above.

⚠ CAUTION

Failure to torque the suspension fasteners periodically can result in abnormal tire wear, and damage to the springs, spring brackets, and frame rail.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 in the *Acterra Maintenance Manual*.

12. Using a center-point bar, determine the difference between the forward-rear and the rearmost axles' center-to-center measurements on each side of the vehicle. For instructions, see **Group 35**. This difference is the approximate distance that the leading end of the rearmost axle will have to be adjusted rearward, or that the trailing end will have to be adjusted forward, to align it at a right angle to the frame, and to align it parallel to the forward-rear axle. See **Fig. 1**.
13. On both sides of the rearmost axle, loosen the axle U-bolts enough to allow the springs to shift on the axle seats.
14. On the side of the vehicle that is to be adjusted, remove the fasteners that attach the rear radius rod to the equalizer bracket. Remove any axle alignment washers.
15. Raise the frame just enough to relieve the weight from the springs. Place safety stands under the frame. Make sure the stands will securely support the weight of the frame.
16. Move the loosened end of the axle forward or backward, by rolling the wheels. Move the axle just enough to provide space to allow installation of alignment washers between the equalizer bracket and the radius rod pin.
17. Between one end of the radius rod pin and the equalizer bracket, insert the additional thickness of alignment washers needed to make up for the difference in center-point bar measurements.

    For example, if one end of the axle was equipped with a 3/16-inch (4.5-mm) thickness of washers, and the difference in the center-point bar measurements is 1/4 inch (6 mm) less on that side, add an additional 1/4 inch (6 mm) of washers (for a total of 7/16 inch [10.5 mm]) to correct the alignment.

    Or, if one end of the axle was equipped with a 1/4-inch (6-mm) thickness of washers, and the difference in center-point bar measurements is 3/16 inch (4.5 mm) more on that side, install a 1/16-inch (1.6-mm) thickness of washers in place of the 1/4-inch (6-mm) thickness.
18. Install the bolt, hardened washers, and locknut in the equalizer bracket and the radius rod pin. Place an equal thickness of alignment washers on the other end of the radius rod pin, and install the fasteners at that end.
19. Tighten the radius rod locknuts to the torque value in **Specifications, 400**.
20. Remove the safety stands, and lower the vehicle.
21. Remove the chocks from the front tires.

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22. Using the center-point bar, check the rearmost axle alignment. If alignment is within specifications, center the spring in the rear spring bracket, if needed. Tighten the axle U-bolt nuts to the applicable torque value in **Specifications, 400**.

    If not in alignment, repeat the applicable steps above.

CAUTION

Failure to periodically torque the suspension fasteners can result in abnormal tire wear, and damage to the springs, spring brackets and frame rail.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 in the *Acterra Maintenance Manual*.

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Specifications

Torque Values			
Description	**Size**	**IFI Grade**	**Torque lbf·ft (N·m)**
Equalizer Bracket-to-Frame Rail Locknut *	3/4–10	C	240 (325)
Forward Spring Bracket-to-Frame Rail Locknut *	3/4–10	C	240 (325)
Rear Spring Bracket-to-Frame Rail Locknut *	5/8–11	C	135 (180)
Axle U-Bolt High Nuts (Tighten in a diagonal pattern as shown in **Fig. 1**.)	7/8–14	C	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420 to 500 (571 to 680)
Radius Rod Locknut *	5/8–18	C	135 (184)
Equalizer Cap and Tube Assembly Locknut *	3/4–16	C	270 (365)
Equalizer Wear Shoe Capscrew	5/8–11	8	135 (184)
Side-Restraint Sleeve Locknut	1/2–13	C	68 (93)

* Cadmium-plated, wax-coated nuts and grade 8 hexbolts with phosphate- and oil-coated threads; both used with hardened washers.

Table 1, Torque Values

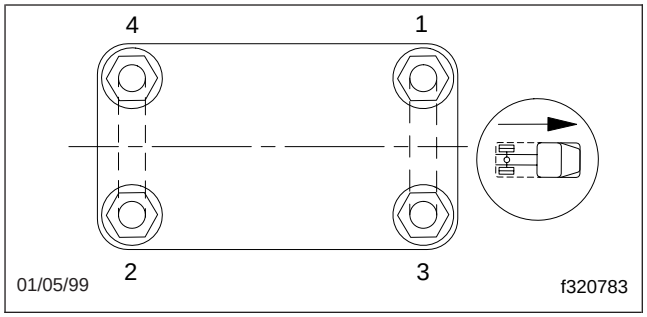


Fig. 1, Tightening Pattern for U-Bolt High Nuts

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General Information

The Chalmers 800 series rear suspension is a walking beam-type tandem axle suspension that uses hollow rubber springs instead of leaf springs or air bags. Each hollow rubber spring is mounted between a frame-rail plate and the center (front-to-rear) of the steel walking beam. A sawhorse bracket assembly is attached to the frame and provides mounting points for the lower torque rods that tie the axles to the frame. The upper torque rods are fastened to brackets that bolt to the frame side rails and to tower assemblies that are welded to the top of the differential housings. See **Fig. 1**.

The 800 series rear suspension allows a high degree of both parallel and diagonal articulation, while maintaining wheel load equalization to within three percent.

The Chalmers suspension design separates the rear suspension's responsibility for supporting/cushioning the load from that of locating/guiding the axles. The suspension is very light, relative to its load carrying capacity, but requires very little maintenance. In fact, there are no lubrication fittings since grease and oil are never needed.

The 800 series rear suspension is available in two different maximum load capacities: 40,000 lb (18,000 kg) and 46,000 lb (21,000 kg). The 40,000 lb version is easily distinguished from the 46,000 lb version since the upper torque rods do not cross over one another on the 40,000 lb version.

The 800 series is also available in three different axle spacings: 54-inch, 60-inch, and 72-inch axle-to-axle. The axle-to-axle spacing dimension is often included as part of the suspension name, e.g. "Chalmers 854 Rear Suspension" or "Chalmers 860 Suspension."

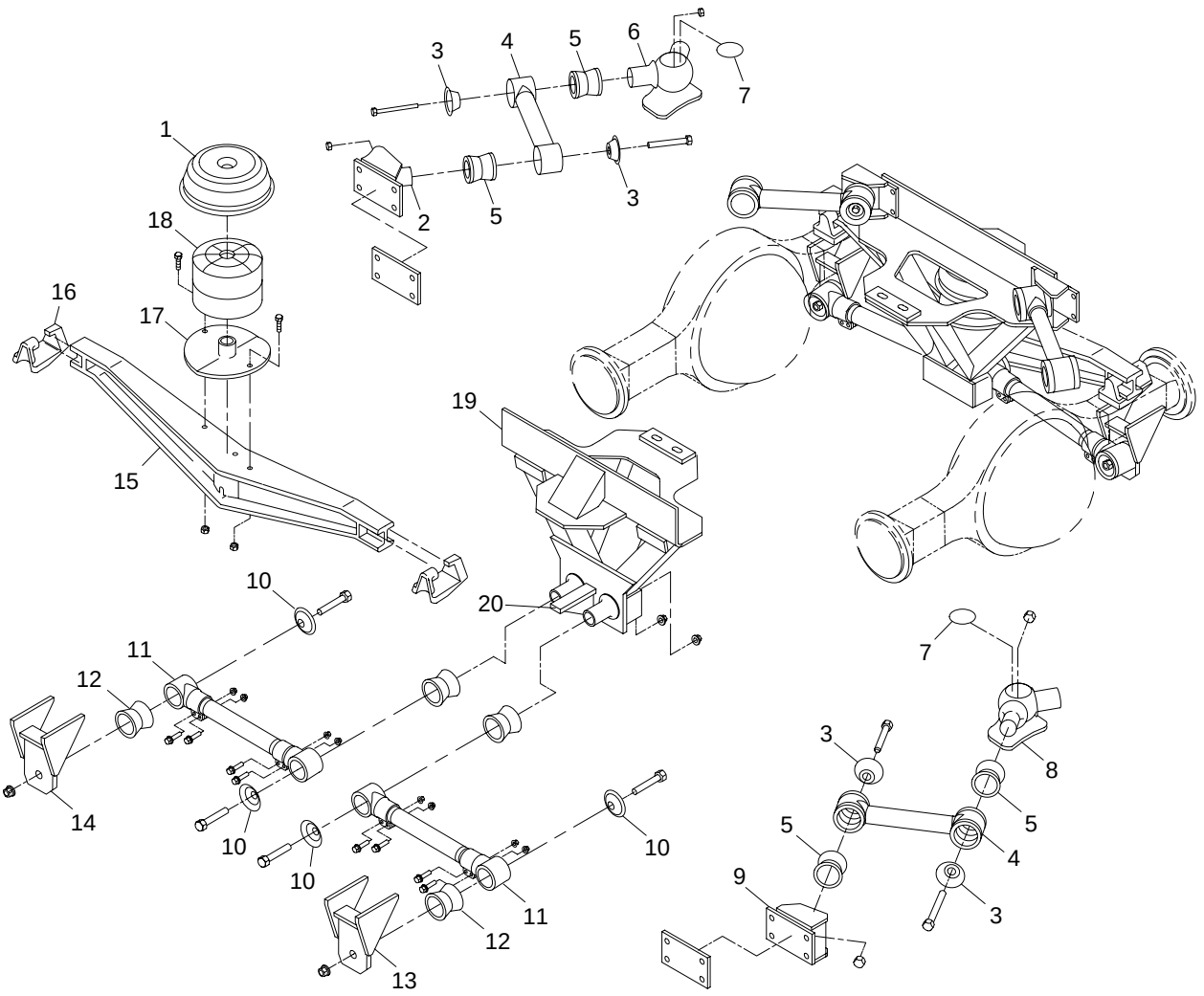
Shock absorbers are optional on all versions of the suspension, and available in two styles: beam mounted and axle housing mounted.

Other variations depend on whether the suspension is installed on a truck (high-mount) or a tractor (low-mount) and whether high center-of-gravity or low center-of-gravity is desired.

The rear suspension may be precision-aligned by adjusting the length of the lower torque rods. These rods have both left- and right- hand threads cut on the same tube so rotating the tube changes the effective length of the tube.

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General Information



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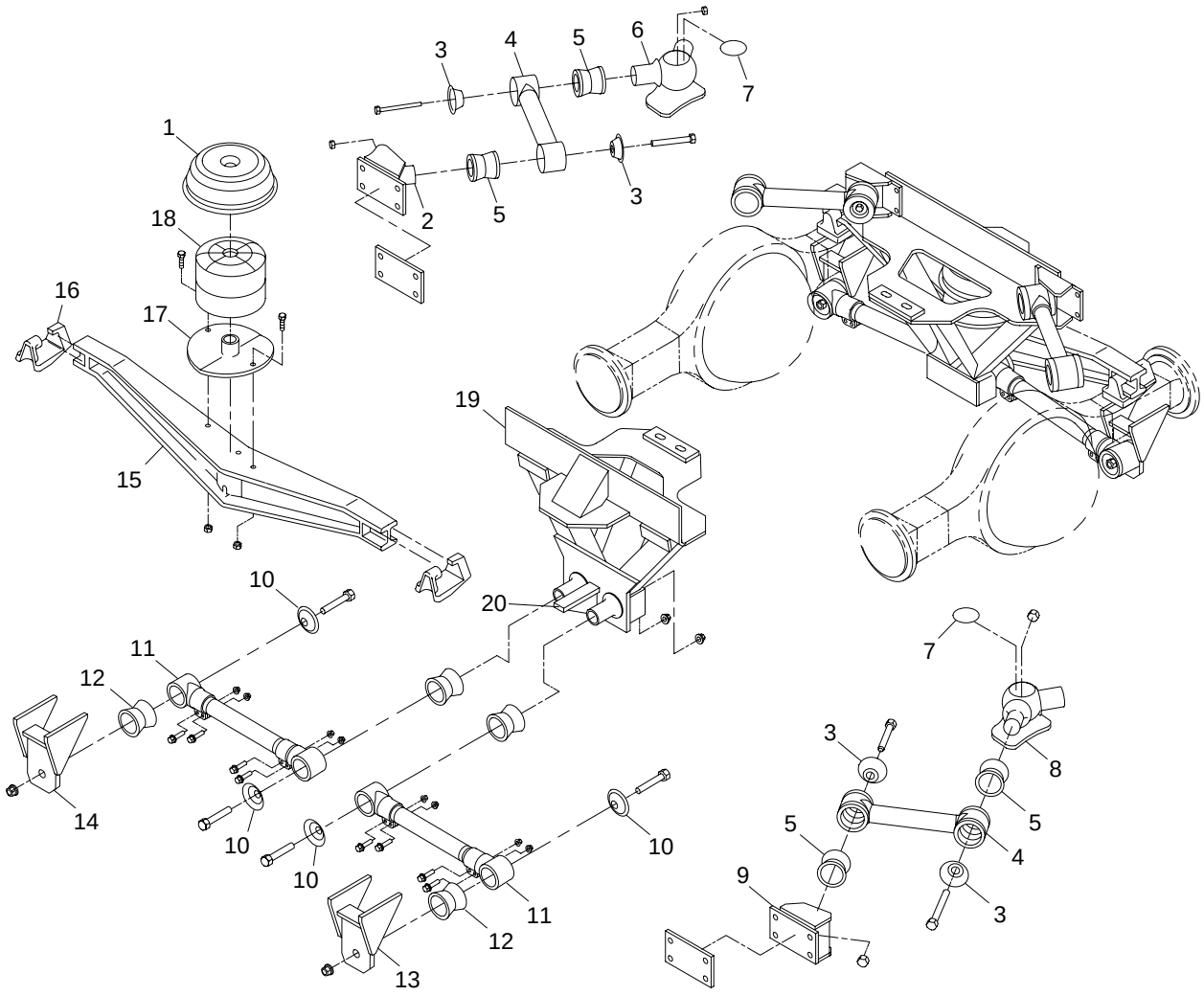
1. Restrictor Can
2. Upper Torque Rod Frame Bracket (left-hand forward)
3. Spigot Cap (upper)
4. Upper Torque Rod
5. Torque Rod Bushing (upper)
6. Forward Rear Axle Tower
7. Rear Axle Tower Plug
8. Rearmost Rear Axle Tower
9. Upper Torque Rod Frame Bracket (left-hand rear)
10. Spigot Cap (lower)
11. Lower Torque Rod (adjustable)
12. Torque Rod Bushing (lower)
13. Lower Torque Rod Axle Housing Bracket (left-hand rear)
14. Lower Torque Rod Axle Housing Bracket (left-hand forward)
15. Beam
16. Axle Housing Beam Saddle Bracket
17. Beam Spring Plate
18. Hollow Rubber Spring
19. Sawhorse Bracket Assembly
20. Beam Stop

Fig. 1, Chalmers 800 Series Tandem Axle Suspension (40k capacity shown without shock absorbers)

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Restrictor Can Removal, Inspection, and Installation

Removal (See Fig. 1)



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1. Restrictor Can
2. Upper Torque Rod Frame Bracket (left-hand forward)
3. Spigot Cap (upper)
4. Upper Torque Rod
5. Torque Rod Bushing (upper)
6. Forward Rear Axle Tower
7. Rear Axle Tower Plug
8. Rearmost Rear Axle Tower
9. Upper Torque Rod Frame Bracket (left-hand rear)
10. Spigot Cap (lower)
11. Lower Torque Rod (adjustable)
12. Torque Rod Bushing (lower)
13. Lower Torque Rod Axle Housing Bracket (left-hand rear)
14. Lower Torque Rod Axle Housing Bracket (left-hand forward)
15. Beam
16. Axle Housing Beam Saddle Bracket
17. Beam Spring Plate
18. Hollow Rubber Spring
19. Sawhorse Bracket Assembly
20. Beam Stop

Fig. 1, Chalmers 800 Series Tandem Axle Suspension (40k capacity shown without shock absorbers)

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Restrictor Can Removal, Inspection, and Installation

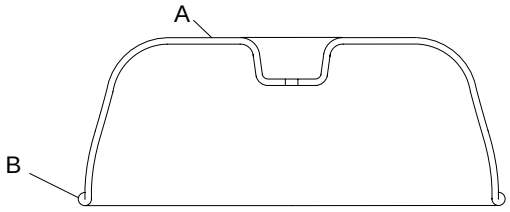
1. If necessary, power wash the spring restrictor can area to remove road dirt accumulation.
2. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
3. Raise the rear of the vehicle just enough to remove all weight from the rear axles, and place safety stands under the frame to support the vehicle in its raised position.
4. Remove the two bolts and nuts that secure the walking beam spring plate to the walking beam assembly. See **Fig. 1**. Discard the fasteners.

NOTE: On 54-inch spread suspensions, it may be necessary to remove either the front or rear tires to allow spring assembly removal.

5. Pull the lower spring plate, rubber spring, and restrictor can as one assembly outward, off the beam assembly. See **Fig. 1**.
6. Separate the restrictor can, spring, and spring plate.

Inspection

1. Carefully inspect the restrictor can for cracks or severe corrosion. Pay special attention to the top surface of the can and the can rim. See **Fig. 2**.



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A. Inspect top surface for cracks or severe corrosion.
B. Carefully inspect can rim for cracks.

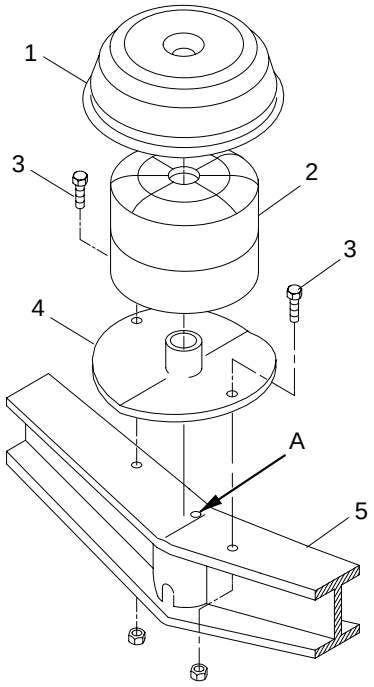
Fig. 2, Restrictor Can Inspection Areas

NOTE: It is recommended that both restrictor cans be replaced at the same time to insure evenness of ride and handling characteristics.

2. Replace a cracked or severely corroded restrictor can.

Installation

1. Using a stiff wire brush or gasket scraper, clean rust and road dirt from the spring plate. Also, make sure that the center vent holes in the plate and in the walking beam are free of rust and debris. See **Fig. 3**.



10/12/95 f320437

A. Make sure that the vent hole in the walking beam is free of rust and debris.

1. Spring Restrictor Can
2. Hollow Rubber Spring
3. Spring Plate Bolt
4. Spring Plate
5. Walking Beam

Fig. 3, Spring Assembly Components

2. Inspect the spring plate for cracks; replace it if any are present.

IMPORTANT: Never use any mineral based oils, greases, jellies, or solvent soaps to aid in the assembly of rubber suspension parts. Use only

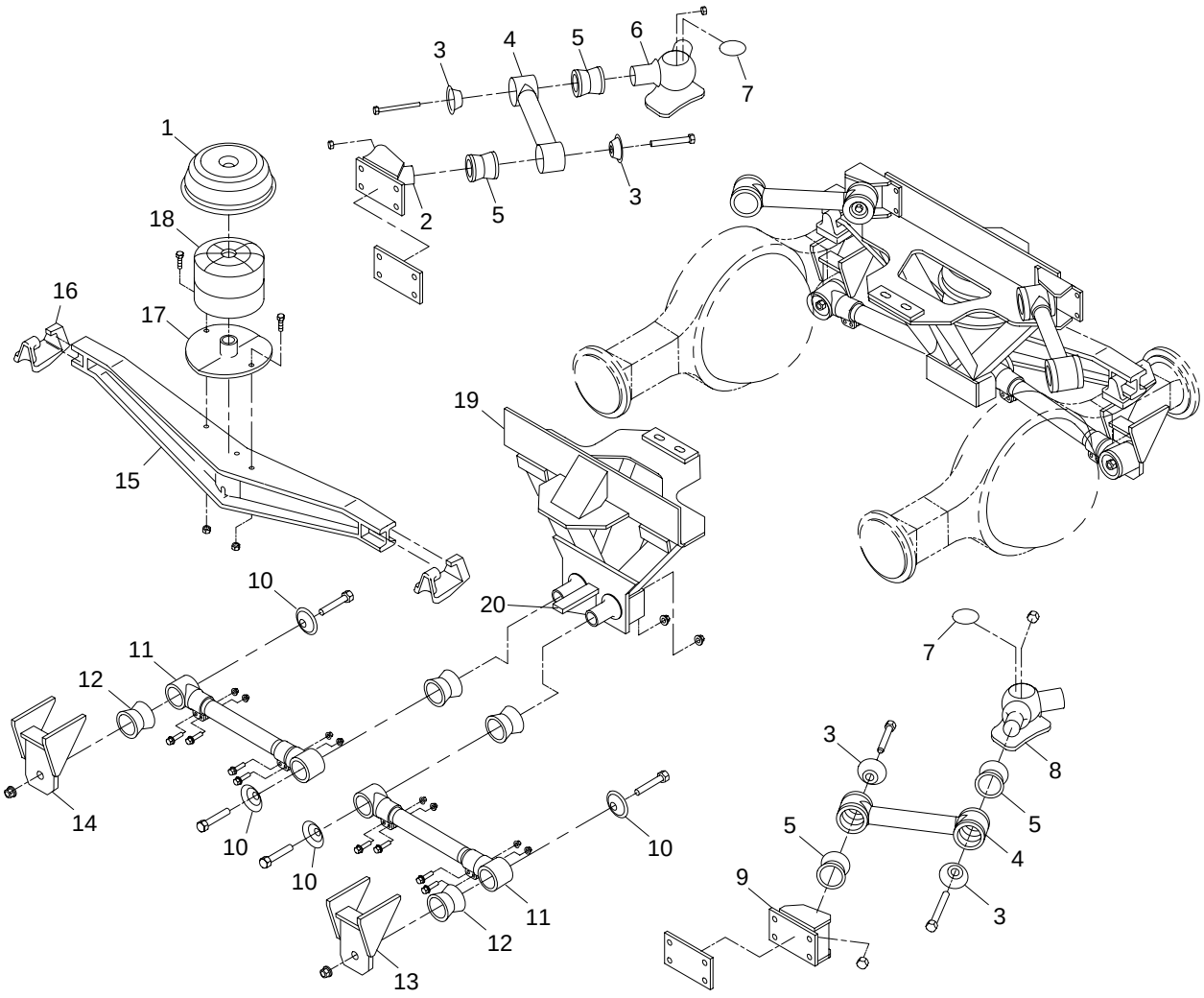
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lubricants specifically designed for use with rubber compounds.

3. Position the rubber spring on the spring plate so it is upside down, relative to its original orientation. Make sure that the spring vent hole is centered on the spring plate tube. Place the new restrictor can over the spring; make sure the can is centered on the spring.
4. Slide, as one assembly, the spring plate, spring, and restrictor cap, into position on the walking beam.
5. Install and tighten the spring plate fasteners 35 lbf·ft (47 N·m).
6. Check the gap between the spring and the restrictor can to make sure it is even, all the way around the can. Rotate the spring and/or can as necessary to make the gap even.
7. Remove the safety stands from under the vehicle, then lower the vehicle.
8. Remove the chocks from the tires.

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Replacement (See Fig. 1)



1. Restrictor Can
2. Upper Torque Rod Frame Bracket (left-hand forward)
3. Spigot Cap (upper)
4. Upper Torque Rod
5. Torque Rod Bushing (upper)
6. Forward Rear Axle Tower
7. Rear Axle Tower Plug
8. Rearmost Rear Axle Tower
9. Upper Torque Rod Frame Bracket (left-hand rear)
10. Spigot Cap (lower)
11. Lower Torque Rod (adjustable)
12. Torque Rod Bushing (lower)
13. Lower Torque Rod Axle Housing Bracket (left-hand rear)
14. Lower Torque Rod Axle Housing Bracket (left-hand forward)
15. Beam
16. Axle Housing Beam Saddle Bracket
17. Beam Spring Plate
18. Hollow Rubber Spring
19. Sawhorse Bracket Assembly
20. Beam Stop

Fig. 1, Chalmers 800 Series Tandem Axle Suspension (40k capacity shown without shock absorbers)

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Rubber Spring Replacement

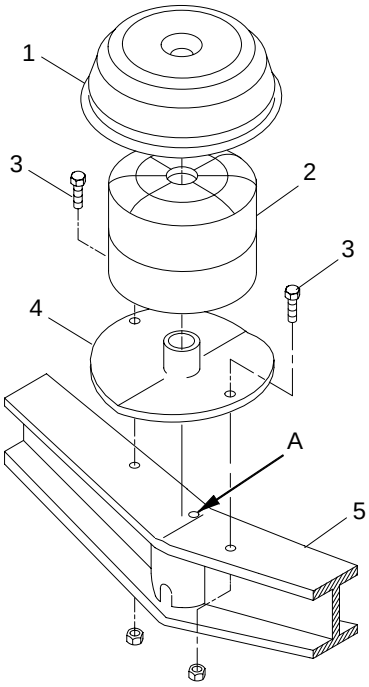
1. If necessary, power wash the spring restrictor can area to remove road dirt accumulation.
2. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
3. Raise the rear of the vehicle just enough to remove all weight from the rear axles, and place safety stands under the frame to support the vehicle in its raised position.
4. Remove the two bolts and nuts that secure the walking beam spring plate to the walking beam assembly. See **Fig. 1**. Discard the fasteners.

NOTE: On 54-inch spread suspensions, it may be necessary to remove either the front or rear tires to allow spring assembly removal.

5. Pull the lower spring plate, rubber spring, and restrictor can as one assembly outward, off the beam assembly. See **Fig. 1**.
6. Separate the restrictor can, spring, and spring plate; discard the spring.
7. Using a stiff wire brush or gasket scraper, clean rust and road dirt from the spring plate. Also, make sure that the center vent holes in the plate and in the walking beam are free of rust and debris. See **Fig. 2**.
8. Inspect the spring plate for cracks; replace it if any are present.

IMPORTANT: Never use any mineral based oils, greases, jellies, or solvent soaps to aid in the assembly of rubber suspension parts. Use only lubricants specifically designed for use with rubber compounds.

9. Position the new rubber spring on the spring plate, making sure that the vent hole is centered on the spring plate tube. Place the restrictor can over the spring; make sure the can is centered on the spring.
10. Slide, as one assembly, the spring plate, spring, and restrictor cap, into position on the walking beam.
11. Install and tighten the spring plate fasteners 35 lbf·ft (47 N·m).



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A. Make sure that the vent hole in the walking beam is free of rust and debris.
1. Spring Restrictor Can
2. Hollow Rubber Spring
3. Spring Plate Bolt
4. Spring Plate
5. Walking Beam

Fig. 2, Spring Assembly Components

12. Remove the safety stands from under the vehicle. Lower the vehicle.
13. Remove the chocks from the tires.

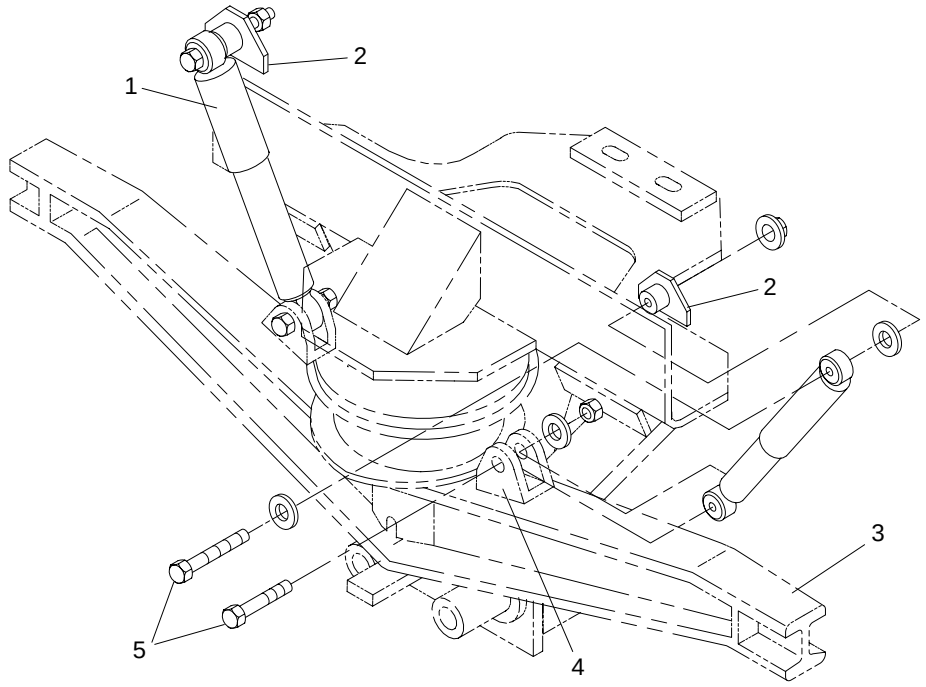
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Replacement

The Chalmers 800 Series Suspension may be fitted with either beam-mounted or axle-mounted shock absorbers. See **Fig. 1** and **Fig. 2**. The replacement procedure is essentially the same for both types of shock absorber.

1. If necessary, power wash the rear suspension to remove road dirt accumulation.
2. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
3. Remove the shock absorber mounting fasteners.
   - 3.1 On beam-mounted shocks, remove the upper and lower bolts. See **Fig. 1**. Discard the fasteners.
   - 3.2 On axle-mounted shocks, remove the upper and lower locknuts and hardened washers. See **Fig. 2**. Discard the fasteners.
4. Remove and discard the shock absorber.
5. On axle-mounted shock absorber installations, the compression sleeve may be rusted to the shock mounting pin and remain on the pin when the shock is removed. See **Fig. 2**. If this occurs, drive the sleeve off of the pin using a small, sharp chisel.
6. On axle-mounted shock absorber installations, clean the shock mounting pin threads using a stiff wire brush or, if necessary, a thread-chaser die.

   Lubricate the threads with a small amount of engine oil.
7. Install the new shock absorbers.



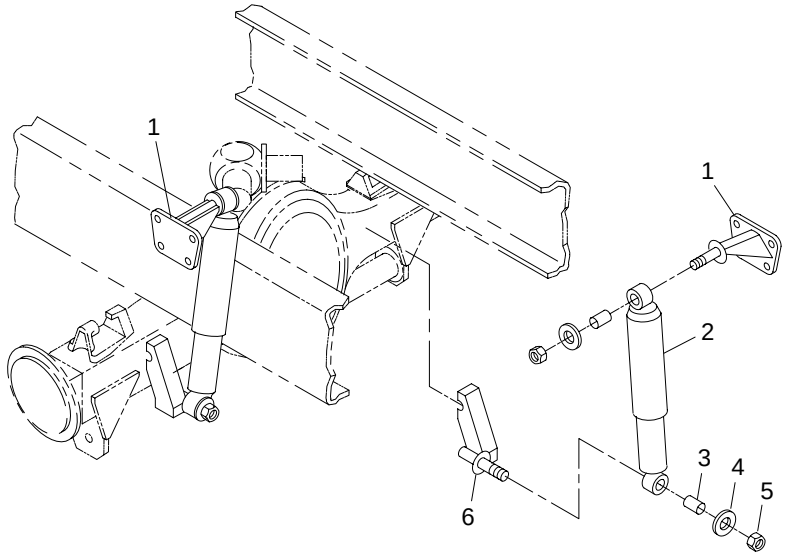
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1. Shock Absorber
2. Frame-Mounted Bracket
3. Walking Beam
4. Beam-Mounted Bracket
5. 3/4-Inch Mounting Bolts

Fig. 1, Shock Absorbers, Beam-Mounted

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Shock Absorber Replacement



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1. Frame-Mounted Bracket
2. Shock Absorber
3. Compression Sleeve
4. Hardened Washer
5. 7/8-Inch Mounting Locknut
6. Axle-Mounted Bracket

Fig. 2, Shock Absorbers, Axle-Mounted

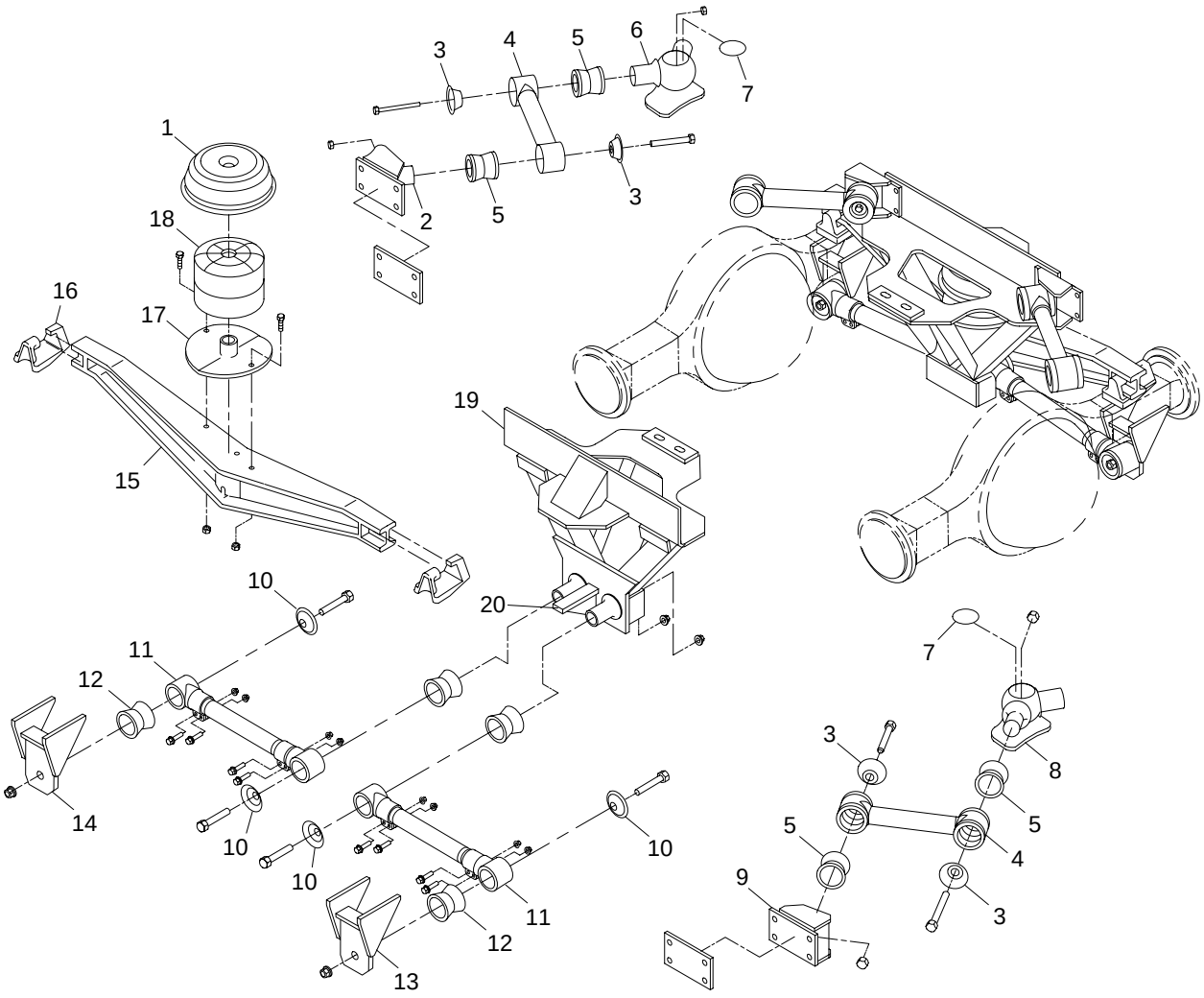
7.1 On beam-mounted shock absorber installations, extend or compress the shock absorber as necessary to install the mounting bolts. Install the locknuts and tighten the fasteners 170 lbf·ft (230 N·m).

7.2 On axle-mounted shock absorber installations, extend or compress the shock absorber as necessary to fit it on the mounting pins. Install the locknuts and tighten them 270 lbf·ft (366 N·m).

8. Remove the chocks from the tires.

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Removal (See Fig. 1)



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1. Restrictor Can
2. Upper Torque Rod Frame Bracket (left-hand forward)
3. Spigot Cap (upper)
4. Upper Torque Rod
5. Torque Rod Bushing (upper)
6. Forward Rear Axle Tower
7. Rear Axle Tower Plug
8. Rearmost Rear Axle Tower
9. Upper Torque Rod Frame Bracket (left-hand rear)
10. Spigot Cap (lower)
11. Lower Torque Rod (adjustable)
12. Torque Rod Bushing (lower)
13. Lower Torque Rod Axle Housing Bracket (left-hand rear)
14. Lower Torque Rod Axle Housing Bracket (left-hand forward)
15. Beam
16. Axle Housing Beam Saddle Bracket
17. Beam Spring Plate
18. Hollow Rubber Spring
19. Sawhorse Bracket Assembly
20. Beam Stop

Fig. 1, Chalmers 800 Series Tandem Axle Suspension (40k capacity shown without shock absorbers)

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Walking Beam Removal, Inspection, and Installation

1. If necessary, power wash the walking beams and axle housing ends to remove road dirt accumulation.
2. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
3. Relieve all drive axle brake or wind-up loads by placing the transmission in neutral and releasing the spring or driveline brakes.
4. Raise the rear of the vehicle to remove all weight from the rear axles, and place safety stands under the frame to secure the vehicle in its raised position.
5. If equipped, disconnect beam-mounted shock absorbers from the walking beam being replaced. See **Subject 120**, if necessary.
6. Remove the two bolts and nuts that secure the walking beam spring plate to the walking beam assembly. See **Fig. 1**. Discard the fasteners.

NOTE: On 54-inch spread suspensions, it may be necessary to remove the front or rear tires to allow spring assembly removal.

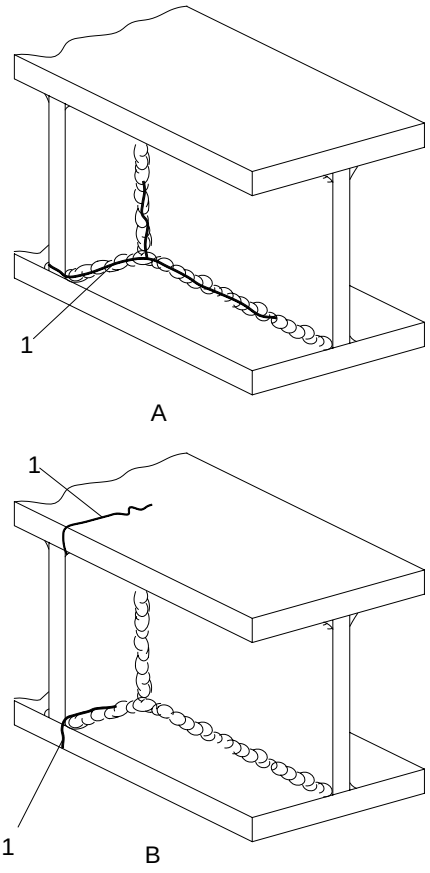
7. Pull the lower spring plate, rubber spring, and restrictor can as one assembly outward, off the beam assembly. See **Fig. 1**.

NOTE: Tag or otherwise mark each torque rod to ensure that it can be re-installed in the same position and orientation.

8. Disconnect the rearmost axle's upper torque rods from the rear axle tower and the lower torque rods from the rear axle housing brackets. See **Fig. 1**.
9. Roll the rear axle rearward just enough to disengage the axle saddles from the walking beam ends.
10. Lift up the free end of the walking beam and slide the beam rearward to disengage it from the front axle saddle; remove the walking beam.

Inspection

1. Inspect the beam ends carefully, looking for cracks. Cracks along weld lines may be repairable, while cracks in or across the beam flanges require walking beam replacement. See **Fig. 2**.



A. Repairable Walking Beam
B. Non-Repairable Walking Beam
1. Cracks

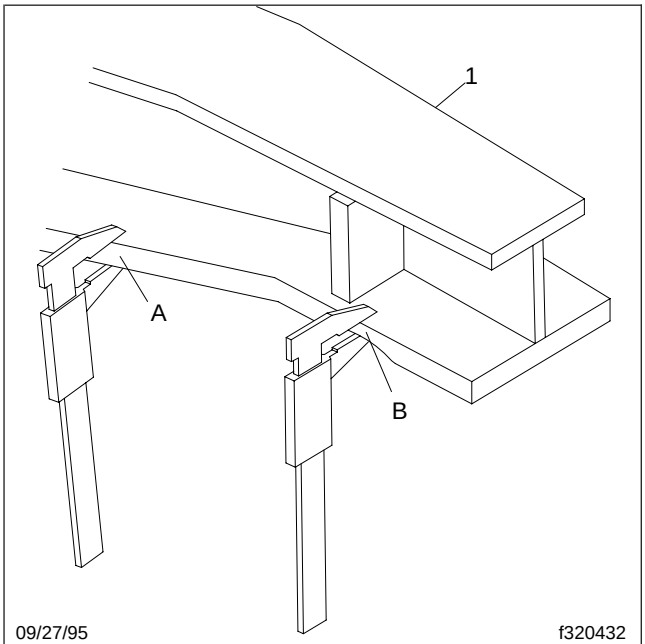
Fig. 2, Repairable/Non-repairable Beam Cracks

NOTE: Take flange thickness measurements at least 1/2 inch (12 mm) from the flange edges. Measurements taken at the flange edges are not an accurate indication of beam wear and may lead to unnecessary beam repair/replacement.

2. Check for excessive wear on the beam flanges, where they contact the axle housing saddle brackets.

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If flange wear is significant, use a micrometer or vernier calipers to take measurements at both unworn and worn areas. The maximum allowable difference between unworn and worn areas is 0.062 inch (1.5 mm). See **Fig. 3**.



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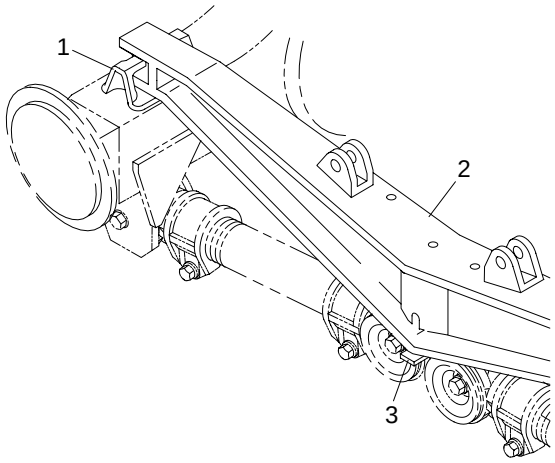
A. Flange thickness measurement taken at unworn area for reference.
B. Flange thickness measurement taken at wear area to assess beam condition.
1. Walking Beam

Fig. 3, Beam Wear Measurement

3. Beams showing excessive wear must be repaired or replaced. See **Subject 140** for beam repair information.

Installation

1. Position the new or repaired walking beam over the rearmost rear axle, with the front end of the beam tilted downward.
2. Slide the beam forward and downward so the front end of the beam enters the axle housing saddle bracket. See **Fig. 4**. Let the middle of the beam rest on the sawhorse bracket beam stop.



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1. Front Axle Housing, Beam Saddle Bracket
2. Walking Beam
3. Beam Stop

Fig. 4, Beam/Saddle Bracket Alignment

NOTE: On 54-inch spread suspensions, it may be necessary to install the spring assembly before the rearmost axle is rolled into place.

3. Carefully roll the rearmost rear axle forward, while lifting the rear end of the walking beam enough so the beam end enters the axle housing saddle bracket.
4. Connect the rearmost axle's upper and lower torque rods to the axle housing brackets. Install and tighten the torque rod bushing through-bolts 135 lbf·ft (183 N·m).
5. Slide, as one assembly, the spring plate, rubber spring, and restrictor cap, into position on the walking beam.
6. Install and tighten the spring plate fasteners 35 lbf·ft (47 N·m).
7. If so equipped, connect the beam-mounted shock absorbers to the beam brackets and tighten the fasteners 170 lbf·ft (230 N·m).
8. Remove the safety stands from under the vehicle. Lower the vehicle.
9. Remove the chocks from the tires.

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Repair

NOTE: This subject addresses only instances where excessive beam flange wear occurs, but cracks in the web or flange are not present.

Cracked webs and/or flanges require walking beam replacement.

Walking beams with excessive flange wear, however, can be repaired by welding a Chalmers wear plate over the worn areas as described below.

1. Remove the walking beam assembly. See **Subject 130** for information.

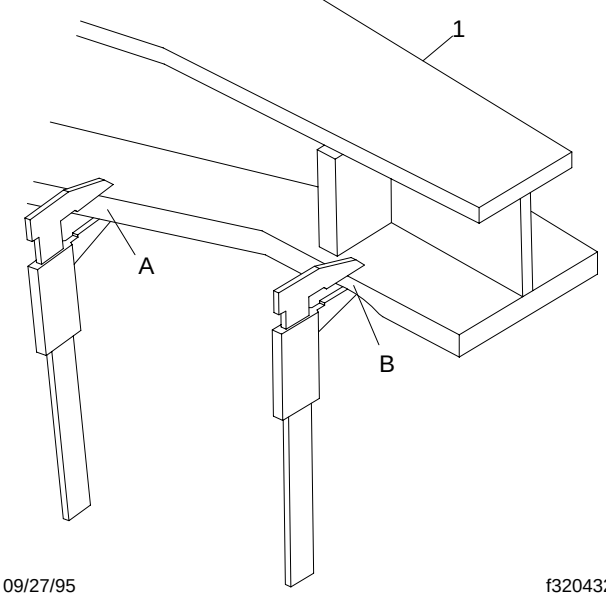
NOTE: Take flange thickness measurements at least 12 mm (1/2 inch) from the flange edges. Measurements taken at the flange edges are not an accurate indication of beam wear and may lead to unnecessary beam repair/ replacement.

2. Confirm that flange wear is severe enough to warrant repairs. Use a micrometer or vernier calipers to take flange thickness measurements at both unworn and worn areas. The maximum allowable difference between unworn and worn areas is 0.062 inch (1.5 mm). See **Fig. 1**.
3. If repair is required, clean the worn area of the beam thoroughly. Make sure that any oil or grease is removed, as well as rust or road dirt accumulation. If necessary, slight grinding of the beam is allowed to smooth raised areas.
4. Clamp Chalmers wear plate No. 700313 to the bottom flange of the beam. Make sure the plate is centered and has good surface-to-surface contact with the beam. Slight grinding is allowable to obtain good plate-to-beam contact.
5. Tack weld the plate to the beam, welding on the sides of the plate only.

CAUTION

Weld at sides of wear plate and beam only. Never weld at the ends of the wear plate.

6. Remove the clamps and weld the plate to the beam, welding on the sides of the plate only. See **Fig. 2**.
7. Prime and paint the repaired area.
8. Install the repaired walking beam assembly. See **Subject 130** for information.



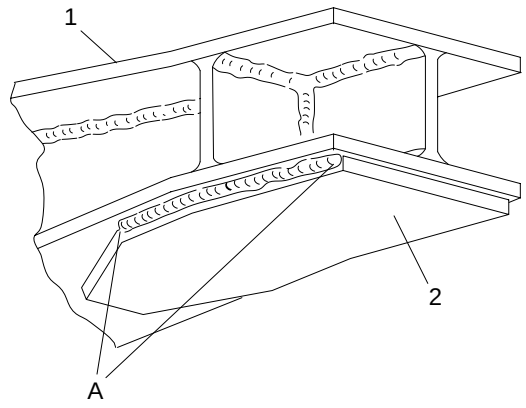
A. Flange thickness measurement taken at unworn area for reference.
B. Flange thickness measurement taken at wear area to assess beam condition.

1. Walking Beam

Fig. 1, Beam Wear Measurement

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Walking Beam Repair



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A. Limit weld to this area only.

1. Walking Beam 2. Wear Plate

Fig. 2, Chalmers Wear Plate Welding

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Torque Rod Removal and Installation

The torque rods hold the rear axles in place, maintaining both axle alignment and pinion nose angle. When servicing the torque rods, it is good practice to remove and install them one at a time to avoid the possibility of mixing them up and affecting the alignment or pinion nose angle.

Several different styles of torque rods and bushing spigots exist. On the 40,000 lb (18,000 kg) version of the 800 Series suspension, the torque rods have tubular steel bodies and the upper rods do not cross over one another. On the 46,000 lb (21,000 kg) version, the lower torque rods have tubular steel bodies, but the upper torque rods are made of "I-beam" shaped ductile iron. These upper torque rods do cross over one another. See **Fig. 1** and **Fig. 2**.

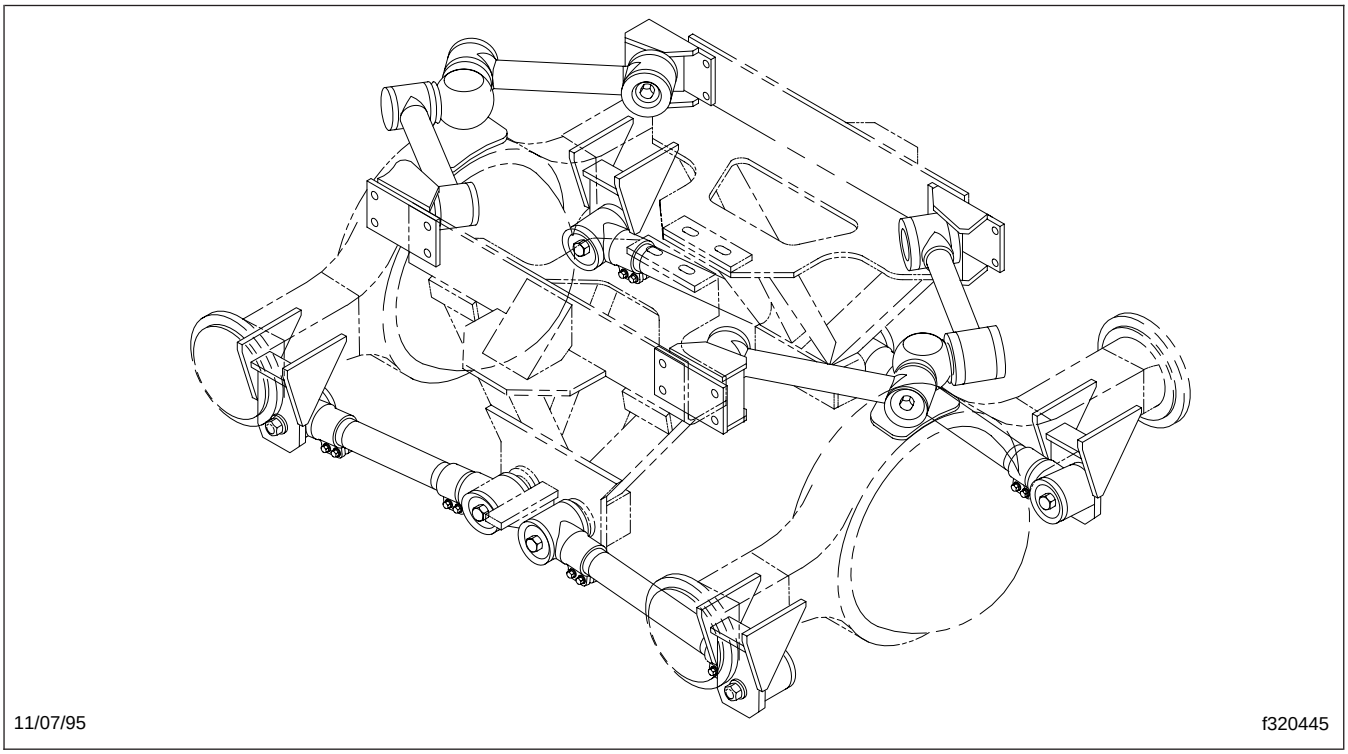


Fig. 1, Torque Rod Arrangement, 40,000-lb Capacity Suspension

Removal

NOTE: Inspect torque rod bushings for free play before removing the torque rods. See **Subject 160** for torque rod bushing inspection information.

1. If necessary, power wash the rear suspension to remove road dirt accumulation.
2. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
3. Relieve all drive axle brake or wind-up loads by placing the transmission in neutral and releasing the spring or driveline brakes.
4. Raise the rear of the vehicle to remove all weight from the rear axles, and place safety stands under the frame to secure the vehicle in its raised position.
5. Working on one torque rod at a time remove the torque rod bolts and spigot caps. Discard the bolts. Set the spigot caps aside for cleaning and inspection.

   Remove the torque rods by prying between the torque rod eye and the spigot base or frame bracket.

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Torque Rod Removal and Installation

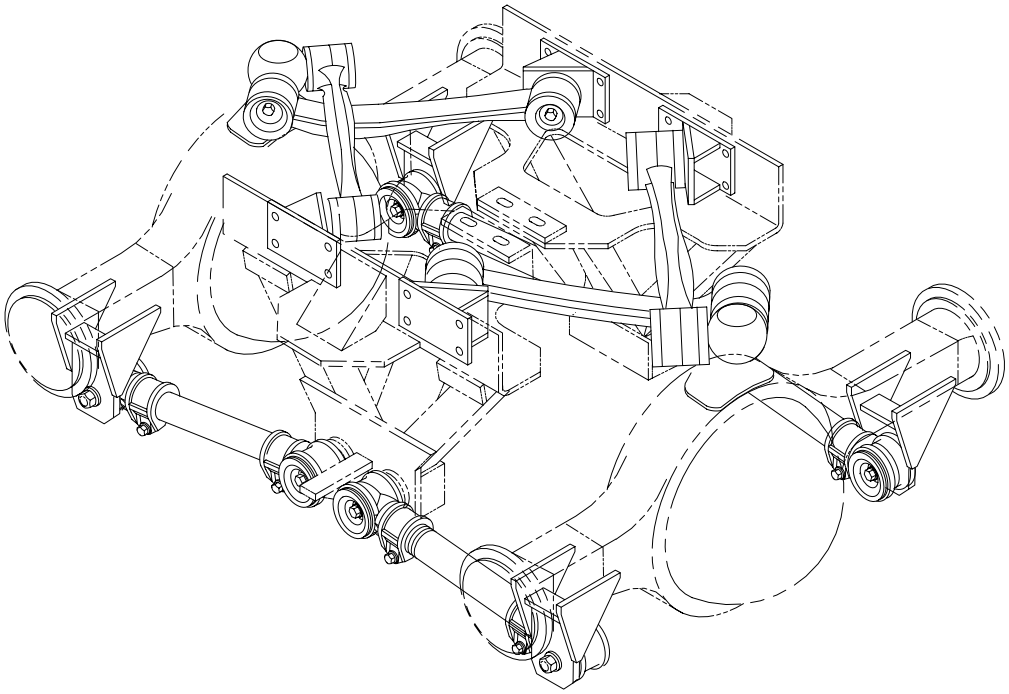


Fig. 2, Torque Rod Arrangement, 46,000-lb Capacity Suspension

NOTE: At the axle housing towers, pry off the tower cap to access the torque rod fasteners.

6. Replace worn or damaged bushings following the instructions in **Subject 160**.
7. Inspect the spigots for damage, severe corrosion, or extensive wear. Replace damaged or severely corroded spigots. To determine whether or not a spigot is worn enough to warrant replacement, see **Fig. 3** and **Table 1**.

   The smaller of the two measurements should be used as the spigot diameter.

Installation

1. Check the torque rod bushings to make sure they are properly installed. They must be centered within the torque rod eye. See **Fig. 4**.

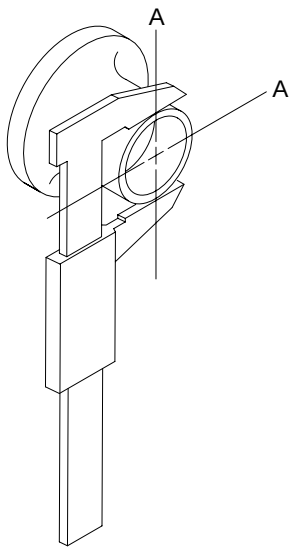
IMPORTANT: Never use any mineral based oils, greases, jellies, or solvent soaps to aid in the assembly of rubber suspension parts. Use only lubricants specifically designed for use with rubber compounds.

2. Lubricate the outside of the spigots and the inside of the rubber bushings with a generous amount of rubber lubricant such as Rimslip® or equivalent.
3. Push the torque rod into position on its spigots. After the torque rod is partially installed, use a heavy soft-faced mallet to drive the torque rod into position until the bushing contacts the spigot bottom face.

NOTE: For easier installation, alternate mallet blows between ends of the torque rod to drive it onto the spigots evenly.

4. Install the spigot caps.
5. Install and tighten the torque rod bushing through-bolts 135 lbf·ft (183 N·m).
6. Remove the safety stands from under the vehicle, then lower the vehicle.
7. Remove the chocks from the tires.

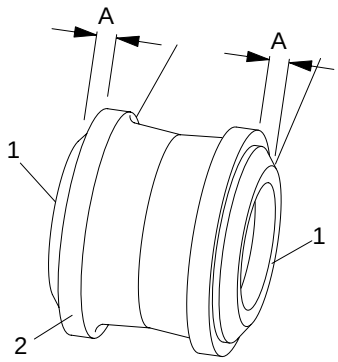
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A. Measure outside diameter at 2 locations, 90 degrees apart.

Fig. 3, Spigot Measurement Points



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A. The amount of rubber protruding from each side of the torque rod eye must be equal.

1. Torque Rod Bushing 2. Torque Rod Eye

Fig. 4, Torque Rod Bushing Protrusion

Spigot Wear Limits				
Spigot Size	**Spigot Part No.**	**Useage**	**Minimum Spigot Diameter With Standard Bushing**	**Minimum Spigot Diameter With Oversize Bushing**
#1	800200	40,000-lb Capacity	2.350 in (59.69 mm)	2.320 in (58.93 mm)
#2	800021	46,000- & 50,000-lb capacity	2.530 in (64.26 mm)	2.500 in (63.50 mm)

Table 1, Spigot Wear Limits

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Torque Rod Bushing Inspection and Replacement

Inspection

1. If necessary, power wash the upper and lower torque rods to remove road dirt accumulation.
2. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
3. Relieve all drive axle brake or wind-up loads by placing the transmission in neutral and releasing the spring or driveline brakes.
4. Using your hands only, attempt to move the torque rod ends, checking for free play. Some movement as the bushings "give" is normal, but only free play is cause for bushing replacement.

NOTE: Never use a lever or pry bar to check for torque rod bushing free play. To do so may result in unnecessary bushing replacement.

5. If free play is detected, replace the bushing as described below.

Replacement

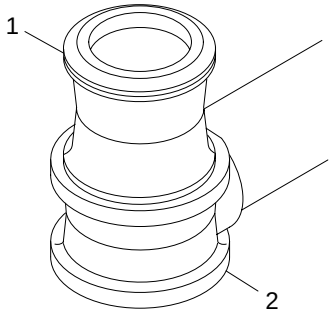
1. Remove the torque rod containing the worn out bushing. See **Subject 150**, if necessary.

NOTE: Remove only one torque rod at a time to avoid mixing-up torque rod positions.

2. Place the torque rod on the floor or a workbench with a bushing open end facing upward. Push the tip of a large screwdriver down between the torque rod eye and the bushing and pry out the bushing. Discard removed bushings.
3. Use a wire brush and/or scraper to clean the torque rod eyes, removing all rust, scale, and rubber accumulations.
4. Inspect the torque rod eyes looking for cracks, distortion, or severe corrosion. Replace torque rods with damaged bushing eyes.

IMPORTANT: Never use any mineral based oils, greases, jellies, or solvent soaps to aid in the assembly of rubber suspension parts. Use only lubricants specifically designed for use with rubber compounds.

5. Lubricate both the inside of the torque rod eye and the outside of the new bushing with a generous amount of rubber lubricant, such as Rimslip® or equivalent.
6. Place the torque rod on a solid level floor with an open end of the eye facing upward. Position a lubricated bushing on the eye, making sure that the tapered shoulder of the bushing is centered on the eye. See **Fig. 1**.



1. Torque Rod Bushing 2. Torque Rod Eye

Fig. 1, Torque Rod Bushing Installation

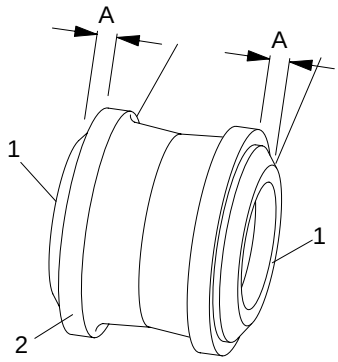
7. Using a heavy, soft-faced mallet, strike the bushing squarely to drive it into the torque rod eye. Flip the torque rod over 180 degrees and tap on the torque rod shaft with the mallet while the bushing rests on the floor.

NOTE: If available, a small press may be used instead of a mallet for bushing installation.

8. The bushing is completely installed when it is centered within the torque rod eye. See **Fig. 2**.
9. Install the re-bushed torque rod. See **Subject 150**, if necessary.
10. Remove the chocks from the tires.

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Torque Rod Bushing Inspection and Replacement



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A. The amount of rubber protruding from each side of the torque rod eye must be equal.

1. Torque Rod Bushing 2. Torque Rod Eye

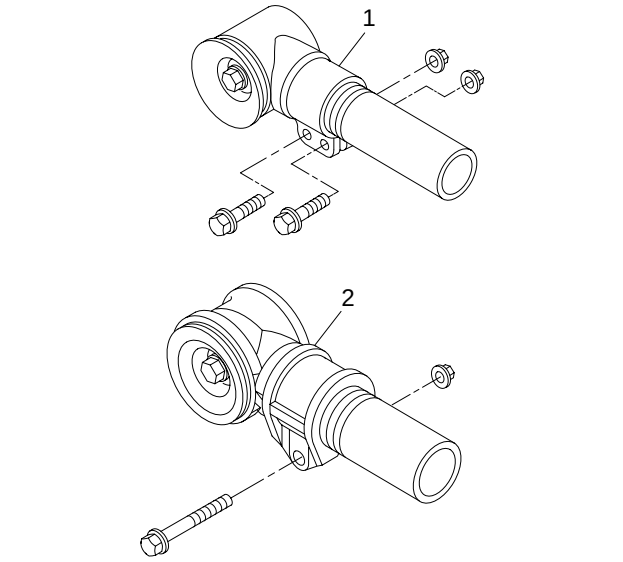
Fig. 2, Torque Rod Bushing Protrusion

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On the Chalmers 800 series rear suspension, the lower torque rods provide the only means for adjusting rear axle alignment. The upper torque rods play no part in the axle alignment process.

The lower torque rod bodies consist of steel tubes, with fine threads cut into the ends of the tube. Left-hand threads are cut into one end of the tube, right-hand threads into the other end. Therefore, by simply twisting the tube body while restraining the ends, the effective length of the tube is changed.

Two different types of torque rod ends are used. On the #1 size, two 1/2-inch clamp bolts secure the rod ends to the tube. On the #2 size, a single 5/8-inch bolt is used. See **Fig. 1**.



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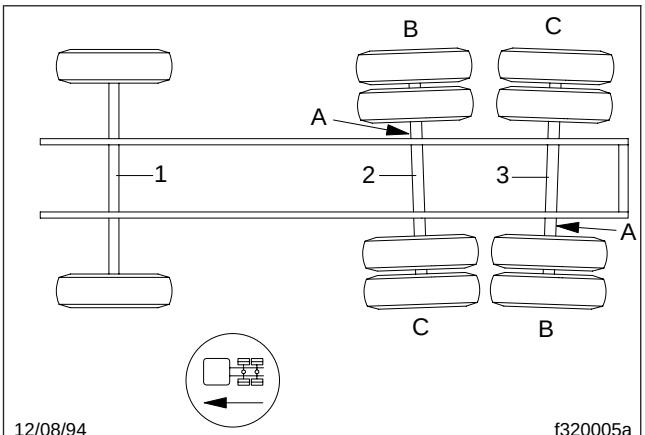
1. #1 Joint 2. #2 Joint

Fig. 1, Adjustable Torque Rod Ends

Adjustment

1. Ensure that the torque rod bushings are in a fully relaxed, neutral state by slowly moving the vehicle back and forth a few times. Apply the service brakes, *not the parking brakes*.
2. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
3. Relieve drive axle brake or wind-up loads by placing the transmission in neutral and releasing the brakes.
4. Using a straightedge and a tape measure, determine the amount of adjustment needed to align the forward-rear axle at right angles to the frame. For instructions, see **Group 35**. The difference in measurements between the sides of the vehicle is the approximate amount that the trailing end of the forward-rear axle will have to be brought forward, or the leading end will have to be moved back to align it at a right angle to the frame. See **Fig. 2**.

   If the forward-rear axle alignment is within specifications, go to step 8.



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A. Adjust here.
B. Leading End
C. Trailing End
1. Front Axle
2. Forward Rear Axle
3. Rearmost Axle

Fig. 2, Tandem Axle, Shown Out of Alignment

5. On the side of the vehicle that is to be adjusted forward or rearward, loosen the torque rod end pinch bolts at both ends of the torque rod.

NOTE: If the pinch bolts are badly corroded or otherwise damaged, remove and discard them. Install new Chalmers fasteners.

6. Attach a pipe wrench to the tube body (chain type preferred) and rotate the tube to shorten or lengthen the torque rod. Continue to rotate the tube until the forward-rear axle is square to the frame.

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Rear Axle Alignment Adjustment

NOTE: If the torque rod tube is difficult to rotate, apply penetrating oil to the tube threads. If this does not help, remove the pinch bolts and drive wedges between the eye lugs to relieve the clamping effect.

7. When the forward-rear axle is square with the frame, tighten the pinch bolts.
   - 7.1 Tighten 1/2-inch UNC bolts on #1 joints 65 lbf·ft (88 N·m).
   - 7.2 Tighten 5/8-inch UNC bolts on #2 joints 135 lbf·ft (183 N·m).
8. Using a center-point bar, determine the difference between the forward-rear and the rearmost axles' center-to-center measurements on each side of the vehicle. For instructions, see **Group 35**. This difference is the approximate distance that the leading end of the rearmost axle will have to be adjusted rearward, or that the trailing end will have to be adjusted forward to align it at a right angle to the frame and to align it parallel to the forward-rear axle. See **Fig. 2**.
9. On the side of the vehicle that is to be adjusted forward or rearward, loosen the torque rod end pinch bolts at both ends of the torque rod.

NOTE: If the pinch bolts are badly corroded or otherwise damaged, remove and discard them. Install new Chalmers fasteners.

10. Attach a pipe wrench to the tube body (chain-type preferred) and rotate the tube to shorten or lengthen the torque rod. Continue to rotate the tube until the rearmost axle is square to the frame.

NOTE: If the torque rod tube is difficult to rotate, apply penetrating oil to the tube threads. If this does not help, remove the pinch bolts and drive wedges between the eye lugs to relieve the clamping effect.

11. When the rearmost axle is square with the frame, tighten the pinch bolts.
    - 11.1 Tighten 1/2-inch UNC bolts on #1 joints 65 lbf·ft (88 N·m).
    - 11.2 Tighten 5/8-inch UNC bolts on #2 joints 135 lbf·ft (183 N·m).
12. Remove the safety stands and lower the vehicle.
13. Remove the chocks from the front tires.
14. Using the center-point bar, check the rearmost axle alignment. If alignment is not within specifications, repeat the applicable steps above.

⚠ CAUTION

Failure to periodically torque the suspension fasteners can result in abnormal tire wear and damage to the suspension.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 of the *Acterra Maintenance Manual*.

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Specifications

Fastener Torques			
Description	**Bolt Size**	**IFI Grade**	**Torque lbf·ft (N·m)**
Beam Spring Plate Bolt	3/8 UNC	8	35 (47)
Torque Rod End Through Bolts	5/8 UNC	8	135 (183)
Shock Absorber (Beam-Mounted) Bolt	3/4	8	170 (230)
Shock Absorber (Axle-Mounted) Nut	7/8	G	270 (366)
#1 Torque Rod End Pinch Bolts	1/2 UNC	8	65 (88)
#2 Torque Rod End Pinch Bolts	5/8 UNC	8	135 (183)

Table 1, Fastener Torques

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General Information

The Hendrickson RS suspension is a heavy-duty tandem drive that uses six rubber load cushions in place of leaf springs to lessen road shocks. See **Fig. 1**. Frame hangers above the four outside cushions have vertical drive pins and bushings that extend down through the cushions. See **Fig. 2**. All driving, braking, and cornering forces are transmitted and controlled through these pins and bushings.

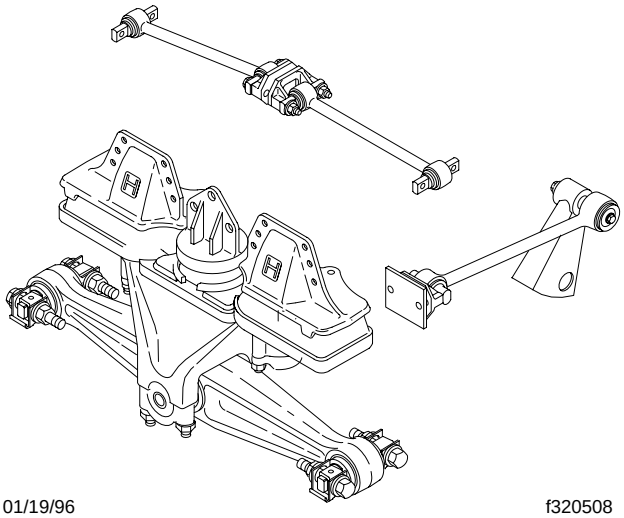
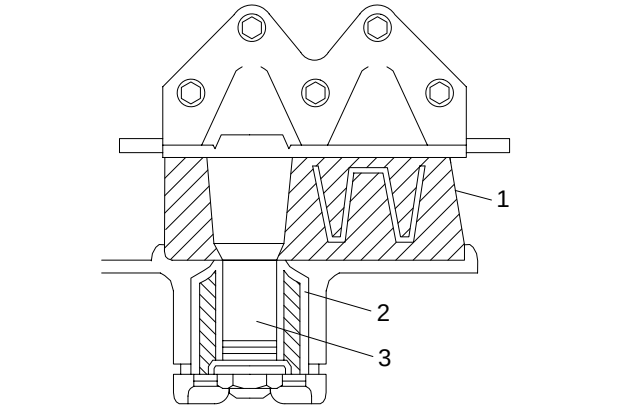


Fig. 1, Hendrickson RS Heavy-Duty Suspension



1. Load Cushion
2. Vertical Drive Pin Bushing
3. Vertical Drive Pin

Fig. 2, Load Cushion Assembly

The axles are attached to beam hangers at the ends of the equalizer beams, allowing an articulating action between the axles to absorb road shock. Torque rods, mounted between the axles and frame rails, stabilize axle and vehicle movement caused by accelerating and braking.

All suspension fasteners require periodic tightening. For suspension inspecting, lubricating, and fastener torque checking instructions, see Group 32 in the *Acterra Maintenance Manual*.

⚠ WARNING

Torque suspension fasteners on a periodic schedule as suggested in the vehicle maintenance manual. Failure to to do so could result in damage to the frame hangers or separation of components. This could cause a loss of vehicle control, resulting in personal injury or property damage.

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Removal (See Fig. 1)

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Drain the vehicle air system.
3. Disconnect all air lines leading to the rear axles, marking the lines for later assembly reference. Plug or cap all lines and fittings to prevent dirt from entering the system.
4. Disconnect the driveline rear universal joint from the forward-rear axle. Remove the interaxle driveline. For instructions, see **Group 41**.
5. Manually release the spring brake chambers. For instructions, see **Group 42**.
6. Remove the torque rods. For instructions, see **Subject 160**.

⚠ WARNING

When the torque rods are disconnected from the axle brackets, the axles become free to pivot on the equalizer beam end bushings. Keep clear of the beam hangers and beam ends to avoid possible injury.

7. Raise the rear of the vehicle so that all weight is removed from the suspension. Block the axles and the frame with safety stands. Make sure the stands will securely support the weight of the axles and the frame.

NOTE: Do not raise the vehicle to the point where the weight of the suspension and axles hangs from the vehicle.

8. Remove the saddle cap nuts and washers from each side of the vehicle, and remove the saddle caps.
9. Raise the rear of the vehicle frame until there is enough clearance to roll the axles out from under the vehicle. Install safety stands under the frame. Roll the axles (with the equalizer beams attached) out from under the vehicle.

Installation (See Fig. 1)

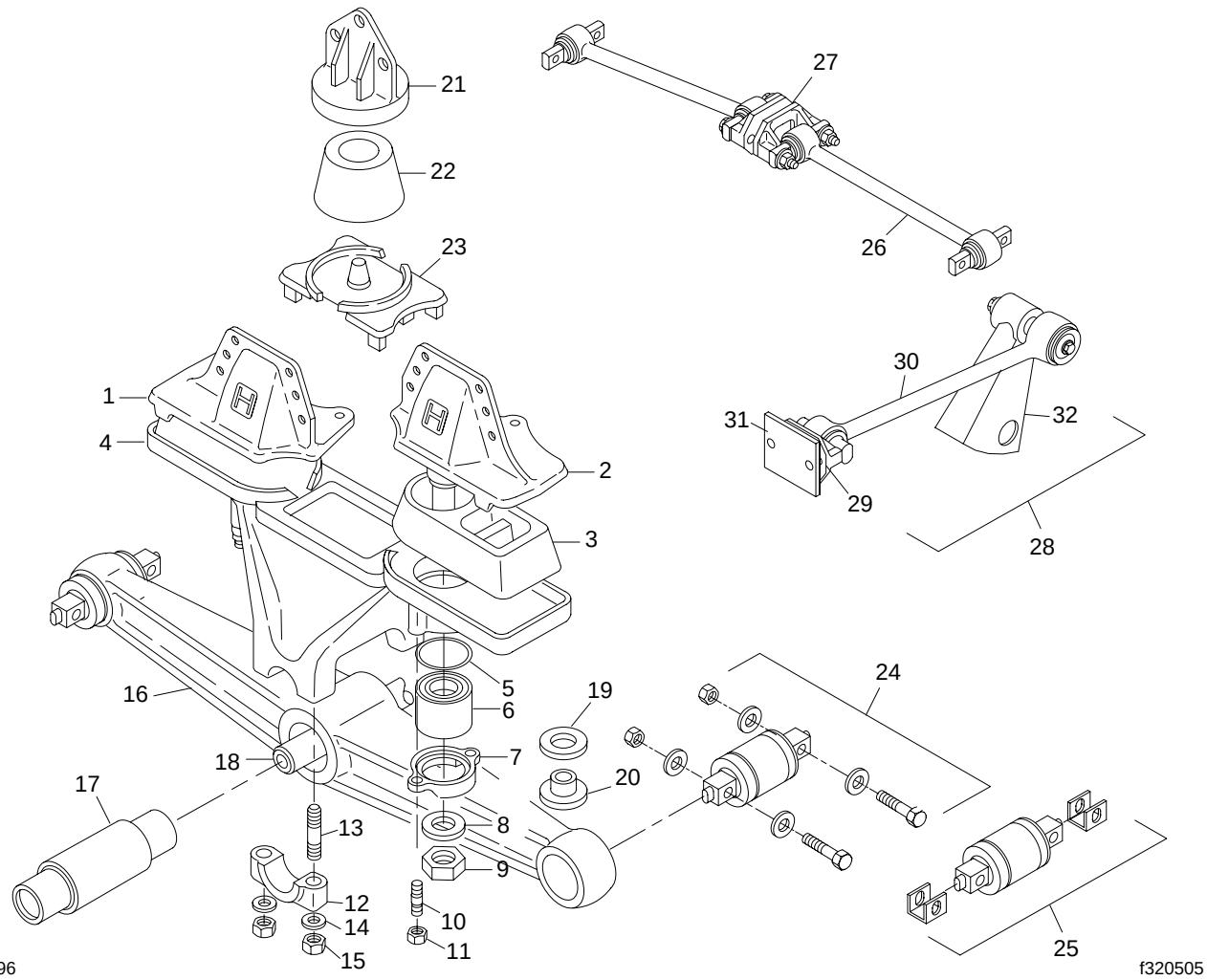
1. Roll the axles under the vehicle frame. Align the center bushing of each equalizer beam with the center of the saddle legs.
2. Raise the vehicle frame off the safety stands. Remove the safety stands.
3. Lower the frame, centering the saddles on the beam center bushings.
4. Install the saddle caps, washers and new self-locking nuts. Do not tighten.
5. Install the torque rods. For instructions, see **Subject 160**.
6. Tighten the saddle cap locknuts 225 to 275 lbf·ft (300 to 375 N·m).

NOTE: Maintain an even gap between the saddle cap and the saddle when tightening the self-locking nuts.

7. Remove the safety stands from under the frame and axle, and lower the vehicle.
8. Manually reset the spring brake chambers. For instructions, see **Group 42**.
9. Connect the driveline rear universal joint to the forward-rear axle. Connect the interaxle driveline. For instructions, see **Group 41** in this manual.
10. Uncap all air lines and fittings. Connect the lines leading to the rear axles.
11. Check the axle pinion angle. For instructions, see **Group 41**.

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Suspension Removal and Installation



1. Frame Hanger
2. Frame Hanger and Vertical Drive Pin
3. Load Cushion
4. Saddle Assembly
5. Saddle Bearing Ring
6. Bushing
7. Cap
8. Washer
9. Nut
10. Stud
11. Nut
12. Saddle Cap
13. Stud
14. Washer
15. Saddle Cap Stud Nut
16. Equalizing Beam
17. Center Bushing
18. Cross Tube
19. Rebound Bumper
20. Stop Nut
21. Frame Hanger
22. Heavy-Duty Load Cushion
23. Saddle Plate
24. Bar Pin Bushing Kit (non-shim type)
25. Bar Pin Bushing Kit (shim type)
26. Torque Rod
27. Torque Rod Frame Bracket
28. Transverse Torque Rod Assembly
29. Transverse Torque Rod Frame Bracket
30. Transverse Torque Rod
31. Backup Plate
32. Axle Bracket

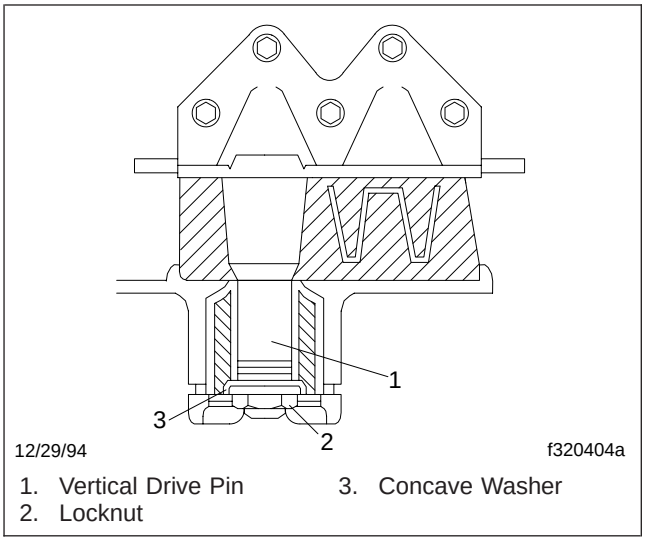
Fig. 1, Hendrickson RS Heavy-Duty Suspension

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Removal

1. Remove the suspension. For instructions, see **Subject 100**.
2. Support the saddle assembly with a floor jack.
3. Remove the vertical drive pin locknuts and the concave washers. See **Fig. 1**.

   On rebound control kit installations, use a 3/4-inch drive socket to remove the stop nuts. Remove the bumper and the concave washers. See **Fig. 2**.



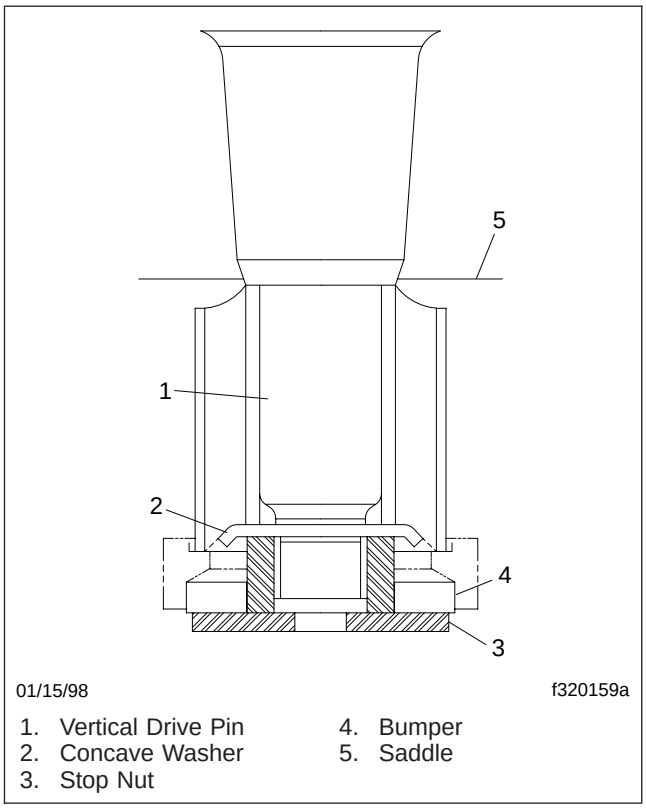
1. Vertical Drive Pin
2. Locknut
3. Concave Washer

Fig. 1, Vertical Drive Pin Assembly

4. Lower the saddle and load cushions from the frame hanger and the vertical drive pins.

Installation

1. Apply Texaco Compound L, or an equivalent rust preventive lubricant, on the vertical drive pins and the vertical drive pin bushings.
2. Position the rubber load cushions on the saddle. Raise the saddle assembly, guiding the vertical drive pin bushings over the vertical drive pin.
3. Install the drive pin washers (with the concave end pointing down) over the threaded ends of the drive pins.
4. Install the vertical drive pin locknuts and tighten 175 to 225 lbf·ft (235 to 300 N·m).



1. Vertical Drive Pin
2. Concave Washer
3. Stop Nut
4. Bumper
5. Saddle

Fig. 2, Rebound Control Kit

5. On rebound control kit installations, install the stop nuts, bumpers, and the concave washers. Tighten the stop nuts 175 to 225 lbf·ft (235 to 300 N·m).
6. Install the suspension. For instructions, see **Subject 100**.

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Load Cushion and Vertical Drive Pin Bushing Replacement

Replacement

1. Remove the saddle assembly. For instructions, see **Subject 110**.

NOTE: If replacing only the heavy-duty load cushions, removal of the saddle assembly is not needed. These cushions can be forced out after raising the frame to open the area between the saddle and the frame hanger brackets.

2. Inspect all of the rubber load cushions for cuts or other damage. Replace a load cushion if these conditions exist.
3. Measure each load cushion. If the height of a load cushion is less than 3-11/16 inches (94 mm), replace it.
4. Remove the retainer locknuts from the drive pin bushing retainer cap, and remove the retainer cap.
5. Using a hydraulic press, press the vertical drive pin bushings out of the saddle from the top.
6. If the outer sleeve of the bushing is frozen in the saddle bore, press out the inner sleeve and rubber insert, then work the outer sleeve out of the saddle bore.

⚠ WARNING

Do not use a cutting torch to remove the vertical drive pin bushings. Using high heat will weaken the saddle, which could cause the saddle to break. This could result in a loss of vehicle control, possible personal injury, and property damage.

7. Using emery cloth, remove small nicks or scratches from the vertical drive pin and the vertical drive pin bushing. Clean the saddle bores with a solvent.
8. Apply Texaco Compound L, or an equivalent rust preventive lubricant, on the drive pin bushings and the saddle bores.
9. Fit the bushings into the saddle bores. Position the drive pin bushing retainer cap and install the retainer cap locknuts. Tighten the locknuts 100 to 125 lbf·ft (135 to 170 N·m).
10. Install the rubber load cushions.
11. Install the saddle assembly. For instructions, see **Subject 110**.

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Equalizer Beam Removal and Installation

Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Remove the saddle cap nuts and washers. Remove the saddle cap. Support the equalizer beam with safety stands.
3. Raise the rear of the vehicle until the saddle studs clear the equalizer beam. Block the axles and frame with safety stands.
4. Remove the wheels and tires. For instructions, see **Group 40**.
5. Apply a penetrating oil to all beam end connections.
6. Remove the bar pins.

NOTE: The bar pin-style beam end connection is a rubber bushing assembly consisting of a rubber insert and outer metal tube with inner casting. It is fastened to the axle by two 1-inch (25-mm) bolts and locknuts. The bolts are positioned parallel to the vehicle's longitudinal axis, making removal and installation easy.

⚠ WARNING

Do not use a cutting torch to remove the equalizer beams from the beam hangers. The equalizer beams are heat-treated, and using a cutting torch could weaken them, causing them to break. This could result in a loss of vehicle control, possible personal injury and property damage.

7. Remove the ends of the equalizer beams from the axle beam hangers.
8. Lower the equalizer beams and the crosstube to the ground. Remove the thrustwashers and pull the beams from the crosstube.

Installation

1. Install the crosstube and thrustwashers in both equalizer beam center bushings.
2. Install the bar pins. Install the crosstube and thrustwashers in both equalizer beam center bushings.

   Position the equalizer beam assembly under the axles, then raise the assembly and place the forward ends of each beam in the forward-rear axle beam hangers. Align the beam end bushings with the beam hangers.
3. Place the rear ends of each beam in the rearmost-axle beam hangers. Align the beam end bushings with the beam hangers.
4. Position the saddle caps on the saddle cap studs, then install the washers and new self-locking nuts. Tighten the nuts 225 to 275 lbf·ft (300 to 375 N·m).
5. Install the bar pin bolt locknuts, and tighten 450 to 600 lbf·ft (610 to 813 N·m).

⚠ WARNING

Tighten the bar pin locknuts to the specified torque values. Otherwise, excessive component wear could result. This could result in separation of suspension components, loss of vehicle control, and possible personal injury or property damage.

6. Install the wheels and tires. For instructions, see **Group 40**.

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Equalizer Beam Rubber Center Bushing Removal and Installation

Removal

NOTE: If using Owatonna tools, removal of the equalizer beam is not required for removal or installation of the rubber center bushing.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Raise the rear of the vehicle so that all weight is removed from the suspension. Block the axles and the frame with safety stands. Make sure the stands will securely support the weight of the axles and the frame.

NOTE: Do not raise the vehicle to the point where the weight of the suspension and axles hangs from the vehicle.

3. Remove the saddle cap nuts and washers from each side of the vehicle, and remove the saddle caps.
4. Raise the rear of the truck frame until the saddle studs clear the equalizer beam. Install safety stands under the frame.
5. Using a 2-1/2 inch diameter hole saw cut out the end plug from the center bushing on each side of the suspension, and remove the crosstube. See **Fig. 1**.

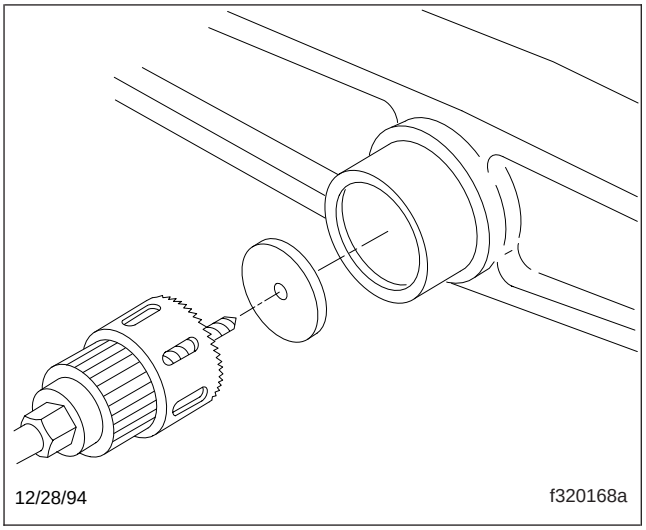
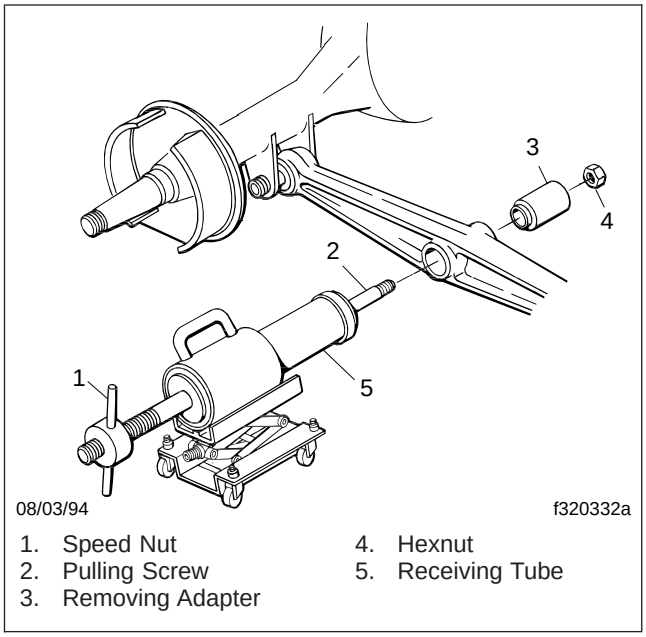


Fig. 1, End Plug Removal

⚠ WARNING

Do not use a cutting torch to remove the beam end bushing. Equalizer beams are heat-treated by the manufacturer. Using a cutting torch could weaken the beams, which could cause the beams to break. This could cause a loss of vehicle control, resulting in injury or property damage.

6. On the inboard side of the equalizer beam, inspect the exposed edge of the bushing's outer sleeve.
7. Chisel or grind off any portion of the outer sleeve that has flared over the surface of the equalizer beam.
8. If using Owatonna tools, remove the rubber center bushings as follows (**Fig. 2**):



1. Speed Nut
2. Pulling Screw
3. Removing Adapter
4. Hexnut
5. Receiving Tube

Fig. 2, Rubber Center Bushings Removal

8.1 Position the hydraulic ram and slide the pulling screw through the center bushing.

8.2 Install the center bushing removing adapter on the inboard side of the beam eye.

IMPORTANT: Align the receiving tube so that the bushing will clear the edges of the tube when force is exerted against the beam. Align the removing adapter so that

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Equalizer Beam Rubber Center Bushing Removal and Installation

force is exerted only on the bushing to ensure a clean pull through the beam.

8.3 Install the hexnut on the pulling screw. Full thread engagement is needed.

8.4 Install spacers between the ram cylinder and the speed nut. Tighten the speed nut and remove any slack in the assembly.

8.5 Connect a hydraulic pumping unit to the ram and apply force until the ram cylinder reaches its stroke limit.

8.6 Release the pressure, add spacers, and tighten the speed nut. About three adjustments are needed to completely remove the bushing.

NOTE: If the pressure gauge on the hydraulic pumping unit reads 10,000 psi (68 900 kPa) and the bushing has not broken loose, stop and check the alignment of the receiving tool and removal adapter. If both tools are aligned correctly, attach a sledging adapter on the speed nut end of the pulling screw. Maintaining hydraulic pressure, strike the sledging adapter with a heavy hammer. A loud noise followed by a sudden drop of the pressure gauge reading indicate that the bushing has broken loose.

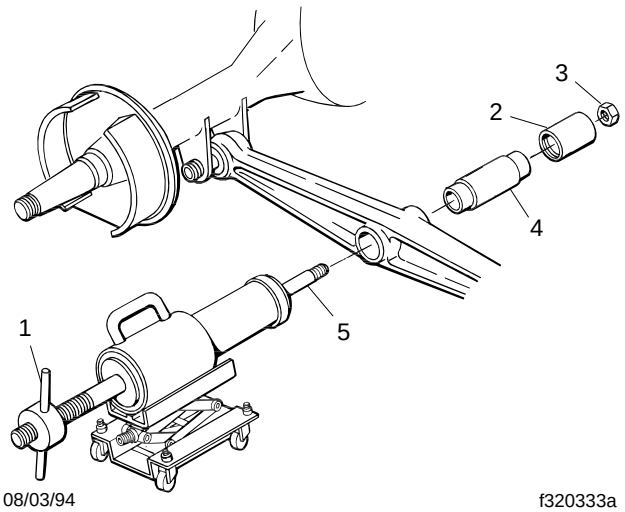
9. If using shop-made adapters, remove the equalizer beams. For instructions, see **Subject 130**.

9.1 Position the equalizer beam on a 50-ton vertical hydraulic press.

9.2 Position the shop-made adapter (see **Specifications 400**) on the outer metal edge of the equalizer beam bushing. Press the center bushing from the beam eye.

Installation

1. Using emery cloth, remove all scale, rust, or corrosion from the beam eyes. Inspect the equalizer beam eyes for cracks, gouges, or damage. Replace the equalizer beam if any of these conditions exist.
2. Using emery cloth, clean the outer sleeves of the new equalizer beam center bushings. Apply a thin coating of Texaco Compound L, or an equivalent rust preventive lubricant, to the surface of the outer sleeves on the new bushing.
3. If using Owatonna tools, install the rubber center bushings as follows (**Fig. 3**):



1. Speed Nut
2. Installing Adapter
3. Hexnut
4. Bushing
5. Pulling Screw

Fig. 3, Rubber Center Bushings Installation

3.1 Center the hydraulic ram and slide the pulling screw through the beam eye.

3.2 Position the bushing on the inboard side of the beam eye.

IMPORTANT: Center the new bushing to ensure a clean pull through the beam eye.

3.3 Fit the installing adapter over the inner sleeve and against the outer sleeve of the bushing.

3.4 Install the hexnut on the pulling screw. Full thread engagement is needed.

3.5 Install spacers between the ram cylinder and the speed nut. Tighten the speed nut and remove any slack in the assembly.

3.6 Connect a hydraulic pumping unit to the ram and apply force until the ram cylinder reaches its stroke limit.

3.7 Release the pressure, add spacers, and tighten the speed nut. About three adjust-

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ments are needed to completely install the center bushing.

NOTE: The pressure gauge on the pumping unit should read 4000 to 5500 psi (27 560 to 37 895 kPa) during installation. If the reading reaches the operating limit of 10,000 psi (68 900 kPa) and the bushing is not going into the beam, check the alignment of the bushing, tooling, and hydraulic equipment. Installation is complete when the installing adapter is flush against the beam.

3.8 Position the crosstube in the center bushings.

3.9 Arc weld new end plugs to the tire side of each center bushing inner sleeve.

NOTE: Heat from welding the end plugs will not affect the beam or the new rubber bushings because of their distance from the point of welding.

4. Position the saddle caps on the saddle cap studs, then install the washers and new self-locking nuts. Tighten the nuts 225 to 275 lbf·ft (300 to 375 N·m).

5. If using shop-made adapters, position the equalizer beam on a 50-ton hydraulic press.

5.1 Using standard center bushings with the end plugs welded in place, position the shop-made adapter (see **Specifications 400**) over the inner sleeve of the bushing. Check that the adapter bottoms against the bushing outer sleeve, then press the new bushing into the beam eye.

5.2 Install the equalizer beams. For instructions, see **Subject 130**.

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Equalizer Beam Bronze Center Bushing Removal and Installation

Removal

NOTE: If using Owatonna tools, you can remove or install the bronze center bushing without removing the equalizer beam.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Raise the rear of the vehicle so that all weight is removed from the suspension. Block the axles and the frame with safety stands. Make sure the stands will securely support the weight of the axles and the frame.

NOTE: Do not raise the vehicle to the point where the weight of the suspension and axles hangs from the vehicle.

3. Remove the saddle cap nuts and washers from each side of the suspension, and remove the saddle caps.
4. Raise the rear of the truck frame until the saddle studs clear the equalizer beam. Install safety stands under the frame.
5. Using a 2-1/2 inch diameter hole saw, cut out the retaining disk from the center bushing on each side of the suspension, and remove the cross-tube.

⚠ WARNING

Do not use a cutting torch to burn out the retaining disk. The equalizer beams are heat treated, and the use of a cutting torch could weaken the beam, causing it to break, which could result in loss of vehicle control, and possible personal injury or property damage.

6. If using Owatonna tools, remove the bronze center bushing as follows (**Fig. 1**):

   6.1 Position the hydraulic ram and slide the pulling screw through the center bushing.

   6.2 Install the center bushing removing adapter on the inboard side of the beam eye.

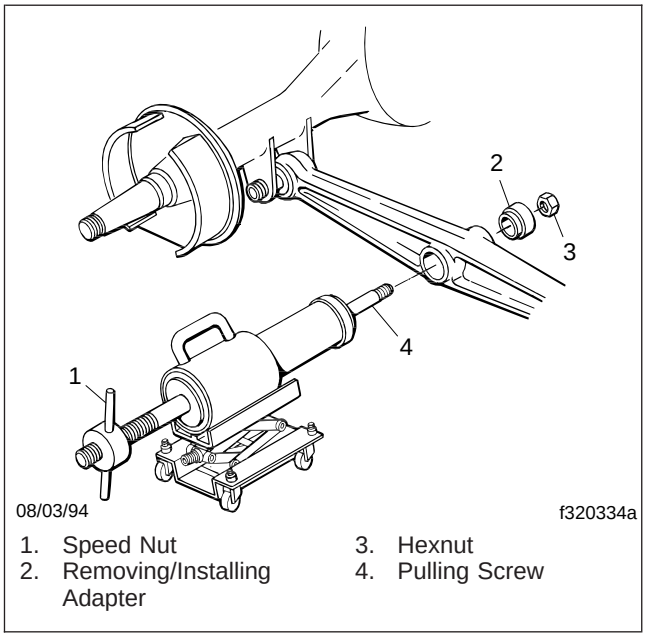
   IMPORTANT: Align the receiving tube so that the bushing will clear the edges of the tube when force is exerted against the beam. Align the removing adapter so that force is exerted only on the bushing to ensure a clean pull through the beam.

   6.3 Install the hexnut on the pulling screw. Full thread engagement is needed.

   6.4 Install spacers between the ram cylinder and the speed nut. Tighten the speed nut and remove any slack in the assembly.

   6.5 Connect a hydraulic pumping unit to the ram and apply force until the ram cylinder reaches its stroke limit.

   6.6 Release the pressure, add spacers, and tighten the speed nut. About three adjustments are needed to completely remove the center bushing.



1. Speed Nut
2. Removing/Installing Adapter
3. Hexnut
4. Pulling Screw

Fig. 1, Bronze Center Bushings Removal

NOTE: If the pressure gauge on the hydraulic pumping unit reads 10,000 psi (68 900 kPa) and the bushing has not broken loose, stop and check the alignment of the receiving tool and removal adapter. If both tools are aligned correctly, attach a sledging adapter on the speed nut end of the pulling screw. Maintaining hydraulic pressure, strike the sledging adapter with a heavy hammer. A loud noise followed by a sudden drop of the pressure gauge reading indicate that the bushing has broken loose.

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Equalizer Beam Bronze Center Bushing Removal and Installation

7. If using shop-made adapters, remove the equalizer beams. For instructions, see **Subject 130**.

   7.1 Position the equalizer beam on a 50-ton vertical hydraulic press.

   7.2 Center the shop-made adapter (see **Specifications 400**) on the center bushing. Press the bushing from the beam eye.

Installation

1. Using emery cloth, remove all scale, rust, or corrosion from the beam eyes. Inspect the equalizer beam eyes for cracks, gouges, or damage. Replace the equalizer beam if any of these conditions exist.
2. Using emery cloth, clean the outer sleeves of the new equalizer beam center bushings. Apply a thin coating of Texaco Compound L, or an equivalent rust preventive lubricant, to the surface of the outer sleeves on the new bushing, and to the inside surface of the beam eye.
3. Position the bushing on the equalizer beam eye.
4. If using Owatonna tools, install the bronze center bushings as follows (**Fig. 2**):

   4.1 Center the hydraulic ram and slide the pulling screw through the beam eye.

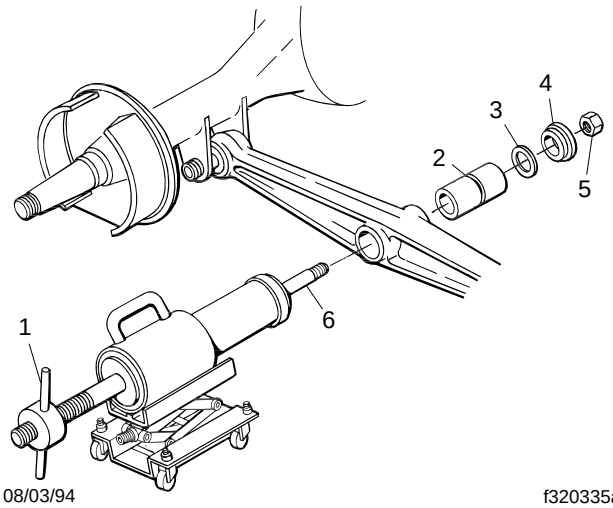
   4.2 Position the bushing on the inboard side of the beam eye. Check that the grooves of the bushing are aligned with the vertical centerline of the equalizer beam. See **Fig. 3**.

   4.3 Fit the installing adapter and the removing/installing adapter against the outer sleeve of the bushing. Make sure the deep ridge on the installing adapter is positioned against the bronze bushing. See **Fig. 4**.

   4.4 Install the hexnut on the pulling screw. Full thread engagement is needed.

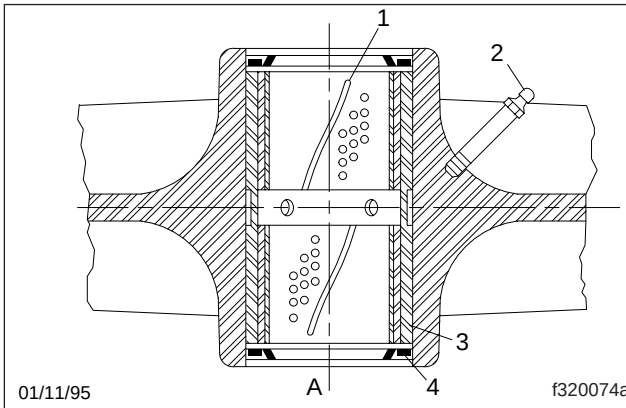
   4.5 Install spacers between the ram cylinder and the speed nut. Tighten the speed nut and remove any slack in the assembly.

   4.6 Connect a hydraulic pumping unit to the ram and apply force until the ram cylinder reaches its stroke limit.



1. Speed Nut
2. Bushing
3. Installing Adapter
4. Removing/Installing Adapter
5. Hexnut
6. Pulling Screw

Fig. 2, Bronze Center Bushings Installation



A. Vertical Centerline of Beam

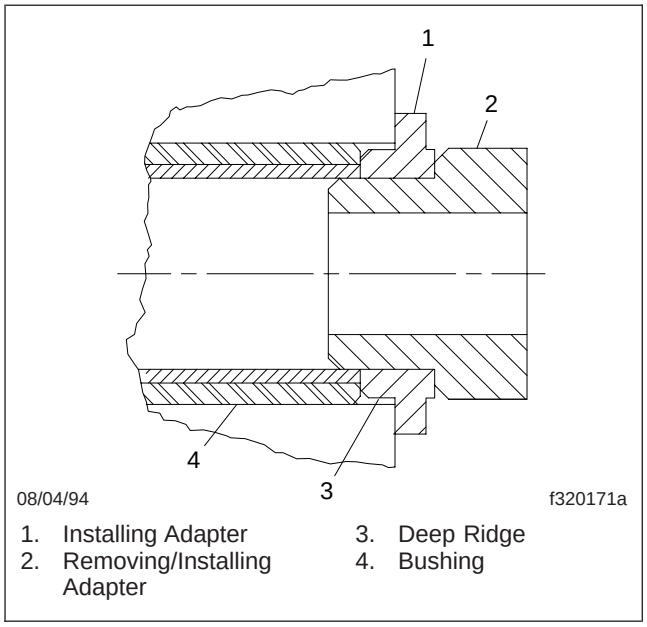
1. Bushing Lube Grooves
2. Grease Fitting
3. Center Bushing Assembly
4. Seal

Fig. 3, Bushing Groove Alignment

4.7 Release the pressure, add spacers, and tighten the speed nut. About three adjustments are needed to completely install the center bushing.

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Equalizer Beam Bronze Center Bushing Removal and Installation



1. Installing Adapter
2. Removing/Installing Adapter
3. Deep Ridge
4. Bushing

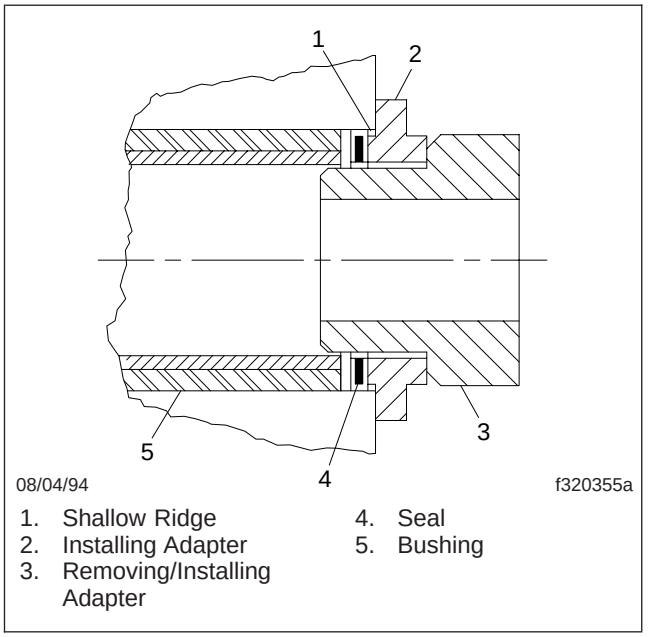
Fig. 4, Installing Adapter Positioning

NOTE: The pressure gauge on the pumping unit should read 4000 to 5500 psi (27 560 to 37 895 kPa) during installation. If the reading reaches the operating limit of 10,000 psi (68 900 kPa) and the bushing is not going into the beam, check the alignment of the bushing, tooling, and hydraulic equipment. Installation is complete when the installing adapter is flush against the beam.

4.8 On the inboard side of the beam, position a grease seal and installing adapter against the center bushing. Make sure the shallow end of the adapter is against the grease seal. See **Fig. 5**. Using a hammer, tap the installing adapter until it is flat against the beam. Using the same procedure, install a grease seal on the outboard side of the beam.

5. If using shop-made adapters, position the equalizer beam on a 50-ton hydraulic press.

5.1 Center the new bushing in the beam eye. Using a standard bushing driver, press the bushing in until there is equal spacing between both bushing ends and the sides of the beam eye.



1. Shallow Ridge
2. Installing Adapter
3. Removing/Installing Adapter
4. Seal
5. Bushing

Fig. 5, Adapter and Grease Seal Positioning

5.2 Install the new grease seals (with the seal lips facing out).

NOTE: Check that the new seals are 1/6 inch (4 mm) inside the beam center hub faces to ensure clearance and protection of the seals when the saddle cap is installed.

6. Apply a thin coating of multipurpose chassis grease to the inside surface of the center bushing. Slide the bushing center sleeve into the bushing.
7. Install the grease fitting into the beam hub. Rotate the center sleeve and apply multipurpose chassis grease in the grease fitting. Lubricate until clean grease appears at both ends of the grease seals.
8. Install the crosstube.
9. Install the saddle caps or the equalizer beam (if removed) on the axle beam hangers. For instructions, see **Subject 130**.

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Torque Rod Removal, Bushing Replacement, and Installation

Removal

IMPORTANT: To ensure that the required tools are available, see **Specifications, 400** before beginning these procedures.

⚠ WARNING

When the torque rods are disconnected from the axle brackets, the axles become free to pivot on the equalizer beam end bushings. Keep clear of the beam hangers and beam ends to avoid possible injury.

1. On fore and aft torque rods, remove the flanged bolts and nuts from the torque rod axle brackets, and the crossmember mounting brackets. See **Fig. 1**. Remove the torque rods.

   On transverse torque rods, remove the nuts and washers from the axle brackets and remove the flanged bolts and nuts from the frame rail mounting brackets. See **Fig. 1**. Remove the torque rods.

NOTE: If necessary, use an impact hammer and tap the top of the axle bracket to disengage the rod stud from the axle bracket.

2. Inspect the torque rods. If bent or cracked, replace. Check the torque rod bushings. If one of the bushings is loose or damaged, replace both of the bushings.
3. Position the press plate on the hydraulic press. Check that the small counterbore of the plate hole is facing up.

NOTE: Some tapered stud torque rod bushings have a large non-removable washer on the stud that will not fit though the press place hole. Loosen the press plate capscrews and separate the halves until the washer clears the counterbore, and the torque rod sets on the press plate. See **Fig. 2**. Tighten the capscrews until the press plate halves are closed.

4. Position the tapered stud removal tool (using the end with the larger inside diameter) on the torque rod stud. Apply lubricating oil. Press the stud out of the bushing. See **Fig. 3**.
5. Position the bushing remover/replacer tool (using the end with the larger outside diameter) on the bushing. Install the cap. Apply lubricating oil to the torque rod bushing.
6. Press the rubber bushing out of the torque rod eye.
7. Position the straddle mount end of the torque rod into the hole of the press plate. Tighten the press plate capscrews.
8. Position the straddle mount pin remover on the straddle mount pin. See **Fig. 4**.
9. Apply lubricating oil to the straddle mount pin. Press the straddle mount pin out of the bushing.
10. Position the end of the rubber bushing remover/replacer tool (using the end that has the larger outside diameter) on the bushing. Install the cap. Apply lubricating oil to the torque rod bushing.
11. Press the rubber bushing out of the torque rod eye.

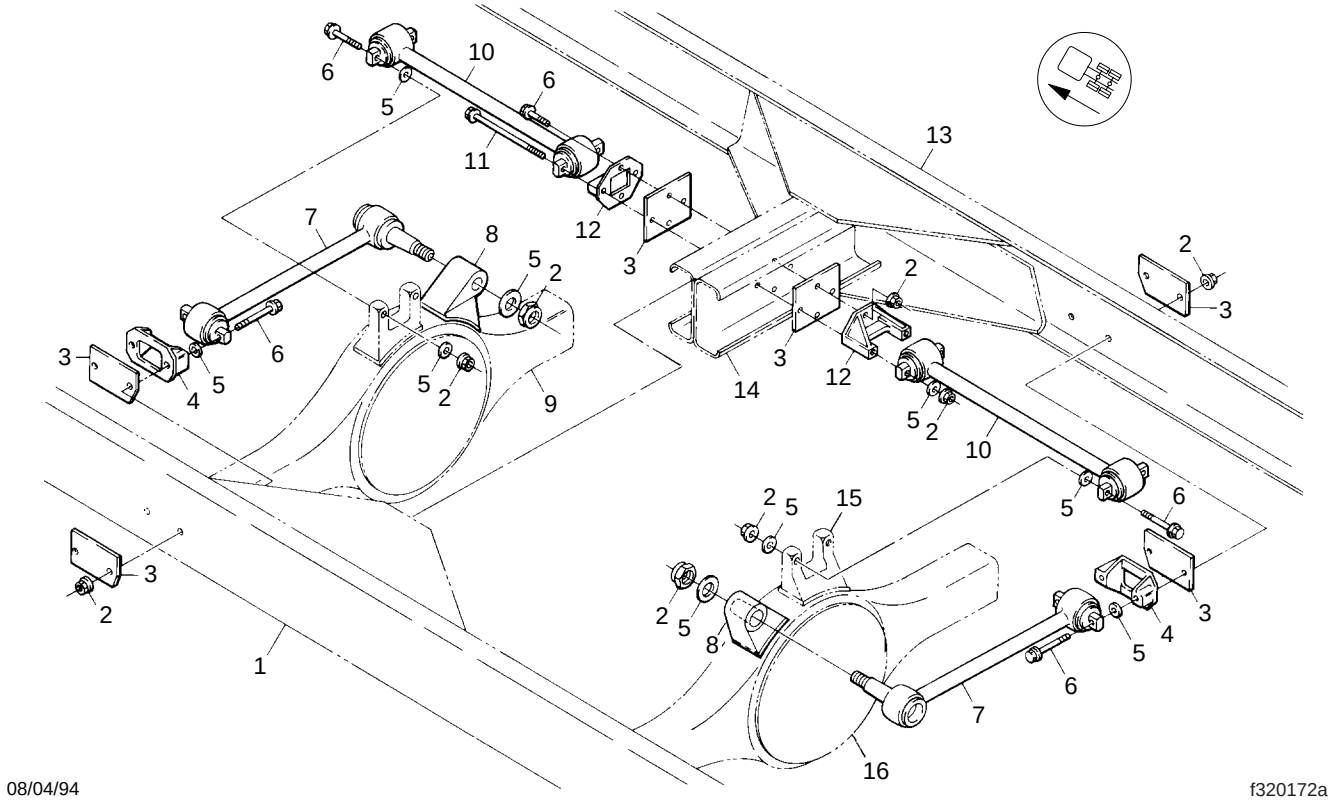
Installation

1. Remove all dirt and grease from the torque rod ends. Apply lubricant on the new bushings and in the torque rod eyes.
2. Position the press plate on the hydraulic press. Check that the small counterbore of the plate hole is facing up.
3. Position the new bushing on the tapered stud of transverse torque rods. Position the clamp and tighten it to compress the rubber. See **Fig. 5**.
4. Place the torque rod end, the bushing, and the clamp on the press plate.
5. Place the remover/replacer tool and cap on top of the clamping tool and press the bushing in the torque rod end. See **Fig. 6**. Check that the bushing sleeve protrudes equally on each side of the torque rod end.
6. On straddle mount end assemblies, align the clamping tool on the bushing as shown in **Fig. 7**. Tighten the clamp to compress the rubber of the new straddle mount bushing.

NOTE: When tightening the clamp, make sure that the position of the bushing pin is at a right angle to the center line of the torque rod shank. See **Fig. 8**.

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Torque Rod Removal, Bushing Replacement, and Installation



1. Left-Hand Frame Rail
2. Flanged Hexnut
3. Spacer
4. Transverse Torque Rod Mounting Bracket
5. Hardened Washer
6. Flanged Hex Bolt
7. Transverse Torque Rod
8. Transverse Torque Rod Axle Mounting Bracket
9. Forward Rear-Axle
10. Fore and Aft Torque Rod
11. Capscrew
12. Fore and Aft Torque Rod Crossmember Mounting Bracket
13. Right-Hand Frame Rail
14. Crossmember
15. Fore and Aft Torque Rod Axle Mounting Bracket
16. Rearmost Axle

Fig. 1, Torque Rod Mounting Assembly

7. Place the torque rod end, the bushing, and the clamp on the press plate.
8. Using the larger end of the remover/replacer tool, position the tool and cap on top of the clamp assembly.
9. Press the bushing in the torque rod end. Check that the bushing's outer sleeve protrudes equally on each side of the torque rod end.
10. Install the fore and aft torque rods as follows (**Fig. 1**):
    - 10.1 Position a torque rod straddle mount pin in the forward-rear axle bracket. Install the flanged bolts through the axle bracket and the straddle mount pin. Install a spacer and nut on each bolt, and tighten 190 lbf·ft (260 N·m).
    - 10.2 Position a torque rod straddle mount pin in the rearmost axle bracket. Install the flanged bolts through the axle bracket and the straddle mount pin. Install a spacer and nut on each bolt, and tighten 190 lbf·ft (260 N·m).
    - 10.3 Position a torque rod spacer and straddle mount bracket on each side of the crossmember. Insert bolts through the upper

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Torque Rod Removal, Bushing Replacement, and Installation

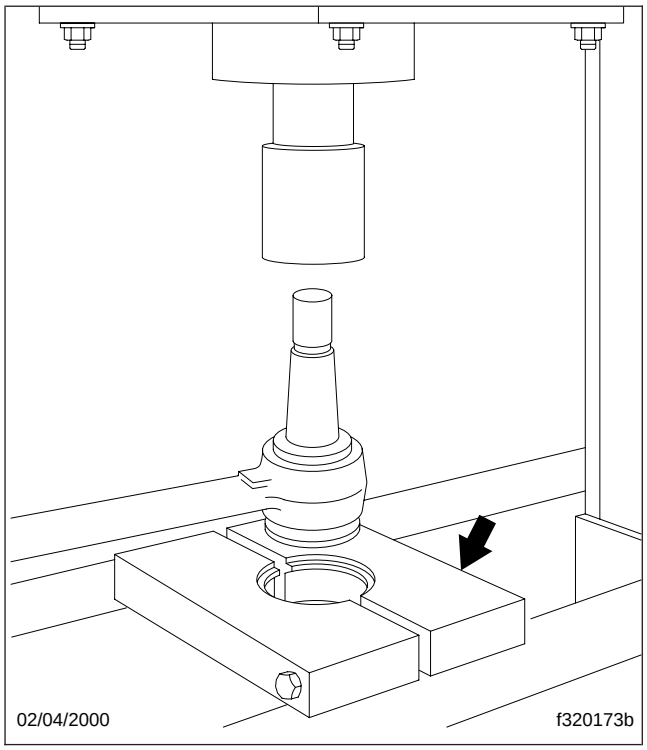


Fig. 2, Clamping Tool

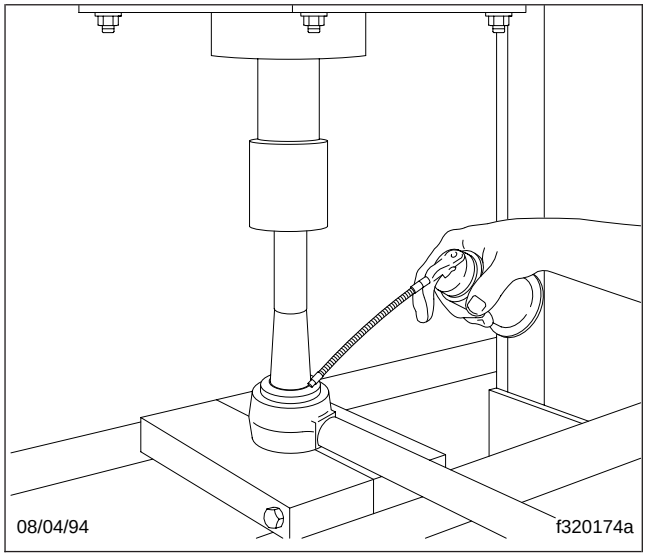


Fig. 3, Applying Lubricating Oil

and lower holes of the forward mounting bracket. Install nuts and tighten 95 lbf·ft (130 N·m).

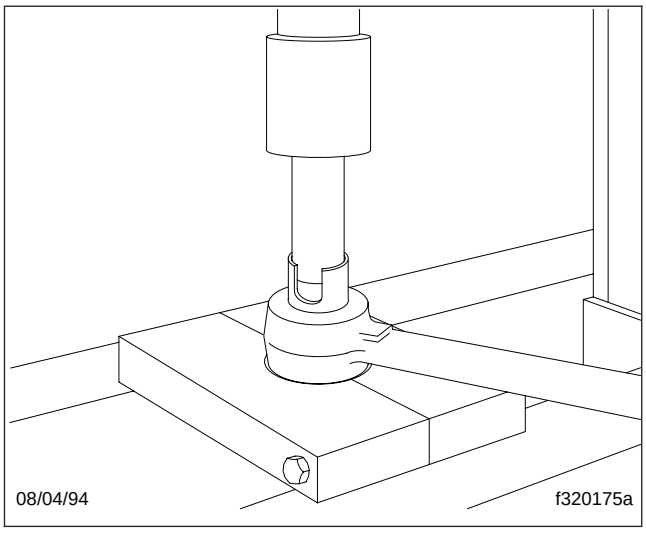


Fig. 4, Straddle Mount Pin Position

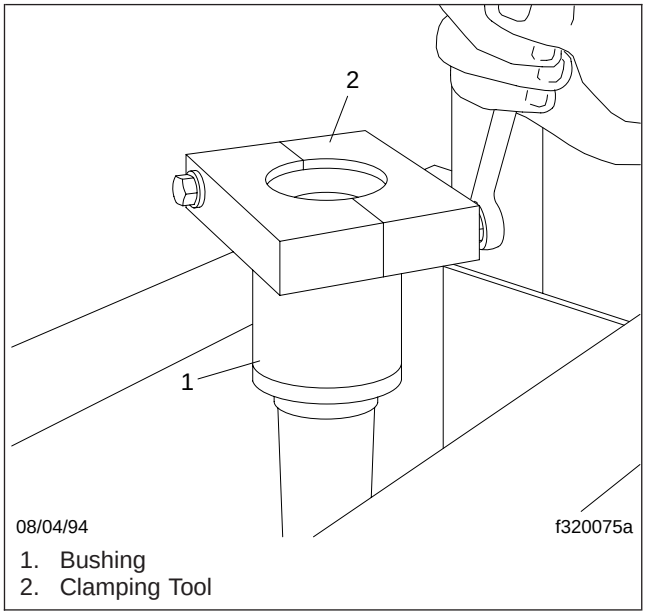


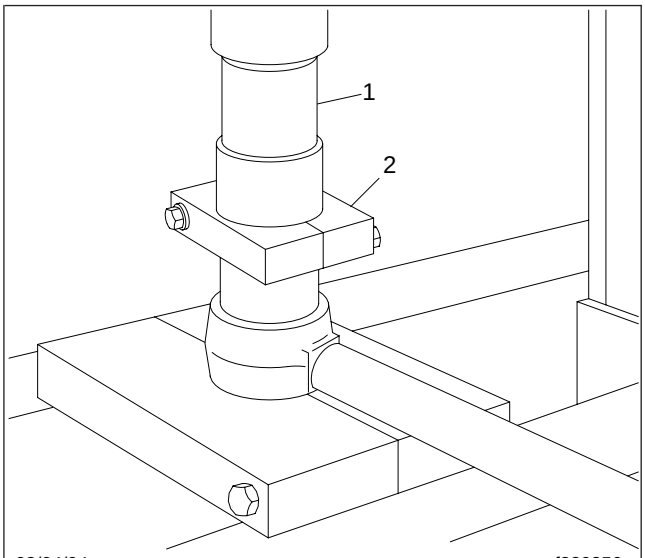
Fig. 5, Tighten Clamping Tool

10.4 Position the straddle mount pin of the forward torque rod in the mounting bracket. Insert bolts through the forward pin, both bracket assemblies, and the straddle mount pin of the rear torque rod. Install the nuts and bearing washers. Tighten the nuts 190 lbf·ft (260 N·m).

11. Install the transverse torque rods as follows (**Fig. 1**):

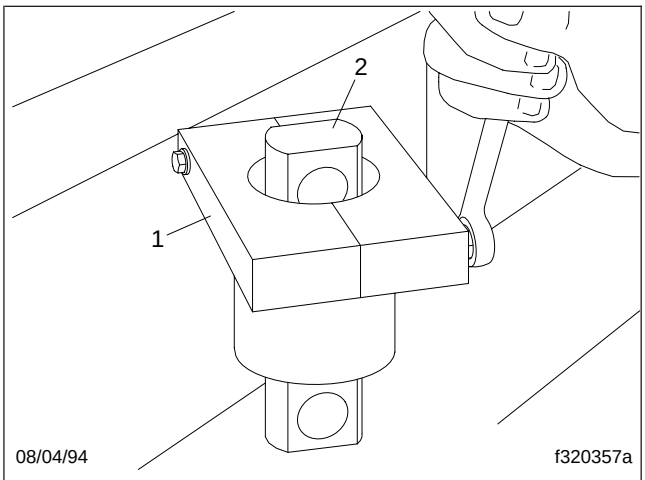
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Torque Rod Removal, Bushing Replacement, and Installation



1. Remover/Replacer Tool
2. Clamping Tool

Fig. 6, Remover/Replacer Tool Positioning



1. Clamping Tool
2. Pin

Fig. 7, Clamping Tool Alignment

11.1 Check that the tapered stud end and the tapered stud bracket hole are clean. Lubricate the tapered stud ends with SAE 20 oil.

11.2 Install the tapered stud in the axle bracket. Install a washer and nut. Tighten the nut 175 to 225 lbf·ft (235 to 300 N·m).

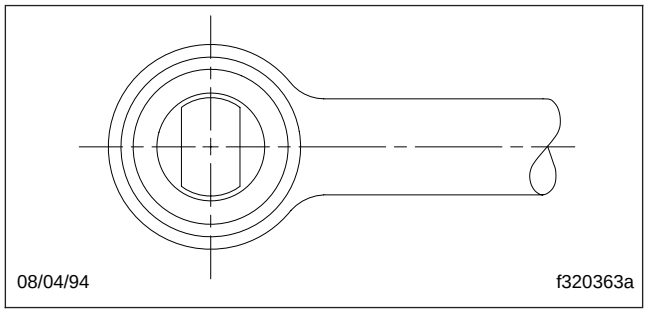


Fig. 8, Bushing Pin Alignment

11.3 Align the straddle mount end, the mounting bracket, and the spacer against the inside frame rail.

11.4 On the inboard side of the frame rail, install the bolts through the mounting assembly and the frame rail.

11.5 On the outboard side of the frame rail, install a spacer over the mounting bolt studs. Install the nuts and tighten them 190 lbf·ft (260 N·m).

12. Check the axle pinion angle. For instructions, see **Group 41**.

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IMPORTANT: Special tools are available from:

Owatonna Tool Company/SPX Corporation
655 Eisenhower Drive
Owatonna, MN 55060-0995
Cust./Tech. Service 800-533-6127

Special Tools (Owatonna Tool Company)		
Part Number	**Tool**	**Usage**
1761	Torque Rod Set	Torque Rod Bushing Removal and Installation
28536	Installing Adapter (5-3/4 in o.d.)	Bronze Center Bushing and Seal Removal and Installation
44119	Receiving Tube	Center and End Bushing Removal and Installation
51678	80-Ton Hydraulic Ram	All Operations
51695	Jack	All Operations
302018	Spacer (3 qty.)	Center and End Bushing Removal and Installation
302023	Pulling Screw	All Operations
302024	Removing and Installing Adapter	Bronze Center Bushing Removal and Installation
302026	Installing Adapter	Rubber Center Bushing Removal and Installation
302027	Removing Adapter	Rubber Center Bushing Removal and Installation
302028	Hexnut	All Operations
302029	Speed Nut	All Operations

Table 1, Special Tools (Owatonna Tool Company)

Shop-Made Adapters		
Tool Number	**Dimensions**	**Usage**
3	4-5/8 inch o.d. by 7 inch	Beam Center Bushing Removal and Installation

Table 2, Shop-Made Adapters

Torque Values		
Description	**Size**	**Torque lbf·ft (N·m)**
Top Pad to Spring Aligning Setscrew	—	100–150 (135–200)
Top Pad Nut	—	275–400 (375–542)
Spring Pin Locknut	1/2–13	45–63 (61–85)
Torque Rod Straddle Mount Nut	5/8–11	190 (260)
Torque Rod Stud Locknut	1-1/4–12	175–225 (235–305)
Saddle Cap Stud	7/8–14	55–65 (75–90)
Saddle Cap Locknut	7/8–14	225–275 (305–373)
Bar Pin Locknut	1–8	450–600 (610–813)
Spring Center Bolt	7/16–20	50–60 (70–80)
	1/2–20	65–75 (90–100)

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Specifications

Torque Values		
Description	**Size**	**Torque lbf·ft (N·m)**
Rebound Spacer Locknut	1/2–13	38–45 (51–61)
Spring Alignment Clip	—	15 (20)
Fore and Aft Torque Rod Mount Nut	—	95 (130)

Table 3, Torque Values

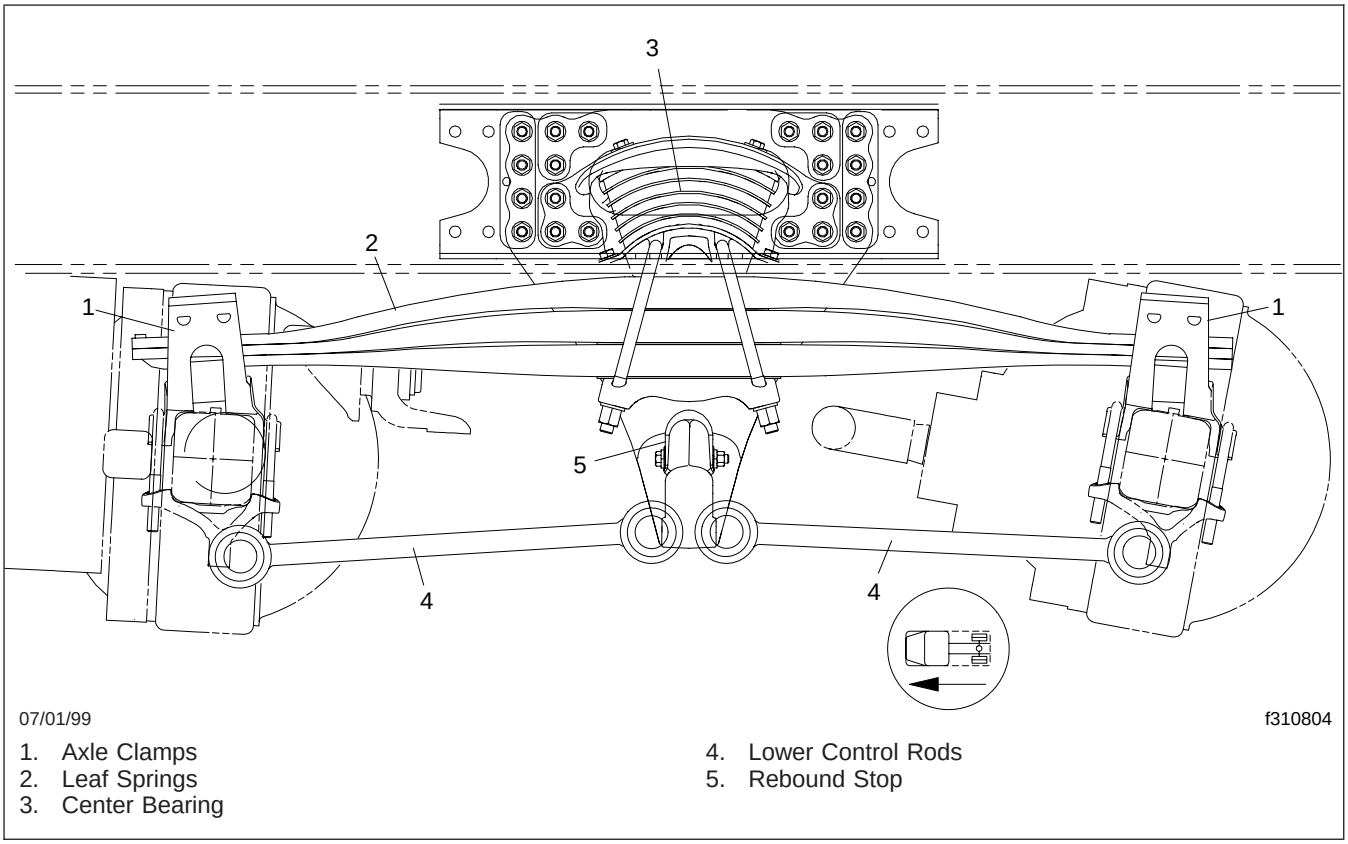
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General Information

The TufTrac™ suspension is a heavy-duty "six rod" tandem-axle suspension option for trucks built for severe on/off highway work. See **Fig. 1**. The TufTrac design allows a truck to maneuver over bumps, ridges and washboard roads that typically generate high rates of axle articulation, without bottoming out the suspension or losing traction.

The TufTrac suspension is available in three weight ratings: 40,000-, 46,000- and 52,000-pound (18 144-, 20 865-, and 23 586-kilogram) capacities. The 40,000-pound (18 144-kilogram) capacity suspension uses two taper leaf springs and has an axle spacing of 54 inches. The 46,000-pound (20 865-kilogram) capacity suspension has three leaf springs (shown in this section), while the 52,000-pound (23 586-kilogram) suspension features four leaf springs. Both the 46,000-pound (20 865-kilogram) and the 52,000-pound (23 586-kilogram) suspensions have a standard axle spacing of 56 inches.

Six functional links in the TufTrac suspension maintain the positions of the axles. Side-to-side axle movement is controlled by two V-rods from the frame to the axles at the top of the suspension. Four bar links from the frame to the axles at the bottom control the forces of driving and braking as well as fore-and-aft road shocks. Vertical loads are carried by the rubber-isolated parabolic taper leaf spring packs.



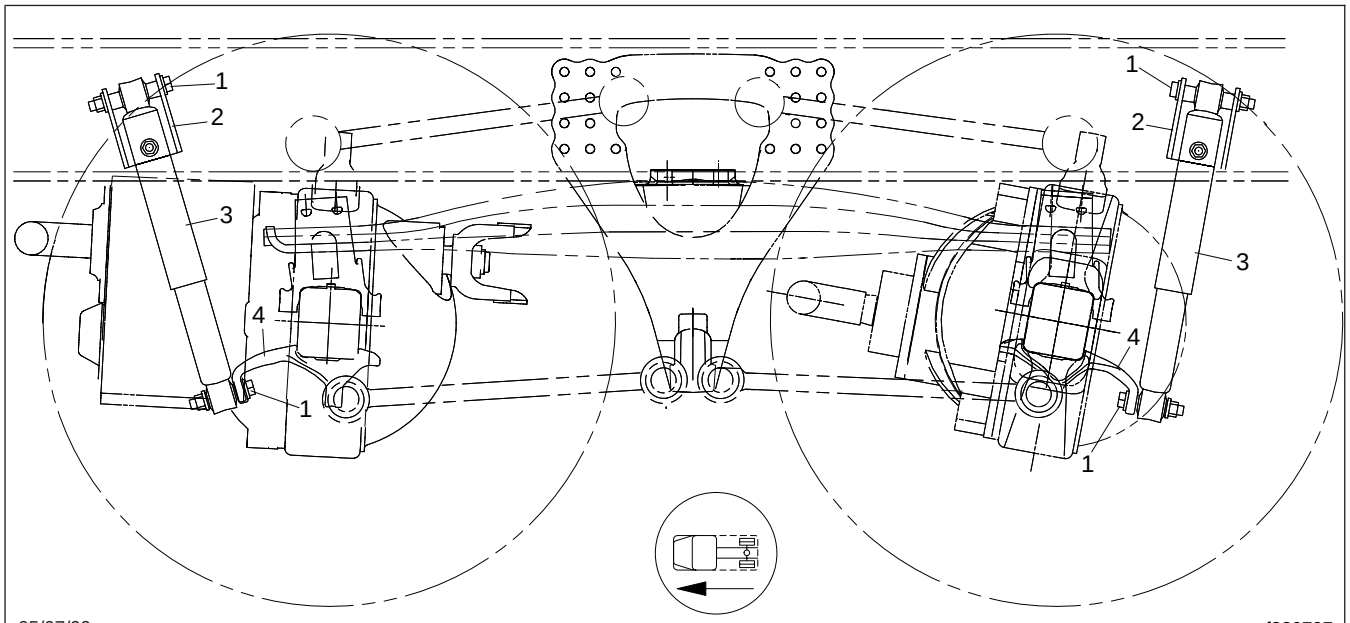
1. Axle Clamps
2. Leaf Springs
3. Center Bearing
4. Lower Control Rods
5. Rebound Stop

Fig. 1, TufTrac Suspension (46,000-lb [20 865-kg] version shown)

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Replacement (See Fig. 1)

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Remove the lower shock mounting nut and washer.
3. Remove the upper shock mounting nut and washer.
4. Remove the upper and lower mounting bolts and remove the shock absorber.
5. Position the new shock absorber in place and install the mounting bolts.
6. Loosely fasten the bolts with the nuts and washers removed from the old shock absorber.
7. Torque each mounting nut 241 lbf·ft (327 N·m).
8. Remove the chocks from the tires.



1. Mounting Bolt
2. Upper Mounting Bracket
3. Shock Absorber
4. Lower Mounting Bracket

Fig. 1, Shock Absorber Replacement

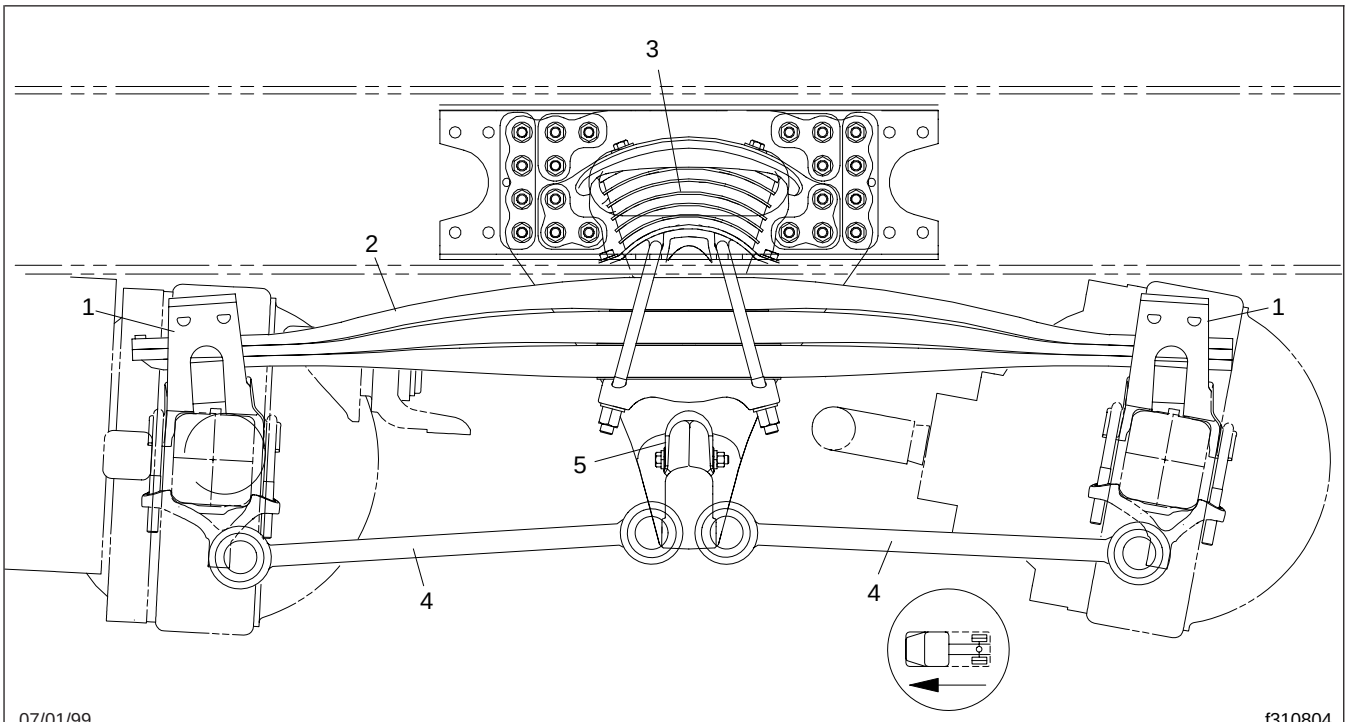
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Replacement

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Remove the rebound stop from the suspension. See **Fig. 1**.
   - 2.1 Remove the nut and bolt securing the rebound stop to the mounting bracket.
   - 2.2 Slide the rebound stop from the mounting bracket.
3. Remove the upper two fasteners on the center bearing.
4. Jack up the vehicle under the rear axle.
5. Support the rear frame rails with jack stands. Lower the jack. This will clear the center bearing from the top of the mounting bracket. See **Fig. 2**.
6. Remove the lower center bearing bolts attached to the spring assembly casting. Discard the bolts.
7. Remove the center bearing. See **Fig. 3**.
8. Position the new center bearing in the mounting bracket.
9. Install the upper mounting bolts and tighten 68 lbf·ft (92 N·m).
10. With the jack, raise the rear axle until the bottom of the center bearing meets the mounting bracket on the leaf springs.

IMPORTANT: Be sure to use new bolts with Loctite® when attaching the center bearing to the leaf spring casting.

11. Install new bolts (p/n 23-12576-125) for attaching the lower center bearing mounting plate to the spring assembly casting. Tighten the bolts 155 lbf·ft (210 N·m).

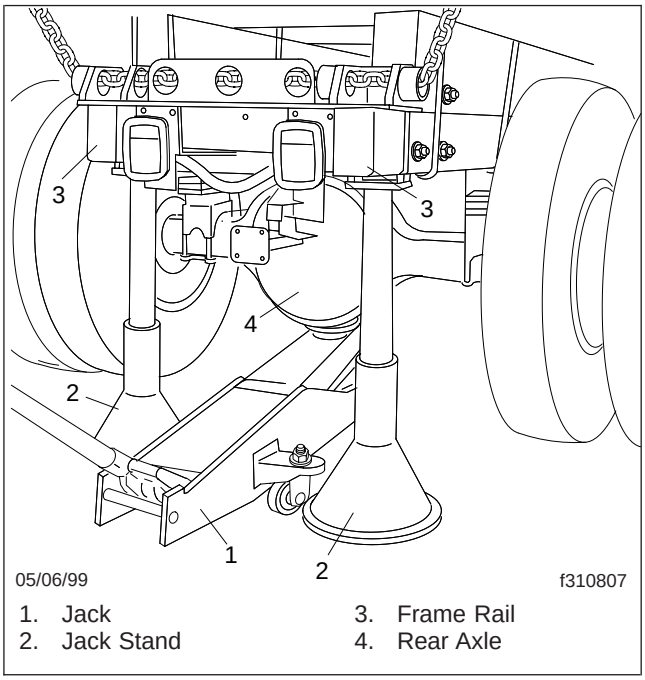


1. Axle Clamps
2. Leaf Springs
3. Center Bearing
4. Lower Control Rods
5. Rebound Stop

Fig. 1, TufTrac Suspension (46,000-lb [20 865-kg] version shown)

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Center Bearing Replacement



1. Jack
2. Jack Stand
3. Frame Rail
4. Rear Axle

Fig. 2, Jack and Jack Stand Placement

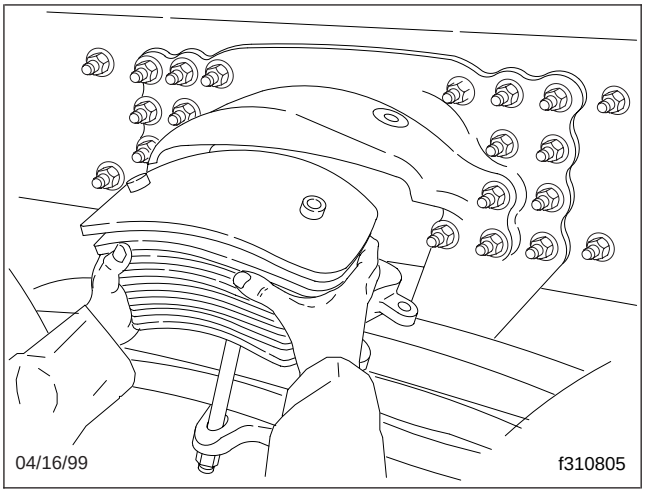


Fig. 3, Center Bearing Removal

12. Return the vehicle to its normal operating position.
13. Install the rebound stop.
14. Remove the chocks from the tires.

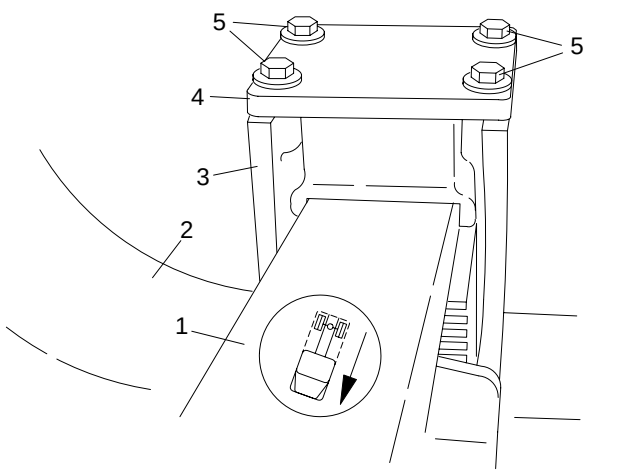
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Spring Assembly Removal, Assembly and Installation

IMPORTANT: The spring pack assembly is not available as an assembled unit in the aftermarket. If the spring pack assembly is to be replaced with a new assembly, the springs, center bearing seat and retainer bracket must be assembled before installation on the vehicle.

Removal

1. Park the vehicle on a level surface. Shut down the engine and apply the parking brakes. Chock the tires.
2. Remove the tip pad bolts above each axle on the axle clamp. There are four bolts on each pad. See **Fig. 1**.



1. Leaf Springs
2. Axle
3. Axle Pad
4. Tip Pad
5. Tip Pad Bolts

Fig. 1, Tip Pad Installation

3. Remove the center bearing. See **Subject 110**.
4. With the vehicle still raised, remove the wheels on both rear axles on the side the spring assembly will be replaced. For instructions, see **Group 40**.

⚠ WARNING

Do not attempt to remove the spring assembly by hand. The assembly is very heavy and attempting to lift it could result in bodily injury.

5. Using a lift (i.e. engine hoist), remove the leaf spring assembly from the vehicle. See **Fig. 2**.

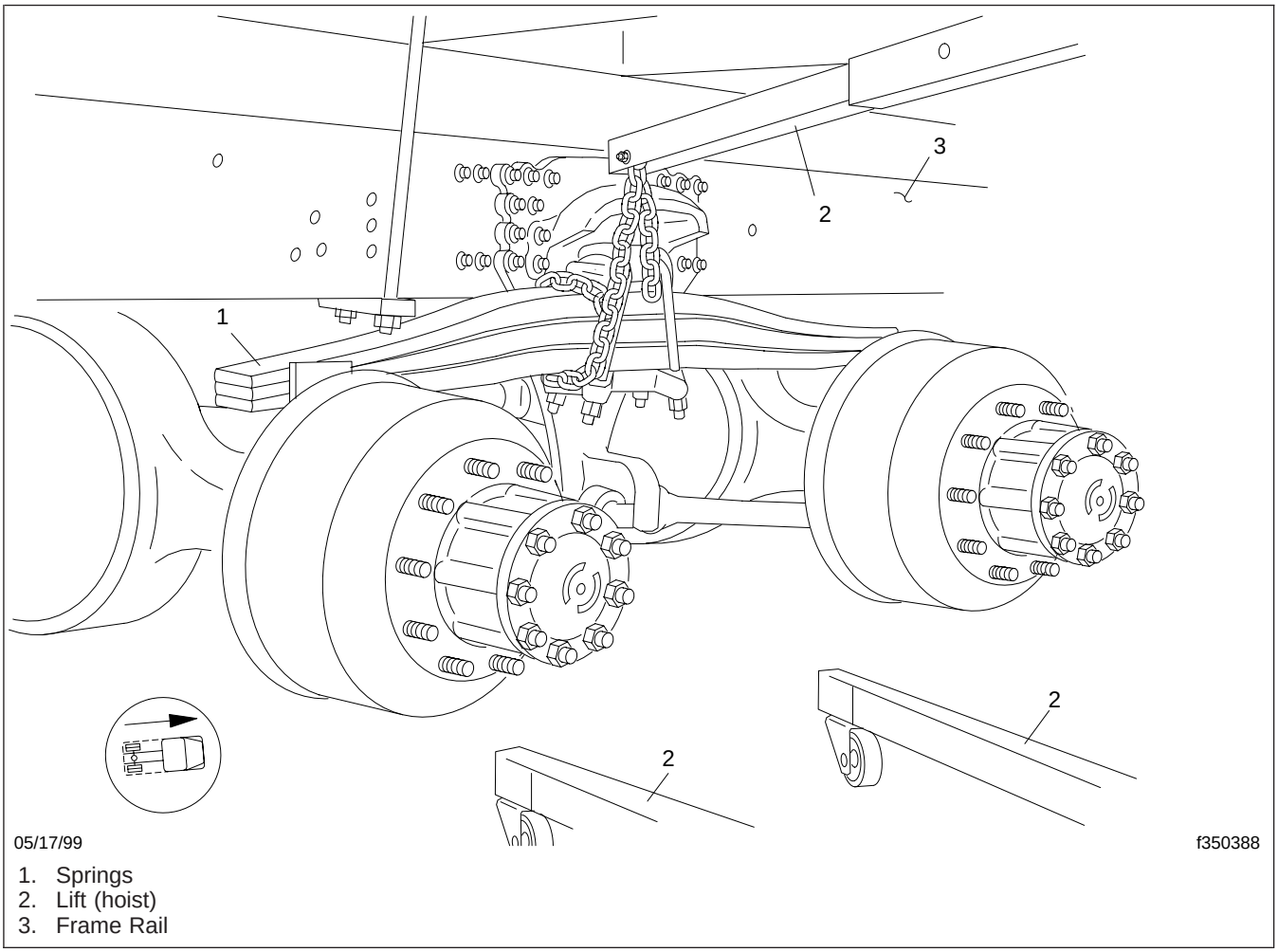
Assembly

IMPORTANT: Leaf springs in a spring pack assembly cannot be replaced individually. The entire spring pack assembly must be replaced.

1. Support both sides of the new spring pack assembly on jack stands. Make sure all the leaf springs are interlocking with the studs and dimples at the centers of the leaf springs.
2. If the assembly contains a spacer, place it on the center of the top leaf spring. Make sure the dimple in the spacer is aligned with the stud in the center of the top leaf spring.
3. Place the center bearing seat on the top of the spacer or leaf spring, as applicable. Make sure the dimple in the middle of the center bearing seat aligns with the stud in the middle of the leaf spring or the spacer.
4. Install the two 3/4-inch U-bolts over the center bearing seat. Make sure the U-bolts rest in the grooves of the center bearing seat.
5. At the bottom of the spring pack, install the U-bolt retainer bracket over the threaded ends of the U-bolts.
6. Holding the retainer bracket in place, install a hardened washer and hexnut over the threaded end of each U-bolt.
7. Tighten the U-bolts in a diagonal sequence as follows:
   - Stage 1: 60 lbf·ft (81 N·m)
   - Stage 2: 200 lbf·ft (271 N·m)
   - Stage 3: 300 lbf·ft (407 N·m)

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Spring Assembly Removal, Assembly and Installation



1. Springs
2. Lift (hoist)
3. Frame Rail

Fig. 2, Leaf Spring Replacement

Installation

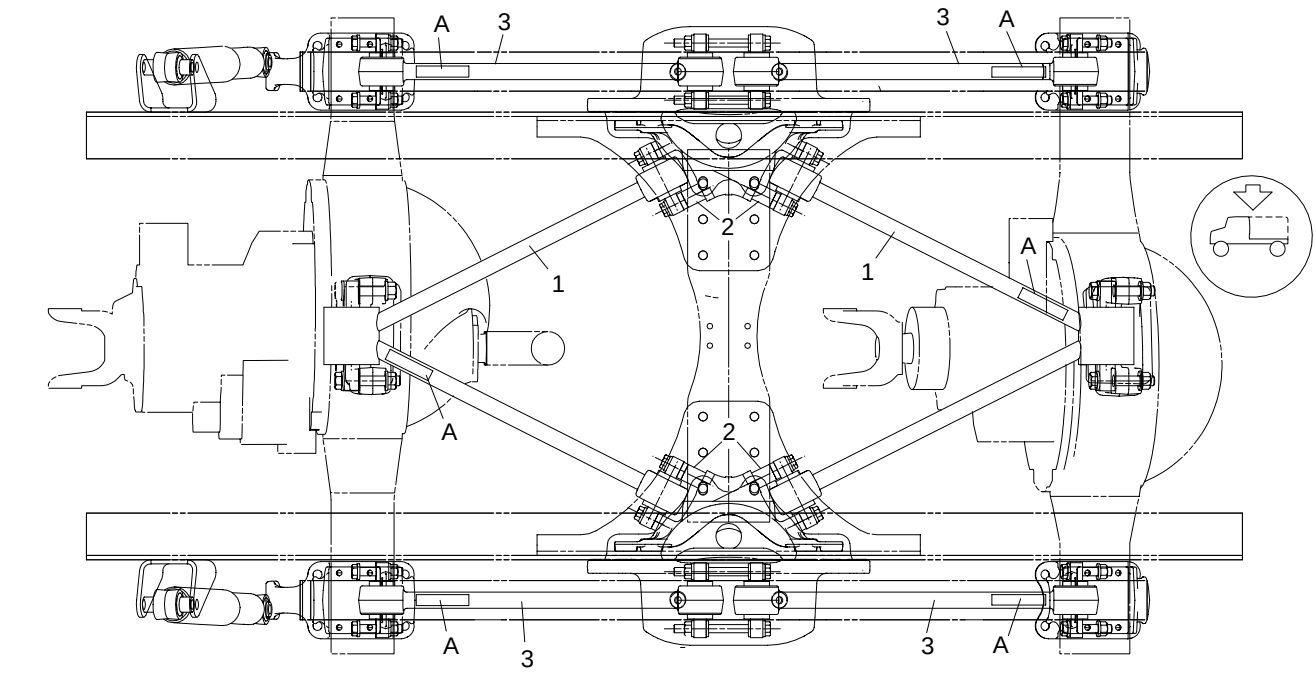
⚠ WARNING

Do not attempt to install the spring assembly by hand. The assembly is very heavy and attempting to lift it could result in bodily injury.

1. Place the new spring assembly on the vehicle.
   - 1.1 Attach the new assembly to the lift.
   - 1.2 Using the lift (hoist), lift the assembly into place on the axle clamps.
2. Install the center bearing. For instructions, see **Subject 110**.
3. Install the tip pad and bolts on each axle clamp. Tighten the bolts 37 lbf·ft (50 N·m). See **Fig. 1**.
4. If not already installed, install the rebound stop and mounting bolt. Tighten the nut 68 lbf·ft (92 N·m).
5. Install the wheels. For instructions, see **Group 40**.
6. Return the vehicle to its normal operating position.
7. Remove the chocks from the tires.

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Lower Control Rod Replacement (See Fig. 1)



A. Label
1. V-Rod
2. Spacer
3. Lower Control Rod

Fig. 1, Control and V-Rod Replacement

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the front tires.
2. Raise the rear axle and support the frame rails with jack stands.
3. Lower the jack under the axle. See **Fig. 2**.
4. Remove the bolts holding both rods between the rear axles, below the rebound stop. See **Fig. 3**.
5. Remove the nut and bolt from the axle clamp.
6. Remove the control rod from the vehicle.

IMPORTANT: When installing the rods make sure the labels on the rods are facing upward. Forward axle rods are marked "FDA" and rear axle rods are marked "RDA."

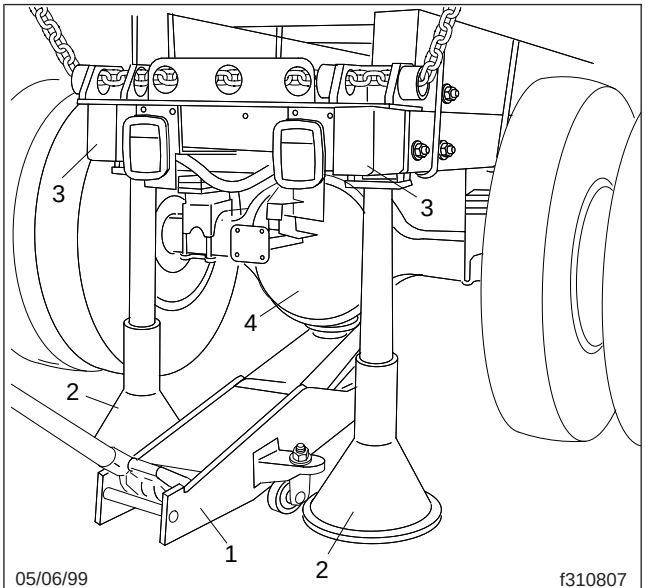
7. Fasten the new control rod to the axle clamp. Tighten the nut 136 lbf·ft (184 N·m).
8. Fasten the other end of the rod to the bracket below the rebound stop. Tighten the nut 136 lbf·ft (184 N·m).
9. Return the vehicle to the normal operating position.

V-Rod Replacement

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Raise the rear axle and support the frame rails with jack stands.
3. Lower the jack under the axle. See **Fig. 2**.

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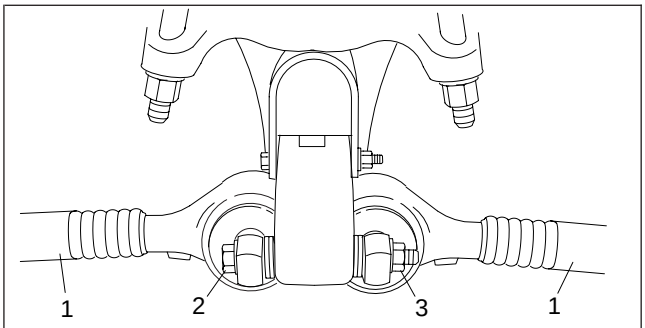
Lower Control Rod and V-Rod Replacement



05/06/99 f310807

1. Jack
2. Jack Stand
3. Frame Rail
4. Rear Axle

Fig. 2, Jack and Jack Stand Placement



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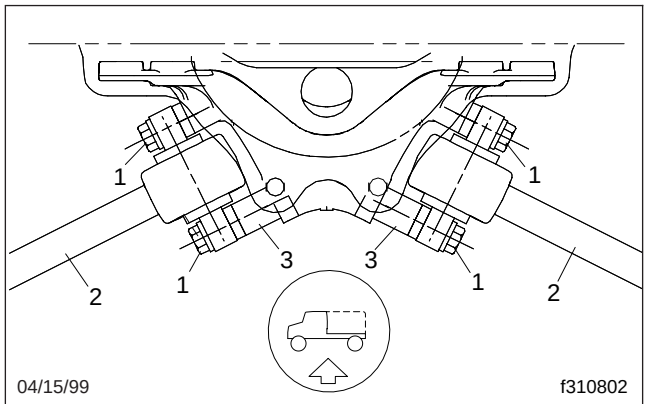
1. Lower Control Rod
2. Mounting Bolt
3. Mounting Nut

Fig. 3, Lower Control Rods

4. Remove all six mounting bolts securing the V-rod to the chassis and axle.
5. Remove the V-rod from the chassis.

IMPORTANT: When installing the rods make sure the labels on the rods are facing upward. Forward axle rods are marked "FDA" and rear axle rods are marked "RDA."

6. Install the V-rod. See **Fig. 4**.



04/15/99 f310802

1. Mounting Bolt
2. V-Rod
3. Spacer

Fig. 4, V-Rod Replacement

6.1 Place the new rod in position between the frame rails.

6.2 Install the bolts and spacers and loosely tighten all connections.

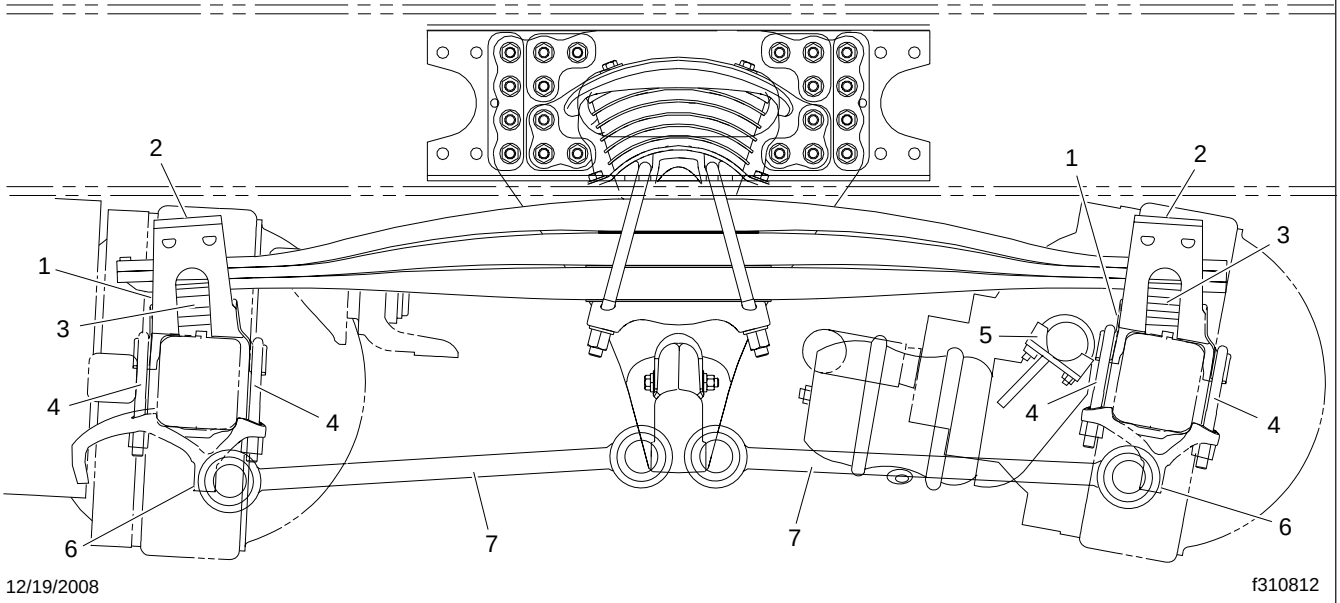
6.3 After all fasteners and spacers are installed, torque the bolts:

- At the frame bracket 136 lbf·ft (184 N·m);
- At the axle bracket 427 lbf·ft (579 N·m).

7. Return the vehicle to normal operating position.
8. Remove the chocks from the tires.

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Replacement (See Fig. 1)



1. Upper Axle Clamp
2. Upper Spring Tip Pad
3. Lower Spring Tip Pad
4. U-Bolt
5. Brake Cam Tube Support Bracket
6. Lower Axle Retainer
7. Lower Control Rods

Fig. 1, TufTrac Suspension (left-side view)

1. Park the vehicle on a level surface, shut down the engine and chock the tires.
2. Remove the two upper spring tip pads and bolts from the left suspension spring.
3. Disconnect the shock absorbers from the lower axle retainer on the left suspension spring.
   - 3.1 Remove the lower shock mounting nuts and washers.
   - 3.2 Remove the lower shock absorber mounting bolts.
4. Disconnect the two lower torque control rods from the lower axle retainers on the left side of the vehicle.
5. Loosen and remove the U-bolt nuts and washers, and discard.
6. Remove the brake cam tube support bracket from the left rear axle.
7. Remove the lower axle retainers from the left forward and left rear drive axles, and discard.
8. Remove the axle U-bolts from the left forward drive axle and the left rear drive axle, and discard.
9. Jack up the center of the left suspension spring (at the center bearing, between the tandem [Fig. 2]) and support with the jack stands at the frame. Make sure that all of the weight has been relieved from the axle clamp group and that there is sufficient clearance to remove the upper axle clamp.
10. Remove the lower spring tip pads from the left forward and left rear drive axles.
11. Remove the upper axle clamps from the left forward and left rear drive axles. Discard the clamps.
12. Install the new upper axle clamps from the applicable warranty kit to the left forward and left rear

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Axle Clamp and Retainer Replacement

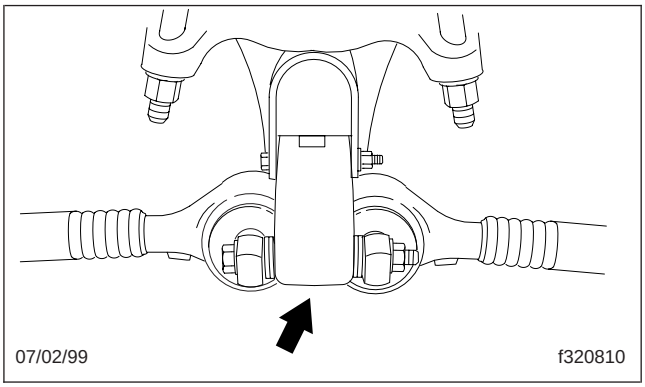


Fig. 2, Jack the Vehicle Here

drive axles. Locate the dowel pin through the hole in the bottom of each axle clamp to confirm proper alignment

NOTE: Confirm that you are installing the correct upper axle clamps before continuing. You are able to visually identify the new upper axle clamp because the step has been removed from the area directly above the U-bolt saddles. See **Fig. 3**.

13. Install the lower spring tip pads into the left front and rear axle clamps.
14. Jack up the left suspension spring, remove the jack stands, and lower the suspension spring. Ensure while the spring is being lowered that it is seated correctly onto the lower spring tip pads.
15. Install the new lower axle retainers onto the left forward and rear drive axles.
16. Install the brake cam tube support bracket onto the left rear axle.
17. Install the U-bolts on the left forward and rear drive axles.

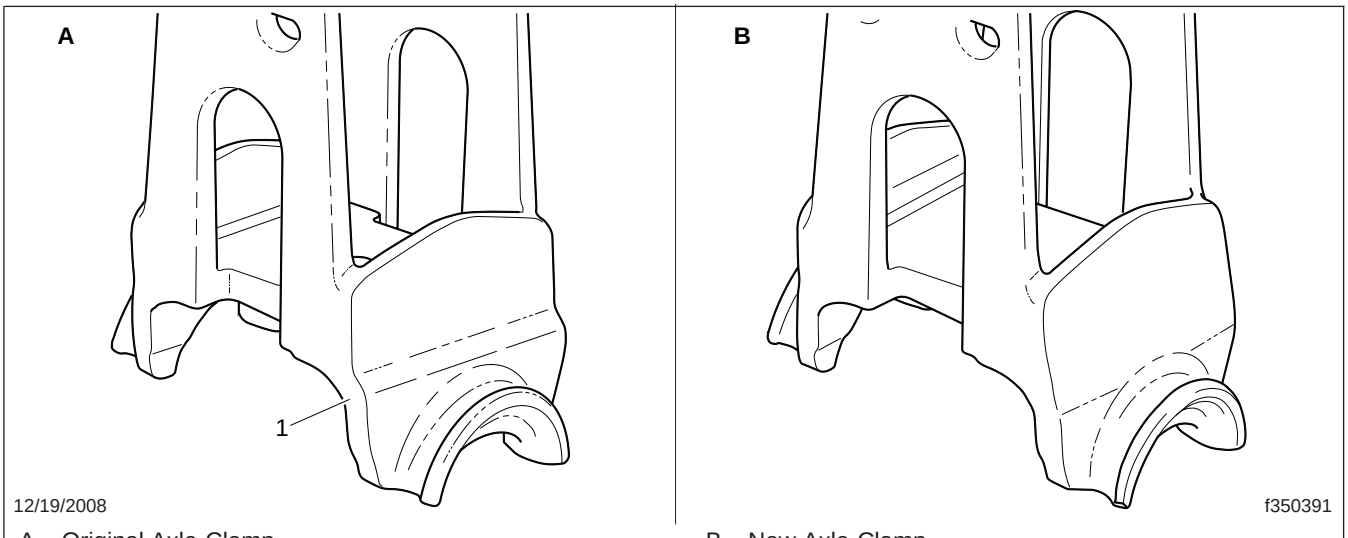
    IMPORTANT: Install two washers for each U-bolt nut.

    17.1 Install each U-bolt over the U-bolt saddle in the upper axle clamp and through the holes in the lower axle retainer.

    17.2 Install the washers and finger-tighten the nuts in the order shown in **Fig. 4**.

    Make sure all brackets are snug against the axle housing before proceeding to the next step.

    IMPORTANT: U-bolt nuts must be tightened in the order shown in **Fig. 4**.

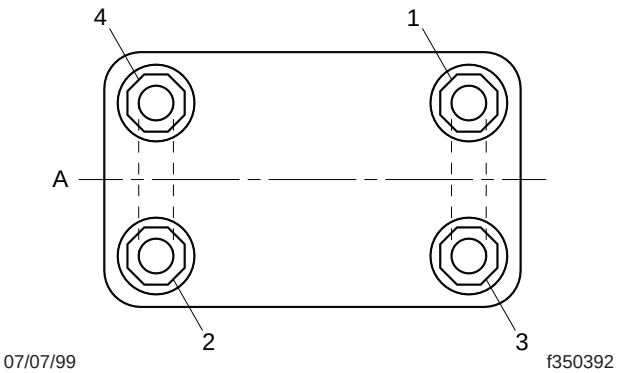


A. Original Axle Clamp
1. Step in U-Bolt Saddle
B. New Axle Clamp

Fig. 3, Upper Axle Clamps

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17.3 Tighten the nuts 60 lbf·ft (81 N·m) and then to 200 lbf·ft (271 N·m) in two separate rotations following the order shown in **Fig. 4**.



A. Center Line of Spring

1. Tighten First
2. Tighten Second
3. Tighten Third
4. Tighten Fourth

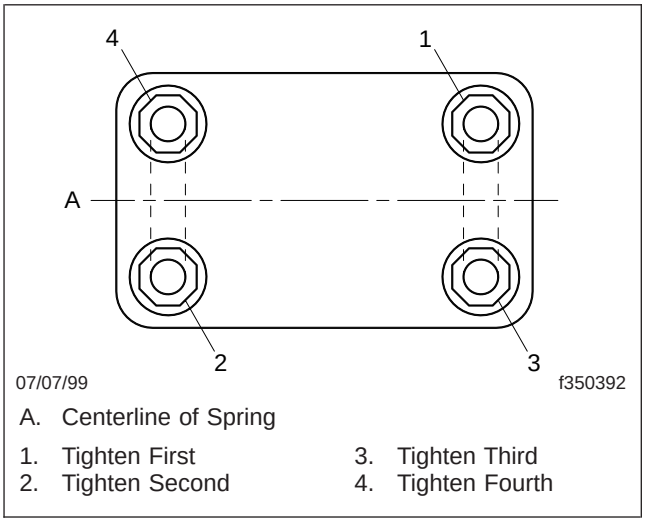
Fig. 4, U-Bolt Nut Tightening Sequence

18. Install the lower torque control rods to the lower axle retainers on the left side of the vehicle and tighten 136 lbf·ft (184 N·m).
19. Install the shock absorbers to the lower axle retainers.
    - 19.1 Install the lower shock mounting bolts.
    - 19.2 Install the lower shock absorber mounting washers and nuts and tighten by hand.
    - 19.3 Tighten the lower shock absorber mounting nuts to 241 lbf·ft (327 N·m).
20. Install the spring tip pads to the left suspension spring.
    - 20.1 Install the spring tip pads to the upper axle clamps.
    - 20.2 Install the bolts to secure each upper spring tip pad and tighten 37 lbf·ft (50 N·m).
21. Repeat the above steps for the right suspension spring.
22. Remove the chocks from the tires.

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Torque Specifications	
Description	**Torque Value lbf·ft (N·m)**
Shock Absorber Mounting Bolt	241 (327)
Center Bearing Upper Mounting Bolts	68 (92)
Center Bearing Lower Mounting Bolts	155 (210)
Tip Pad Bolts	37 (50)
Rebound Stop Mounting Bolt	68 (92)
Lower Control Rod Mounting Bolts	136 (184)
V-Rod Frame Bracket Mounting Bolts	136 (184)
V-Rod Axle Bracket Mounting Bolts	427 (579)
5/8–18 Axle Clamp U-Bolt Nuts (Tighten as shown in **Fig. 1**.)	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271)
3/4-Inch Spring Pack U-Bolt Nuts	Stage 1: 60 (81) Stage 2: 200 (271) Stage 3: 300 (407)

Table 1, Torque Specifications



A. Centerline of Spring

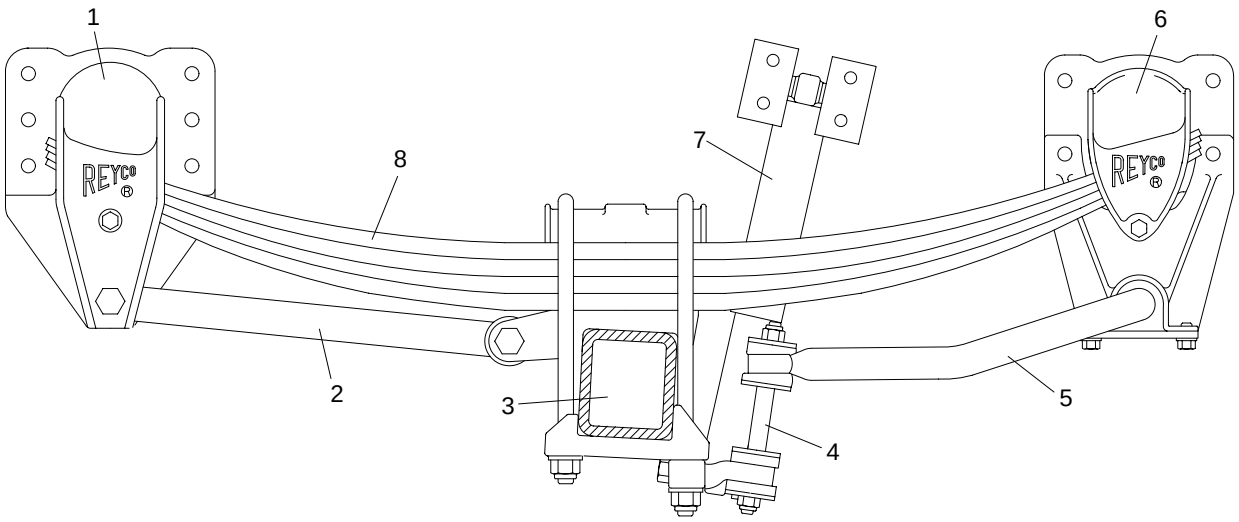
1. Tighten First
2. Tighten Second
3. Tighten Third
4. Tighten Fourth

Fig. 1, U-Bolt Nut Tightening Sequence

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General Information (See Fig. 1)

The Reyco 79KB suspension uses a full-floating spring design. Semi-elliptical spring assemblies, or optional parabolic springs, are attached to the axles with U-bolt assemblies. The spring ends ride in hangers that are mounted on the frame rails. Adjustable torque rods are attached to the forward spring hanger and axle seat to hold the axle in alignment.



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1. Forward Spring Hanger
2. Torque Rod
3. Axle
4. Anti-Sway Bar End-Link (optional)
5. Anti-Sway Bar (optional)
6. Rear Spring Hanger
7. Shock Absorber
8. Leaf Spring

Fig. 1, Reyco 79KB Suspension

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Torque Rod Removal and Installation

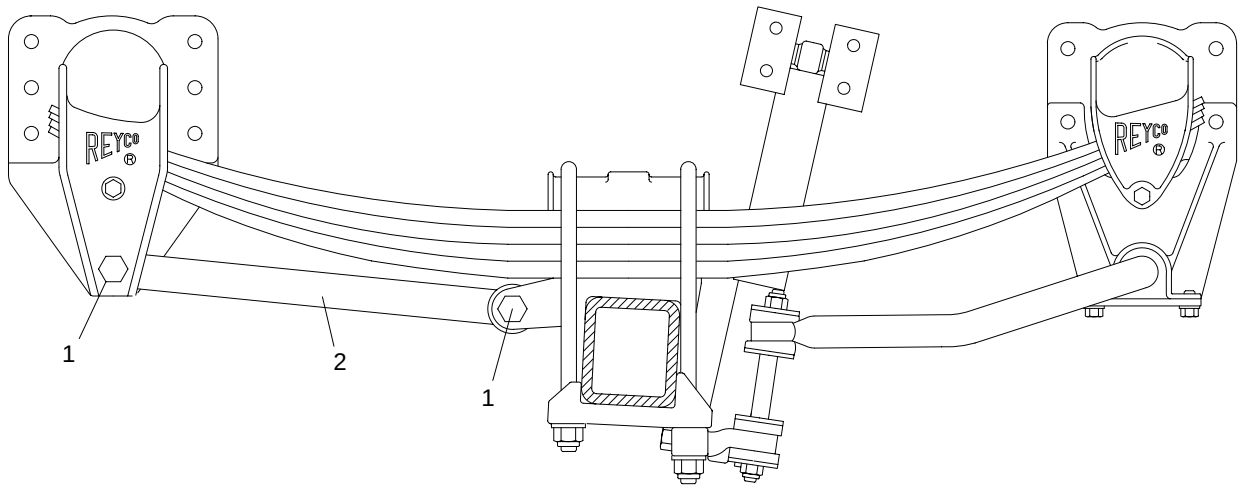
Removal

There are two torque rods installed on the Reyco 79KB suspension. The right-side torque rod is not adjustable (rigid). The left-side torque rod is adjustable to allow proper axle alignment.

1. Park the vehicle on a level surface. Shut down the engine.
2. Apply the parking brakes and chock the front tires.
3. Use a lifting device and raise the rear of the tractor until the rear tires are elevated above the ground. Place jack stands under the frame rails to unload the suspension, and lower the lifting device until only the jack stands are supporting the vehicle weight.
4. Place the lifting device under the axle and raise the axle to unload the torque rod. Place jack stands under the axle.
5. Remove the two torque rod bolts and nuts, and remove the torque rod. See **Fig. 1**.

Installation

1. Place the torque rod on the forward frame hangar and install a torque rod bolt to hold it in place. See **Fig. 1**.
2. Raise the opposite end of the torque rod on the lower axle mounting plate.
3. Install a bolt on the torque rod
4. Tighten the torque rod locknuts 400 to 450 lbf·ft (540 to 610 N·m).
5. Raise the axle and remove the jack stands. Lower the axle to the ground.
6. Raise the rear of the vehicle and remove the jack stands. Lower the vehicle to the ground.
7. Remove the chocks from the tires.
8. Check the axle alignment. For instructions, see **Group 35**. If necessary, adjust the rear axle alignment, using the instructions in **Subject 130**.



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1. Torque Rod Bolt
2. Torque Rod

Fig. 1, Reyco 79KB Torque Rod

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Spring Assembly Replacement

Removal (See Fig. 1)

⚠ WARNING

Do not replace individual leaves of a damaged leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

1. Park the vehicle on a level surface. Shut down the engine. Apply the parking brakes and chock the front tires.
2. Raise the frame so that all weight is removed from the leaf springs. Support the frame with safety stands.
3. Raise the rear axle until the spring no longer contacts the spring retainer rollers. Support the axle with safety stands. Make sure the stands will securely support the weight of the axles and frame.
4. Remove the wheel assembly. See **Group 40** for instructions.
5. Remove the U-bolt high nuts and washers. Remove the axle clamp. Remove the U-bolts and the U-bolt pad.
6. Remove the spring retaining bolts, spring rollers and nuts.
7. Use a pry tool to lift the leaf spring assembly off of the spring seat.

⚠ WARNING

Leaf spring assemblies weigh approximately 100 to 190 lbs (45 to 86 kg). Do not attempt to remove a leaf spring assembly without assistance. Personal injury and property damage may result.

8. With assistance, carefully move the leaf spring assembly forward to clear the rear hanger. Raise the rear of the leaf spring assembly and move it rearward to clear the front hanger. Remove the leaf spring from the vehicle.

Installation

⚠ WARNING

Leaf spring assemblies weigh approximately 100 to 190 lbs (45 to 86 kg). Do not attempt to install a leaf spring assembly without assistance. Personal injury and property damage may result.

1. With assistance, position the leaf spring assembly on the axle.
2. Place the front of the leaf spring assembly through the hanger. Place the rear of the leaf spring assembly through the rear hanger.

NOTE: There is a projection at the center of the leaf spring assembly to locate the spring.

3. Install the projection at the center of the leaf spring assembly on the spring seat.
4. Install the U-bolt pad on the leaf spring assembly.
5. Install the U-bolts over the U-bolt pad and axle tube. Insert the U-bolts through the axle clamp. Install the U-bolt washers and high nuts. Tighten the U-bolt high nuts as described in **Specifications, 400**.
6. Install the spring retainer bolts, rollers and locknuts. Tighten the spring retaining bolt locknuts 60 to 80 lbf·ft (85 to 110 N·m).
7. Move the torque rod into position with the spring seat.
8. Install the torque rod mounting bolt and locknut. Tighten the locknut 350 to 400 lbf·ft (475 to 545 N·m).
9. Install the wheel assembly. See **Group 40** for instructions.
10. Raise the axle assembly, remove the safety stands and lower the axle to the ground.
11. Raise the frame, remove the safety stands and lower the frame.
12. Remove the chocks from the tires.

⚠ CAUTION

Failure to periodically torque the suspension fasteners can result in abnormal tire wear, and

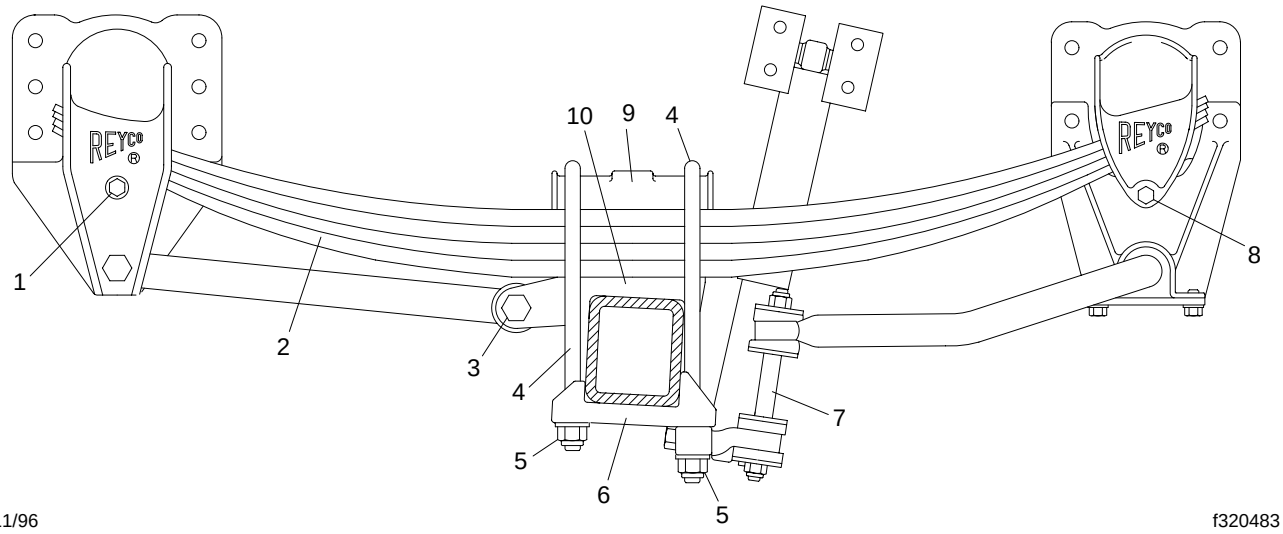
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Spring Assembly Replacement

damage to the springs, spring brackets, and frame rail.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 of the *Acterra Maintenance Manual*.

13. Check the axle alignment. For instructions, see **Group 35** in this manual. If necessary, adjust the rear axle alignment, using the instructions in **Subject 130**.



1. Forward Hanger Spring Retainer Bolt
2. Leaf Spring
3. Torque Rod Bolt
4. U-Bolt
5. U-Bolt High Nut
6. Axle Clamp
7. Anti-Sway Bar End Link (optional)
8. Rear Hanger Spring Retainer Bolt
9. U-Bolt Pad
10. Spring Seat

Fig. 1, Reyco 79KB Leaf Spring Replacement

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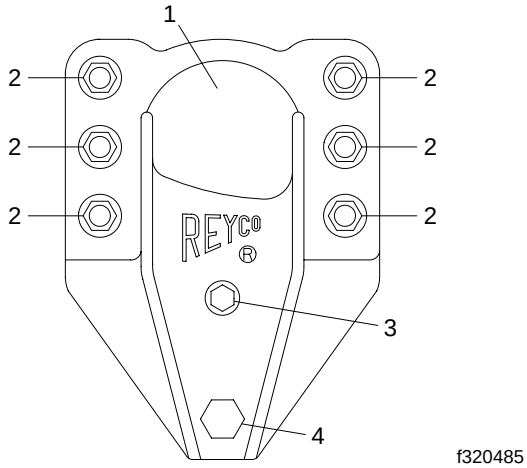
Spring Hanger Replacement

Removal

⚠ WARNING

Replace worn, cracked, or damaged spring hangers. Failure to do so could result in bracket breakage, possibly leading to loss of vehicle control and resulting in personal injury or property damage.

1. Park the vehicle on a level surface. Apply the spring or driveline brakes, and chock the front tires.
2. Place a lifting device under the vehicle frame. Lift the frame until the leaf spring assemblies are no longer in contact with the hangers, and support the frame with safety stands.
3. Remove the torque rod mounting bolt located on the forward hanger. See **Fig. 1**.

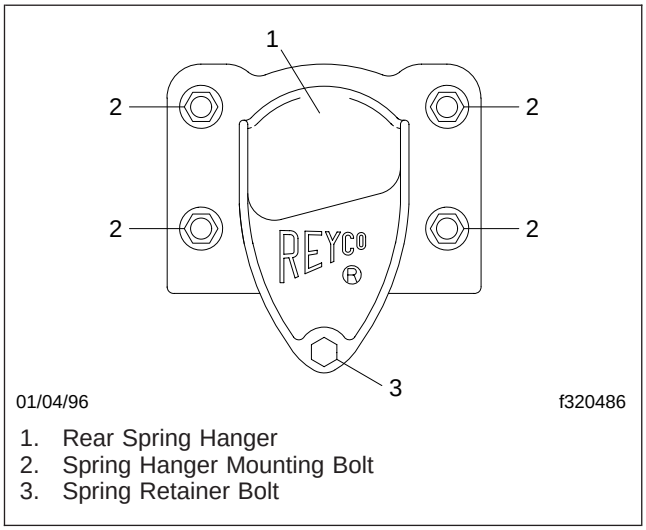


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1. Forward Spring Hanger
2. Forward Spring Hanger Mounting Bolt
3. Spring Retainer Bolt
4. Torque Rod Bolt

Fig. 1, Reyco 79KB Forward Spring Hanger

4. Remove the spring retainer bolt from the forward hanger. See **Fig. 1**.
5. Remove the six hanger mounting bolts and nuts. See **Fig. 1**.
6. Remove the forward hanger from the frame rail.
7. Remove the spring retainer bolt from the rear hanger. See **Fig. 2**.



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1. Rear Spring Hanger
2. Spring Hanger Mounting Bolt
3. Spring Retainer Bolt

Fig. 2, Reyco 79KB Rear Spring Hanger

8. Remove the anti-sway bar end links, if equipped. See **Fig. 3**.
9. Remove the lower spring hanger mounting bolts (**Fig. 2**) and remove the anti-sway bar mounting bracket, if equipped. See **Fig. 3**.
10. Remove the upper spring hanger mounting bolts and remove the rear hanger. See **Fig. 2**.

⚠ CAUTION

Failure to torque the suspension fasteners periodically can result in abnormal tire wear, and damage to the springs, spring brackets, and frame rail.

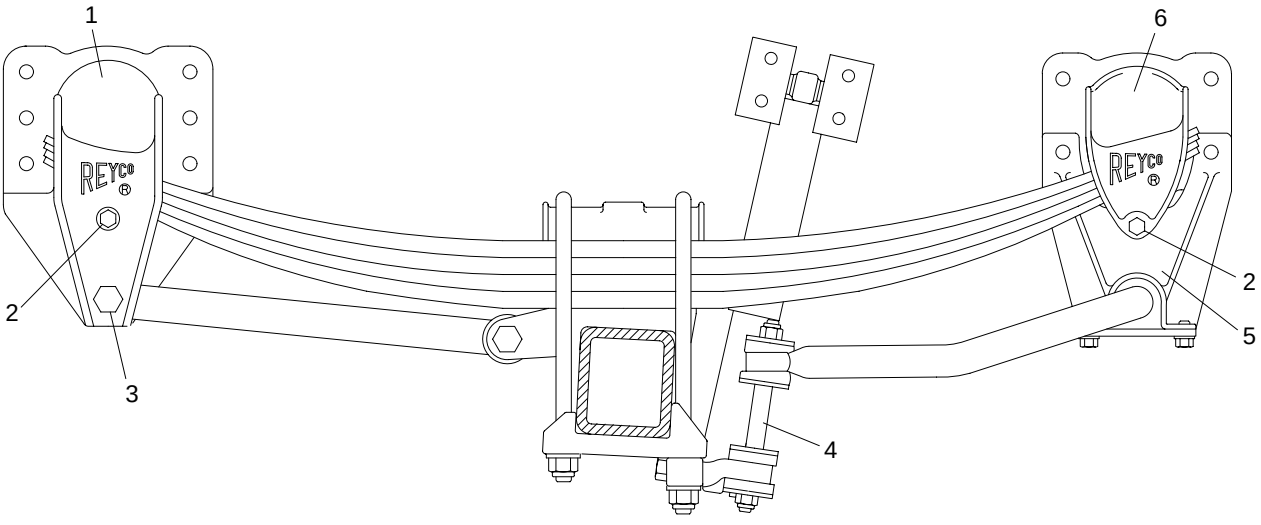
IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 of the *Acterra Maintenance Manual*.

Installation

1. Install the rear spring hanger on the frame rail, then install the two upper mounting bolts.
2. If equipped, position the anti-sway bar mounting bracket over the lower bolt holes on the rear hanger, and install the two lower mounting bolts.
3. Tighten the rear spring hanger mounting bolts 190 lbf·ft (258 N·m).

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Spring Hanger Replacement



1. Forward Spring Hanger
2. Spring Retainer Bolt
3. Torque Rod Bolt
4. Anti-Sway Bar End Link (optional)
5. Anti-Sway Bar Mounting Bracket (optional)
6. Rear Spring Hanger

Fig. 3, Reyco 79KB Frame Hangar Components for Removal

4. Install the anti-sway bar end link and bushings, if equipped. Tighten the end link capscrew. See **Group 00** for torque specifications.
5. Install the spring retainer bolt, roller, and nut. Tighten the spring retainer bolt 60 to 80 lbf·ft (85 to 110 N·m).
6. Install the forward spring hanger on the frame rail, then install the mounting bolts. Tighten the mounting bolts 190 lbf·ft (258 N·m).
7. Install the torque rod mounting bolt. Tighten the torque rod mounting bolt 350 to 400 lbf·ft (475 to 545 N·m).
8. Install the spring retainer bolt, roller, and nut. Tighten the spring retainer bolt 60 to 80 lbf·ft (85 to 110 N·m).
9. Raise the vehicle frame with a lifting device, and remove the safety stands. Lower the vehicle to the ground.
10. Remove the wheel chocks.

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Adjustment

CAUTION

Failure to periodically torque the suspension fasteners can result in abnormal tire wear, and damage to the springs, spring brackets and frame rail.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see Group 32 of the *Acterra Maintenance Manual*.

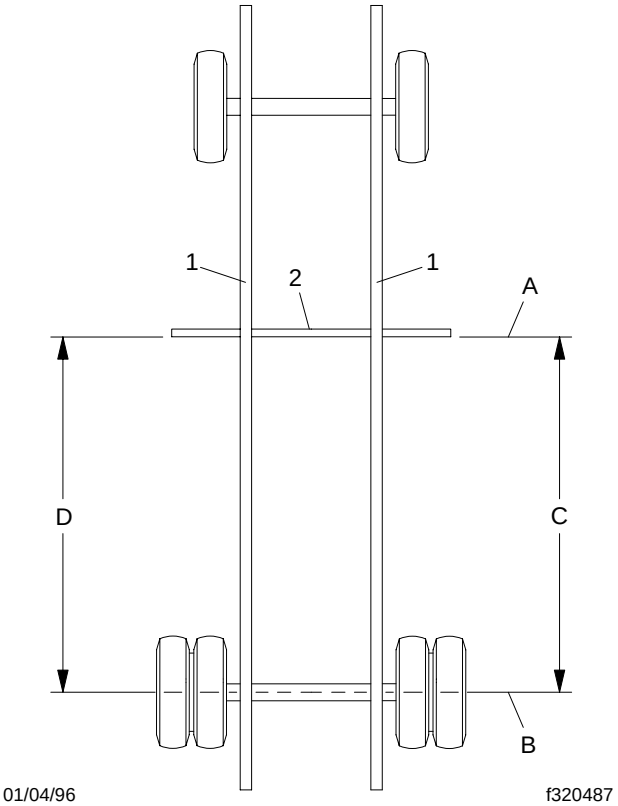
1. Park the vehicle on a level surface. Move the vehicle slowly back and forth several times without using the brakes to free all of the suspension joints. Shut down the engine. Do not apply the spring, or driveline brakes.
2. Chock the front tires.

NOTE: Check that the leaf springs are not binding in the frame hangars. Make sure that the U-bolts and torque rod bolts are torqued to specification, and all of the bushings are in good condition.

3. Position an 8 ft (2-1/2 m) length of bar stock or angle iron across the frame. Square the bar across the frame using a carpenter's square, and clamp it in place on the frame rail. See **Fig. 1**.

NOTE: Position the bar as far forward of the drive axle as possible.

4. Start on the fixed (right) torque rod side. Measure the distance from the bar stock to the centerline of the drive axle. Repeat the same procedure on the adjustable (left) torque rod side. See **Fig. 1**.
5. If the distance varies more than 1/8-inch, alignment is necessary.
6. Loosen the torque rod clamp bolts. See **Fig. 2**.
7. Use a pipe wrench or other suitable tool and slowly turn the torque rod.
8. Turn until the measurement on both sides of the axle are within 1/8-inch. Tighten the torque rod clamp bolts 125 to 150 lbf·ft (170 to 203 N·m).



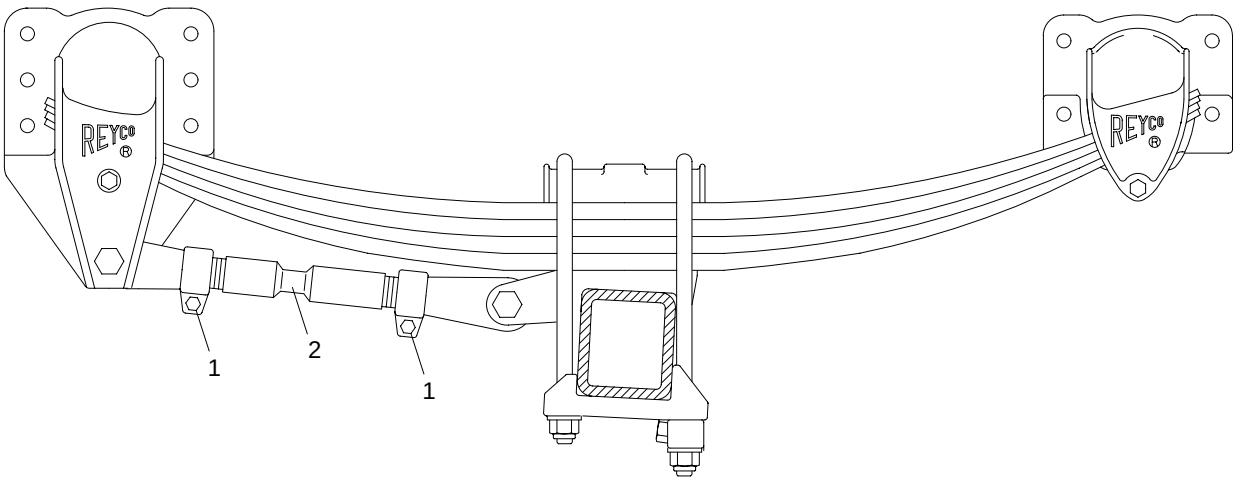
A. Trailing Edge
B. Drive Axle Centerline
C. Fixed Torque Rod Side
D. Adjustable Torque Rod Side
1. Frame Rail
2. Bar Stock

Fig. 1, Measuring Axle Alignment

9. Remove the wheel chocks and drive the vehicle through a short series of turns.
10. Recheck the alignment.

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Rear Axle Alignment Adjustment



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1. Torque Rod Clamp Bolt
2. Torque Rod Adjustment Location

Fig. 2, Adjustable Torque Rod

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Reyco 79KB Torque Values		
Description	**Size**	**Torque lbf·ft (N·m)**
Forward Spring Hanger	5/8	190 (258)
Rear Spring Hanger	5/8	190 (258)
U-bolt High Nuts (Tighten in a diagonal pattern as shown in **Fig. 1**.)	3/4–16	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 270 to 330 (367 to 449)
	7/8–14	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420 to 500 (571 to 680)
Torque Rod Bolts	7/8	400 to 450 (545 to 615)
Torque Rod Clamp Nuts	5/8	125 to 150 (170 to 203)
Spring Retainer Bolts	1/2	60 to 80 (85 to 110)

Table 1, Reyco 79KB Torque Values

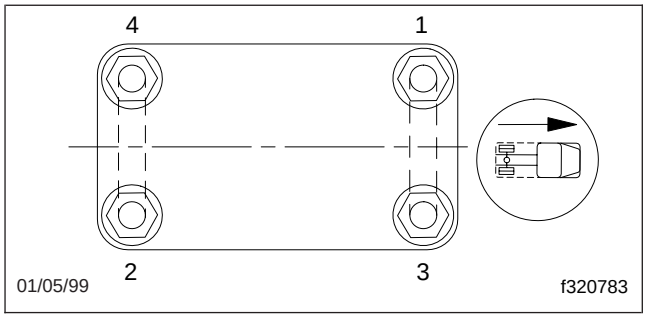


Fig. 1, Tightening Pattern for U-Bolt High Nuts

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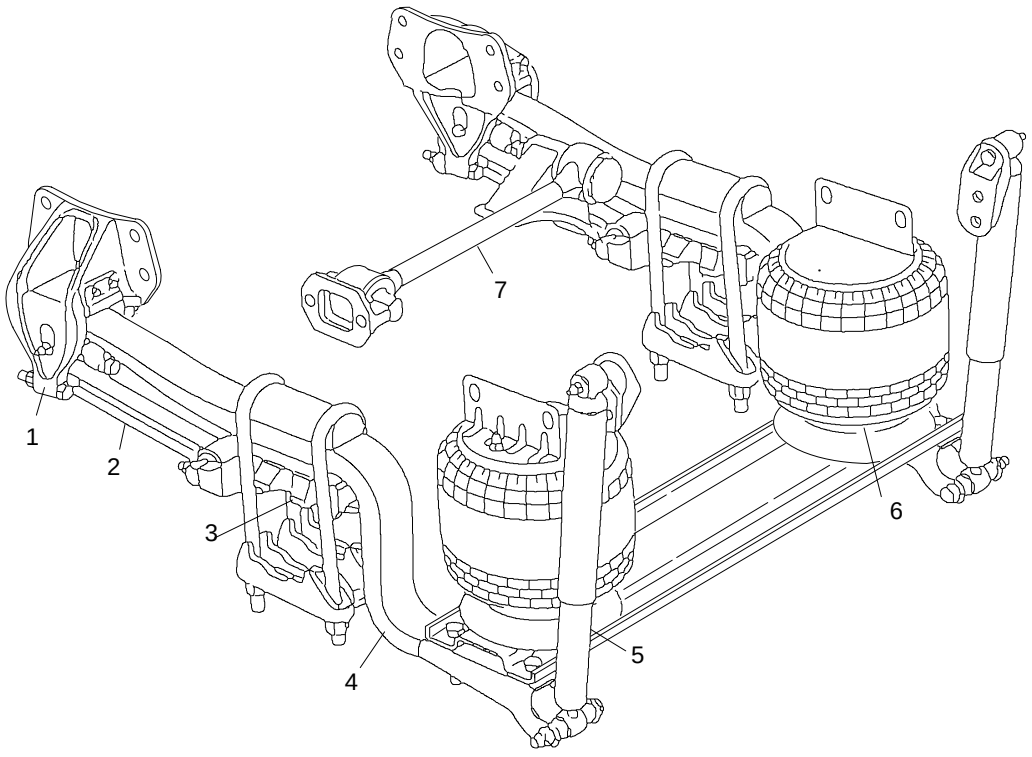
General Information

The Hendrickson HAS suspension uses air bags to support the sprung weight. See **Fig. 1**. The air bags (air springs) mount on a crossmember between the two main support beams that are fastened to the axle housing and pivot on forward-mounted hanger brackets on the frame. Torque rods, running from the hanger brackets to the axle seats, transfer vehicle motion to the frame. Lateral stability is provided by transverse torque rods from the inside of the frame rails to brackets on the axle housings. The shock absorbers help to dampen the oscillations of the air springs and control the torque reaction of the axle housings on acceleration.

AIR CONTROL SYSTEM

The Hendrickson HAS air suspension system allows for a smooth ride while maintaining a constant ride height, even with varying loads. Although most vehicles with the HAS system use only one height control valve for the rear suspension, some vehicles with uneven loading may have a height control valve for each side of the vehicle. An optional suspension dump system permits the driver to temporarily lower the frame for trailer coupling or uncoupling without having to leave the cab. See **Specifications, 400** for a schematic of the air control system.

The suspension air control system uses air supplied from the secondary air brake system. The air supply line is connected to a secondary air manifold located behind the instrument panel. If a loss of air pressure



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1. Hanger Bracket
2. Torque Rod
3. Spring Seat
4. Main Support Beam
5. Shock Absorber
6. Air Spring
7. Transverse Rod

Fig. 1, Rear Suspension, Hendrickson HAS Series

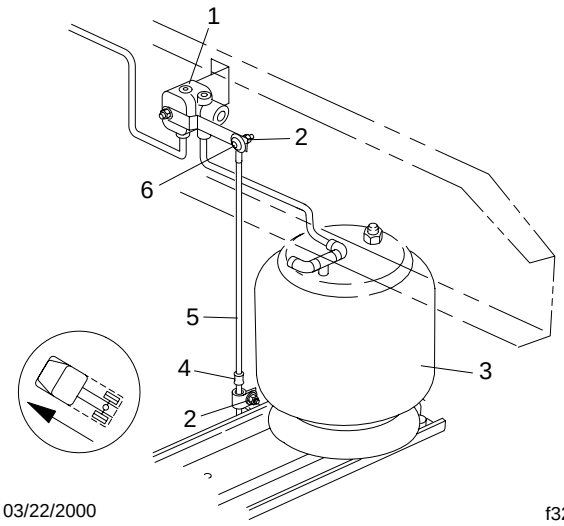
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occurs forward (upstream) of the protection valve, the air spring system will be isolated and maintain the air pressure within the suspension system until repairs can be made. However, if a loss of air occurs rearward (downstream) of the protection valve, the air in the brake system will be protected, but the air pressure in the air springs will be lost.

The vehicle ride height is maintained by a height control valve mounted on the frame and linkage that connects the valve to the suspension crossmember. See **Fig. 2**. As the frame-to-axle housing clearance changes due to a change in the vehicle load, the linkage moves the lever on the height control valve, causing air to move in or out of the air bags. A slight delay in the operation of the height control valve prevents the system from trying to adjust the ride height for each suspension movement.

The optional air suspension dump system is used to deflate the rear suspension air springs during trailer coupling and uncoupling operations. The dump control valve is located on the dash in the cab. When the dump control valve is toggled, supply air flows through the dump control valve delivery port and pressurizes the signal line to the relay valve. The pressurization of the signal line closes the relay valve supply port while opening the ports from the air bags to the atmosphere. Air from the air bags exhausts through the relay valve until the dump control valve is released or until the frame rests on the stops inside the air bags. A pressure switch in the signal line to the relay valve senses the signal pressure and switches on an optional red status light on the dash. To allow the air springs to inflate after being dumped, the dump control valve must be first toggled downward to exhaust the pressure in the signal line.

The pilot-operated relay valve is used for rapid deflation of the air bags for trailer coupling and uncoupling. When pilot pressure from the dump control valve is applied to the relay valve, the supply air from the height control valve is stopped from flowing through the relay valve and, simultaneously, the air spring pressure is exhausted directly to the atmosphere through passages in the relay valve.



1. Height Control Valve
2. Extension Arm Locknut
3. Air Spring
4. Extension Arm Clamp
5. Threaded Extension Rod
6. Rubber Grommet

Fig. 2, Height Control Valve Assembly

REAR SUSPENSION COMPONENTS

The axle housing, the lower shock mounts and the lower air bag mounts are all solidly attached to the HAS main support arms. See **Fig. 1**. The main support arm hanger brackets, the upper shock mounts and the upper air bag mounts are all solidly mounted to the frame rails. The torque rods, with flexible bushings in each end, connect the hangers to the axle seats. When the vehicle travels over a bump, the axle housing suddenly rises and compresses the air bags. The pressure in the air bags increases immediately, which absorbs most of the energy of the upward-moving axle housing without transferring that movement to the frame. The shock absorbers then help absorb the release of that higher pressure by slowing the downward movement of the axle housing after the bump.

The front of each main support arm is allowed to pivot and slide on replaceable slipper pads in the hanger brackets. A torque rod is attached to each hanger bracket and to each axle seat bracket by rubber bushings with internal pins, installed in the torque rods at specified angles. Shims are used for adjustment at the front of each torque rod to make sure that the wheels run parallel to the frame rails.

The torque rods control the forward and aft movement of the unsprung pieces during suspension travel. The flexible rubber bushings in the torque

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rods allow vertical movement of the axle housing while limiting its forward and aft movement. The driveline angles are kept within the specified limits by the torque rods' control of the rotational forces on the axle housings during acceleration and deceleration. The torque rods transfer the forward motion of the axle housing to the frame rails on acceleration and pull back on the frame during braking.

The transverse rods, also with rubber bushings in each end, connect the brackets on the axle housings to the brackets on the frame rails. The transverse rods keep a constant lateral relationship of the frame to the axle housing, while still allowing vertical movement of the axle housings.

The Hendrickson HAS suspension is available in varying capacities and for limited off-highway use. The heavy-duty or off-highway suspensions have thicker main support arms, heavier crossmembers and torque rods, and heavy-duty air bags and shock absorbers. There are two HAS ride height specifications (measured from the bottom of the frame rail to the bottom of the main support arm at the axle seat) depending on which suspension is used. The HAS suspensions are available for single axle vehicles and can be ordered with or without the suspension dump feature.

REAR SUSPENSION SERVICE NOTES

⚠ WARNING

Do not subject main support members to heat, nicks or gouges. A main support member that has been subjected to heat, nicks or gouges can fail, causing loss of vehicle control and possible personal injury or property damage.

Never reinstall used suspension fasteners. Always use the same part number when replacing any suspension fastener.

All fasteners must be tightened to their specified torque and the U-bolts must be tightened in stages as described in **Specifications, 400**.

Check the axle alignment after replacing components that affect alignment, such as a main support beam, a torque rod or a hanger.

NOTE: During installation, apply pipe sealant with Teflon® D8AZ-19554-A or equivalent meeting specification WSK-M2G350-A2 or ESR-M18P7-A to the air fitting threads.

NOTE: When replacing the torque rod bushings, lubricate the new bushings with a vegetable-based oil only. Make sure the new bushings are centered in the torque rod bores.

NOTE: A shim pack of three 0.11 inch (2.8 mm) thick spacers are used to adjust axle lateral tracking offset. Install the spacers as required to adjust tracking.

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Main Support Member Removal and Installation

Removal

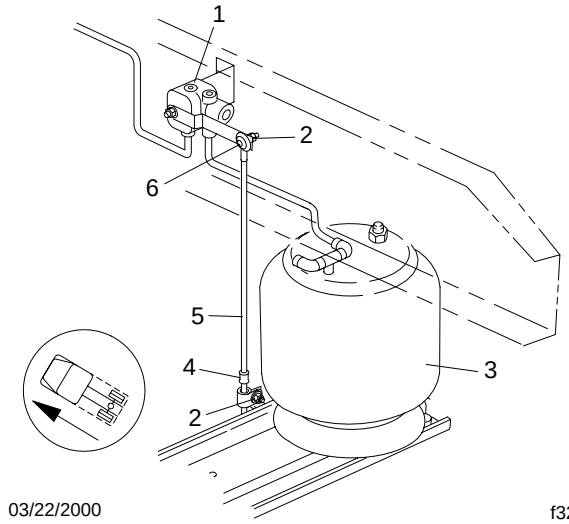
NOTE: Operation of the HAS suspension will result in wear between the main support member and the spring hanger slipper pad. In normal use, these components will function satisfactorily even though they show some wear. Premature wear may occur, however, and requires the replacement of one or both parts. A main support member should be replaced if it has 3/8 inch (9.5 mm) or more wear at the hanger cam contact area.

1. Park the vehicle on a level surface, shut down the engine and apply the parking brakes. Chock the front and rear tires.
2. Support the axle housing with a jack stand under the pinion nose to prevent the axle housing from rotating when the U-bolts are removed.

⚠ WARNING

The air suspension system will start moving the frame when the lever for the ride height control valve is moved from its center position. To avoid injury or property damage, make sure that your hands and all objects are away from any pinch points when the lever is moved.

3. Disconnect the vertical linkage for the height control valve at the end of the horizontal lever. See **Fig. 1**. Lift the lever on the height control valve so that the air bags raise the frame about 3 inches (75 mm). Support the frame at that position with jack stands.
4. Remove the locknuts, washers and bolts that connect the cross channel and shock absorber brackets to both main support members. See **Fig. 2**.
5. Use a floor jack to raise the cross channel about 3 inches (75 mm). Support the cross channel assembly with jack stands.
6. Remove the locknut, washers and bolt from the rebound roller assembly at the front hanger. See **Fig. 3**. Remove the rebound roller and spacer.
7. Remove the U-bolt high nuts and washers, then remove the bottom cap, U-bolts and the top pad and Delrin liner.



1. Height Control Valve
2. Extension Arm Locknut
3. Air Spring
4. Extension Arm Clamp
5. Threaded Extension Rod
6. Rubber Grommet

Fig. 1, Height Control Valve Assembly

8. Slide the main support member out of the hanger and remove the main support assembly from the vehicle.
9. Inspect the main support member for wear. Replace the main support member if worn more than 3/8 inch (9.5 mm) at the hanger end where it contacts the slipper pad or if it has cracks, nicks or signs of the application of heat from a torch or welder.
10. Inspect the slipper pad for wear. Replace the slipper pad if worn. Remove the four bolts and washers that hold the slipper pad to the hanger. If rivets were installed instead of bolts to hold the slipper pad, use a grinder to remove the rivet heads.

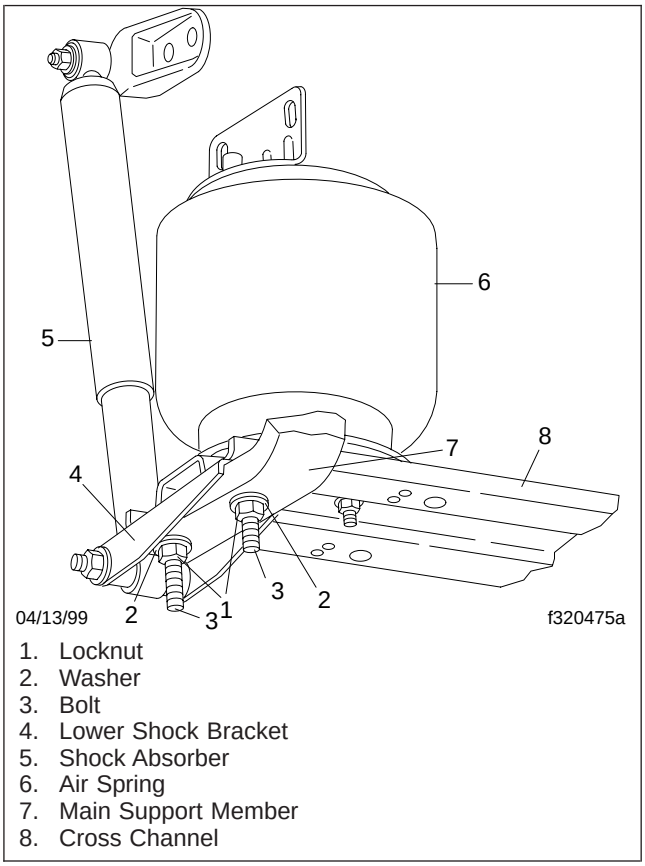
Installation

⚠ WARNING

Always use new fasteners when installing suspension components. Reuse of fasteners can lead to component damage and loss of vehicle

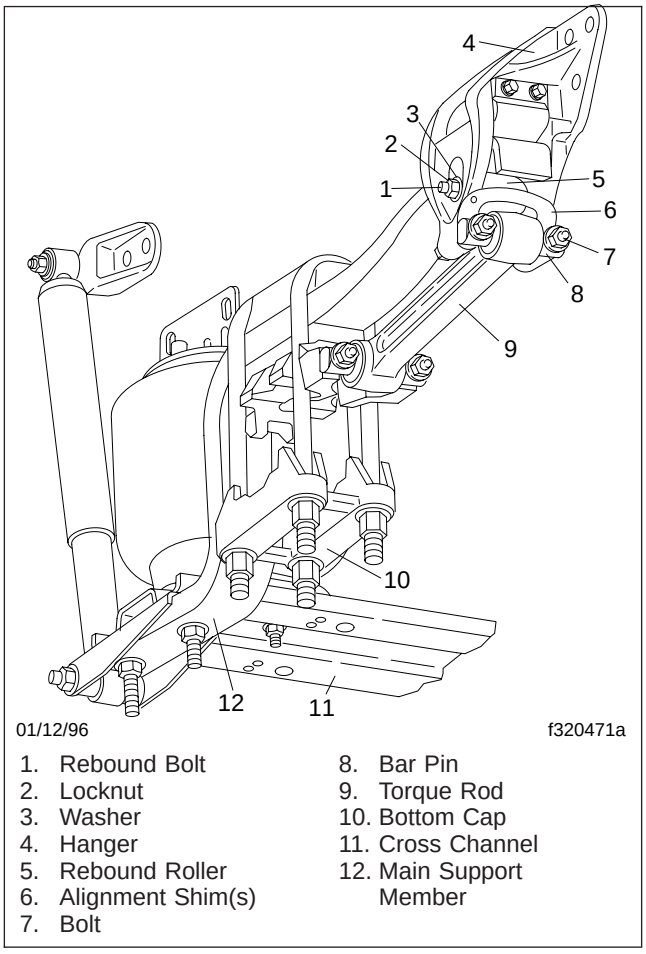
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Main Support Member Removal and Installation



1. Locknut
2. Washer
3. Bolt
4. Lower Shock Bracket
5. Shock Absorber
6. Air Spring
7. Main Support Member
8. Cross Channel

Fig. 2, Main Support Member



1. Rebound Bolt
2. Locknut
3. Washer
4. Hanger
5. Rebound Roller
6. Alignment Shim(s)
7. Bolt
8. Bar Pin
9. Torque Rod
10. Bottom Cap
11. Cross Channel
12. Main Support Member

Fig. 3, Removing the Rebound Roller

control, possibly resulting in personal injury or property damage.

1. Install the slipper pad, bolts and washers into the hanger. Tighten the bolts 25 lbf·ft (34 N·m). Install new rivets if so equipped.
2. Slide the main support member into the hanger assembly.
3. Position the main support member on the axle seat, or on the spacer plate if the vehicle is so equipped, with the main support member center dowel sliding into the hole in the axle seat or spacer plate.
4. The Delrin liner must be positioned on the top of the main support member. Install the U-bolt top pad on the Delrin liner. Install the U-bolts over the top pad and liner and around the main support member, the spacer (if so equipped), the axle seat assembly, the axle housing, and the bottom cap. Install the washers and high nuts and tighten with your fingers, but do not fully tighten the U-bolt high nuts at this time.
5. Lower the floor jack under the cross channel until the cross channel is against the main support members. Install the shock absorber bracket (if so equipped) and bolts into the cross channel and main support members. See **Fig. 2**. Install the washers and tighten the locknuts 280 lbf·ft (380 N·m).
6. Install the rebound roller into the hanger. Install the bolt, washer and locknut. Tighten the locknut 60 lbf·ft (82 N·m).
7. Center the main support member between the hanger legs. Move the lever for the height control

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valve up to lift the frame from its jack stands. Remove the jack stands from the frame.

8. Tighten the U-bolt locknuts in stages as described in **Specifications, 400**. Rap the top of the U-bolts with a hammer. Tighten the high nuts 500 lbf·ft (680 N·m).

IMPORTANT: Do not exceed the specified torque on the U-bolt high nuts. Tighten the U-bolt high nuts after 1000 miles (1600 km).

9. Move the lever for the height control valve down to lower the frame until the upper ball joint stud in the vertical linkage exactly aligns with the hole in the lever when the lever is in the horizontal position. Install the height control valve ball joint stud, washer and locknut. Tighten the locknut 125 lbf·in (1412 N·cm).
10. Remove the jack stand from under the nose of the axle housing.
11. Remove the chocks from the tires.
12. Check and adjust the ride height as described in **Subject 230**.
13. Check the alignment after new main support members are installed.

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Spring Seat Removal and Installation

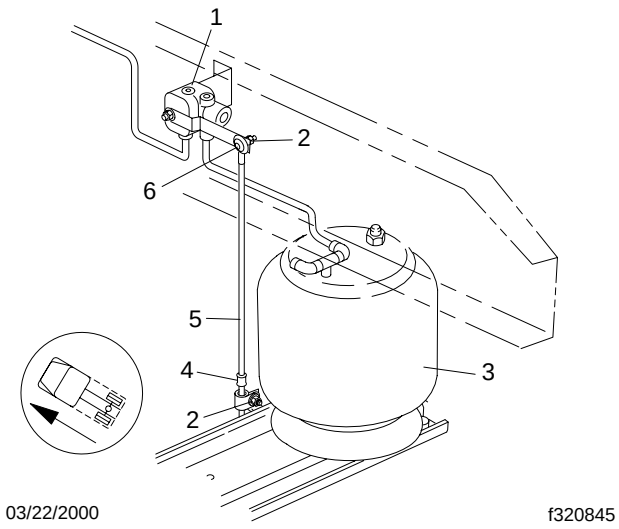
Removal

1. Stop the vehicle on a level surface, shut down the engine and apply the park brakes. Chock the front and rear tires.
2. Support the axle housing with a jack stand under the pinion nose to prevent the axle housing from rotating when the U-bolts are removed.

⚠ WARNING

The air suspension system will start moving the frame when the lever for the ride height control valve is moved from its center position. To avoid injury or property damage, make sure that your hands and all objects are away from any pinch points when the lever is moved.

3. Disconnect the vertical linkage for the height control valve at the end of the horizontal lever. See **Fig. 1**. Lift the lever on the height control valve so that the air bags raise the rear of the frame about 3 inches (75 mm). Support the frame at that position with jack stands.

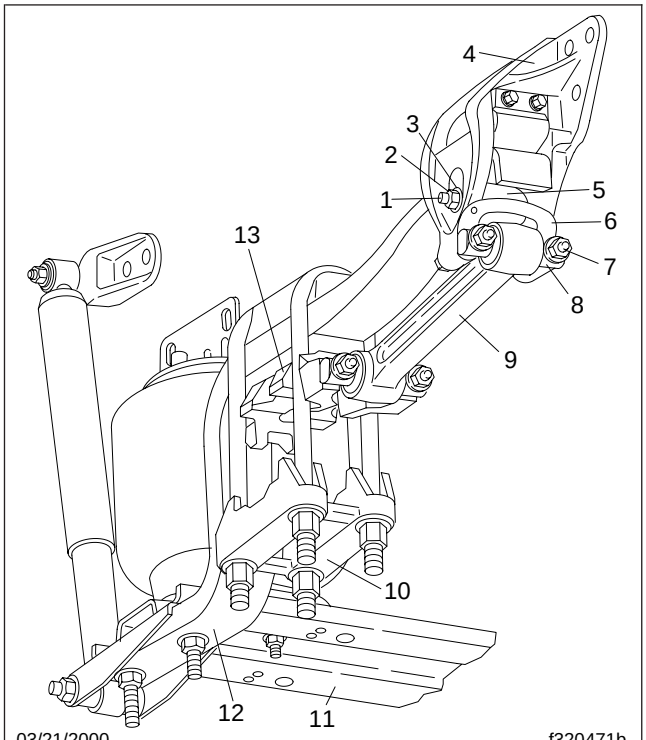


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1. Height Control Valve
2. Extension Arm Locknut
3. Air Spring
4. Extension Arm Clamp
5. Threaded Extension Rod
6. Rubber Grommet

Fig. 1, Height Control Valve Assembly

4. Remove the nuts, washers and bolts that hold the torque rod to the hanger legs.
5. Remove the nuts and washers that hold the torque rod to the spring seat. Remove the torque rod.
6. Remove the high nuts from the U-bolts and remove the bottom cap and top pad and Delrin liner.
7. Use a floor jack to raise the cross channel and main support member just enough to remove the spring seat.
8. Remove the spring seat. See **Fig. 2**.



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1. Rebound Bolt
2. Locknut
3. Washer
4. Hanger
5. Rebound Roller
6. Alignment Shim(s)
7. Bolt
8. Bar Pin
9. Torque Rod
10. Bottom Cap
11. Cross Channel
12. Main Support Member
13. Spring Seat

Fig. 2, Removing the Spring Seat

9. If the spring seat studs need replacement, remove them with a hammer and brass drift or use a stud puller.

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Spring Seat Removal and Installation

Installation

⚠ WARNING

Always use new fasteners when installing suspension components. Reuse of fasteners can lead to component damage and loss of vehicle control, possibly resulting in personal injury or property damage.

1. If required, install the new studs with a stud driver. Insert the stud in the hole of the spring seat and tap into position with a hammer and brass drift. To assure proper assembly, the stud should be inserted from the dog point end (tap end) first and bottom out in the threaded hole of the spring seat. Tighten 60 to 70 lbf·ft (81 to 95 N·m).
2. Lift the main support member with a floor jack and install the spring seat on the top of the axle housing. Install the spacer (if so equipped) above the spring seat.
3. Position the main support member on the spring seat, or on the spacer plate if the vehicle is so equipped, with the main support member center dowel sliding into the hole in the spring seat or spacer plate.
4. The Delrin liner must be positioned on the top of the main support member.
   - 4.1 Install the U-bolt top pad on the Delrin liner.
   - 4.2 Install the U-bolts over the top pad and liner and around the main support member, the spacer (if so equipped), the spring seat assembly, the axle housing and the bottom cap.
   - 4.3 Install the washers and high nuts and finger-tighten. Do not fully tighten the U-bolt high nuts at this time.
5. Install the torque rod on the spring seat so that the holes in the bushing pin align with the spring seat studs. Install the washers and nuts, but do not tighten at this time.
6. Install the front end of the torque rod onto the hanger legs and install any shims that were removed. Install the bolts through the hanger legs, shims and the front bushing pin.
7. Tighten the nuts on the front of the torque rod 175 lbf·ft (237 N·m).
8. Tighten the nuts for the torque rod pin at the spring seat 175 lbf·ft (237 N·m).
9. Move the lever for the height control valve up to lift the frame from its jack stands. Remove the jack stands from the frame.
10. Tighten the U-bolt locknuts in stages as described in **Specifications, 400**. Rap the top of the U-bolts with a hammer. Tighten the high nuts 500 lbf·ft (680 N·m).

IMPORTANT: Do not exceed the specified torque on the U-bolt high nuts. Tighten the U-bolt high nuts after 1000 miles (1600 km).

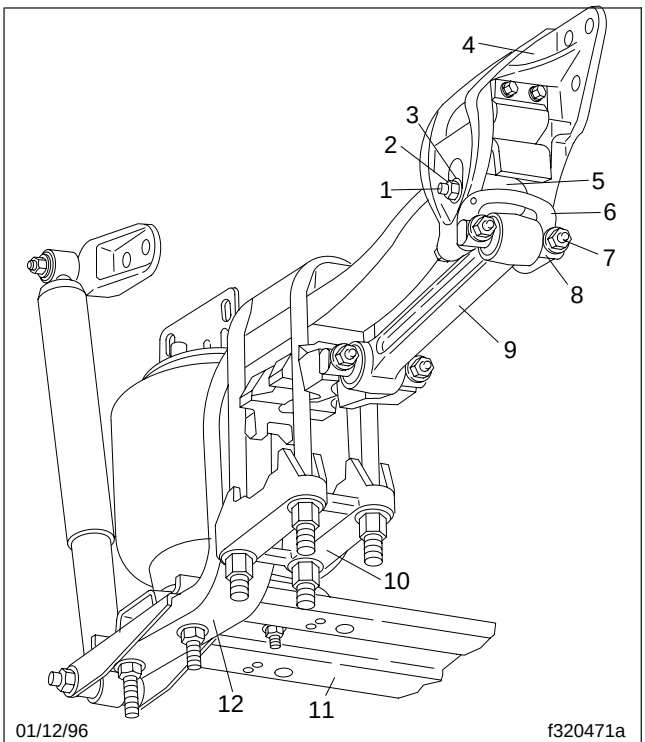
11. Move the lever for the height control valve down to lower the frame until the upper ball joint stud in the vertical linkage exactly aligns with the hole in the lever when the lever is in the horizontal position. Install the height control valve ball joint stud, washer and locknut. Tighten the locknut 125 lbf·in (1412 N·cm).
12. Remove the jack stand from under the nose of the axle housing.
13. Check and adjust the ride height as described in **Subject 230**.
14. Check the alignment after new spring seats are installed.

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Torque Rod Bushing Replacement

Replacement (See Fig. 1)

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires and the tires of the drive axles.
2. Remove the bar pin locknuts and washers at the axle end of the torque rod. See **Fig. 1**.



1. Rebound Bolt
2. Locknut
3. Washer
4. Hanger
5. Rebound Roller
6. Alignment Shim(s)
7. Bolt
8. Bar Pin
9. Torque Rod
10. Bottom Cap
11. Cross Channel
12. Main Support Member

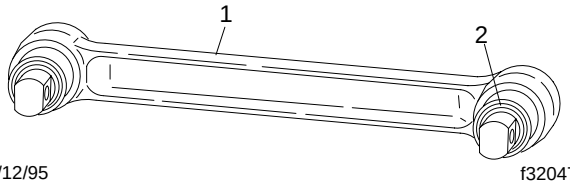
Fig. 1, Torque Rod Installation

3. Loosen the rebound bolt locknut in the hanger.
4. Remove the bar pin locknuts, bolts and washers, and any alignment shims at the hanger end of the torque rod. Note the number of shims, as the same thickness shim pack must be reinstalled to avoid affecting the vehicle's alignment.
5. Push out the old bushings. Use a vertical shop press with a capacity of at least 10 tons. A 5-inch (127-mm) piece of 2-inch by 1/4-inch (50-mm by 6-mm) wall, steel-tubing receiving tool is required. The bushings are not cartridge-type bushings and do not have a metal outer sleeve.
6. Support the torque rod end on the receiving tool with the end tube of the torque rod centered on the tool.

⚠ WARNING

Do not use heat or a cutting torch to remove the bushings from the torque rod. The use of heat will weaken the torque rod, which could cause the rod to break. This could result in a loss of vehicle control, possibly causing personal injury or property damage.

7. Push directly on the bar pin until the bushing is pushed out of the torque rod end tube.
8. Clean and inspect the torque rod ends. Remove any nicks with emery cloth.
9. Lubricate the torque rod ends and the new rubber bushings with a vegetable-based oil. Do not use a petroleum-based or soap-based lubricant.
10. Press in the new bushings while supporting the torque rod end on the receiving tool with the end tube of the torque rod centered on the receiving tool. The bushings must be installed with the mounting flats on the bar pin positioned zero degrees to the shank of the torque rod. See **Fig. 2**.



1. Torque Rod
2. Bar Pin Bushing

Fig. 2, Positioning the Bar Pin Mounting Flats

11. Press directly on the bar pin of the bushings, which must be centered within the torque rod end tubes. When pressing in the new bushings, overshoot the final position by approximately 3/16 inch (5 mm).
12. Press the bushing again from the opposite side to center the bushing within the torque rod end.

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Torque Rod Bushing Replacement

13. Position the torque rod into the axle seat and attach it with the washers and locknuts. Hand-tighten the locknuts.
14. Position the torque rod onto the forward face of the hanger legs. Assemble the bolts, washers and locknuts, and any alignment shims. Tighten locknut 175 lbf·ft (237 N·m). See **Fig. 1**.
15. Tighten locknuts at the axle end of the torque rods 175 lbf·ft (237 N·m).
16. Tighten rebound bolt locknut 60 lbf·ft (81 N·m).
17. Remove the chocks from the tires.

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Height Control Valve Removal and Installation

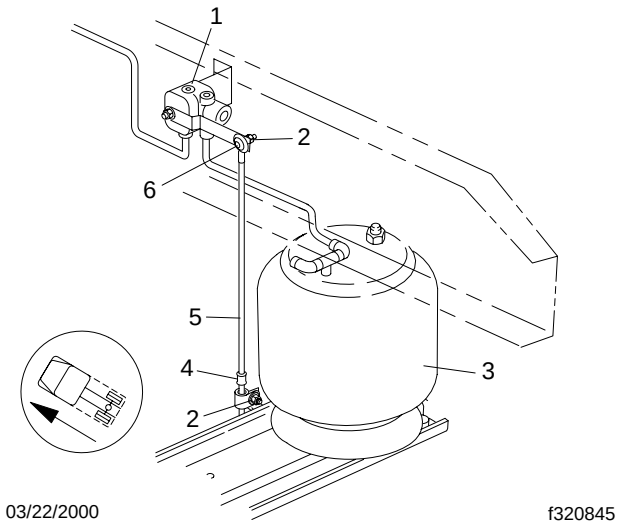
Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Drain the vehicle air system.

⚠ WARNING

The air suspension system will start moving the frame when the lever for the ride height control valve is moved from its center position. To avoid injury or property damage, make sure that your hands and all objects are away from any pinch points when the lever is moved.

3. Remove the height control valve vertical rod from the valve lever by removing the nut and lockwasher. Push down on the lever of the height control valve to exhaust the air from the rear suspension air bags.
4. Remove the air lines attached to the height control valve. See **Fig. 1**.



1. Height Control Valve
2. Extension Arm Locknut
3. Air Spring
4. Extension Arm Clamp
5. Threaded Extension Rod
6. Rubber Grommet

Fig. 1, Height Control Valve Assembly

5. Remove the locknuts, washers and bolts that attach the height control valve to the frame.
6. Remove the brass air fittings from the height control valve.

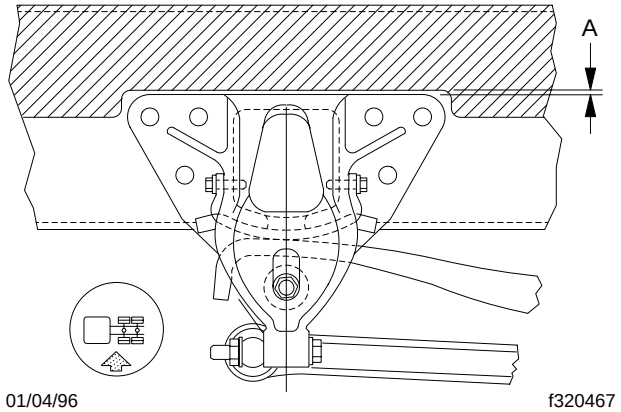
Installation

1. Install the brass air fittings into the height control valve ports.
2. Install the bolts, washers and locknuts that attach the valve to the frame rail.
3. Attach the air lines to the height control valve.
4. Attach the height control valve vertical linkage rod to the height control valve lever. Install the lockwasher and nut. See **Fig. 1**.
5. Return air to the system.
6. Adjust the height control valve for proper ride height as described in **Subject 230**.
7. Remove the chocks from the tires.

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Information

The HAS front hangers must have at least 1/4-inch (6-mm) clearance between the top of the hanger and the bottom of the fifth wheel mounting bracket on the sides of the frame rails. In some cases, the fifth wheel mounting bracket may have to be cut out to provide the correct clearance. See **Fig. 1** for an example of a fifth wheel mounting bracket that has been modified.



A. Clearance: 1/4 inch (6 mm)

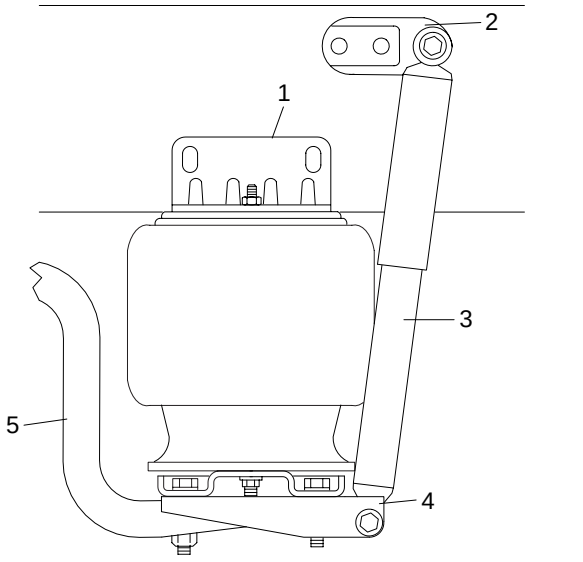
Fig. 1, Fifth Wheel Mounting Angle Clearance

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Replacement

NOTE: Shock absorbers are 1-3/8 inches (35 mm) in diameter with a compressed length of 18-1/3 inches (466 mm) and an extended length of 30 inches (762 mm).

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Remove the nut, washer and bolts that attach the shock absorber to the frame hanger bracket. See **Fig. 1**.



1. Air Spring Frame Hanger
2. Upper Bracket
3. Shock Absorber
4. Lower Bracket
5. Main Support Member

Fig. 1, Shock Absorber Mount

3. Remove the fasteners that attach the shock absorber to the lower bracket.
4. Remove the shock absorber.
5. Install the new shock absorber with the rod and shield tube at the top. Install the bolts, washers and nuts in the lower bracket and the frame hanger bracket. Install washers at both sides of each shock bushing; four washers per shock absorber.
6. Tighten the fasteners 60 lbf·ft (81 N·m).
7. Remove the chocks from the tires.

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Slipper Pad Removal and Installation

Removal

NOTE: Operation of the HAS suspension will result in wear between the main support member and the hanger slipper pad. In normal use, these components will function satisfactorily even though the components indicate some wear.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front tires.

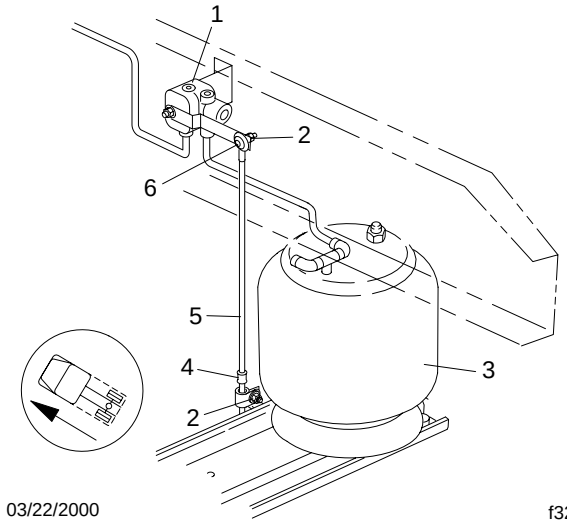
⚠ WARNING

The air suspension system will start moving the frame when the lever for the ride height control valve is moved from its center position. To avoid injury or property damage, make sure that your hands and all objects are away from any pinch points when the lever is moved.

2. Disconnect the vertical linkage from the lever of the height control valve and lift the lever to raise the rear of the frame about 3 inches (75 mm). See **Fig. 1**.
3. Support the frame with jack stands.
4. Apply an upward force on the cross channel by pushing down on the height control lever to lift the cross channel. This will cause the tips of the main support members to drop away from the slipper pad. See **Fig. 2**.

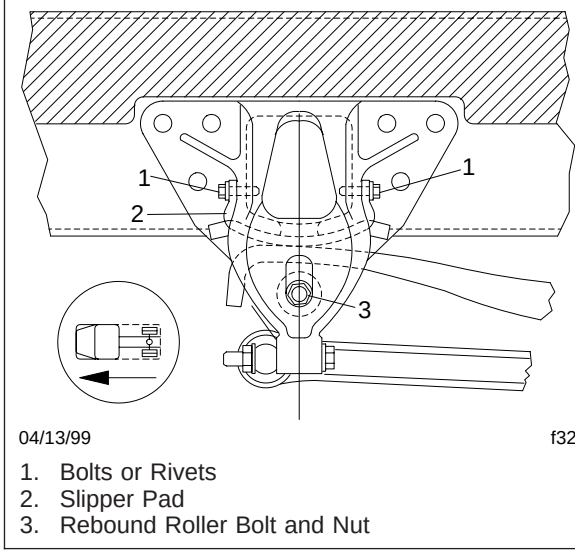
IMPORTANT: Do not nick or gouge the cross channel.

5. Remove the fasteners and the slipper pad. In some instances, the screws may have to be drilled out using a 1-1/32 inch drill size. See **Fig. 3**.
6. In some instances, remove the rebound roller to gain enough clearance to remove the slipper pad. Loosen the rebound bolt locknut, remove the washer, the bolt and the rebound roller assembly.
7. For rivets, remove the four 1/4-inch (6-mm) rivets by grinding away the rivet heads. With a drift pin, punch the rivets through the holes and remove the slipper pad.



1. Height Control Valve
2. Extension Arm Locknut
3. Air Spring
4. Extension Arm Clamp
5. Threaded Extension Rod
6. Rubber Grommet

Fig. 1, Height Control Valve Assembly



1. Bolts or Rivets
2. Slipper Pad
3. Rebound Roller Bolt and Nut

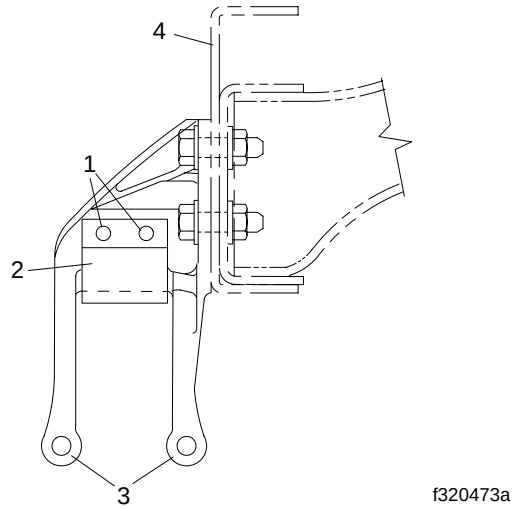
Fig. 2, Slipper Pad Installation

Installation

1. Position the slipper pad and retainer plate on the frame hanger.

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Slipper Pad Removal and Installation



1. Bolts or Rivets
2. Slipper Pad
3. Hanger Legs
4. Frame Rail

Fig. 3, Hanger Assembly

2. Tighten the hexhead self-tapping screws 25 lbf·ft (34 N·m), or install the rivets using a rivet gun.
3. Raise the frame off the jack stands by pulling up on the height control valve lever. Remove the jack stands.
4. Push down on the height control valve lever to lower the frame until the upper ball stud on the vertical linkage rod exactly aligns with the hole in the lever when the lever is horizontal.
5. Install the ball stud into the hole in the lever and install the washer and nut. Tighten the nut 125 lbf·in (1412 N·cm).
6. Remove the chocks from the tires.

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Cross Channel Removal and Installation

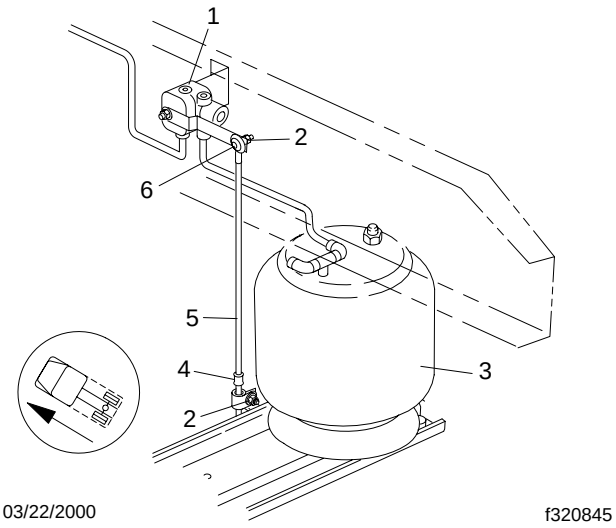
Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front and rear tires.

⚠ WARNING

The air suspension system will start moving the frame when the lever for the ride height control valve is moved from its center position. To avoid injury or property damage, make sure that your hands and all objects are away from any pinch points when the lever is moved.

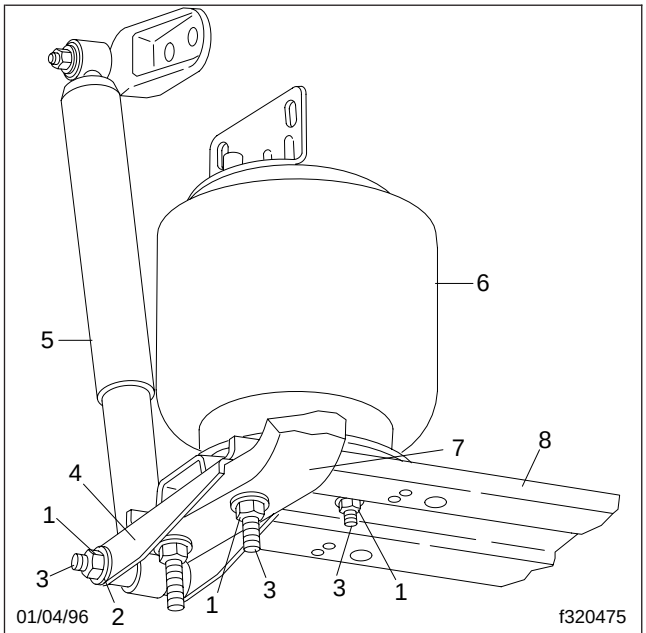
2. Disconnect the vertical linkage for the height control valve at the end of the horizontal lever. See **Fig. 1**. Lift the lever on the height control valve so that the air bags raise the rear of the frame about 3 inches (75 mm). Support the frame at that position with jack stands.



1. Height Control Valve
2. Extension Arm Locknut
3. Air Spring
4. Extension Arm Clamp
5. Threaded Extension Rod
6. Rubber Grommet

Fig. 1, Height Control Valve Assembly

3. Remove the locknuts and washers that attach both the air springs to the cross channel. See **Fig. 2**.



1. Locknut
2. Washer
3. Bolt
4. Lower Shock Bracket
5. Shock Absorber
6. Air Spring
7. Main Support Member
8. Cross Channel

Fig. 2, Main Support Member

4. Remove the locknuts, washers and bolts that attach the cross channel to the main support members and to the shock absorber lower mounting brackets.
5. Raise the cross channel by pushing down on the height control lever to compress the air springs just enough to clear the studs on the bottom of the air springs. Remove the cross channel.

Installation

1. Position the cross channel so that the holes in the cross channel are aligned under the studs of the air springs. Install the washers and nuts. Tighten the nuts on the air spring studs 25 lbf·ft (34 N·m).
2. Lower the cross channel assembly onto the main support members by pushing down on the height control valve lever.
3. Install the bolts, washers and locknuts that connect the cross channel to the main support mem-

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Cross Channel Removal and Installation

ber and lower shock absorber mounts. Tighten the locknuts 290 lbf·ft (393 N·m).

4. Raise the frame by lifting the height control valve lever and remove the jack stands.
5. Attach the ball joint stud of the vertical linkage rod to the height control valve link and tighten the locknut on the ball joint stud 125 lbf·in (1412 N·cm).
6. Remove the chocks from the tires.

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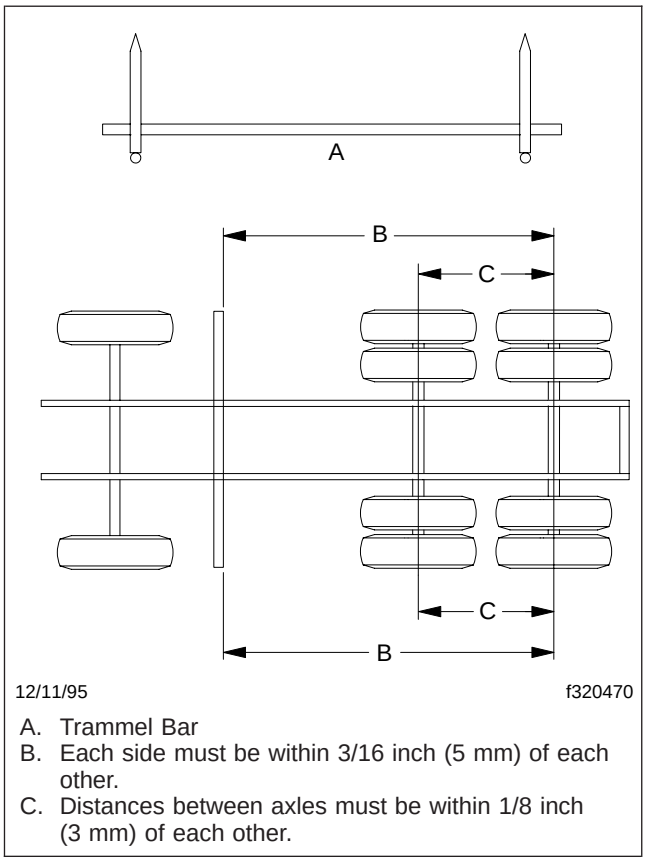
Check and Adjustment

Use the following procedure after all repairs to the suspension:

1. Park vehicle on a level surface. Free and center all suspension joints by slowly moving the vehicle back and forth several times without applying the brakes.
2. Chock the front tires and the tires of the drive axles.
3. C-clamp a 9-ft (2.74-m) piece of straight bar stock or angle iron across the frame. Select a location as far forward of the forward drive axle as possible where components will not interfere. The lower frame flange may be preferred on some vehicles, otherwise use the upper frame flange.
4. Align the straight bar stock or angle iron on the frame using a carpenter's square.
5. Check the rear drive axle first. See **Fig. 1**. Use a trammel bar or its equivalent to measure from the straight edge to the center line of the rear axle on both sides of the vehicle. If both sides measure within 3/16 inch (5 mm) of being the same, the alignment of the rear drive axle is acceptable. If the sides differ by more than 3/16 inch (5 mm), loosen the rebound locknut. Adjust the rear drive axle by loosening up the torque rod bar pin locknuts on the hangers. Add or remove drop-in shims as needed.

NOTE: The torque rod bar pin must be mounted to the forward face of the hanger legs. No more than four shims may be used (for a maximum thickness of 1/4 inch [6 mm]).

6. Snug the torque rod bar pin locknuts but do not torque to specification.
7. With the rear drive axle properly aligned, the front drive axle alignment can be checked by measuring forward from the center of the axle shafts on the rear drive axle using a trammel bar. If the forward drive axle spacing measurements differ by more than 1/8 inch (3 mm), add or subtract shims at the forward hangers.
8. Following the adjustment of both axles, move the vehicle back and forth several times prior to removing the straight edge from the frame. Recheck the alignment.



A. Trammel Bar
B. Each side must be within 3/16 inch (5 mm) of each other.
C. Distances between axles must be within 1/8 inch (3 mm) of each other.

Fig. 1, Drive Axle Tracking Alignment

9. Tighten the torque rod bar pin locknuts 180 lbf·ft (244 N·m).
10. Remove the chocks from the tires.

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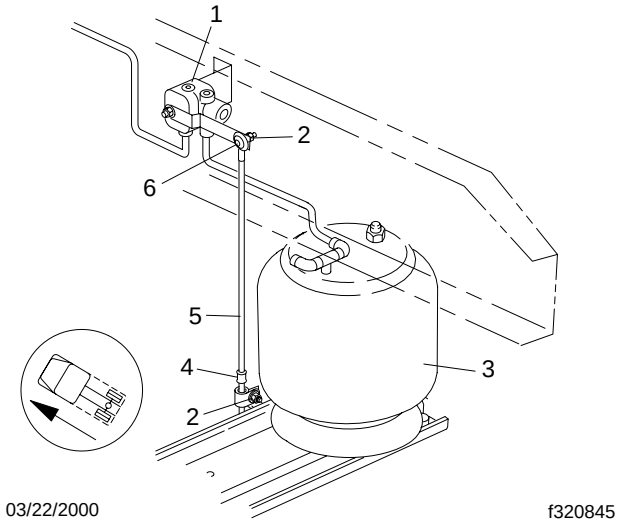
Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.
2. Support the frame with jack stands.

⚠ WARNING

The air suspension system will start moving the frame when the lever for the ride height control valve is moved from its center position. To avoid injury or property damage, make sure that your hands and all objects are away from any pinch points when the lever is moved.

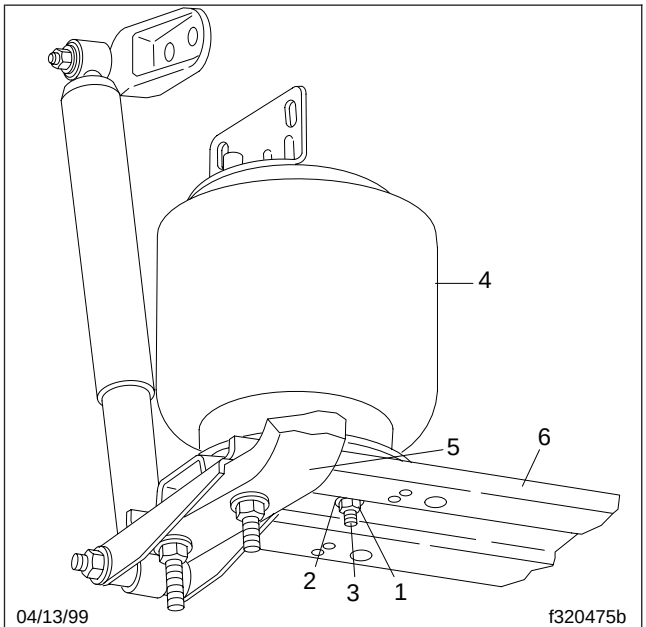
3. Remove the upper ball joint nut and stud from the lever on the height control valve. See **Fig. 1**. Move the height control valve lever down to exhaust all the air from the air bags.



1. Height Control Valve
2. Extension Arm Locknut
3. Air Spring
4. Extension Arm Clamp
5. Threaded Extension Rod
6. Rubber Grommet

Fig. 1, Height Control Valve Assembly

4. Remove the locknuts and washers that attach the air spring to the cross channel. See **Fig. 2**.
5. Disconnect the air lines to the air spring.
6. Remove the brass air fittings from the air spring.
7. Remove the locknuts and washers that attach the air spring to the upper air spring frame hanger.
8. Remove the air spring.
9. Attach the new air spring to the air spring frame hanger by inserting the studs into the appropriate holes.
10. Attach the air spring to the cross channel. Tighten the nuts 25 lbf·ft (34 N·m).
11. Tighten the outboard locknut that attaches the air spring to the air spring frame hanger 25 lbf·ft (34 N·m).



1. Locknut
2. Washer
3. Bolt
4. Air Spring
5. Main Support Member
6. Cross Channel

Fig. 2, Air Spring Mounting

12. Attach the brass fittings to the air spring using a Teflon thread seal.
13. Connect the air lines to the air spring.
14. Connect the ball stud on the vertical linkage rod to the lever for the height control valve. Install the washer and tighten the nut 125 lbf·in (1412 N·cm).

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Air Spring Replacement

15. Remove the jack stands.
16. Check the ride height as described in **Subject 230**.
17. Remove the chocks from the tires.

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Air Spring Frame Hanger Removal and Installation

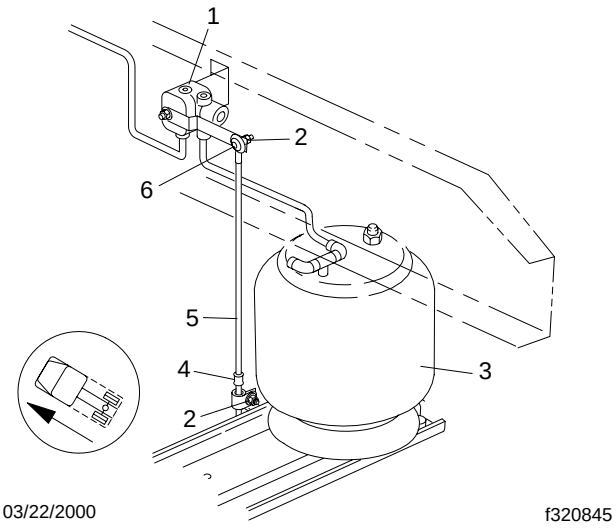
Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.

⚠ WARNING

The air suspension system will start moving the frame when the lever for the ride height control valve is moved from its center position. To avoid injury or property damage, make sure that your hands and all objects are away from any pinch points when the lever is moved.

2. Disconnect the vertical linkage for the height control valve at the end of the horizontal lever. See **Fig. 1**. Lift the lever on the height control valve so that the air bags raise the rear of the frame about 3 inches (75 mm). Support the frame at that position with jack stands.



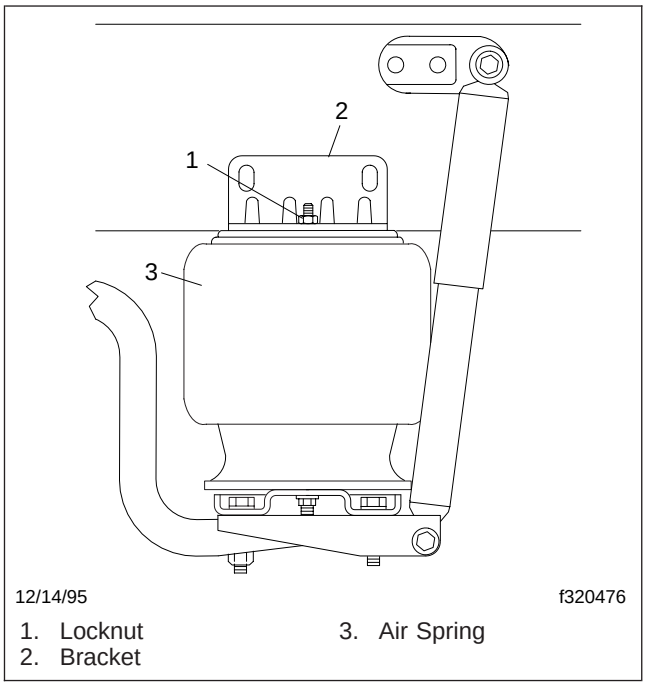
1. Height Control Valve
2. Extension Arm Locknut
3. Air Spring
4. Extension Arm Clamp
5. Threaded Extension Rod
6. Rubber Grommet

Fig. 1, Height Control Valve Assembly

3. Lower the lever on the height control valve to exhaust the air from the air springs.
4. Disconnect the air lines from the air spring fittings.
5. Remove the brass air fittings from the air spring.
6. Remove the locknuts and washers that attach the air springs studs to the upper bracket on the frame rail. See **Fig. 2**.
7. Remove the nuts, washers and bolts that hold the upper air spring bracket to the frame rail. Remove the air spring bracket.

Installation

1. Position the air spring upper bracket on the frame rails. Install the bolts through the frame rail and upper bracket and install the washers, and locknuts. Tighten the locknuts 340 lbf·ft (461 N·m).
2. Attach the air spring to the air spring frame bracket. Tighten the outboard locknut 25 lbf·ft (34 N·m).



1. Locknut
2. Bracket
3. Air Spring

Fig. 2, Air Spring Installation

3. Attach the brass air fittings to the air spring port using Teflon® thread sealant.
4. Connect the air lines to the air spring fittings.

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Air Spring Frame Hanger Removal and Installation

5. Raise the height control lever to lift the frame off the jack stands. Remove the jack stands and lower the vehicle.
6. Align the ball joint stud in the vertical linkage rod with the hole in the height control lever. Install the ball joint stud, the washer and locknut. Tighten the locknut 125 lbf·in (1412 N·cm).
7. Check the ride height as described in **Subject 230**.
8. Remove the chocks from the tires.

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Shock Absorber Bracket Removal and Installation

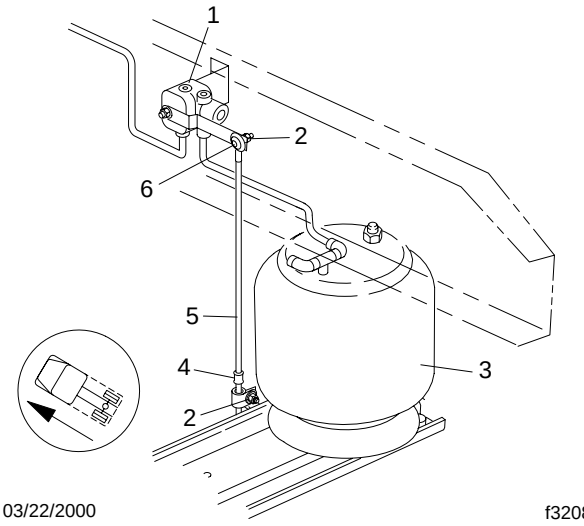
Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.

⚠ WARNING

The air suspension system will start moving the frame when the lever for the ride height control valve is moved from its center position. To avoid injury or property damage, make sure that your hands and all objects are away from any pinch points when the lever is moved.

2. Remove the locknut and washer and disconnect the ball joint stud on the top of the vertical linkage rod from the height control valve lever. See **Fig. 1**.



1. Height Control Valve
2. Extension Arm Locknut
3. Air Spring
4. Extension Arm Clamp
5. Threaded Extension Rod
6. Rubber Grommet

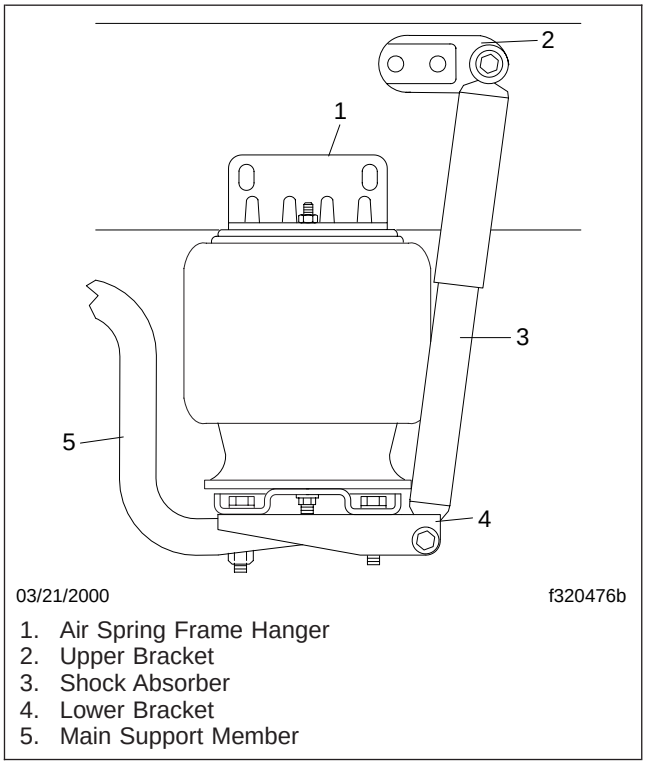
Fig. 1, Height Control Valve Assembly

3. Lift the height control lever to raise the rear of the frame enough to remove the load from the suspension.

   NOTE: The front of the main support member will move downward as the load is removed. Support the frame in this position with jack stands.

4. Remove the shock absorber. For instructions, see **Subject 150**.

5. Remove nuts, washers and bolts from the shock absorber frame hanger bracket. See **Fig. 2**. Remove the top shock absorber bracket from the frame.



1. Air Spring Frame Hanger
2. Upper Bracket
3. Shock Absorber
4. Lower Bracket
5. Main Support Member

Fig. 2, Shock Absorber Mount

6. Remove the nuts, washers and bolts that attach the cross channel and lower shock absorber bracket to the rear of the main support member.

7. Remove the lower bracket by sliding the bracket to the rear.

Installation

1. Install the bolts and washers that attach the frame hanger bracket from the inboard side of the frame. Install the brackets, washers and locknuts.

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Shock Absorber Bracket Removal and Installation

2. Position the lower bracket between the cross channel and the main support member.
3. Install the bolts and washers from the top of the cross channel, through the shock bracket and main support member. Install the washers and locknuts and tighten the locknuts attaching the cross channel to the main support member 290 lbf·ft (393 N·m).
4. Install the shock absorber. Install the washers at both sides of each shock bushing for a total of four washers per shock absorber.
5. Tighten shock absorber locknuts 60 lbf·ft (81 N·m).
6. Lift the lever of the height control valve to raise the rear of the frame off the jack stands. Remove the jack stands and lower the frame by pushing down on the height control valve lever.
7. Align the ball joint stud in the vertical linkage rod with the hole in the height control valve lever. Install the washer and locknut. Tighten the locknut 125 lbf·in (1412 N·cm).
8. Remove the chocks from the tires.

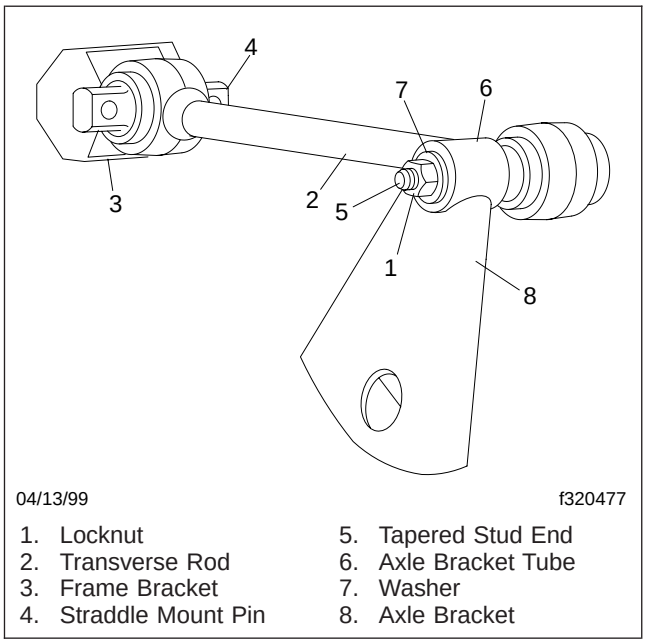
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Transverse Rod Removal and Installation

Removal (See Fig. 1)

NOTE: This procedure is for replacement of a transverse rod with a tapered stud at the axle connection and a straddle mount pin at the frame bracket end. Some installations have straddle mounts at both ends of the transverse rod.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front and rear tires.
2. Remove the nuts and washers from the bolts that fasten the pin in the transverse rod bushing to the frame bracket. Disconnect the transverse rod where it is attached to the frame bracket.
3. Remove the nut from the tapered stud in the tube bracket on the axle housing. Hit the top of the axle bracket tube hard with a large hammer to momentarily distort the tube and loosen the tapered stud. Remove the stud and transverse rod from the bracket on the axle housing.



1. Locknut
2. Transverse Rod
3. Frame Bracket
4. Straddle Mount Pin
5. Tapered Stud End
6. Axle Bracket Tube
7. Washer
8. Axle Bracket

Fig. 1, Transverse Rod Assembly

Installation

1. Clear the tapered hole in the axle bracket of all foreign matter.
2. Insert the tapered stud and torque rod bushing into the bracket.
3. Attach the washer and locknut to the stud. Tighten 200 lbf·ft (271 N·m).
4. After tightening, hit the top of the axle bracket tube with a hammer to seat the tapered stud. Tighten 200 lbf·ft (271 N·m).
5. Position the straddle mount end of the transverse rod at the frame bracket and tighten 200 lbf·ft (271 N·m).
6. Remove the chocks from the tires.

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General Information

Adjust the vehicle ride height with the unloaded vehicle on a level surface. The frame slope, driveline angles and axle mounting alignment should be checked after the ride height has been changed.

⚠ CAUTION

Failure to adjust the vehicle ride height could adversely affect driveline angles. If the air springs are set too high, it may be impossible to back the vehicle under a trailer. If the air springs are set too low, rapid wear of suspension parts will result.

Ride Height Adjustment

The vehicle ride height for Hendrickson HAS air suspension systems is changed by adjusting the length of the vertical linkage at the ride height control valve.

IMPORTANT: Before checking the ride height, make sure there is no load on the chassis. For tractors, unhitch the trailer. Trucks must be empty when checking the ride height.

1. Stop the vehicle on a level surface, using a light application of the brakes. Slowly move the vehicle forward and back several times without using the brakes to center the suspension joints. Do not apply the parking brakes.
2. Have an assistant chock the front tires.
3. Make sure the front and rear tires are properly inflated.
4. Put the transmission in neutral. Build the secondary air pressure to at least 100 psi (690 kPa). Shut down the engine.

   NOTE: Allow several minutes for the air pressure to equalize in the system before checking the ride height.
5. Mark the location of the front and rear tires on the floor so that the vehicle can be checked in the same location after a test drive. Chock the front tires.

IMPORTANT: Any difference in height between the two sides of the vehicle must be corrected using spacers between the main support arm and the rear axle housing before setting the vehicle ride height.

6. Measure the distance from the bottom of the frame rail to the bottom of the main support arm at the rear axle U-bolts. See **Fig. 1**. The correct measurement for Hendrickson HAS 120/150 suspensions is 3/4 to 1 inch (19 to 25 mm).

   If the measurement is the same as the specification at each support arm, the ride height is correctly adjusted.

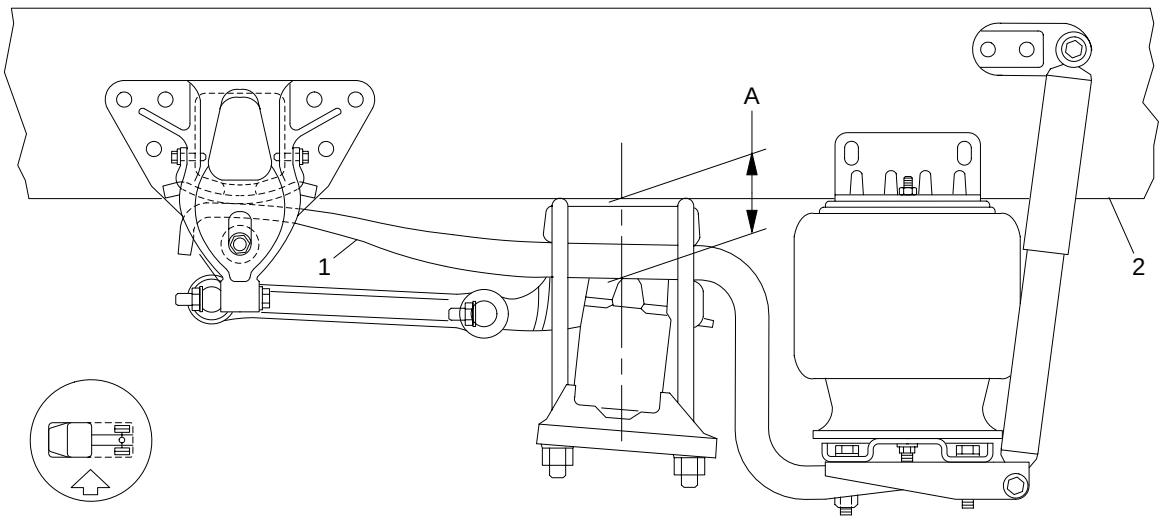
⚠ WARNING

The air suspension system will start moving the frame when the lever for the ride height control valve is moved from its center position. To avoid injury or property damage, make sure that your hands and all objects are away from any pinch points when the lever is moved.

7. Loosen the jam nuts a few turns at the top and bottom of the vertical rod that attaches to the height control lever. See **Fig. 2**.
8. Rotate the vertical rod to adjust ride height.
9. Tighten the jam nuts to 125 lbf·in (1412 N·cm) without changing the length of the vertical rod.
10. Apply the parking brakes. Remove the chocks from the tires. Drive the vehicle unloaded for about 1/4 mile (1/2 km). Stop the vehicle in the exact location (as previously marked) of the original measurement.
11. Park the vehicle using only a light brake application. Chock the tires on one axle only and put the transmission in neutral. Do not apply the parking brakes.
12. Check the adjusted distance between the bottom of the frame and the bottom of the main support arm at the U-bolts. See **Fig. 1**.
13. If the distance is still not correct, loosen the jam nuts on the vertical rod and turn the rod to adjust the ride height. Lengthen the vertical rod to raise the frame or shorten the rod to lower the frame to the correct ride height. Drive the vehicle and again check the ride height.
14. Apply the parking brakes. Remove the chocks from the tires.

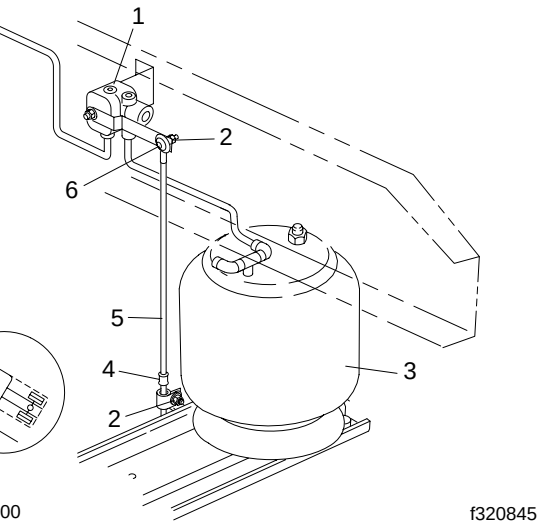
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Ride Height Adjustment



A. Measure ride height here.
1. Bottom of Main Support Arm
2. Bottom of Frame Rail

Fig. 1, Measuring the Ride Height



1. Height Control Valve
2. Extension Arm Locknut
3. Air Spring
4. Extension Arm Clamp
5. Threaded Extension Rod
6. Rubber Grommet

Fig. 2, Height Control Valve Assembly

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Troubleshooting Tables

Problem—All Air Bags are Deflated

Problem—All Air Bags are Deflated	
Possible Cause	**Remedy**
Low vehicle air system pressure	Run the engine until the air gauge indicates 100 psi (690 kPa).
Air leaking from vehicle air system	Listen for air leakage at the air fittings, tanks and brake components. Repair or replace fittings as needed.
Disconnected or maladjusted linkage for the height control valve	Connect the linkage and adjust as described in **Subject 230**.
Activated suspension dump valve	Toggle the dump control valve to the normal position.
Stuck open relay valve	Check and repair the relay valve.
Air bags leak	Listen for leaks at the air bags, tubes, and fittings.
Height control valve not operating correctly	Disconnect the linkage and raise and lower the lever to check the operation of the height control valve. Make sure that no air flows through the valve when the lever is in the center position. Replace the valve if it is bad.
Obstruction in lines to height control valve	Check the air pressure at the height control valve supply port. Remove any obstruction or restriction to air flow to the valve.
Pressure protection valve not allowing air to flow to height control valve	Check the operation of the pressure protection valve between the secondary air tank and the height control valve. Replace the valve if it is not operating correctly.

Problem—One Side of the Vehicle is Higher Than the Other

Problem—One Side of the Vehicle is Higher Than the Other	
Possible Cause	**Remedy**
Axle seat spacer thickness not same on each side	Adjust the spacers so that the frame is level before adjusting the ride height.
Uneven load distribution on vehicle	Change the position of the load to ensure equal weight on each side.
Obstruction in air flow to air bags on one side of vehicle	Disconnect the fittings and test the flow to the air bags on the lower side of the vehicle.
Internal restriction in height control valve or relay valve	Check for the same pressure at the ports on each side of the valve. Replace the valve if the pressure is not the same.
Leaking air bags or fittings	Listen for leaks at the air bags, tubes, and fittings. Tighten the fittings, if loose, or replace any bad parts.

Problem—The Ride Height is Not Constant

Problem—The Ride Height is Not Constant	
Possible Cause	**Remedy**
Air leaking from air bags or lines	Listen or use soap bubbles to find air leaks. Tighten or replace leaking fittings or air bags.

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Troubleshooting

Problem—The Ride Height is Not Constant	
Possible Cause	**Remedy**
Height control valve not working correctly	Make sure that no air is exhausted from the height control valve when the lever is in the horizontal position and that the air bags inflate when the lever is raised. The bags must deflate when the lever is pushed down. There must be a slight delay between the lever movement and the valve operation. Check for fluid leaks from the height control valve. Replace the valve if damaged.
Obstruction in air flow to air bags	Disconnect the fittings and test the flow to the air bags.
Restriction at exhaust port of height control valve	Check for air exhausting from the valve when the height control lever is pushed down.
Loose height control linkage	Make sure that all the jam nuts are tight and that the ball sockets are not worn.

Problem—The Ride Height Measurement is Not Correct

Problem—The Ride Height Measurement is Not Correct	
Possible Cause	**Remedy**
Loaded vehicle	The ride height of a loaded vehicle will be slightly lower than that of an unloaded vehicle. Adjust the ride only when the vehicle is unloaded.
Ride height adjustment not correct	Adjust the ride height as described in **Subject 230**.
Air leaking from air bags or lines	Listen or use soap bubbles to find air leaks. Tighten or replace leaking fittings or air bags.
Height control valve not working correctly	Make sure that no air is exhausted from the height control valve when the lever is in the horizontal position and that the air bags inflate when the lever is raised. The bags must deflate when the lever is pushed down. There must be a slight delay between the lever movement and the valve operation. Check for fluid leaks from the height control valve. Replace the valve if damaged.
Obstruction in air flow to air bags	Disconnect the fittings and test the flow to the air bags.
Restriction at exhaust port of height control valve	Check for air exhausting from the valve when the height control lever is pushed down.
Loose height control linkage	Make sure that all the jam nuts are tight and that the ball sockets are not worn.

Problem—The Air Springs Have Cuts

Problem—The Air Springs Have Cuts	
Possible Cause	**Remedy**
Ride height adjusted too high	Adjust the ride height so that the air bags are not continually overinflated.
Tires are too wide and are rubbing air bags	Install the correct tires.
Broken shock absorber or mount	Replace any broken components.

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Problem—The Vehicle Does Not Track Straight

Problem—The Vehicle Does Not Track Straight	
Possible Cause	**Remedy**
Axle alignment not correct	Adjust the alignment with shims at the front of the torque rods.
Worn bushings in torque rods	Replace the worn bushings.
Worn bushings in transverse rods	Replace the worn bushings.
Broken shock absorber or mount	Replace any broken components.
Loose U-bolt high nuts	Periodically tighten the nuts as described in **Specifications, 400**.
Loose or damaged suspension fasteners	Tighten or replace the fasteners.

Problem—The Vehicle Vibrates When Driven

Problem—The Vehicle Vibrates When Driven	
Possible Cause	**Remedy**
Ride height not correct	Adjust the ride height as described in **Subject 230**.
Axle housing rotational alignment not correct	Adjust the rotational alignment of the axle housing with wedge-shaped shims at the axle seats. The driveline U-joint angles must be with 1 percent of each other.
Worn or disconnected shock absorbers	Replace the shock absorbers, if worn, or tighten the mounting fasteners.
Worn bushings in torque rods	Replace the worn bushings.
Loose U-bolt high nuts	Periodically tighten the nuts as described in **Specifications, 400**.
Loose or damaged suspension fasteners	Tighten or replace the fasteners.
Frame not level from front to rear	Check and adjust the ride height at the front suspension and each rear axle. The frame should not slope more than 1/2 inch (13 mm). Correct the ride height if not at specifications.

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Specifications

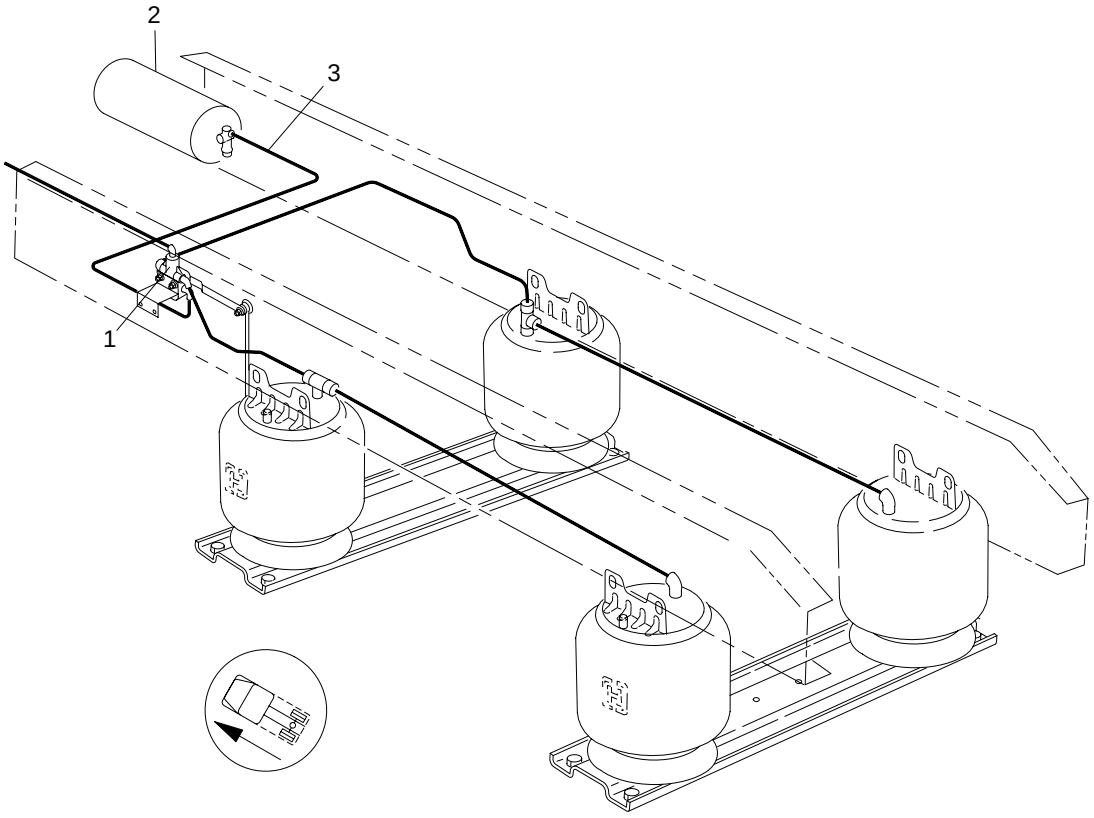
See **Fig. 1** and **Fig. 2** for an overview of the Hendrickson HAS air system plumbing.

Torque Values			
Description	**Size**	**Torque**	
		lbf·ft (N·m)	**lbf·in (N·cm)**
U-Bolt High Nuts (Tighten in a diagonal pattern as shown in **Fig. 3**.)	7/8–14	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420 to 500 (571 to 680)	—
	1–14	Stage 1: Hand-Tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 520 to 600 (707 to 816)	—
Torque Rod Bar Pin Locknut	5/8–11	180 (244)	—
Axle Seat Stud	5/8–11	65 (88)	—
Rebound Bolt Locknut	1/2–13	60 (81)	—
Upper Shock Absorber Locknut	1/2–13	60 (81)	—
Lower Shock Absorber Locknut	3/4–10	60 (81)	—
Cross Channel to Main Support Member Locknut	3/4–10	290 (393)	—
Air Spring to Frame Hanger Locknut	1/2–13	25 (34)	—
Air Spring to Cross Channel Locknut	1/2–13	25 (34)	—
Transverse Rod Locknut	1-1/4–12	200 (271)	—
Extension Arm Jam Nut	5/16–24	—	125 (1412)
Extension Arm Locknut	5/16–24	—	125 (1412)

Table 1, Torque Values

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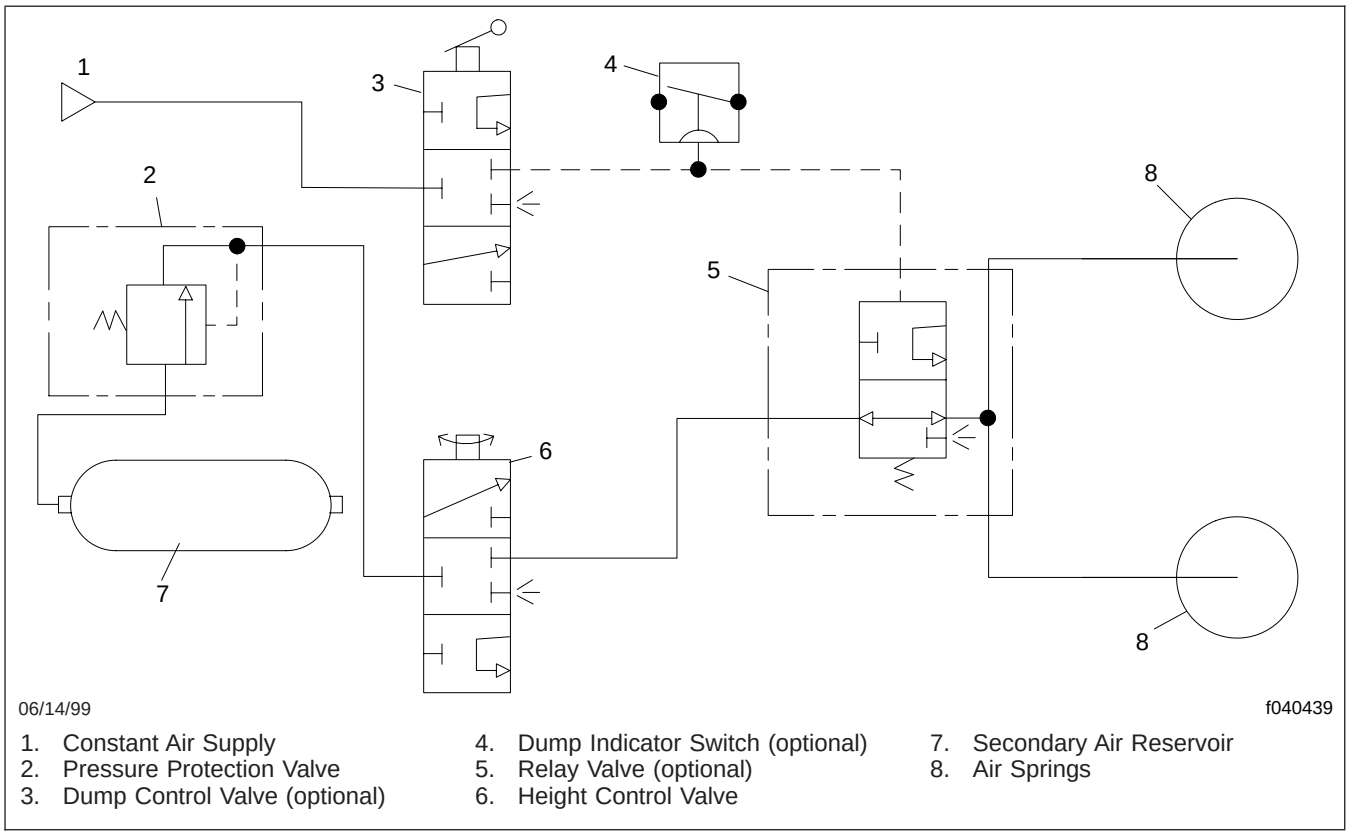
Specifications



1. Height Control Valve
2. Air Tank
3. Air Supply Line

Fig. 1, Suspension Air Plumbing

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1. Constant Air Supply
2. Pressure Protection Valve
3. Dump Control Valve (optional)
4. Dump Indicator Switch (optional)
5. Relay Valve (optional)
6. Height Control Valve
7. Secondary Air Reservoir
8. Air Springs

Fig. 2, Air Suspension Dump System Schematic (typical)

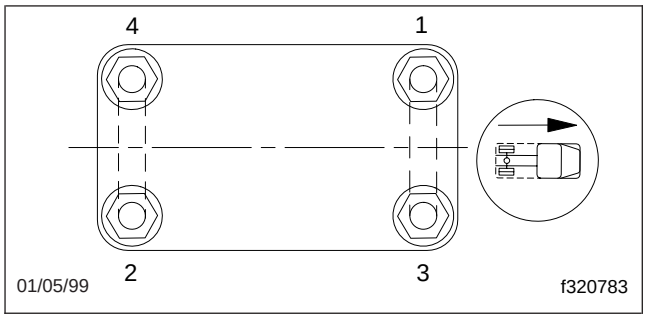


Fig. 3, Tightening Pattern for U-Bolt High Nuts

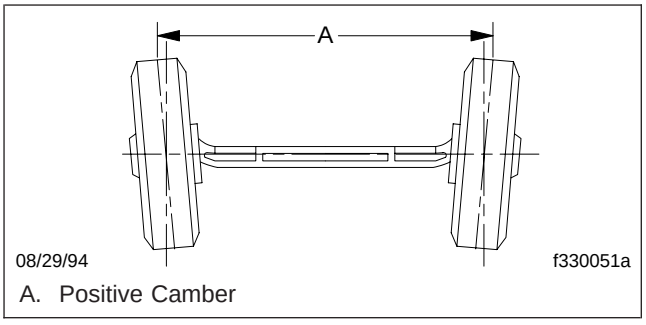
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General Information

Correct front axle wheel alignment is needed to ensure long tire life, ease of handling and steering stability.

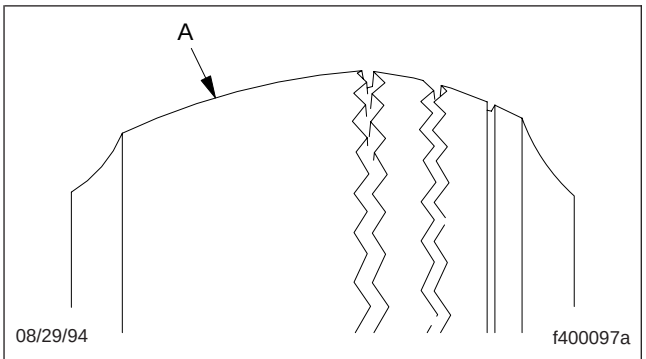
Three factors are involved in wheel alignment: camber angle, caster angle and wheel toe-in.

Camber angle is the vertical tilt of the wheel as viewed from the front of the vehicle. See **Fig. 1**. Camber angle is measured in degrees and is not adjustable. Positive camber is the outward tilt of the wheel at the top. Excessive positive camber in one wheel causes the vehicle to pull in the opposite direction, rapidly wearing the outboard side of the tire tread. Negative camber is the inward tilt of the wheel at the top. Excessive negative camber in one wheel causes the vehicle to pull in the same direction that the negative-camber wheel is on, wearing the inboard side of the tire tread. If camber angles are not correct, the tires will wear smooth around the edge on one side. See **Fig. 2**.



A. Positive Camber

Fig. 1, Camber Angle



A. One side of tread worn excessively.

Fig. 2, Tire Damage Due to Excessive Camber

Caster angle is the tilt of the knuckle pin (or kingpin) as viewed from the side. See **Fig. 3**. Caster angle is measured in degrees and it is adjustable. A positive caster angle is the tilt of the top of the knuckle pin toward the rear of the vehicle. A negative caster angle is the tilt of the top of the knuckle pin toward the front of the vehicle. Caster angles are based on the design load of the vehicle. An incorrect caster angle does not cause tire wear. However, a positive caster angle that exceeds specifications could cause vehicle shimmy, road shock and an increased steering effort. A negative caster angle that does not meet specifications could cause unstable steering. The vehicle may wander and weave and extra steering effort may be necessary. After leaving a turn, the tendency to return to and maintain a straight-ahead position is reduced. Too much or too little caster in one wheel can cause erratic steering when the service brakes are applied to stop the vehicle.

Wheel toe-in is the distance in inches that the front of the wheels are closer together than the rear of the wheels, as viewed from the top. See **Fig. 4**. Wheel toe-in is adjustable. If it is not adjusted correctly, the vehicle could pull to one side while driving. Wheel shimmy and cupped tire treads (indentations on the road contact surface of the treads) could occur. Also, rapid or severe tire wear on the steering axle could occur, usually in a feather-edged pattern. See **Fig. 5**.

Advanced wear patterns can be seen, but less severe wear patterns are detected only by rubbing the palm of your hand flat across the tire tread.

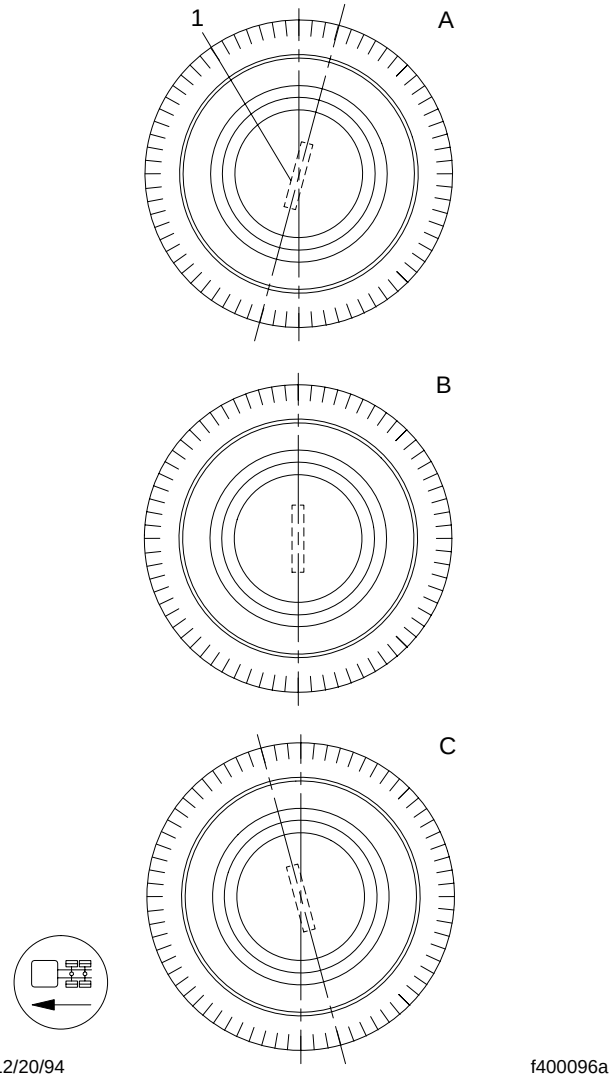
Feather-edging more often affects the front tire on the passenger's side of the vehicle and is usually more apparent on the outside grooves of the tire.

If any of the conditions listed above occur, the vehicle could need a front end wheel alignment and possibly drive axle alignment. However, in some cases these conditions are not wheel alignment related. See **Troubleshooting, 300** for other possible causes.

If excessive tire tread wear has resulted from incorrect wheel alignment, replace the damaged tires. For minimum tread wear specifications, see Group 40 of the *Acterra Maintenance Manual*.

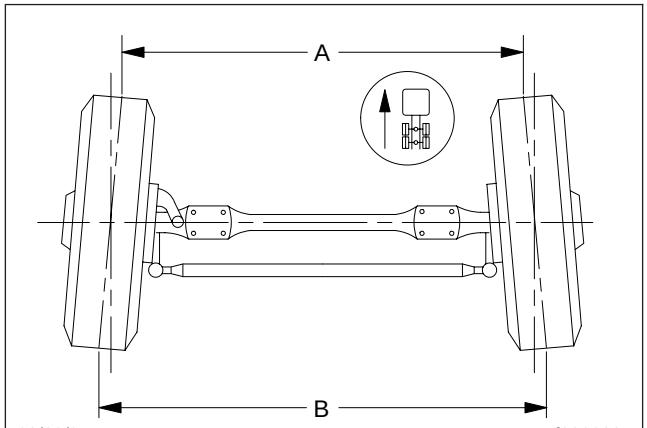
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General Information



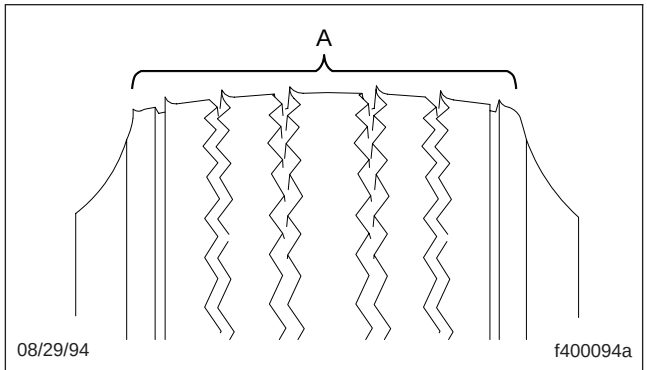
A. Positive Caster
B. Zero Caster
C. Negative Caster
1. Knuckle Pin (kingpin)

Fig. 3, Caster Angle



NOTE: B minus A equals Toe-In

Fig. 4, Wheel Toe-In (overhead view)



A. Feathered Edge

Fig. 5, Tire Damage Due to Excessive Toe-In or Incorrect Drive Axle Alignment

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Preliminary Checks

Precision instruments and equipment are needed for accurately measuring and adjusting wheel alignment. See the operating instructions provided by the wheel alignment equipment manufacturer.

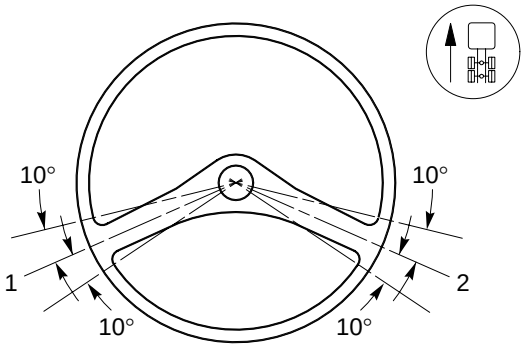
Before checking or correcting wheel alignment, make sure the vehicle is at curb weight. Curb weight is the weight of the unloaded vehicle complete with accessories and full fuel tanks.

If a road test is necessary, the route should be one that allows full left and right turns and full stops. It should also include a length of straight, level road to check the steering wheel position during straight-ahead driving.

During the road test, note any steering effort and possible roughness. Check for looseness, too much wheel play, any tendency for the vehicle to lead in one direction, and for pull during stopping.

Note the position of the steering wheel while driving on a straight, level road. When the steering gear is centered, the steering wheel spokes should be within 10 degrees of the 4 and 8 o'clock positions. See **Fig. 1**.

NOTE: These steering wheel location specifications are for reference and apply only for the conditions of this road test. Variations outside of these specifications may occur later when the vehicle is placed in service.



1. 8 o'Clock
2. 4 o'Clock

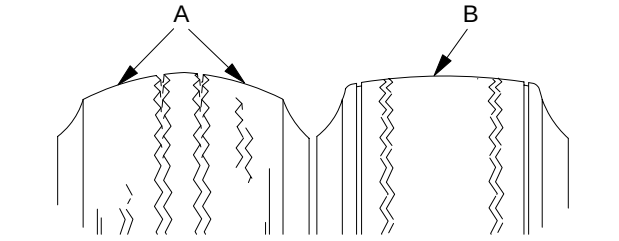
Fig. 1, Steering Wheel Position

If there are any problems, see **Troubleshooting, 300**.

1. Steering axle wheel assemblies should be balanced, especially for vehicles that travel at sustained speeds of more than 50 mph (80 km/h). Off-balance wheel assemblies cause vibrations that result in severely shortened life for tires and steering suspension parts.
2. Do not mix tires of different size, type or weight. Tire wear should be even and not worn to limits exceeding government specifications. See **Group 40** in this manual and Group 40 in the *Acterra Maintenance Manual* for more information. Replace any tire that is excessively worn.
3. Check the inflation pressure of the tires. See **Group 40** in this manual for recommended pressures. An underinflated tire causes tread wear completely around both tire shoulders. An overinflated tire causes tread wear in the center of the tire. See **Fig. 2**.
4. Check for out-of-round wheels, rims, or wheel stud holes. Replace the wheel if any of these conditions exist.
5. On each side of the vehicle, check the height of the chassis above the ground. Sagging, fatigued or broken suspension springs create a lopsided vehicle appearance. This causes an unbalanced weight distribution. Anything that changes the ratio of weight on the springs affects the alignment angles and also the tire tread contact area. Replace damaged springs as instructed in **Group 32**.
6. Inspect the front axle beam (also called the axle center) for bends or twists. If the axle beam is bent or twisted over 1/2 degree, replace it before aligning the front axle wheels.
7. Check for damaged, worn or bent steering gear or linkage parts. Make sure the steering gear is centered. Replace damaged components and adjust the steering gear using the instructions in **Group 46**.
8. Check the steering angle and adjust the axle steering stops as needed. See **Subject 110**.

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Preliminary Checks



A. Shoulder Wear (underinflation)
B. Center Tread Wear (overinflation)

Fig. 2, Tire Damage Due to Underinflated or Overinflated Tires

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Check and Adjustment

Steering (or turning) angle is the degree of front wheel movement from a straight-ahead position to either an extreme right or left position. Although front wheel movement can be limited by the amount of internal travel in the steering gear, it generally depends on how much clearance there is between chassis components and the tire and wheel assemblies. All axles have adjustable stopscrew-and locknut-type axle stops which are located on the rear side of each front axle spindle. See **Fig. 1**.

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Acterra dealers must have proof of this calibration history.

1. Make sure the steering gear is in the center of travel when the wheels are in a straight-ahead position. Center the gear using the instructions in the steering gear section in **Group 46**. Bottoming of the steering gear must not occur when making an extreme right or left turn.
2. If using stationary turnplates or turntables, drive the vehicle on the plates; the tires must be exactly straight ahead. See **Fig. 2**. Apply the parking brakes.

   If using portable gauges, apply the parking brakes, chock the rear tires and raise the front of the vehicle. Place a turnplate or turntable under each tire. With the tires exactly straight ahead, lower the vehicle so that the tires rest on the center of the gauges.
3. Remove the lockpins from the gauges and adjust the dials so that the pointers on both gauges read zero.
4. With the brakes fully applied, turn the steering wheel clockwise to the end of travel. Have someone check both sides of the vehicle for interference at the tires and wheels. There must be at least 0.50 inch (13 mm) clearance from any fixed object and 0.75 inch (19 mm) from any moving object.

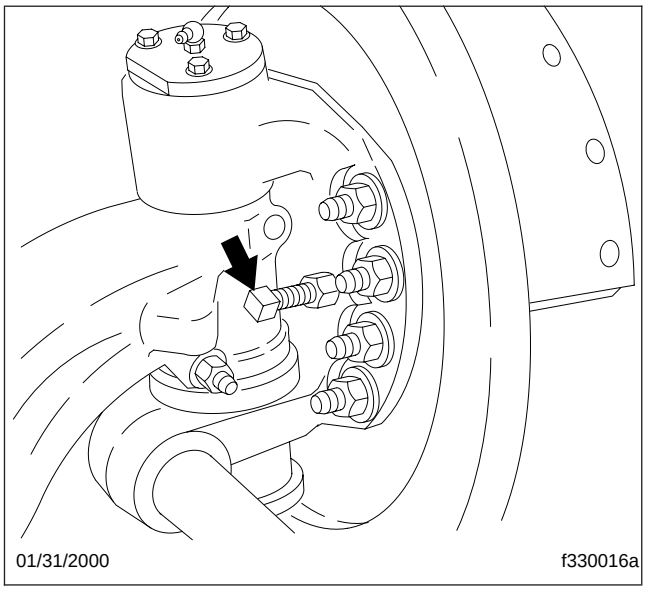


Fig. 1, Axle Stop on Front Axle Spindle Stopscrew and Locknut

   If necessary, loosen the stopscrew locknut; adjust the stopscrew to contact the axle when the maximum turning angle of the wheels is determined.

   Tighten the locknut to the value in the torque table in **Specifications, 400**.

   Repeat the step with the steering wheel turned counterclockwise. Adjust the axle stop, as needed.

NOTE: The turning angle may not be the same on both sides.

5. Adjust the steering gear so that pressure is released ahead of the axle stop. This will prevent possible damage to the steering or axle components. For poppet valve adjustment instructions, see the steering gear section in **Group 46**.
6. Drive the vehicle off the turnplates or turntables or remove them from under the tires and lower the vehicle.

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Steering Angle Check and Adjustment

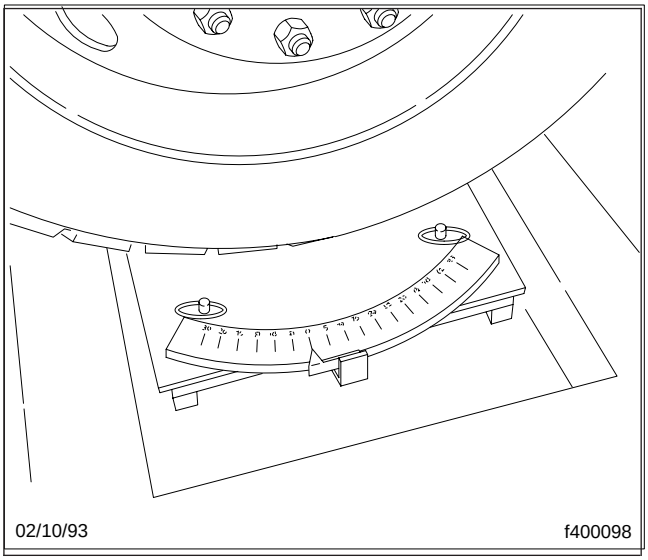


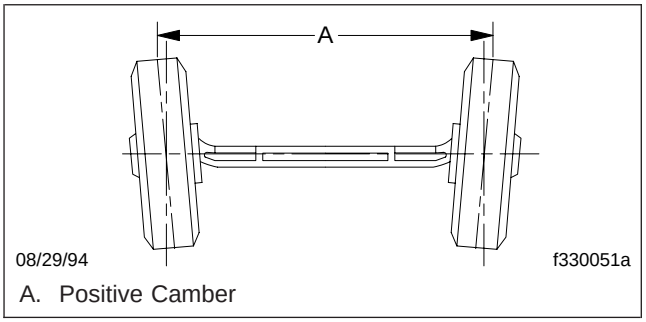
Fig. 2, Turnplate (Turntable), Stationary Type

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Check (See Fig. 1)

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turnplates for the front wheels must rotate freely without friction and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Acterra dealers must have proof of this calibration history.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Raise the front of the vehicle until the tires clear the ground. Place safety stands under the axle; make sure the stands will support the weight of the cab, frame, and front axle.
3. Before measuring camber, check the front wheel bearings for wear and incorrect adjustment. Try moving the wheel on the axle spindle (steering knuckle) either by grasping the front tire on the top and bottom, or by using a bar for leverage. If movement between the brake drum and the backing plate or other axle-mounted reference point is 0.05 inch (1 mm) or more, the bearings may be worn or incorrectly adjusted. Inspect the wheel bearings for damage. If needed, replace or adjust the bearings using the instructions in **Section 33.01** of this manual.
4. Remove the safety stands and lower the vehicle to the ground.
5. Using the alignment equipment manufacturer's instructions, measure the front wheel camber.



A. Positive Camber

Fig. 1, Camber Angle

6. Compare the camber angles with those shown in the applicable table in **Specifications, 400**. Differences between the measurements taken in this subject and the angles in the applicable table in **Specifications, 400** are caused by damaged (bent) axle components.

   Incorrect camber angles could be caused by damage in one or more of the following front axle components: the knuckle pin, the knuckle pin bushings, the axle spindle or the axle beam. Replace twisted or otherwise damaged components. Do not try to straighten twisted or bent components; replace them with new components. If a bent or twisted front axle knuckle pin, axle spindle or axle beam has been straightened, the axle warranty will be voided.

⚠ WARNING

Trying to straighten a twisted or bent front axle component can crack or weaken it. A cracked or weakened axle component could result in a collapsed front axle or the loss of a wheel, which could cause serious personal injury.

7. Remove the chocks from the tires.

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Check and Adjustment (See Fig. 1)

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turnplates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Acterra dealers must have proof of this calibration history.

Using the alignment equipment manufacturer's operating instructions, measure the front wheel caster.

Compare the caster angles with those shown in the applicable table in **Specifications, 400**. If needed, adjust the caster angle by placing wedge-shaped shims between the axle spacer and the axle beam, as follows (see **Fig. 2**):

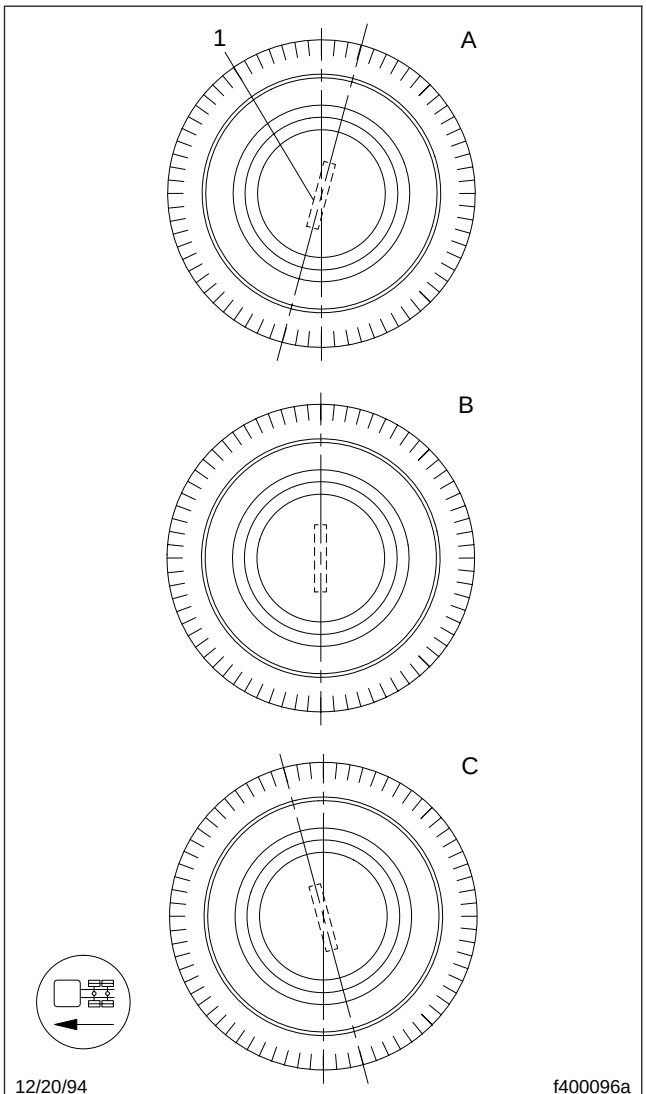
IMPORTANT: Extreme angle shims cannot be used to correct caster angles that vary by more than 2 degrees from the values in the table in **Specifications, 400**. Weak or broken leaf springs or worn shackle bushings can cause extreme deviations to caster angles. Replace damaged parts before doing caster adjustments.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front and rear tires.
2. Back off the U-bolt high nuts from the U-bolts on one side of the front axle. See **Fig. 2**.
3. Raise the spring away from the axle enough to allow removal of the front caster shim.
4. Remove the shim and install one that will provide the correct caster angle as specified in the table in **Specifications, 400**. Install the dowel pin and check penetration.

IMPORTANT: Place front caster shims between the axle beam and the axle spacer. See **Fig. 2**.

5. Lower the vehicle onto the axle.
6. Coat the threaded ends of the U-bolts with chassis lube or an antiseize compound, such as Loctite® 242. Tighten the U-bolt nuts to the value in the torque table in **Specifications, 400**.

   U-bolt high nuts need periodic retightening.



A. Positive Caster
B. Zero Caster
C. Negative Caster
1. Knuckle Pin (Kingpin)

Fig. 1, Caster Angle

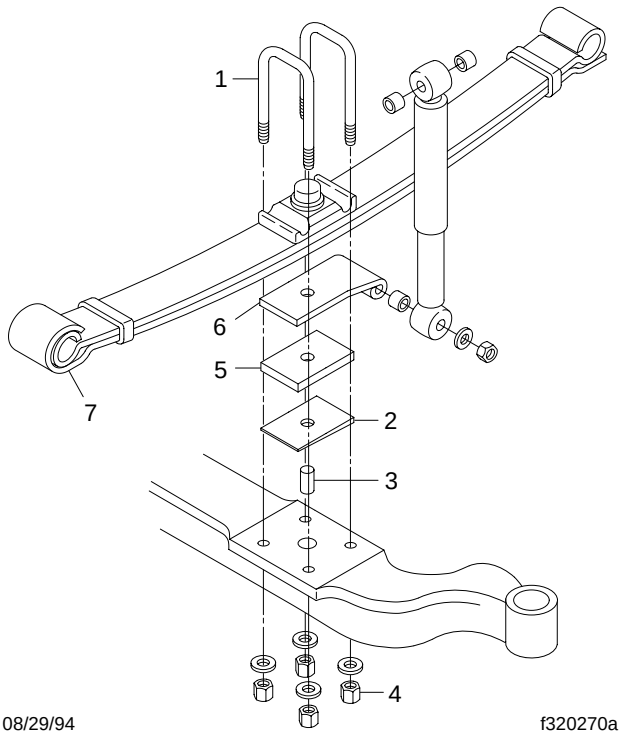
CAUTION

Failure to periodically retighten the U-bolt high nuts could result in spring breakage and abnormal tire wear.

7. Using the steps above, replace the shim on the other side of the axle.

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Caster Angle Check and Adjustment



1. Axle Spring U-Bolt
2. Front Caster Shim
3. Dowel Pin
4. U-Bolt High Nut
5. Spacer
6. Shock Absorber Lower Mounting Bracket
7. Leaf Spring Assembly

Fig. 2, Front Axle End With Leaf Spring Assembly

8. Remove the chocks from the tires. Do a final caster angle check.

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Check and Adjustment (See Fig. 1)

NOTE: If using electronic alignment equipment, measure the wheel toe-in following the manufacturer's operating instructions. Compare the measurement with that shown in the table in **Specifications, 400**. If corrections are needed, go to the step in this subject which describes loosening the tie rod clamp nuts and proceed.

If electronic alignment equipment is not available, do all the steps.

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turnplates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Acterra dealers must have proof of this calibration history.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Raise the front of the vehicle until the tires clear the ground. Place safety stands under the axle. Make sure the stands will support the weight of the cab, axle, and frame.
3. Using spray paint or a piece of chalk, mark the entire center rib of each front tire.
4. Place a scribe or pointed instrument against the marked center rib of each tire, and turn the tires. The scribes must be held firmly in place so that a single straight line is scribed all the way around each tire.
5. Place a turnplate or turntable under each tire. Remove the safety stands from under the axle, then lower the vehicle. Remove the lockpins from the gauges; make sure the tires are exactly straight ahead.
6. Place the trammel bar at the rear of the front tires; locate the trammel pointers at spindle height, and adjust the pointers to line up with the scribe lines. Lock in place. Make sure that the scale is set on zero.

NOTE: If turnplates or turntables are not available, lower the vehicle. Remove the chocks from the rear tires and release the parking brakes. Move the vehicle backward and then forward about 6 ft (2 m).

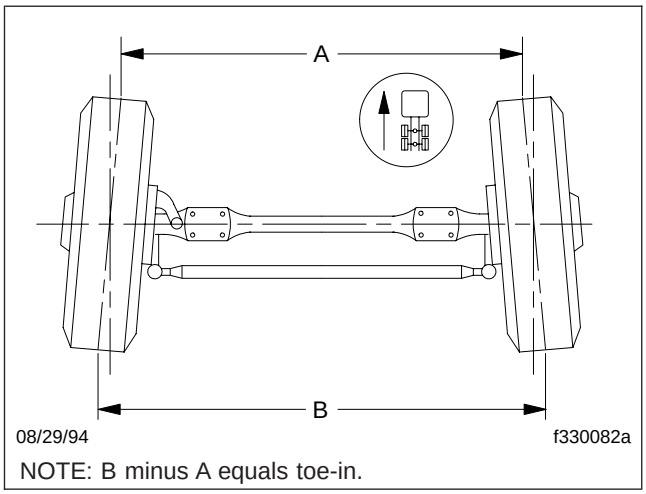


Fig. 1, Wheel Toe-In (overhead view)

7. Place the trammel bar at the front of the tires as shown in **Fig. 2**. Adjust the scale end so that the pointers line up with the scribe lines. See **Fig. 3**.
8. Read the toe-in from the scale. Compare the toe-in with the value in the table in **Specifications, 400**. Make corrections if necessary.
9. Loosen the tie rod (cross tube) clamp nuts, and turn the tie rod as needed.

   If the vehicle is not on turnplates or turntables, move the vehicle backward and then forward about 6 ft (2 m). This is important when setting the toe-in on vehicles equipped with radial tires.

   Do a final wheel toe-in check to make sure that it is correct.

   Tighten the clamp nuts to the values in the table in **Specifications, 400**.
10. If not already done, remove the chocks from the rear tires. Road test the vehicle.

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Wheel Toe-In Check and Adjustment

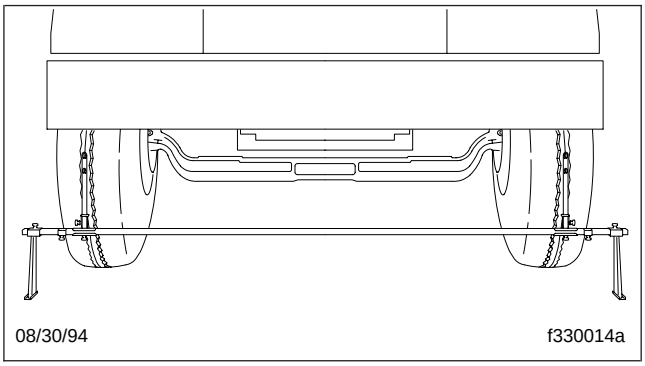


Fig. 2, Trammel Bar Positioning

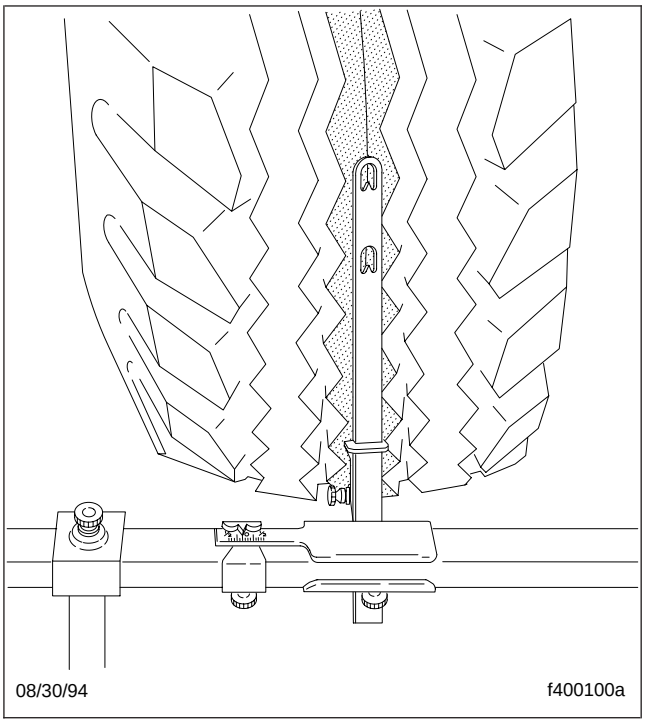


Fig. 3, Calculating Wheel Toe-In

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Troubleshooting Tables

NOTE: Service instructions for most of the remedies below are found by referring to the index in the back of this manual. For axles, see the service literature provided by the axle manufacturer. For tire inflation pressures, see **Group 40** in this manual. For more steering system troubleshooting information, see **Group 46** in this manual.

Problem—Hard Steering

Problem—Hard Steering	
Possible Cause	**Remedy**
Low tire pressure in one or both front tires	Inflate tires to the correct pressure.
Binding in steering gear due to lack of lubrication	Lubricate the steering gear. For instructions, see Group 46 in the *Acterra Maintenance Manual*.
Too much caster angle in front wheels	Check the caster angle and adjust as needed.
Sagging front suspension due to damaged spring	Repair or replace the spring as needed. For instructions, see **Group 32** in this manual.
Bent axle spindle	Replace the spindle.
Misaligned frame	Check the frame alignment and correct as needed.
Low pressure in power steering system	Repair the power steering system.
Steering gear incorrectly assembled	Assemble the steering gear correctly.
Binding king pins	Replace the king pins.
Incorrect steering arm geometry	Service the steering system as necessary.
Hard to move tie rod ends	Replace the tie rod ends.
Worn thrust bearing	Replace the thrust bearing.

Problem—Erratic Steering When the Brakes are Applied

Problem—Erratic Steering When the Brakes are Applied	
Possible Cause	**Remedy**
Low tire pressure in one or both front tires	Inflate the tires to the correct pressure.
One or more loose front axle spring U-bolt nuts	Check the U-bolt nuts for looseness. If loose, check the U-bolt for damage. Replace damaged parts; tighten loose nuts.
Brakes not evenly adjusted	Adjust the brakes on all axles. Check the operation of the slack adjusters.
Grease or oil contamination of the brake linings reducing brake effectiveness	Replace the brake linings and clean the drums. Find and correct the cause of grease or oil contamination.
Wrong caster angle	Check and adjust as needed.
Bent axle spindle	Replace the axle spindle.
Worn or incorrectly adjusted front axle wheel bearings	Check the bearings for wear or damage; replace as needed.

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Troubleshooting

Problem—Vehicle Pulls to One Side During Operation

Problem—Vehicle Pulls to One Side During Operation	
Possible Cause	**Remedy**
Low tire pressure in one or both front tires	Inflate the tires to the correct pressure.
One or more incorrect alignment measurements	Check all the alignment measurements. Correct as needed.
Out-of-round wheels or tires	Inspect the wheels and tires. Replace out-of-round parts.
Too tightly adjusted front axle wheel bearings	Check the bearings for wear or other damage. Replace the bearings if needed.
Sagging front suspension due to a damaged spring	Repair or replace the spring as needed. For instructions, see **Group 32** in this manual.
Bent axle spindle	Replace the spindle.
Misaligned frame	Check the frame alignment and correct as needed.
Out of alignment rear axle(s)	Check the rear axle alignment and adjust if needed.

Problem—Front Wheel Wander

Problem—Front Wheel Wander	
Possible Cause	**Remedy**
One or more out-of-balance wheels or brake drums	Balance the wheels. Check for out-of-round brake drums and correct as needed.
Weak or broken front springs	Repair or replace the spring as needed. For instructions, see **Group 32** in this manual.

Problem—Front Wheel Shimmy

Problem—Front Wheel Shimmy	
Possible Cause	**Remedy**
Low tire pressure in one or both front tires	Inflate the tires to the correct pressure.
One or more out-of-balance wheels or brake drums	Balance the wheels. Check for out-of-round brake drums, correct or replace as needed.
One or more out-of-round or bulged tires	Replace the tire.
Worn or incorrectly adjusted front axle wheel bearings	Check the bearings for wear or other damage. Replace the bearings if needed.
Worn steering gear or linkage	Test for play in the steering gear and linkage with the front tires off the ground. Replace parts as needed.
Bent axle spindle	Replace the spindle.
One or more incorrect alignment measurements	Check all alignment measurements and correct as needed.
Loose knuckle pin due to worn bushings	Inspect the knuckle pin and bushings for damage. Replace worn or damaged parts as needed.
Worn or damaged shock absorbers	Check the shock absorbers and replace if needed.
Out of adjustment caster	Adjust the caster.

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Troubleshooting

Problem—Vehicle Wanders

Problem—Vehicle Wanders	
Possible Cause	**Remedy**
Low tire pressure in one or both front tires	Inflate the tires to the correct pressure.
One or more incorrect alignment measurements	Check all of the alignment measurements and correct as needed.
Out of alignment rear axle(s)	Check the rear axle alignment and adjust as needed.
Worn steering gear or linkage	Test for play in the steering gear and linkage with the front tires off the ground. Replace parts as needed.
Loose knuckle pin due to worn bushings	Inspect the knuckle pin and bushings for damage. Replace worn or damaged parts.
Bent axle spindle	Replace the spindle.

Problem—Cupped Tires

Problem—Cupped Tires	
Possible Cause	**Remedy**
Too low or too high tire pressure in one or both front tires	Inflate or deflate the tires to the correct pressure.
One or more out-of-balance wheels or brake drums	Balance the wheels. Check for eccentric brake drums and correct or replace as needed.
Incorrect wheel toe-in	Adjust the wheel toe-in.
Brakes not evenly adjusted	Adjust the brakes on all axles. Check the operation of the slack adjusters.
Worn or incorrectly adjusted front axle wheel bearings	Check the bearings for wear or other damage and replace them if needed.
Camber angle not within specifications	Check the front wheel camber angle. If not correct, find and replace the damaged axle component.

Problem—Steering Wheel Spokes Do Not Point at the 4 and 8 o'Clock Positions

Problem—Steering Wheel Spokes Do Not Point at the 4 and 8 o'Clock Positions	
Possible Cause	**Remedy**
Steering gear not centered	Center the steering gear.
Out of adjustment drag link	Adjust the drag link.
Steering wheel incorrectly installed (positioned) on the steering column	Reposition the steering wheel on the steering column.
Pitman arm incorrectly aligned with the timing mark on the steering gear output shaft	Reposition the pitman arm on the steering gear output shaft. For instructions, see **Group 46** in this manual.

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Troubleshooting

Problem—Tires Wear Out Quickly or Have Uneven Tire Tread Wear

Problem—Tires Wear Out Quickly or Have Uneven Tire Tread Wear	
Possible Cause	**Remedy**
Incorrect tire air pressure	Inflate or deflate the tires to the correct pressure.
Out of balance tires	Balance or replace the tires.
Incorrect tandem axle alignment	Align the tandem axles.
Incorrect toe-in setting	Adjust toe-in to the specified setting.
Incorrect steering arm geometry	Service the steering arm as necessary.

Problem—Ends of the Cross Tube are Worn

Problem—Ends of the Cross Tube are Worn	
Possible Cause	**Remedy**
Cross tube ends need lubrication	Lubricate the ends of the cross tube. Make sure lubrication schedule is followed.
Vehicle operated in severe conditions	Operate the vehicle correctly.
Damaged boot on end of cross tube	Replace the boot.
Incorrectly installed add-on type of power steering cylinders	Install the power steering cylinders correctly.

Problem—Bent or Broken Cross Tube, Ball Stud, Steering Arm or Cross Tube Arm

Problem—Bent or Broken Cross Tube, Ball Stud, Steering Arm or Cross Tube Arm	
Possible Cause	**Remedy**
Too much pressure in power steering system	Adjust the power steering system to the specified pressure.
Out of adjustment cut-off pressure in power steering system	Adjust the power steering system to the specified pressure.
Incorrectly operated vehicle	Make sure vehicle is operated correctly.
Incorrectly installed add-on type power steering system	Install the add-on power steering system correctly.

Problem—Worn or Broken Steering Ball Stud

Problem—Worn or Broken Steering Ball Stud	
Possible Cause	**Remedy**
Drag link fasteners tightened past specified torque	Tighten the drag link fasteners to the specified torque.
Incorrect lubrication or lack of lubrication	Lubricate the linkage with specified lubricant.
Out of adjustment power steering stops	Adjust the stops to specified dimension.

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Problem—Worn Kingpins and Knuckle Bushings

Problem—Worn Kingpins and Knuckle Bushings	
Possible Cause	**Remedy**
Worn or missing seals and gaskets	Replace the seals and gaskets.
Incorrect lubricant	Lubricate the axle with specified lubricant.
Axle not lubricated at scheduled frequency	Lubricate the axle at scheduled frequency.
Incorrect lubrication procedures	Use the correct lubrication procedures.
Lubrication schedule does not match operating conditions	Change the lubrication schedule to match the operating conditions.

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Specifications

IMPORTANT: When aligning the front axle, it is essential that the rear axle(s) be checked for correct alignment at the same time. Alignment of the rear axle(s) has a direct impact on how the vehicle tracks. See **Section 35.00**.

NOTE: The alignment specifications below are for unloaded vehicles. These specifications will vary as weight is added to the vehicle and transferred to the front axle.

Camber and Toe-In					
Axle Manufacturer	**Axle Model**	**Left Camber: degrees**	**Right Camber: degrees**	**Toe-In Limits: in (mm)**	**Toe-In Target: in (mm)**
Meritor	All	–1/4 ± 7/16	–1/4 ± 7/16	0 to +1/8* (0 to 3.2)	+1/16 (+1.6)
Sterling	All				
Dana/Eaton	All E Series	+1/4 ± 7/16	0 ± 7/16		

* If adjustment is required, set the toe-in as close as possible to +1/16 inch (+1.6 mm).

Table 1, Camber and Toe-In

Caster					
Axle Manufacturer	**Beissbarth: degrees**	**Bee Line**		**Hunter: degrees**	**Target, All Models: degrees**
		Except LC 4000: degrees	**LC 4000: degrees**		
Meritor and Sterling	+3 to +6-1/2	+3 to +6-1/2	+2-1/4 to +4-3/4	+2 to +5	+3-1/2 ± 1-1/2
IMPORTANT: Caster settings for the left and right sides *must* be within 1/2 degree of each other. It is necessary for only one side to be within the specifications given in this table.					

Table 2, Caster

Tie Rod Clamp Nut Torque Values				
Axle Manufacturer	**Axle Model**	**Tie Rod Clamp Nut Size**	**Plain Nut Torque:* lbf·ft (N·m)**	**Locknut Torque:* lbf·ft (N·m)**
Meritor	All	5/8–11	50–60 (68–81)	50–60 (68–81)
Sterling	All	5/8–11	60–80 (81–108)	60–80 (81–108)
Dana/Eaton	All E Series	5/8–18	40–60 (55–81)	40–60 (55–81)

* All torque values in this table apply to parts lightly coated with rust-preventive type oil.

Table 3, Tie Rod Clamp Nut Torque Values

Miscellaneous Torque Values		
Description	**Size**	**Torque: lbf·ft (N·m)**
U-Bolt High Nut	5/8–11	195 (264)
	3/4–16	335 (454)
Stopscrew Locknut	—	58 (78)

Table 4, Miscellaneous Torque Values

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General Information

The front axle full-floating wheel hub assembly is made up of four major components: tapered wheel bearings, the wheel hub, wheel studs, and the brake drum or rotor. See **Fig. 1**.

TAPERED WHEEL BEARINGS

A typical tapered wheel bearing assembly consists of a cone, tapered rollers, a roller cage, and a separate cup that is press-fit in the hub. See **Fig. 2**. All components carry the load, with the exception of the cage, which spaces the rollers around the cone.

Each hub has a set of inner and outer tapered wheel bearing assemblies. The bearing setting is locked in place on the axle spindle (steering knuckle) by an adjusting nut and jam nut. See **Fig. 3**.

WHEEL HUB

The wheel and the brake drum or rotor are mounted on a steel or iron wheel hub. See **Fig. 4**.

Both the inner and outer wheel bearing cups and the wheel studs are press-fit in the hub.

Spoke wheels combine the wheel and hub into a single unit.

WHEEL STUDS

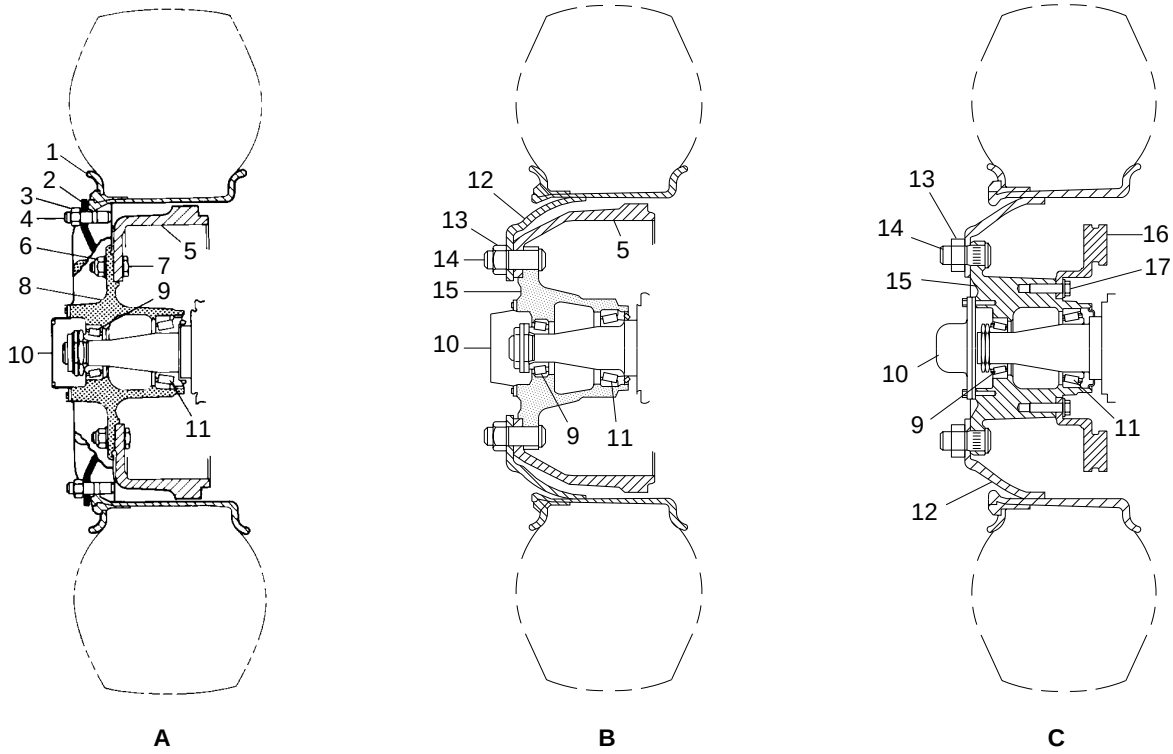
A headed wheel stud is used on front axle disc wheel hub assemblies and has serrations on the stud body to prevent the stud from turning in the wheel hub. See **Fig. 5**.

The end of the stud that faces away from the vehicle is stamped with an "L" or "R," depending on which side of the vehicle the stud is installed. Studs stamped with an "L" are left-hand threaded and are installed on the left side of the vehicle. Studs stamped with an "R" are right-hand threaded and are installed on the right side of the vehicle.

Spoke wheels have rim studs. Rim studs are threaded on both ends, with a nonthreaded section midway along the shaft of the stud. The studs are coated with an anaerobic locking compound.

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General Information



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A. Spoke Wheel Assembly with Drum Brakes
B. Disc Wheel Assembly with Drum Brakes
C. Disc Wheel Assembly with Disc Brakes

1. Rim
2. Rim Clamp
3. Rim Stud Nut
4. Rim Stud
5. Brake Drum
6. Brake Drum Nut
7. Brake Drum Bolt
8. Spoke Wheel
9. Outer Wheel Bearing
10. Hub Cap
11. Inner Wheel Bearing
12. Disc Wheel
13. Wheel Nut
14. Wheel Stud
15. Hub
16. Brake Rotor
17. Rotor Bolt

Fig. 1, Tapered Wheel Bearing Assembly

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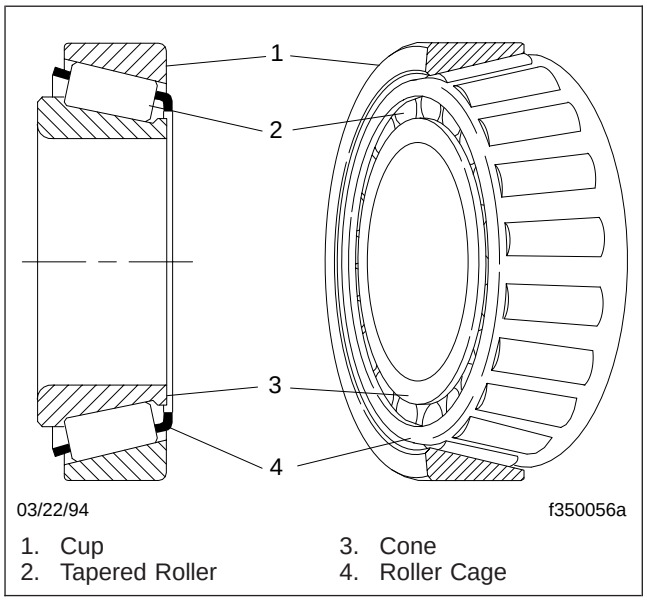
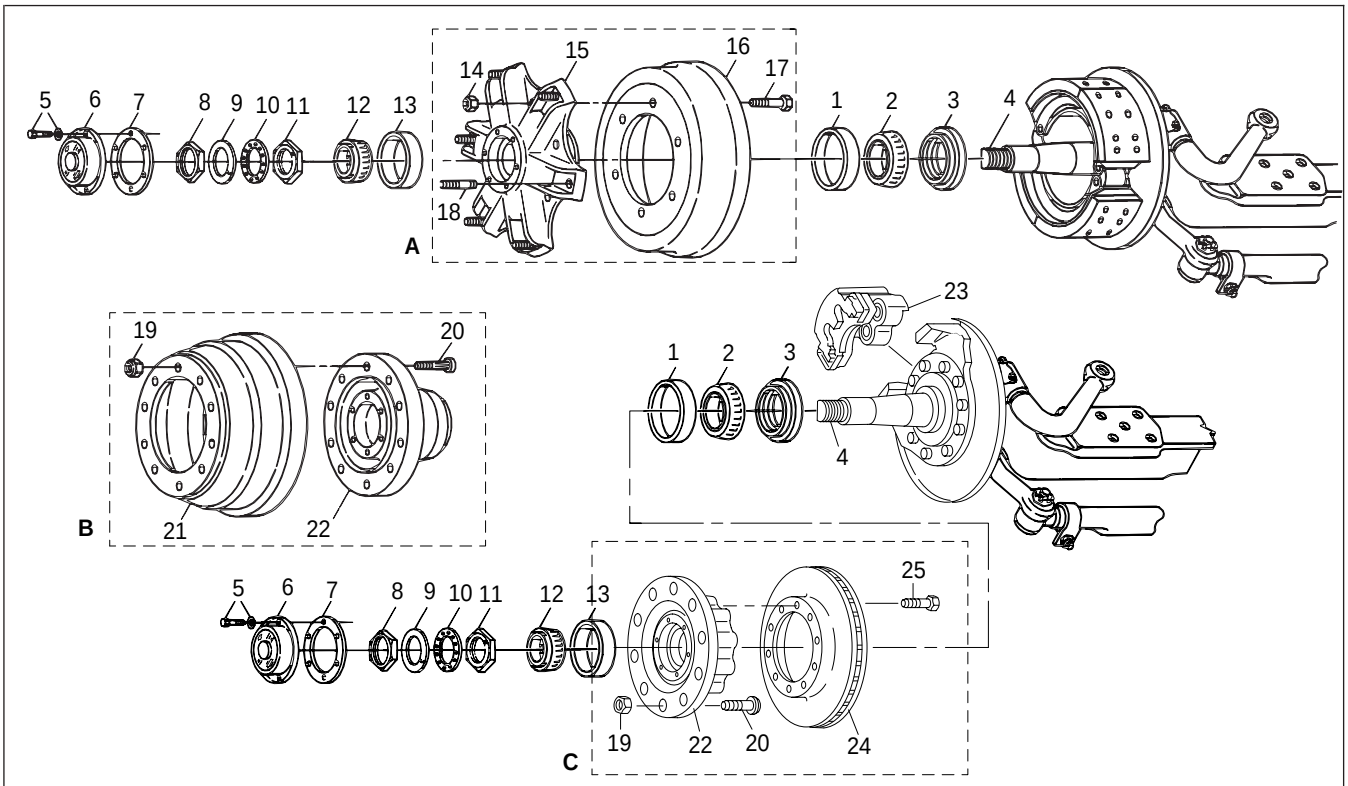


Fig. 2, Wheel Hub Assembly

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General Information



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A. Spoke Wheel and Drum Assembly
B. Outboard Mounted Hub and Drum Assembly
C. Disc Brake Assembly

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle (steering knuckle)
5. Hub Cap Capscrew and Washer
6. Hub Cap
7. Hub Cap Gasket
8. Jam Nut
9. Lockwasher
10. Lockring
11. Wheel Bearing Adjusting Nut
12. Outer Wheel Bearing
13. Outer Wheel Bearing Cup
14. Brake Drum Nut
15. Spoke Wheel
16. Brake Drum, Inboard-Mounted
17. Brake Drum Bolt
18. Rim Stud
19. Wheel Nut
20. Wheel Stud
21. Brake Drum, Outboard-Mounted
22. Wheel Hub
23. Brake Caliper
24. Brake Rotor
25. Rotor Bolt

Fig. 3, Wheel Bearing Assemblies on Hubs

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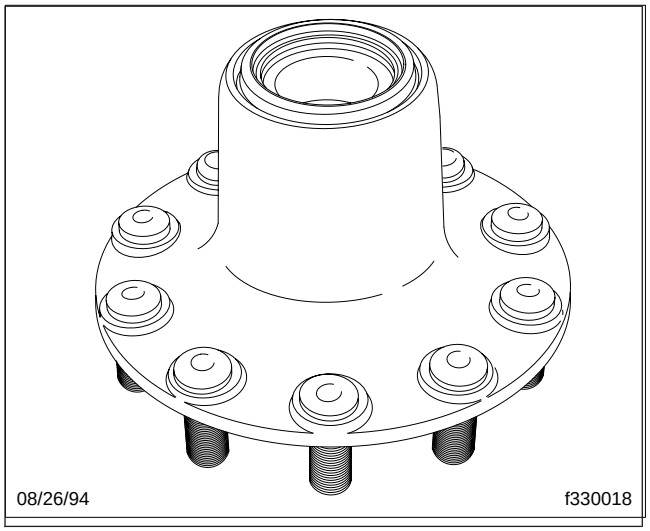


Fig. 4, Front Axle Wheel Hub

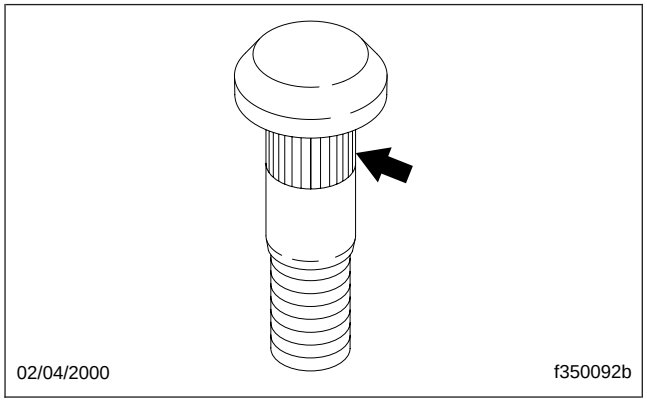


Fig. 5, Headed Wheel Stud Serrations

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Hub Assembly Removal and Installation, Disc Wheels

Removal

IMPORTANT: Make sure the required oil seal installation tools are available before beginning the service procedures described here.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine, and chock the rear tires.
2. Raise the front of the vehicle until the tires clear the ground. Place safety stands under the axle.
3. Remove the wheel and tire assembly. See **Group 40** for instructions.

⚠ WARNING

Breathing brake lining dust, asbestos or non-asbestos, could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

4. To minimize the possibility of creating airborne brake lining dust, remove the dust from the brake drum, brake backing plate, and brake assembly using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Use a rag soaked in water and wrung until nearly dry to remove any remaining dust. Do not use compressed air or dry brushing to clean the brake assembly.
5. Remove the brake drum or caliper. For instructions, see **Group 42**.

NOTE: On vehicles equipped with oil-lubricated bearings, oil will spill as the hub cap and wheel hub are removed. Place a suitable container under the axle spindle to catch any spilled oil. Dispose of the oil properly.

6. Remove the capscrews, washers, and hub cap. Remove and discard the hub cap gasket. See **Fig. 1**.
7. Remove the axle spindle jam nut, bend-type locking washer, and lockring or cotter pin. See **Fig. 2** for the cotter pin or **Fig. 3** for the lockring.
8. Back off the wheel bearing adjusting nut about two turns, enough to allow the weight of the hub to be lifted from the wheel bearings.
9. Lift the hub until all weight is off the wheel bearings. Remove the adjusting nut.
10. Move the hub about 1/2 inch (13 mm) to jar loose the outer wheel bearing. Allow the hub assembly to rest on the axle spindle, being careful not to damage the axle spindle threads.
11. Carefully remove the outer wheel bearing. Handle the bearing assembly with gloves or clean, dry hands. Wrap all bearing assembly parts in clean oil-proof paper or lint-free rags.

⚠ CAUTION

Do not spin the bearing rollers, and keep them very clean. Dirt or grit can scratch their surfaces and cause rapid wear of the bearing assembly. Treat good used bearings as carefully as new ones.

12. Remove the hub from the axle spindle. Be careful not to damage the axle spindle threads as the assembly is removed.
13. Remove the oil or grease seal from the hub with a seal removal tool.
14. Remove the inner wheel bearing from the hub. Handle the bearing assembly with clean gloves, or clean, dry hands.

    If the bearing is not easy to remove, place a protective cushion to catch it, then use a hardwood drift and a light hammer to gently tap the bearing (and seal, if needed) out of the cup. Wrap all bearing assembly parts in clean, oil-proof paper or lint-free rags.

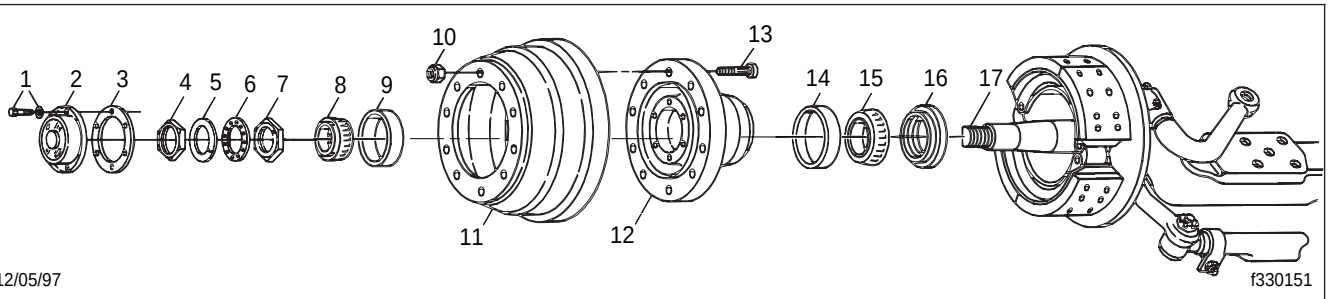
IMPORTANT: Be very careful in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other debris can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

15. Use an emery cloth or file to remove all burrs from the hub shoulder. See **Fig. 4** or **Fig. 5**.

    Clean any metal filings from the parts. For instructions, see **Subject 120**.

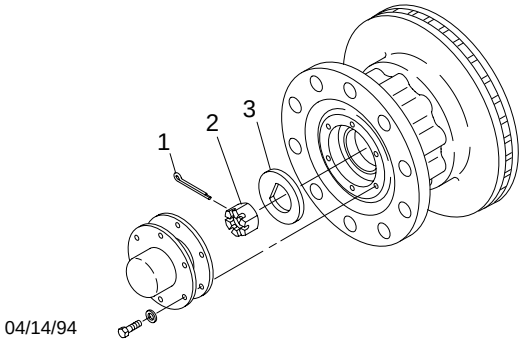
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Hub Assembly Removal and Installation, Disc Wheels



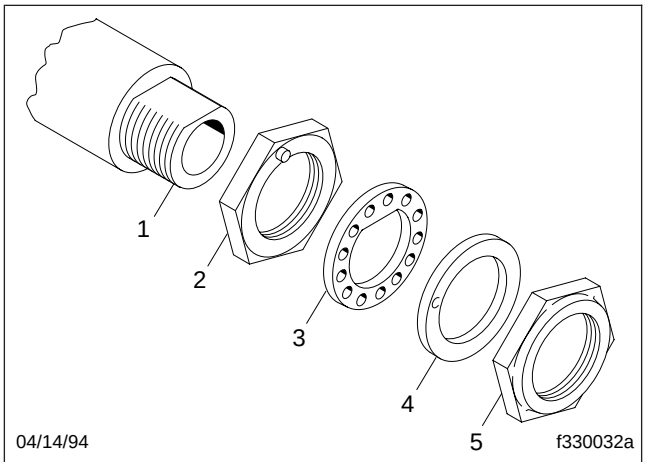
1. Hub Cap Capscrew and Washer
2. Hub Cap
3. Hub Cap Gasket
4. Jam Nut
5. Lockwasher
6. Lockring
7. Wheel Bearing Adjusting Nut
8. Outer Wheel Bearing
9. Outer Wheel Bearing Cup
10. Wheel Nut
11. Brake Drum, Outboard-Mounted
12. Wheel Hub
13. Wheel Stud
14. Inner Wheel Bearing Cup
15. Inner Wheel Bearing
16. Oil Seal
17. Axle Spindle

Fig. 1, Disc Wheel Drum Brake Front Axle Assembly



1. Cotter Pin
2. Adjusting Nut
3. Thrustwasher ("D" Washer)

Fig. 2, Single-Nut Adjustment Hub Assembly, Shown With Disc Brakes



1. Axle Spindle
2. Adjusting Nut
3. Lockring
4. Lockwasher
5. Jam Nut

Fig. 3, Axle With Jam Nut and Lockring

Installation

1. Use clean solvent to remove the old oil or grease from the axle spindle and the disassembled parts. Allow the parts to dry, or dry them with a clean, absorbent, and lint-free cloth or paper.
2. Wrap a protective layer of friction tape on the axle spindle threads.

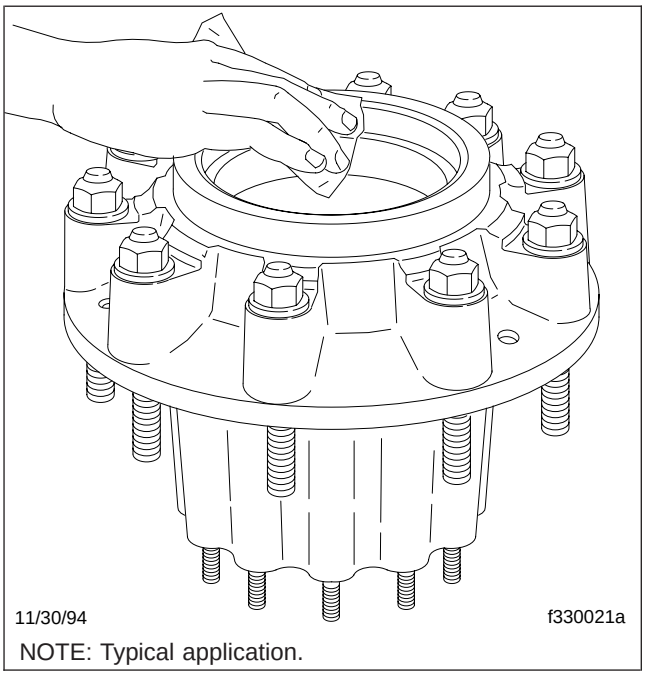
⚠ CAUTION

Make sure that both bearing assemblies are coated with fresh oil. Use only fresh oil on the bearing assemblies; old oil could be contaminated with dirt or water (both are corrosive) and could cause damage to both wheel bearing assemblies and the wheel hub.

3. If the axle is equipped with oil-lubricated bearings, coat them with fresh oil; if equipped with greased bearings, pack them using a pressure packer, if possible. If a packer is not available, pack the bearing by hand. Starting from the large end of the cone, force lithium-based wheel bearing grease into the cavities between the rollers and the cage. For lubricant specifications, see **Specifications, 400**.

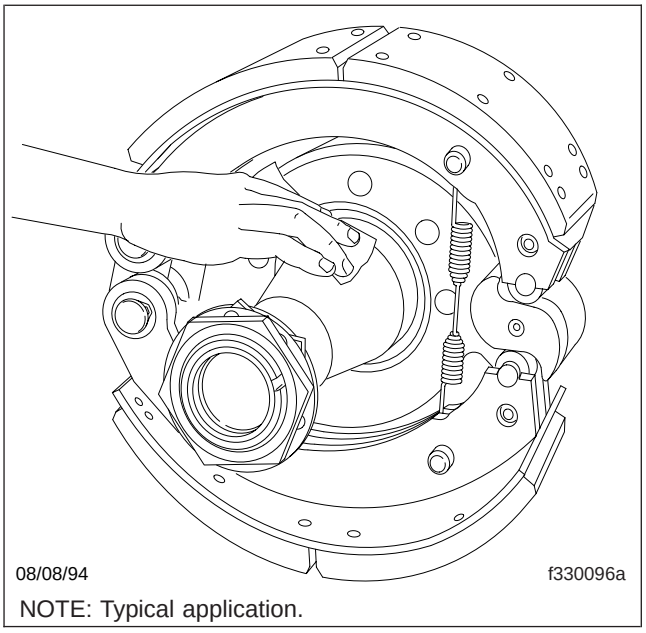
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Hub Assembly Removal and Installation, Disc Wheels



NOTE: Typical application.

Fig. 4, Cleaning the Hub Shoulder



NOTE: Typical application.

Fig. 5, Cleaning the Spindle

Install the inner wheel bearing and oil or grease seal. Handle the bearing assembly with clean, dry hands.

4. Wipe a film of axle oil or grease, depending on the type of lubricant used on the axle, onto the axle spindle, to prevent rust from forming behind the inner wheel bearing.

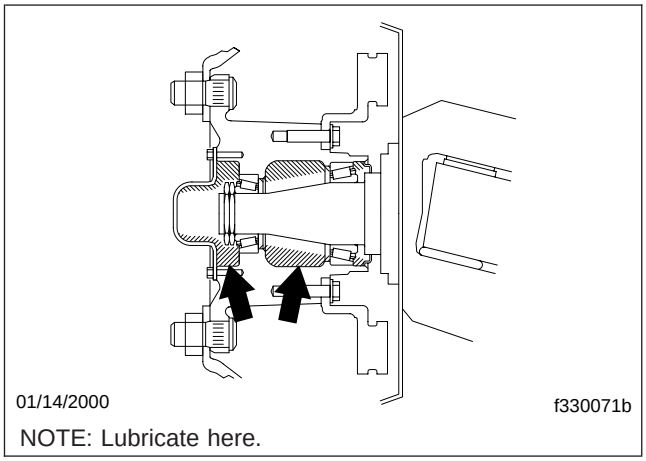
CAUTION

Take care not to damage the tone wheel on vehicles equipped with WABCO ABS. The tone wheel can be damaged, if the hub is dropped or laid down improperly.

5. Install the new oil or grease seals. See **Section 33.02** for instructions; for lubricant specifications, see **Specifications, 400**.
6. Carefully mount the hub and inner wheel bearing assembly on the axle spindle. Be careful not to unseat the inner wheel bearing or seal.
7. If the axle is equipped with oil-lubricated bearings, fill the hub cavity with oil. If it is equipped with greased bearings pack the hub between the bearing cups with lubricant, to the level of the smallest diameter of the cups. See **Fig. 6**.

   Install the outer wheel bearing.

   - Handle the bearing assembly with clean, dry hands.
   - Be careful not to damage the bearing while seating it in the cup.
   - Remove the friction tape from the axle spindle threads.



NOTE: Lubricate here.

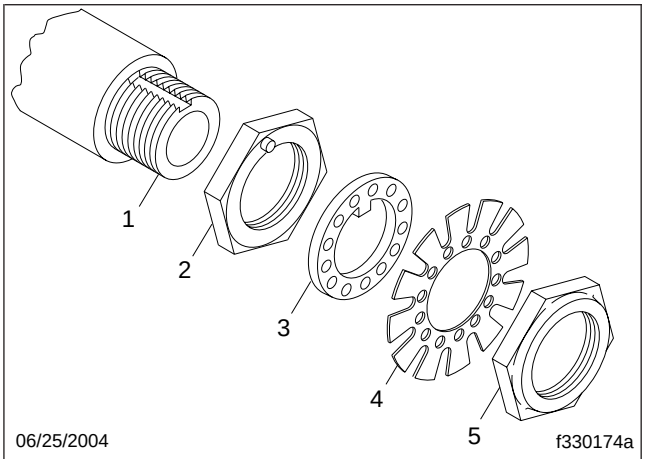
Fig. 6, Bearing Lubrication Areas

8. Install the wheel bearing adjusting nut. See **Fig. 2** for single-nut assemblies, **Fig. 3** for dual-

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Hub Assembly Removal and Installation, Disc Wheels

nut assemblies with a plain lockring, or **Fig. 7** for dual-nut assemblies with a tanged nut-lock.



1. Axle Spindle
2. Adjusting Nut
3. Tanged Nut-Lock
4. Lockwasher
5. Jam Nut

Fig. 7, Axle With Jam Nut and Tanged Nut-Lock

8.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner adjusting nut finger-tight.

8.2 While rotating the wheel hub assembly, tighten the inner adjusting nut 100 lbf·ft (136 N·m).

8.3 Back off the adjusting nut completely.

8.4 Tighten the adjusting nut 20 lbf·ft (27 N·m) while rotating the wheel hub assembly.

8.5 Back off the adjusting nut one-third turn (two flats of the adjusting nut).

9. Install the locking device and jam nut.

   On single-nut assemblies, install a new cotter pin and go on to the next step.

   On dual-nut assemblies, install the jam nut and locking device as follows:

   NOTE: Occasionally on a wheel bearing with a pierced lockring, no hole in the lockring aligns with the dowel on the adjusting nut. If that happens, remove the lockring, turn it over and install it again. If still no hole aligns with the dowel, loosen the adjusting nut just enough to align the dowel with a hole in the lockring.

   9.1 Install the locking device (tanged nut-lock, lockring, lockwasher with a lockring, or nut-lock with a lockring).

   9.2 Install the jam nut, and tighten it to the torque indicated in **Table 1**.

10. With the jam nut installed and tightened, adjust the wheel bearings.

Dual-Nut Wheel Bearing Lock Torque Values		
Application	**Size**	**Torque: lbf·ft (N·m)**
Adjusting Nut	—	Stage 1: Tighten to 100 (135)
		Stage 2: Back Off Completely
		Stage 3: Tighten to 20 (25) While Rotating Hub
		Stage 4: Back Off 1/3 Turn
Jam Nut (with Wheel Bearing Nut, Pierced Lockwasher, and Bendable Lockwasher)	1-1/8	Target: 175 (235) Permissible Range: 150–225 (205–305)
	1-1/2 to 2-1/2	Target: 250 (340) Permissible Range: 200–300 (270–405)
	2-5/8 or Larger	Target: 325 (440) Permissible Range: 250–400 (340–540)

Table 1, Dual-Nut Wheel Bearing Lock Torque Values

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Hub Assembly Removal and Installation, Disc Wheels

IMPORTANT: Do not adjust the wheel bearings with the wheel mounted on the hub. Bearing end play cannot be accurately adjusted or measured with the wheel mounted on the hub.

10.1 Attach a dial indicator to the hub, and set the point of the indicator in line with the end of the axle spindle.

If the hubs are aluminum, it may be necessary to install the brake drum on the hub to provide a steel base for the magnet of the dial indicator. Mount the drum on the hub's drum pilot. Secure the drum using the stud at the 12 o'clock position, then the studs at about the 4 o'clock and 8 o'clock positions.

10.2 Release the brakes, if you used them to hold the drum while installing it.

10.3 Grip the sides of the hub at the three o'clock and nine o'clock positions. Push in on the hub (and drum, if applicable) to seat the inboard bearing set. Zero the dial indicator.

10.4 Once again, grip the sides of the hub at the three o'clock and nine o'clock positions. This time, pull out on the hub (and drum, if applicable). Read the dial indicator and note the end play.

10.5 Push the hub back in, to confirm that the needle of the dial indicator returns to zero.

11. Adjust the end play. The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm). If the end play is not within this range, adjust it to spec:

11.1 Remove the jam nut and locking device, and back off or tighten the inner adjusting nut.

IMPORTANT: *If using a nut-lock,* turning the adjusting nut 1/4 turn will change the end play about 0.014 inch (0.36 mm).

If using a lockring, turning the adjusting nut one lockring hole will change the end play about 0.005 inch (0.13 mm). If you take the lockring off and reverse it, then turn the adjusting nut to the next hole, it will change the end play about 0.0025 inch (0.064 mm).

11.2 Install the locking device and jam nut as described earlier, and measure the end play. Adjust the end play, as described above, if it is not in the 0.001 to 0.005 inch (0.03 and 0.13 mm) range.

11.3 When the correct end play is set, rotate the hub in both directions. It should turn freely with no dragging or binding.

11.4 Once the end play is correct, bend the nut-lock or lockwasher to lock and hold the setting.

12. If the axle is equipped with grease-packed bearings, pack the hub between the bearing cups with lithium-based wheel bearing grease, to the level of the smallest diameter of the cups. See **Fig. 6**.

13. Place the hub cap and a new gasket in position, then install the washers and capscrews. Tighten the capscrews 15 lbf·ft (20 Nm).

⚠ WARNING

Failure to add oil to the wheel hub after the hub has been serviced will cause the wheel bearings to overheat and seize during vehicle operation. See Fig. 8. Seized bearing rollers can cause sudden failure of the tire or axle, possibly causing loss of vehicle control, property damage, and personal injury.

14. If the axle is equipped with oil-lubricated bearings, add fresh oil to the wheel hub to the level shown on the hub cap. See **Specifications, 400** for recommended axle lubricants.

14.1 Turn the hub so the drain/fill plug on the hub cap is at the top.

14.2 Remove the drain/fill plug and put a funnel in the hole.

14.3 Add about 2 oz (60 mL) oil to the hub, to bring the level up to the bottom of the vent plug. See **Fig. 9**.

14.4 Install the drain/fill plug, and rotate the hub several times to distribute the oil.

14.5 Once the oil level has stabilized in the hub cap, check the level in the window and if needed, add enough oil to bring the level up to the bottom of the vent plug.

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Hub Assembly Removal and Installation, Disc Wheels

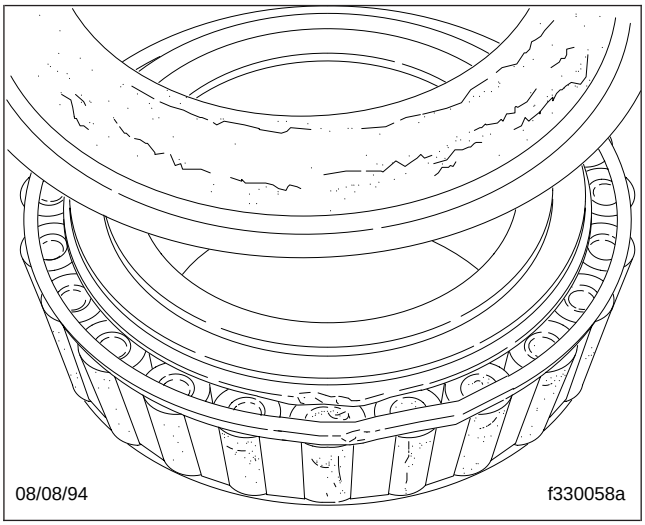
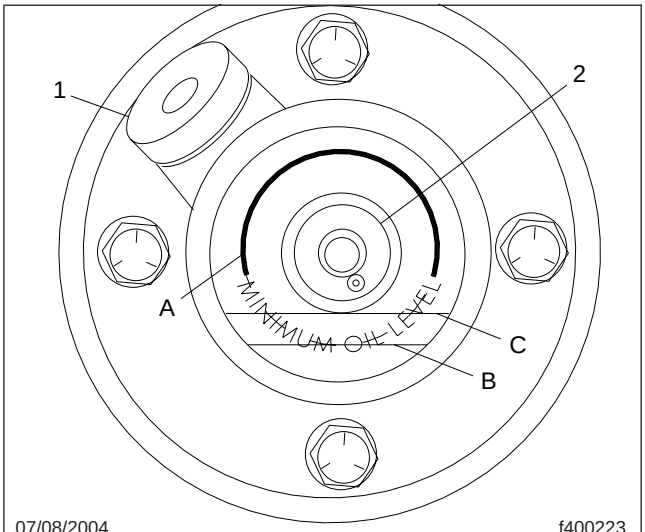


Fig. 8, Bearing Damage Resulting from Inadequate Lubrication



A. Minimum Oil Level Line
B. Minimum Oil Level
C. Normal Oil Level

1. Drain/Fill Plug
2. Vent Plug

Fig. 9, Hub Oil Levels

14.6 Let the hub sit for about 30 minutes, then check the oil level again. Add oil as needed.

15. Install the brake drum or caliper on the wheel hub. See **Group 42** for instructions.

16. Install the wheel and tire assembly. See **Group 40** for instructions.

⚠ WARNING

If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking action and the wheel hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when these conditions exist could result in the loss of a wheel, loss of vehicle control, and possible personal injury.

17. Remove the safety stands from under the axle, and lower the vehicle.

18. Remove the chocks from the rear tires.

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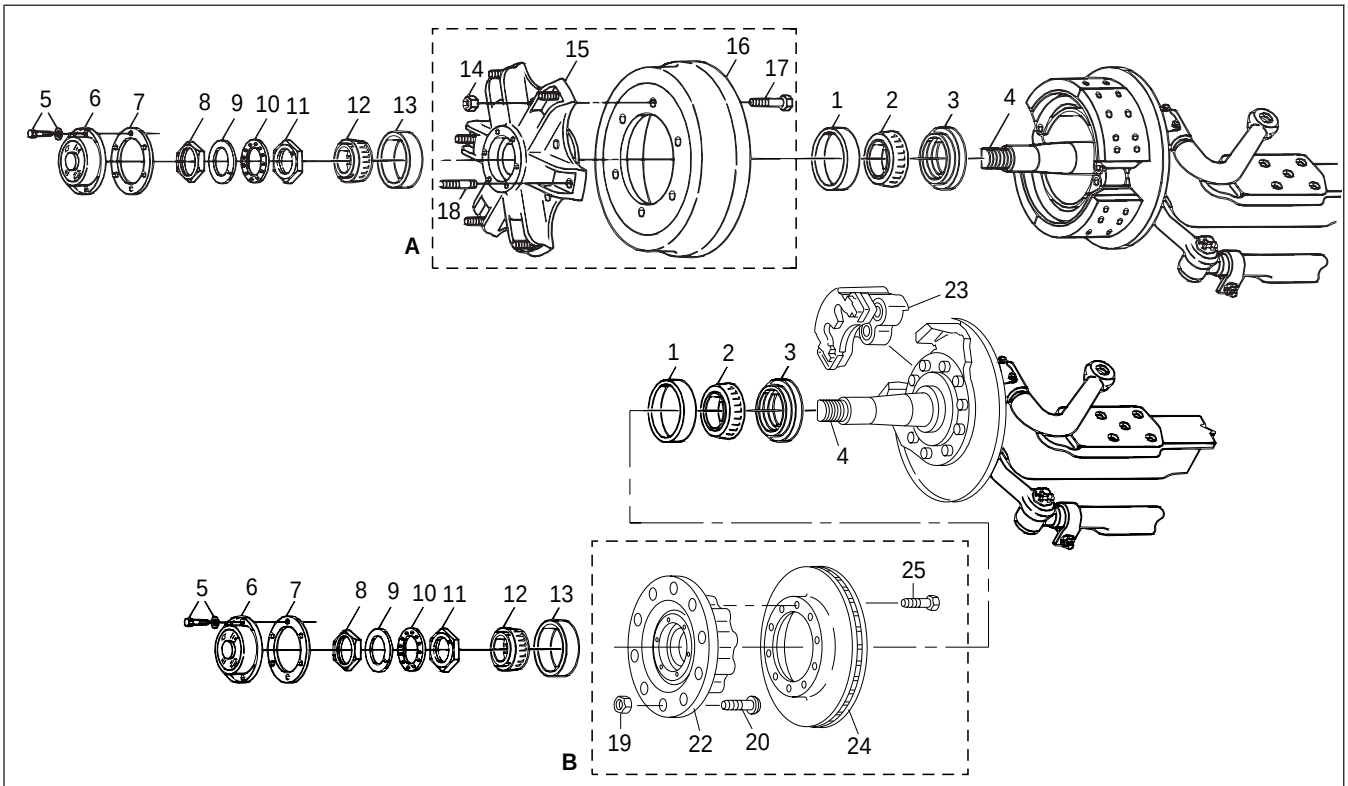
Hub Assembly Removal and Installation, Spoke Wheels

Removal

See **Fig. 1** for this procedure.

1. Apply the parking brake, and chock the rear tires.
2. Raise the front of the vehicle until the tires clear the ground, and place safety stands under the axle. Position a jack, or wheel-and-tire dolly under the tire.

   See **Fig. 1** for this procedure.
3. Remove the rim and tire assembly. See **Group 40** for instructions.



01/11/2006 f330069b

A. Spoke Wheel and Inboard-Mounted Drum Assembly
B. Spoke Wheel and Disc Brake Assembly

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle (Steering Knuckle)
5. Hub Cap Capscrew and Washer
6. Hub Cap
7. Hub Cap Gasket
8. Jam Nut
9. Lockwasher
10. Lockring
11. Wheel Bearing Adjusting Nut
12. Outer Wheel Bearing
13. Outer Wheel Bearing Cup
14. Brake Drum Nut
15. Spoke Wheel
16. Brake Drum, Inboard-Mounted
17. Brake Drum Bolt
18. Rim Stud
19. Wheel Nut
20. Wheel Stud
21. Brake Drum, Outboard-Mounted
22. Wheel Hub
23. Brake Caliper
24. Brake Rotor
25. Rotor Bolt

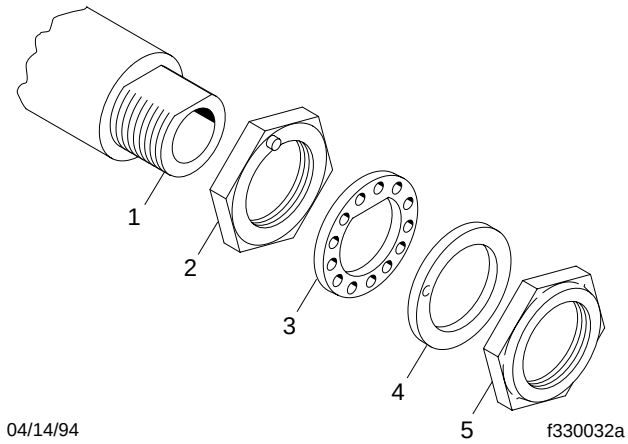
Fig. 1, Typical Spoke Wheel Front Hub Assembly

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Hub Assembly Removal and Installation, Spoke Wheels

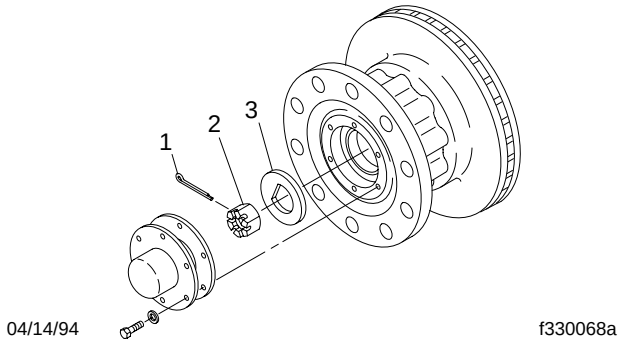
NOTE: On axles equipped with oil-lubricated bearings, oil will spill as the hub cap is removed. Place a suitable container under the wheel to catch any spilled oil. Dispose of the oil properly.

4. Remove the capscrews, washers, and hub cap. Remove and discard the hub cap gasket and oil.
5. Remove the axle spindle jam nut, lockwasher, and lockring or cotter pin. See **Fig. 2** or **Fig. 3**.



1. Axle Spindle
2. Adjusting Nut
3. Lockring
4. Lockwasher
5. Jam Nut

Fig. 2, Axle With Jam Nut and Lockring



1. Cotter Pin
2. Adjusting Nut
3. Thrustwasher ("D" Washer)

Fig. 3, Single Nut Adjustment Hub Assembly, With Disc Brakes Shown

6. Back off the wheel bearing adjusting nut about two turns, or enough to allow the weight of the wheel and drum assembly to be lifted from the wheel bearings.
7. Use an adjustable wheeled support to raise the wheel and drum assembly until all weight is removed from the bearings. Remove the adjusting nut.
8. Carefully remove the outer wheel bearing. Handle the bearing assembly with clean, dry hands. If the bearing hasn't loosened from the cup, move the wheel assembly about 13 mm (1/2 inch) to jar loose the outer wheel bearing. Be careful to not drop the bearing. Wrap all bearing assembly parts in clean oil-proof paper or lint-free rags.

⚠ CAUTION

Do not spin the bearing rollers, and be careful to keep them clean. Dirt or grit can scratch their surfaces and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

9. Use the wheeled support to pull the wheel assembly away from the vehicle. Be careful not to damage the axle spindle threads as the assembly is removed.

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air-purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, from removal of the wheels through assembly.

Never use compressed air or dry brushing to clean brake dust away. Both methods can spread hazardous particles beyond the work area.

10. To minimize exposure to brake lining dust, clean the brake drum, brake backing plate and brake assembly, using OSHA-approved materials and methods. Do not use compressed air or dry brushing to clean the brake assembly; they spread brake lining material beyond the work area.

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Hub Assembly Removal and Installation, Spoke Wheels

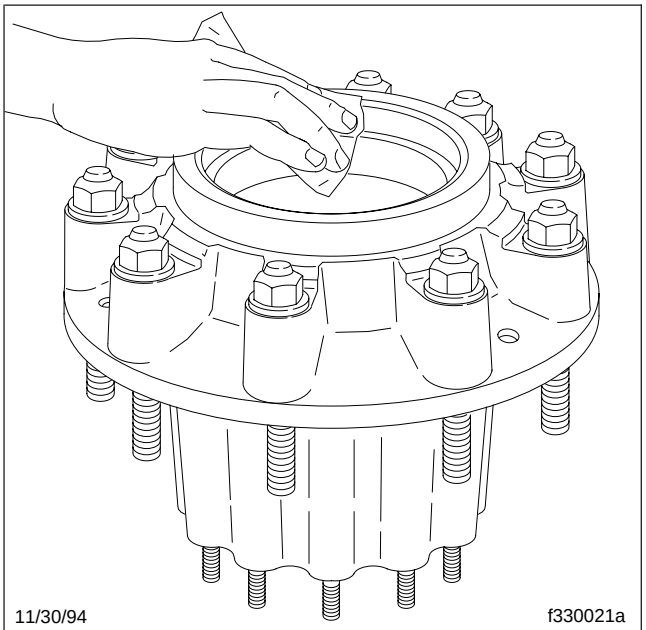
11. Remove the brake drum or rotor nuts (see **Fig. 1**) and detach the brake drum or rotor from the wheel.
12. Remove the oil or grease seal using a seal removal tool.
13. Remove the inner wheel bearing from the hub. Handle the bearing assembly with clean, dry hands.

    If the bearing is difficult to remove, place a protective cushion to catch it, then, use a hardwood drift and a light hammer to gently tap the bearing (and seal, if needed) out of the cup. Wrap all bearing assembly parts in clean, oil-proof paper or lint-free rags.

IMPORTANT: Dirt, metal filings, or other debris can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly. Be very careful when cleaning the wheel hub cavity and axle spindle.

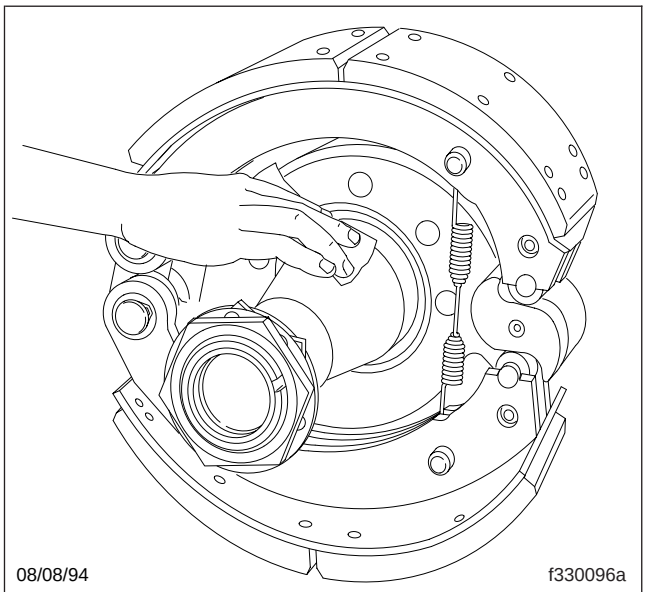
14. Use an emery cloth or file to remove all burrs from the hub shoulder. See **Fig. 4** or **Fig. 5**.

    Clean any metal filings from the parts. For instructions, see **Subject 110**.



NOTE: Typical application.

Fig. 4, Cleaning the Hub Shoulder



NOTE: Typical application.

Fig. 5, Cleaning the Spindle

Installation

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air-purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, from removal of the wheels through assembly.

Never use compressed air or dry brushing to clean brake dust away. Either method can spread dangerous particles beyond the work area.

1. Use clean solvent to remove the old oil or grease from the axle spindle (steering knuckle) and the disassembled parts. Inspect and clean the wheel hub cavity and the wheel bearings. Allow the parts to dry, or dry them with a clean, absorbent, and lint-free cloth or paper.
2. Wrap a protective layer of friction tape on the axle spindle threads.
3. If it was removed, attach the brake drum or rotor to the hub. Install the bolts and nuts, then tighten the nuts 240 lbf·ft (325 N·m) for drum brakes and 130 lbf·ft (175 N·m) for disc brakes.

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Hub Assembly Removal and Installation, Spoke Wheels

4. If the axle is equipped with oil-lubricated bearings, coat them with fresh oil; If equipped with greased bearings, pack them using a pressure packer, if possible. If a packer is not available, pack the bearing by hand. Starting from the large end of the cone, force lithium-based wheel bearing grease into the cavities between the rollers and the cage. For lubricant specifications, see **Specifications, 400**.

   Install the inner wheel bearing. Handle the bearing assembly with clean, dry hands.

5. Install the new oil or grease seals.

   5.1 Seat the small outer diameter of the seal in the recess of the tool adaptor. See **Fig. 6**. The correct adaptor is identified on the box.

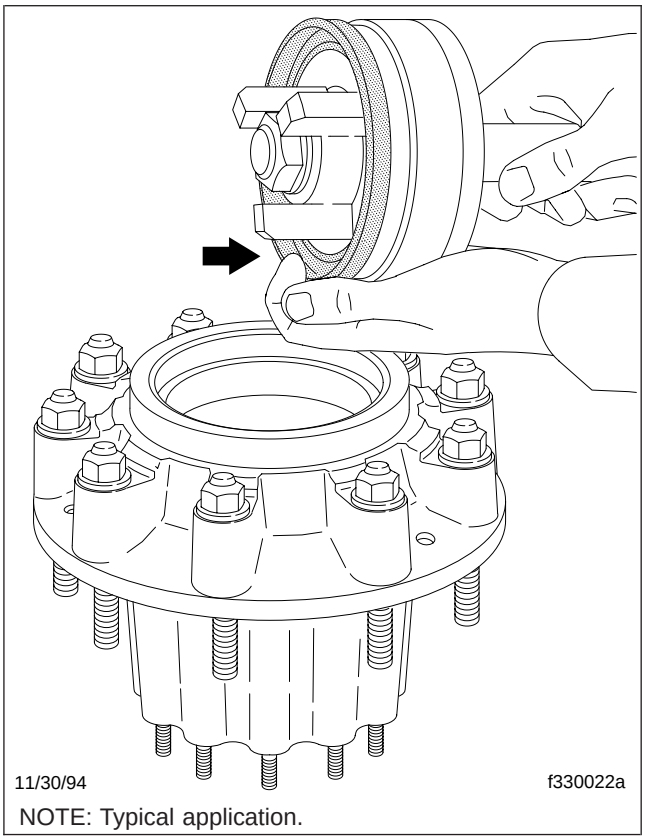


Fig. 6, Inserting the Seal into the Tool

   5.2 Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 7**. The plug prevents cocking of the seal in the bore.

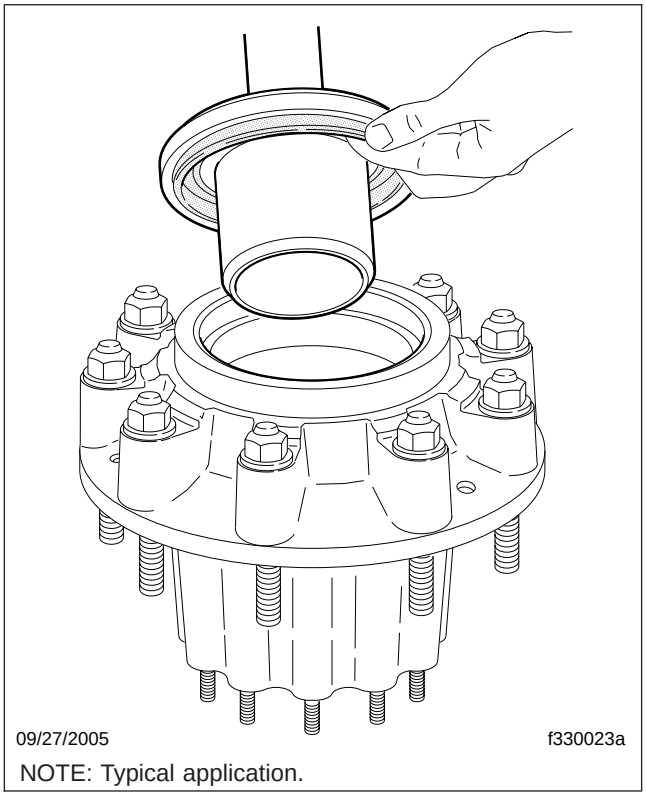


Fig. 7, Inserting the Tool into the Hub

   5.3 Hold the tool handle firmly, and strike it until the sound of the impact changes as the tool flange bottoms out against the hub face. See **Fig. 8**. Hold the tool firmly to prevent bouncing and unseating of the seal from the adaptor.

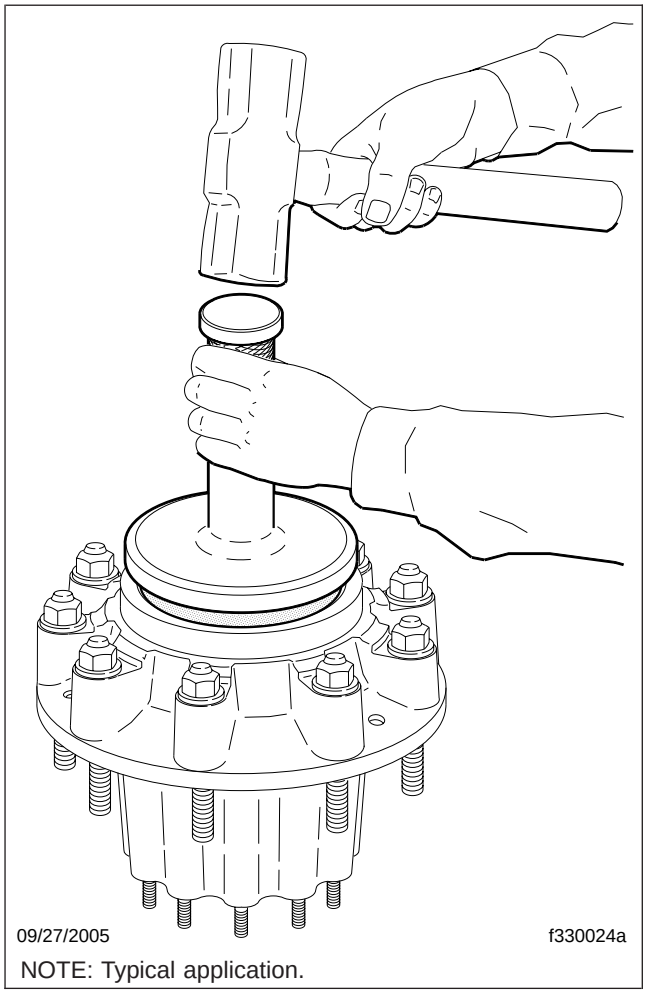
   5.4 When the seal is flush with the hub face, check for freedom of movement by manually moving the interior rubber part of the seal back and forth. If it is not damaged, the seal should move slightly.

6. Depending on the type of bearing lubricant used on the axle, wipe a film of axle oil or grease on the axle spindle, to prevent rust from forming behind the inner wheel bearing.

7. Use a wheeled support to mount the wheel and drum assembly on the axle spindle; be careful not to unseat the bearing or seal.

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Hub Assembly Removal and Installation, Spoke Wheels



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NOTE: Typical application.

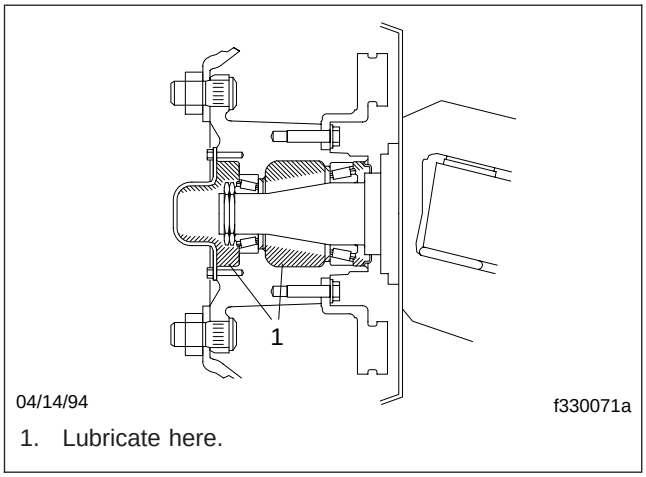
Fig. 8, Striking the Tool

8. If the axle is equipped with oil-lubricated bearings, fill the hub cavity with oil; if equipped with greased bearings, pack the hub between the bearing cups with lubricant to the level of the smallest diameter of the cups. See **Fig. 9**.

   Install the outer wheel bearing. Handle the bearing assembly with clean, dry hands or gloves. Use care not to damage the bearing, while seating it in the cup. Remove the friction tape from the axle spindle threads.

9. Install the wheel bearing adjusting nut. Tighten the nut finger-tight. Adjust the bearings (see **Fig. 2** or **Fig. 3**).

   IMPORTANT: Be sure there is sufficient clearance between the brake shoe and the brake drum, so brake shoe drag won't interfere with bearing adjustment.



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1. Lubricate here.

Fig. 9, Bearing Lubrication Points

9.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner (adjusting) nut 200 lbf·ft (271 N·m) while rotating the wheel hub assembly.

9.2 Back off the inner nut one full turn.

9.3 While rotating the wheel hub assembly, tighten the inner nut 50 lbf·ft (68 N·m).

9.4 Back off the inner nut one quarter turn.

9.5 Where one is used, install a new cotter pin (see **Fig. 3**), or install the jam nut and locking device as follows:

NOTE: If you are securing the wheel bearings with a pierced lockring, but no hole in the lockring aligns with the dowel on the adjusting nut, remove the lockring, turn it over and install it again. If a hole still doesn't align with the dowel, loosen the adjusting nut, but only enough to align the dowel with a hole in the lockring.

9.6 Install the locking device:

- Tanged nut-lock
- Lockring
- Lockwasher *and* a lockring
- Nut-lock *and* a lockring

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Hub Assembly Removal and Installation, Spoke Wheels

Install the jam nut, and tighten it to the torque indicated in **Table 1**.

IMPORTANT: Do not adjust the wheel bearings with the wheel mounted on the hub. You cannot accurately adjust or measure bearing end play with the wheel mounted on the hub.

9.7 With the jam nut installed and tightened, attach a dial indicator to the hub and set the point of the indicator in line with the end of the axle spindle.

NOTE: If using a stud-piloted hub and a steel drum, install 1-1/4 inch washers between the nuts and the drum.

9.8 Grip the sides of the hub at the three o'clock and nine o'clock positions, then push the hub to seat the inboard bearing set. Zero the dial indicator.

Grip the sides of the hub at the three o'clock and nine o'clock positions, then pull the hub. Read the dial indicator, and note the end play.

Push the hub back in to confirm that the needle of the dial indicator returns to zero.

The end play must be between 0.001 and 0.005 inch (0.025 and 0.127 mm).

10. If the end play is not within this range, remove the jam nut and locking device, and back off or tighten the inner (adjusting) nut to adjust the end play. Keep the following in mind:

If you are using a nut-lock: turning the inner nut 1/4 turn will change the end play about 0.014 inch (0.355 mm).

If you are using a lockring: turning the inner nut one lockring hole will change the end play about 0.005 inch (0.127 mm). If you take the lockring off and reverse it, then turn the inner nut to the next hole, the end play changes about 0.0025 inch (0.0635 mm).

Install the locking device and jam nut as described earlier, and measure the end play. The end play should be between 0.001 and 0.005 inch (0.025 and 0.127 mm); if it is not, adjust the inner (adjusting) nut again.

11. Once the end play is correct, bend the nut-lock or lockwasher as needed to lock the jam nut and/or adjusting nut in place.
12. Rotate the wheel in both directions. It should turn freely with no dragging or binding.
13. If the axle is equipped with grease-packed bearings, pack the hub between the bearing cups with lithium-based wheel bearing grease to the level of the smallest diameter of the cups (see **Fig. 9**).

Dual-Nut Wheel Bearing Lock Assembly Torque Values		
Application	**Size (Grade 8)**	**Torque: lbf·ft (N·m)**
Adjusting Nut	—	Stage 1: Tighten to 100 (135)
		Stage 2: Back Off Completely
		Stage 3: Tighten to 20 (25) While Rotating Hub
		Stage 4: Back Off 1/3 Turn
Jam Nut (with Wheel Bearing Nut, Pierced Lockwasher, and Bendable Lockwasher)	1-1/8	Target: 175 (235) Permissible Range: 150–225 (205–305)
	1-1/2 to 2-1/2	Target: 250 (340) Permissible Range: 200–300 (270–405)
	2-5/8 or Larger	Target: 325 (440) Permissible Range: 250–400 (340–540)

Table 1, Dual-Nut Wheel Bearing Lock Assembly Torque Values

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14. Place the hub cap and a new gasket in position, then install the washers and capscrews. Tighten the capscrews to the value from the torque table in **Specifications, 400**.
15. Install the rim and tire assembly. See **Group 40** for instructions.

⚠ WARNING

If the rim nuts cannot be tightened to minimum torque values, the rim studs have lost their locking ability, and the wheel hub flange is probably damaged. In this case, install a new wheel. Failure to replace the wheel when these conditions exist could result in loss of a wheel, or loss of vehicle control, physical damage, and possible personal injury.

16. Lower and remove the jack or wheel-and-tire dolly from under the tires.
17. If the axle is equipped with oil-lubricated bearings, add fresh oil to the wheel hub to the level shown on the hub cap. See **Specifications, 400** for recommended axle lubricants.

⚠ WARNING

Failure to add oil to the wheel hub, after the hub has been serviced, will cause the wheel bearings to overheat and seize during vehicle operation. See Fig. 10. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury due to loss of vehicle control.

18. Adjust the front axle brakes. For instructions, see **Group 42**.
19. Remove the safety stands from under the axle; lower the vehicle.
20. Remove the chocks from the rear tires.

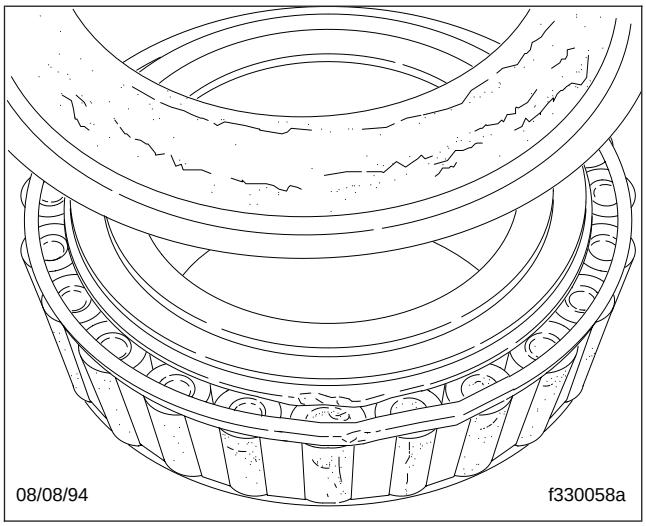


Fig. 10, Bearing Damage Resulting from Inadequate Lubrication

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Wheel Hub Assembly Inspection

1. Inspect the wheel hub mounting flange. A loose wheel assembly will cause the flange to be worn, jagged, or warped. See **Fig. 1**. Replace the wheel hub if any of these conditions exist.

   Inspect the flange surface around the wheel studs. Improperly torqued wheel nuts will cause worn or cracked stud grooves on the hub. See **Fig. 2**. If wear spots or cracks appear anywhere on the hub, or if the hub is otherwise damaged, replace it with a new one.

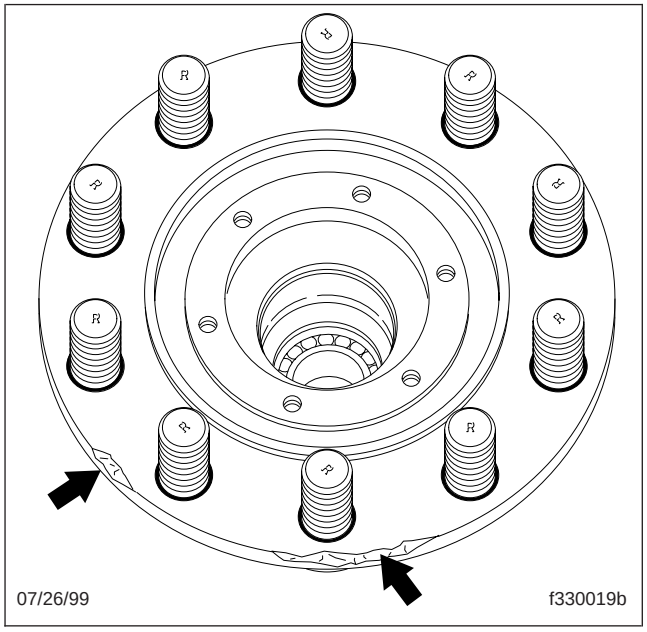


Fig. 1, Wear Spots

2. Remove all the old oil or grease from the spoke wheel or hub cavity. Inspect the inner surface of the wheel or hub for cracks, dents, wear, or other damage. Replace the wheel or hub if damaged.
3. Remove all the old grease or oil from the surfaces of the wheel bearing cups. Inspect the cups for cracks, wear, spalling, or flaking. See **Fig. 3**. Replace the cups if damaged in any way. See **Subject 130**.
4. Inspect the wheel nuts on disc wheel installations, or the rim nuts on spoke-wheel installations. Damaged nuts usually caused by inadequate tightening, must be replaced with new ones. See **Fig. 4**.

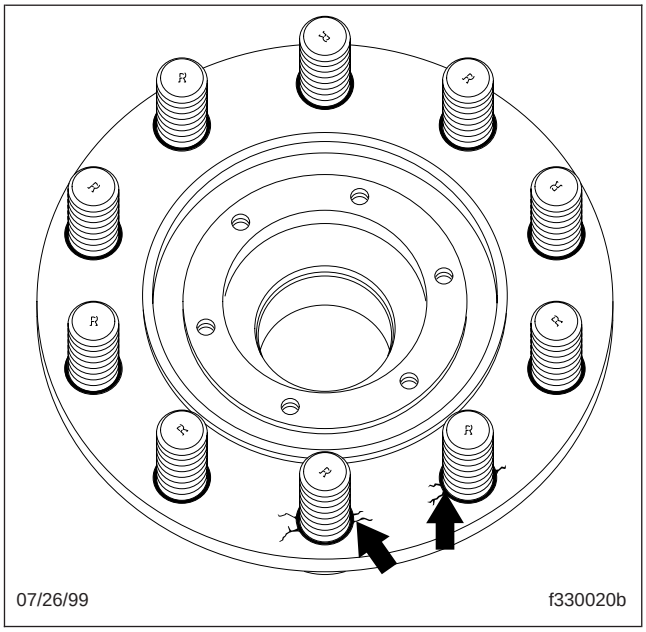
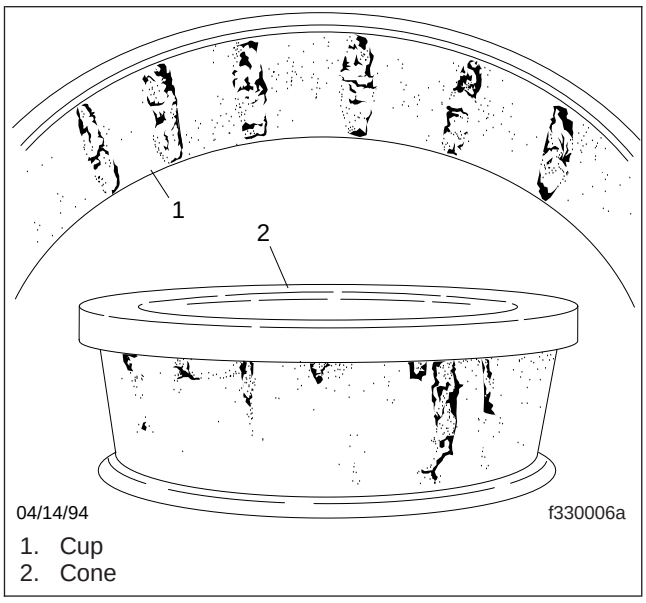


Fig. 2, Cracked Stud Grooves



1. Cup
2. Cone

Fig. 3, Spalling (Flaking) of Wheel Bearing Assembly

5. Inspect the wheel studs or rim studs. Replace studs that are stripped, broken, bent, or otherwise damaged. See **Subject 140** or **Subject 150**.

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Axle Components Cleaning and Inspection

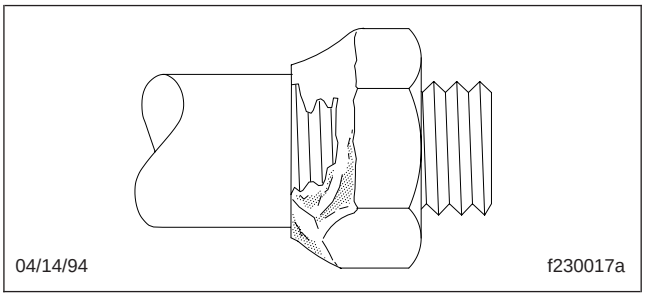


Fig. 4, Damaged Wheel Stud Nut

Wheel Bearing Cleaning and Inspection

CLEANING

⚠ WARNING

To prevent skin irritation, wear chemical resistant gloves when working with diesel fuel or kerosene. Also, do not expose these fluids to flames or heat exceeding 100°F (38°C); both are combustible and could cause personal injury if ignited.

⚠ CAUTION

Do not spin the bearing rollers at any time. Dirt or grit can scratch the roller surface and cause premature wear of the bearing assembly. Treat a used bearing as carefully as a new one.

Wheel bearings should be very closely inspected at the time of disassembly. The best inspection conditions are possible only after the bearings have been thoroughly cleaned using kerosene or diesel fuel oil, and a stiff brush. See **Fig. 5**. Before inspecting, clean the bearings as described below.

1. Clean all old oil or grease from the bearings and hub cavities, with kerosene or diesel fuel and a stiff brush. See **Fig. 5**. Do not use gasoline or heated solvent.
2. Allow the cleaned parts to dry, or dry them with a clean absorbent cloth or paper.

   Clean and dry your hands and all tools used in the maintenance operation. Oil will not stick to a surface that is wet with kerosene or diesel fuel and the kerosene or diesel fuel may dilute the lubricant.

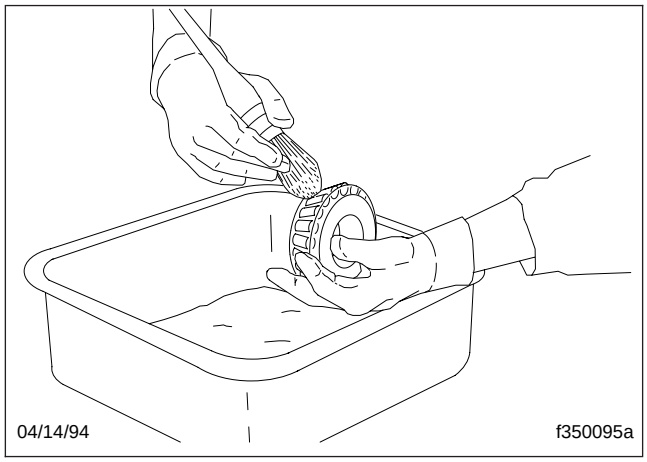


Fig. 5, Wheel Bearing Cleaning

INSPECTION

After the bearings are cleaned, inspect the assemblies, which include the rollers, cones, cups, and cages. If any of the conditions below exist, replace the bearing assemblies.

A. The large ends of the rollers are worn flush to the recess; the radii at the large ends of the rollers are worn sharp. These are signs of advanced wear. See **Fig. 6**.

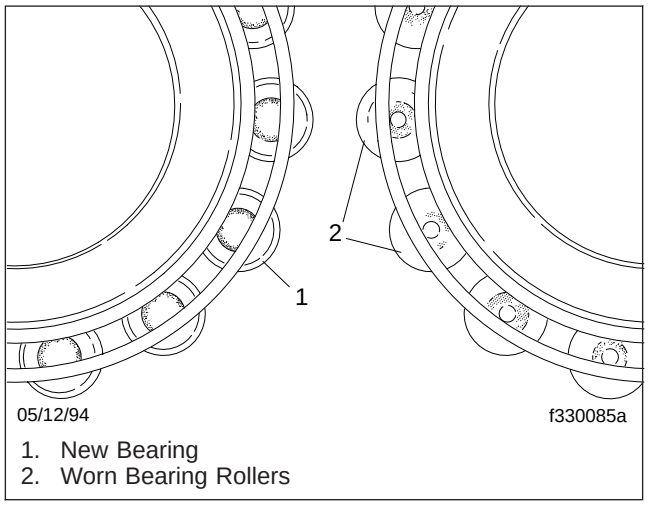


Fig. 6, Wheel Bearing Roller Wear

B. Visible step wear, especially at the small end of

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the roller track, or deep indentations, cracks, or breaks in the cone surfaces. See **Fig. 7**.

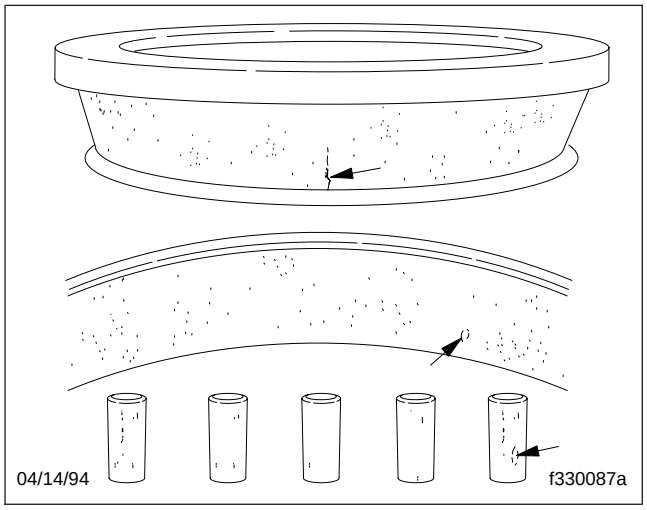


Fig. 7, Indentations, Cracks, or Breaks in Bearing Surfaces

C. Bright rubbing marks on the dark phosphate surfaces of the bearing cage. See **Fig. 8**.

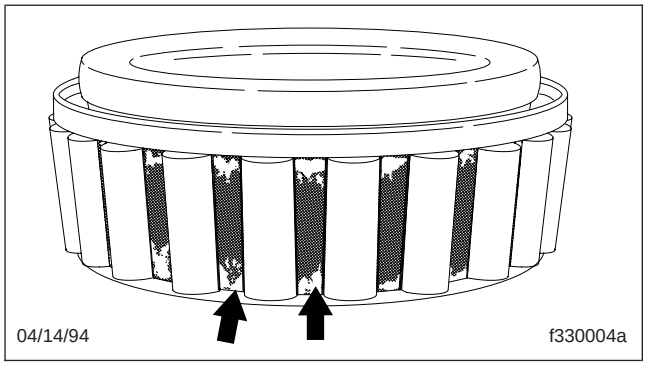


Fig. 8, Rubbing Marks on Bearing Cage

D. Water etch on any bearing surface. Water etch appears as gray or black stains on the steel surface, and it greatly weakens the affected area. If water etch is present, check the bearing seal sealing surfaces.

E. Etching or pitting on functioning surfaces. See **Fig. 9**.

F. Spalling (flaking) of the bearing cup, roller, or cone surfaces. See **Fig. 3**.

After inspection, pack the bearings with fresh axle lubricant. If a packer is not available, pack the bearing by hand. Starting from the large end of the cone, force lithium-based wheel bearing grease into the cavities between the rollers and the cage. For installation, see **Subject 100** or **Subject 110**.

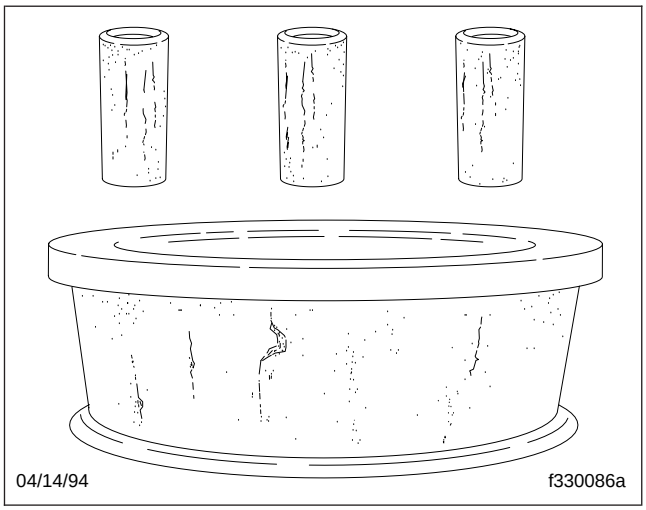


Fig. 9, Etching (Pitting) on Bearing Surfaces

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Wheel Bearing Cup Removal and Installation, Ferrous Hubs

Removal

Wheel bearing cups in ferrous hubs are removed by driving them out; there is no need to first heat the hubs.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly.
2. Using a mild-steel rod through the opposite end of the hub, drive against the inner edge of the bearing cup. Alternately drive on opposite sides of the cup to avoid cocking the cup and damaging the inside of the hub.

Installation

Wheel bearing cups are installed in ferrous hubs by pressing them in; there is no need to first heat the hubs.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Coat the hub-contact surface of the replacement bearing cup with a film of grease.
4. Position the cup in the hub and press it into place, using a suitable driving tool. Cups must seat against the shoulder in the hub.

⚠ WARNING

To prevent skin irritation, wear chemical resistant gloves when working with diesel fuel or kerosene. Also, do not expose these fluids to flames or heat exceeding 100°F (38°C); both are combustible and could cause personal injury if ignited.

5. Wipe off the accumulation of grease left after the bearing cup has been seated. Using a clean lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

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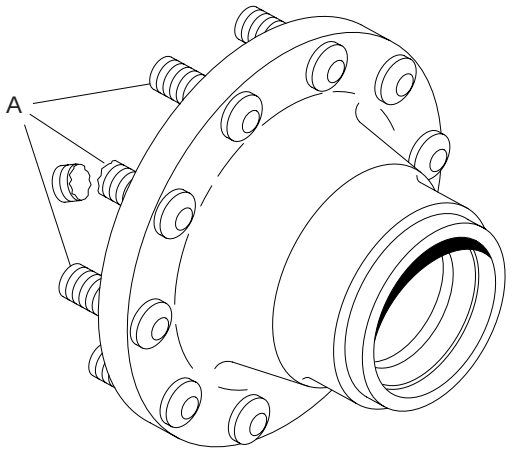
Wheel Stud Replacement, Disc Wheels

Replacement

WARNING

If a wheel stud breaks, the remaining studs are subjected to undue strain and could fail due to fatigue. When a broken stud is replaced, replace the stud on each side of it. See Fig. 1. If more than one stud is broken, replace all of the studs. Failure to replace the studs could result in the loss of a wheel or loss of vehicle control, possibly resulting in personal injury.

1. Remove the wheel hub from the axle. For instructions, see **Subject 100**.
2. If a bent portion of a wheel stud will have to pass through the wheel stud bore, cut off the bent portion before removing the wheel stud.
3. Place the wheel hub on a suitable press; make sure the hub flange is evenly supported around and next to the stud being removed. With steady movement, press the damaged stud out of the hub.



A. Replace the stud on both sides of the broken stud.

Fig. 1, Broken Stud Replacement

CAUTION

Do not use a drift and hammer or concentrated heat for removing and installing the wheel studs. Constant, smooth movement of the wheel stud is needed to ensure the least amount of metal removal from the wheel stud bore. Concentrated heat will damage the hub. If the hub is damaged during wheel stud removal or installation, replace it.

4. Apply a coat of clean axle grease to the entire shaft on headed studs.
5. With the hub on a suitable press, make sure the hub flange is evenly supported around and next to the stud being installed.
6. Position the stud in its hole.

CAUTION

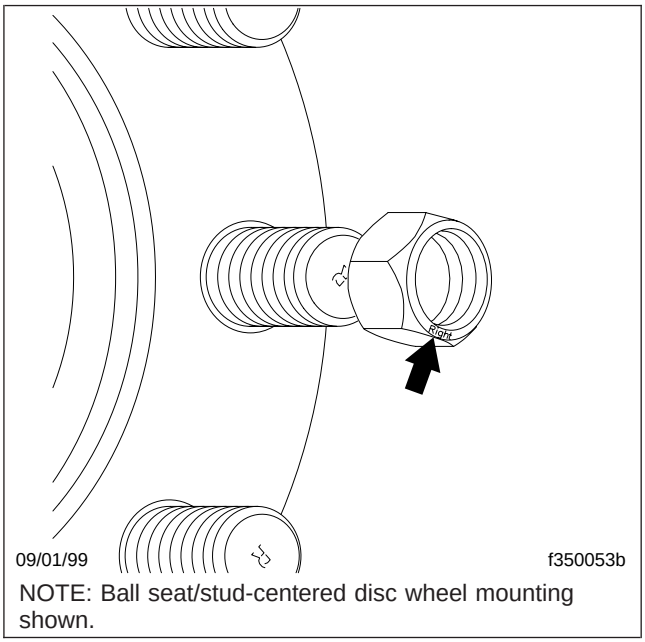
Position the teeth of the serrated portion in the notches carved by the original wheel studs during factory installation. If additional metal is scraped from the wheel stud bores, the locking action provided by the serrations will be greatly weakened. Loss of locking action will prevent achieving final torque of the wheel nuts during wheel installation. If final wheel nut torques cannot be achieved, replace the wheel hub assembly.

IMPORTANT: If the left side of the vehicle is being serviced, the replacement wheel stud must be stamped with an "L" (left-hand threaded) and the nut's face must be stamped "Left." If the right side of the vehicle is being serviced, the replacement stud must be stamped with an "R" (right-hand threaded) and the nut's face must be stamped "Right". See **Fig. 2**.

7. With steady movement, press the new stud all the way into the hub.
8. Make sure the stud is fully seated and that its head (flange) is not embedded in the hub. If the head of the stud is embedded in the hub, replace the hub.
9. Wipe off any grease on the wheel studs and hub. Install wheel nuts on dry wheel studs only.
10. Install the wheel hub on the axle. For instructions, see **Subject 100**.

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Wheel Stud Replacement, Disc Wheels



NOTE: Ball seat/stud-centered disc wheel mounting shown.

Fig. 2, Right Thread Stamp Location

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Rim Stud Replacement, Spoke Wheels

Replacement

1. Remove the rim and tire assembly from the spoked wheel. For instructions, see **Group 40**.
2. If enough threads remain on the damaged stud, remove it by double-nutting the stud. Turn the inner nut with a wrench in order to remove the stud. Go to the step for tapping out the rim stud hole.

   If the rim stud is broken near the surface of the wheel, the stud should be center-drilled using a high-speed drill, and removed with an easy-out tool. If needed, grind off a flat surface on the damaged stud. Centerpunch the surface as a starting point for drilling. Remove the stud.

   2.1 Determine the correct drill diameter by referring to the easy-out tool manufacturer's guidelines. At no time should it be large enough to penetrate the threads of the stud; if the stud threads in the wheel are damaged, replace the wheel.

   2.2 Do not drill more than 1-1/4 inches (32 mm) into the broken stud, as measured at the stud's entrance into the wheel. Drilling through the bottom of the rim stud could damage the wheel. If the wheel is drilled into, replace it.

   2.3 While drilling, keep the cutting surfaces of the drill well lubricated with oil, which acts as a coolant. Allow the drill and drill bit to cool frequently.
3. After the damaged stud is removed, tap out the rim stud hole in the wheel to rid the threads of old stud-locking compound. Use an appropriate tap size, depending on the original rim stud installation size.
4. Be sure the threads of the new stud are clean and dry. Coat the insertion end of the rim stud with an anaerobic thread-lock compound.
5. Using double nuts on the fine thread portion of the stud, install the new stud. Seat the rim stud using the torques values in the torque table in **Specifications, 400**.
6. Allow enough time for the thread-lock compound to set, as suggested by the manufacturer.
7. Install the rim and tire assembly. For instructions, see **Group 40**.

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Troubleshooting Tables

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals	
Possible Cause	**Remedy**
Not enough, or the wrong type of oil or grease used on bearings	Clean, then inspect the bearings for wear. Replace worn seals. Coat the bearing assemblies with fresh oil or grease. For lubricant specification, see **Specifications, 400**.
Foreign matter or corrosive agents entered the bearing assembly; dirt or metallic debris from the bearings not removed	Clean and inspect the bearings for wear. Replace worn seals. Also clean the wheel hub, the axle spindle and any other part in contact with the bearing lubricant.
Noise and wear, due to incorrect adjustment of wheel bearings	Adjust the wheel bearings following the instructions in **Subject 100** and **Subject 110**.
Flat spots or dents on the roller surface caused by skidding of roller, or improper handling of wheel bearing during installation	Clean, then inspect the bearing rollers. Replace the bearing if damaged. Coat the replacement bearings with fresh oil. For lubricant specifications, see **Specifications, 400**.

Problem—Broken Wheel or Rim Studs

Problem—Broken Wheel or Rim Studs	
Possible Cause	**Remedy**
Overtightened wheel or rim nuts	Replace the wheel or rim studs. See **Group 40** for the wheel or rim nut tightening sequence.
Incorrect nut tightening sequence used	
Overloaded vehicle	Do not exceed the maximum load-carrying capacity of the vehicle.

Problem—Damaged Hub

Problem—Damaged Hub	
Possible Cause	**Remedy**
Bent flange; incorrect installation of the wheel studs, such as using a hammer and drift or the hub flange was not fully supported on the press during wheel stud replacement	Replace the hub assembly. Replace the wheel studs as instructed in **Subject 140**.
Insufficient tightening of wheel nuts to wheel hub	Replace the hub assembly and tighten the wheel nuts to the values in the torque table in **Specifications, 400**

Problem—Loss of Lubricant from the Wheel Hubs

Problem—Loss of Lubricant from the Wheel Hubs	
Possible Cause	**Remedy**
Worn or damaged seals or gaskets	Replace worn or damaged parts.

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Troubleshooting

Problem—Vehicle Does Not Slow Down Quickly Enough When the Brakes are Applied

Problem—Vehicle Does Not Slow Down Quickly Enough When the Brakes are Applied	
Possible Cause	**Remedy**
Worn, heat-checked or cracked brake drums	Install new brake drums.

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Specifications

Dual-Nut Wheel Bearing Lock Torque Values		
Application	**Size**	**Torque: lbf·ft (N·m)**
Adjusting Nut	—	Stage 1: Tighten to 100 (135).
		Stage 2: Back Off Completely.
		Stage 3: Tighten to 20 (25) While Rotating Hub.
		Stage 4: Back Off 1/3 Turn (two flats of the adjusting nut).
Jam Nut (with Wheel Bearing Nut, Pierced Lockwasher, and Bendable Lockwasher)	1-1/8	Target: 175 (235) Permissible Range: 150–225 (205–305)
	1-1/2 to 2-1/2	Target: 250 (340) Permissible Range: 200–300 (270–405)
	2-5/8 or Larger	Target: 325 (440) Permissible Range: 250–400 (340–540)

Table 1, Dual-Nut Wheel Bearing Lock Assembly Torque Values

Meritor Axle Recommended Lubricant			
Lubricant Type	**Ambient Temperature**	**SAE Viscosity Grade**	**Meritor Specification**
Hypoid Gear Oil API Service Classification GL–5	+10°F (–12.2°C) and up*	85W–140	0–76–A
	–15°F (–26.1°C) and up*	80W–140	0–76–B
	–15°F (–26.1°C) and up*	80W–90	0–76–D
	–40°F (–40°C) and up*	75W–90	0–76–E
	–40°F (–40°C) to +35°F (+2°C)	75W	0–76–J
	–40°F (–40°C) and up*	75W–140	0–76–L
Synthetic Gear Oil	–40°F (–40°C) and up*	75W–90	0–76–N
	–40°F (–40°C) and up*	75W–140	0–76–M

* There is no upper limit on these ambient temperatures, but axle sump temperature must never exceed 250°F (121°C).

Table 2, Meritor Axle Recommended Lubricant

Grease Specification Meritor Axles With Grease-Lubricated Bearings	
Lithium-Based Wheel Bearing Grease	Standard: 0-617A or equivalent
	Optional: 0-617B or equivalent

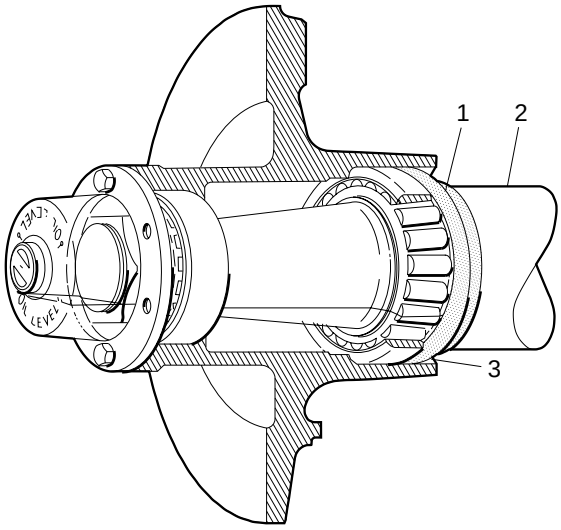
Table 3, Meritor Axles With Grease-Lubricated Bearings

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General Information

Wheel oil seals (also called "oil bath seals" or "hub seals") work as a dam to keep oil in the hub cavity so that it constantly "bathes" the wheel bearings. The seals also protect the wheel bearings by keeping dirt, dust, and water out of the hub.

The oil seal fits between the hub bore and the axle spindle (see **Fig. 1**), and the sealing element either turns with the wheel (*hub-mounted seals*) and seals against the axle spindle, or the sealing element stays stationary with the axle spindle (*spindle-mounted seals*) and seals against the turning hub.



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1. Wheel Oil Seal
2. Axle Spindle
3. Wheel Hub Bore

Fig. 1, Spindle-Mounted Wheel Oil Seal (typical)

Most wheel oil seals consist of four basic parts (**Fig. 2**):

- The outside edge (also called the outer "cup" or "case")
- The inside edge (also called the inner "cup" or "case")
- The sealing element
- The garter spring

The outside edge is usually metal coated with rubber or another sealing agent so that it grips the hub bore tightly enough to prevent oil escaping between the outer edge of the seal and the hub bore.

The inside edge is usually metal or rubber with a metal ring within it to prevent the sealing element from wearing a groove in the axle spindle.

The sealing element is usually molded rubber, leather, or a synthetic such as nitrile or silicone. The element is molded into lips which will seal against the axle spindle or against the outside or inside edge described above. The innermost lip, called the "primary lip," keeps the oil inside the hub cavity. The outermost lip, called the "secondary lip," keeps dirt out of the hub cavity.

The garter spring is a coiled wire spring with its ends connected to make a loop. On hub-mounted seals, the spring runs around the outside of the sealing element to press the element inwards against the sealing surface. On spindle-mounted seals, the spring runs around the inside of the sealing element to press the element outward against the sealing surface.

Two brands of axle oil seals are used on this vehicle:

- Chicago Rawhide (Scotseal® and Scotseal Plus XL®)
- Dana Spicer (Outrunner™)

Chicago Rawhide

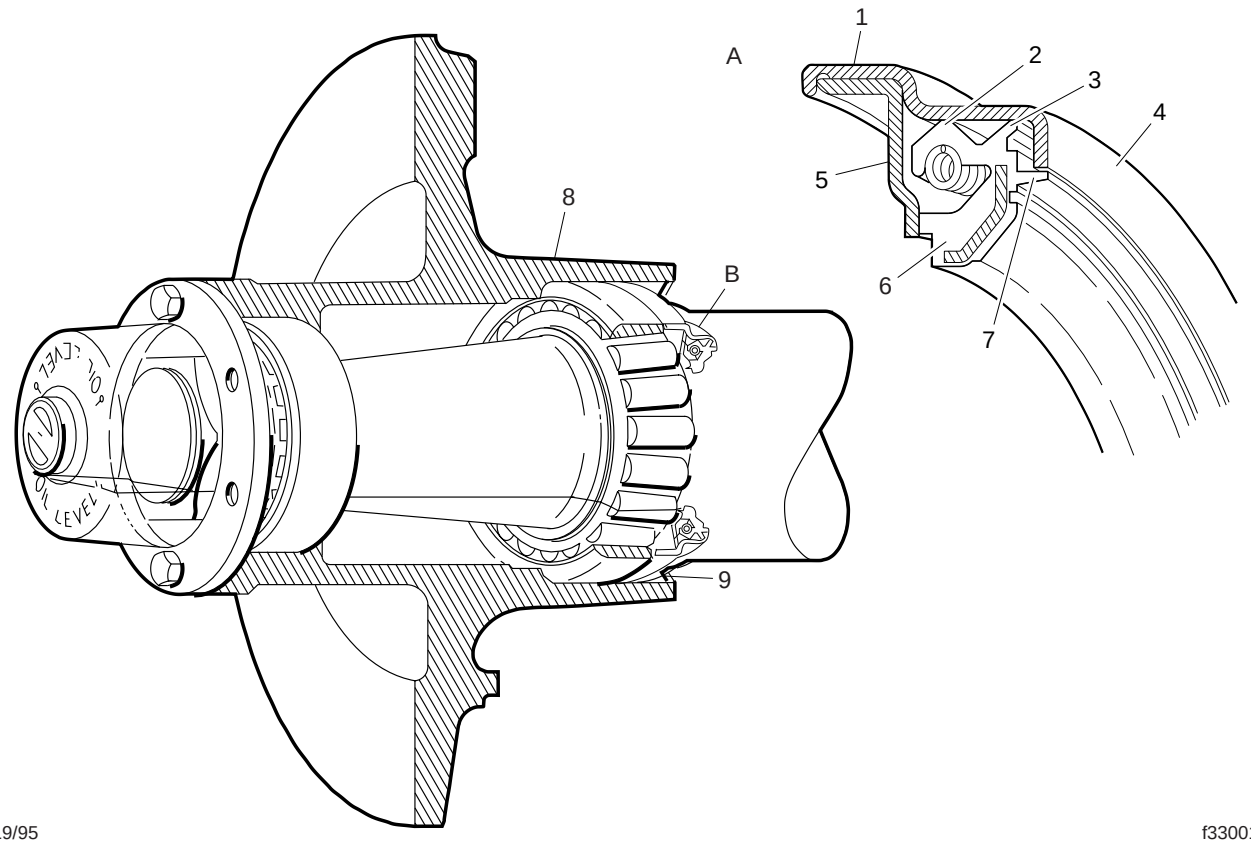
The Chicago Rawhide Scotseal is a unitized, one-piece design consisting of a sealing element (packing) that is assembled between metal outer and inner cups. See **Fig. 2**. The sealing element consists of three sealing lips; a spring-loaded primary sealing lip that is factory pre-lubed and two dirt exclusion lips. The seal is press fit into the hub bore using Scotseal service installation tools. *Do not install the Scotseal directly onto the axle spindle.*

Although you install the Scotseal into the hub bore, the seal's element grips the axle spindle tightly enough that the sealing element stays stationary with the spindle and seals against the outer cup which turns with the hub.

The Chicago Rawhide Scotseal maintains a metal-to-metal contact between the outer cup and the hub bore surface as well as a metal-to-metal contact between the sealing element inside edge and the axle spindle.

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General Information



A. Detail A
B. Oil Seal (See detail A)

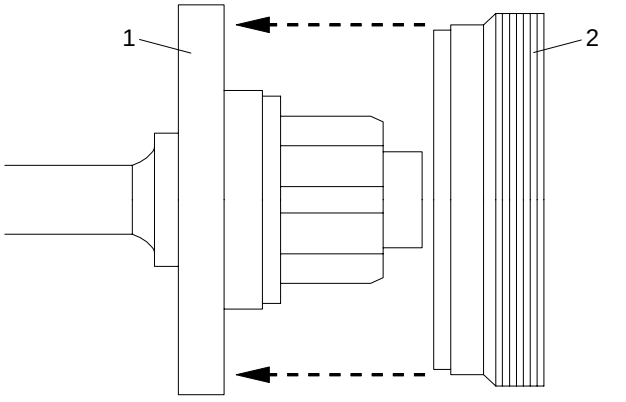
1. Bore-Tite® Coating
2 Primary Sealing Lip
3. Dirt Lip
4. Outer Cup
5. Inner Cup
6. Sealing Element (Packing)
7. Bumper Lip
8. Hub
9. Hub Bore

Fig. 2, Chicago Rawhide Scotseal

Dana Spicer

The Dana Spicer Outrunner has a rubber-coated outside edge and is installed in the hub bore using Dana Spicer installation tools. See **Fig. 3**.

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1. Dana Spicer Outrunner Installation Tool
2. Dana Spicer Outrunner Seal

Fig. 3, Dana Spicer Outrunner Seal

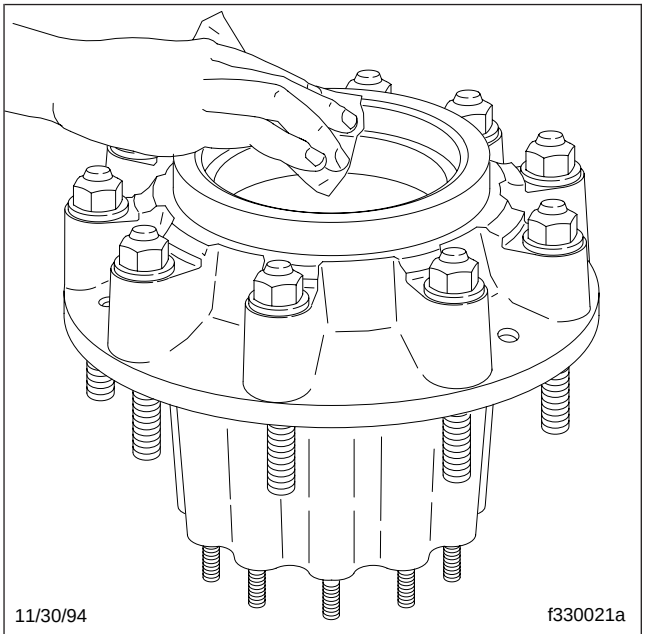
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Seal Replacement, Chicago Rawhide

Replacement

NOTE: This procedure applies to the Chicago Rawhide Scotseal®.

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 33.01**.
2. Remove the oil seal from the hub.
3. Remove the inner wheel bearing assembly from the hub. Handling the bearings with clean dry hands, wrap the bearings in clean oil-proof paper or lint-free cloths. Occasionally, the inner wheel bearing cone assembly will remain in the hub after the seal is removed. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing out of the inner wheel bearing cup.
4. Clean the spindle, spindle threads, seal bore, and the hub cavity. See **Fig. 1** and **Fig. 2**.
5. Remove all burrs from the shoulder and the seal bore with an emery cloth or a file. Clean any metal filings from the components.



NOTE: Rear hub shown.

Fig. 1, Clean the Hub

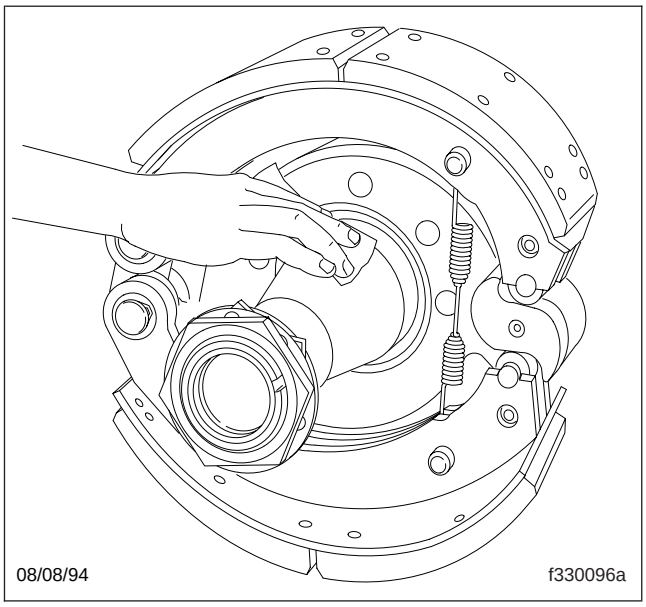


Fig. 2, Clean the Spindle

⚠ CAUTION

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

6. Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.
7. Coat the wheel bearing cones with oil.
8. Install the inner wheel bearing cone in the inner wheel bearing cup.
9. Seat the small outside edge of the seal in the recess of the tool adaptor. See **Fig. 3**. The correct adaptor is identified on the box.
10. Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 4**. The plug prevents cocking of the seal in the bore.
11. Hold the tool handle firmly, and strike it until the sound of the impact changes as the seal bottoms

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Seal Replacement, Chicago Rawhide

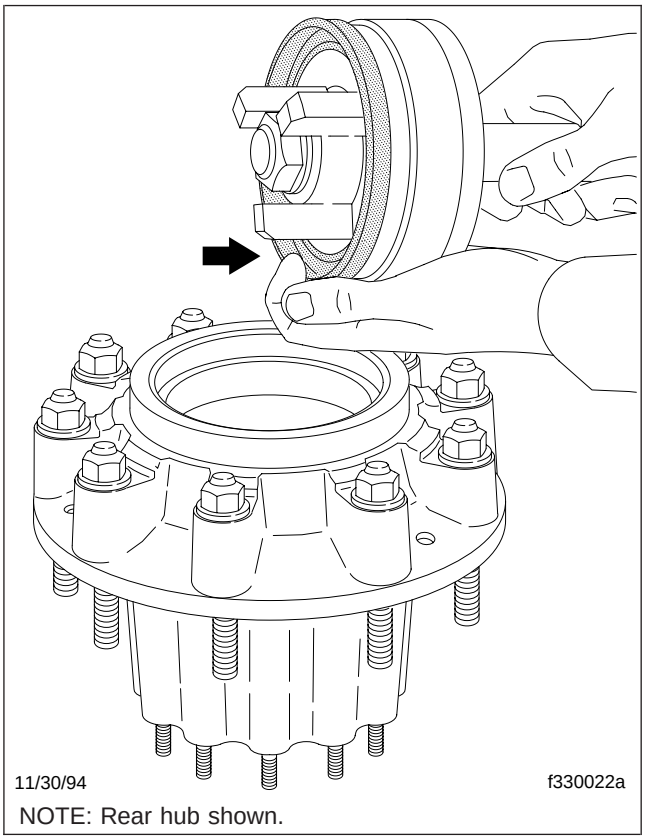


Fig. 3, Place the Seal on the Installation Tool

out. See **Fig. 5**. Hold the tool firmly to avoid bounce or unseating of the seal from the adaptor.

12. After the seal is bottomed in the bore, check for freedom of movement by manually moving the interior rubber part of the seal back and forth. A slight movement indicates a damage-free installation.
13. Install the wheel hub on the axle, and adjust the wheel bearings. For instructions, see **Section 33.01**.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

14. Place the hubcap and a new gasket in position, then install the capscrews. Tighten the capscrews 15 lbf·in (20 N·m).
15. Fill the hub with oil to the level shown on the hubcap. See **Fig. 6**. Do not overfill.

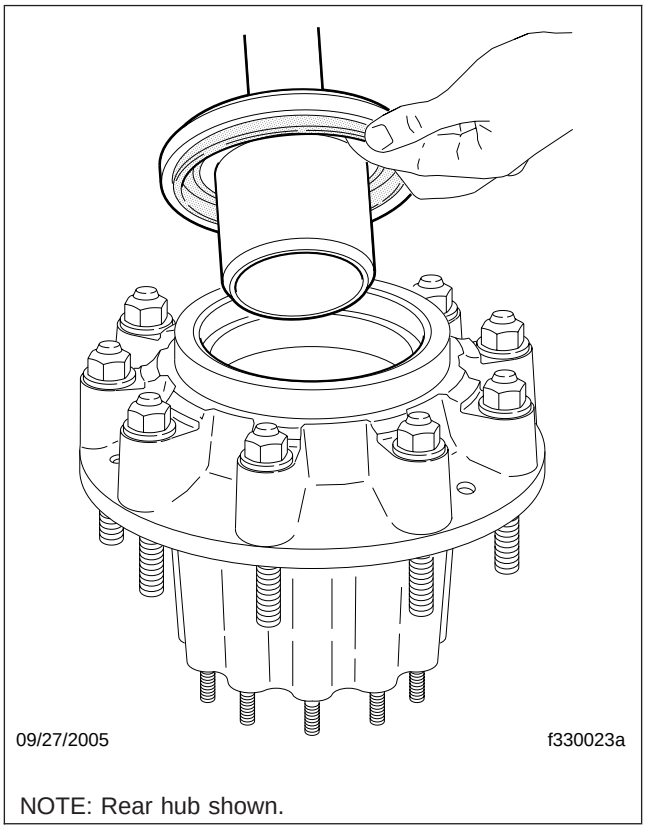
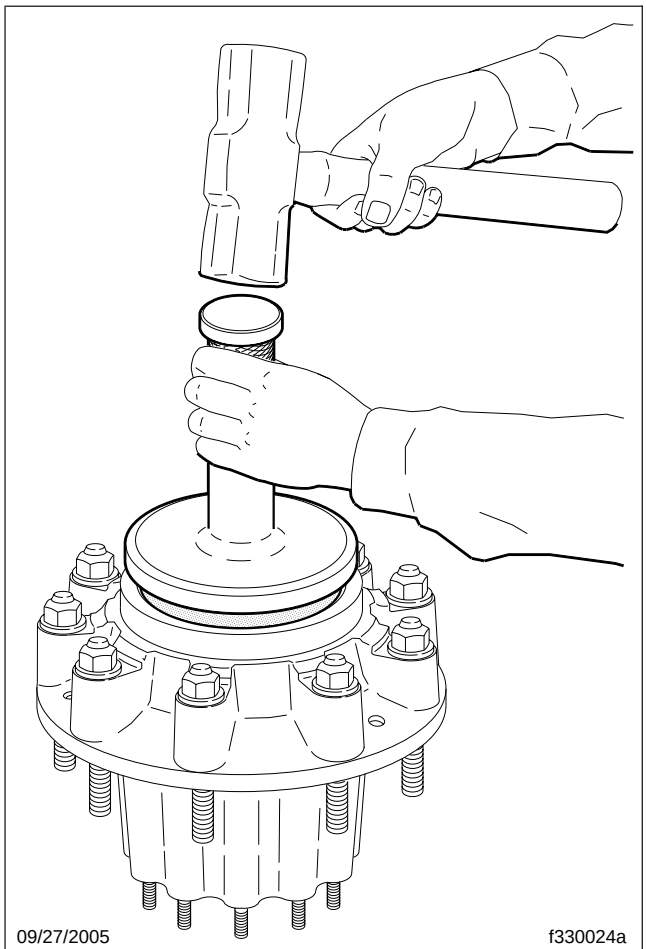


Fig. 4, Insert the Tool in the Hub Bore

16. Spin the wheel and check the oil level.
17. Adjust the brake shoe-to-drum clearance. For instructions, see Group 42 of the *Acterra® Maintenance Manual*.

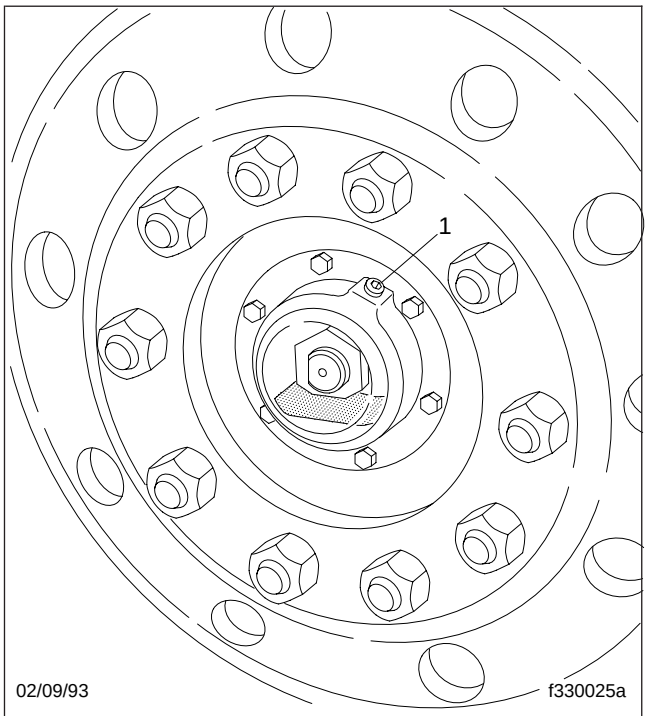
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Seal Replacement, Chicago Rawhide



NOTE: Rear hub shown.

Fig. 5, Strike the Tool



1. Filler Plug

Fig. 6, Fill the Hub With Oil

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Replacement

NOTE: This procedure applies to the Dana Spicer Outrunner™ seal.

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 33.01**.
2. Remove the oil seal from the hub.
3. Remove the inner wheel bearing assembly from the hub. Handling the bearings with clean dry hands, wrap the bearings in clean oil-proof paper or lint-free cloths. Occasionally, the inner wheel bearing cone assembly will remain in the hub after the seal is removed. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing out of the inner wheel bearing cup.
4. Clean and inspect the bearings, the spindle, spindle threads, seal bore, and the hub cavity.

   IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

   4.1 Inspect the inner hub bore. Remove dirt and contaminants from all recesses and corners. Smooth any sharp edges with emery cloth, and fill in any grooves with filler. See **Fig. 1**.

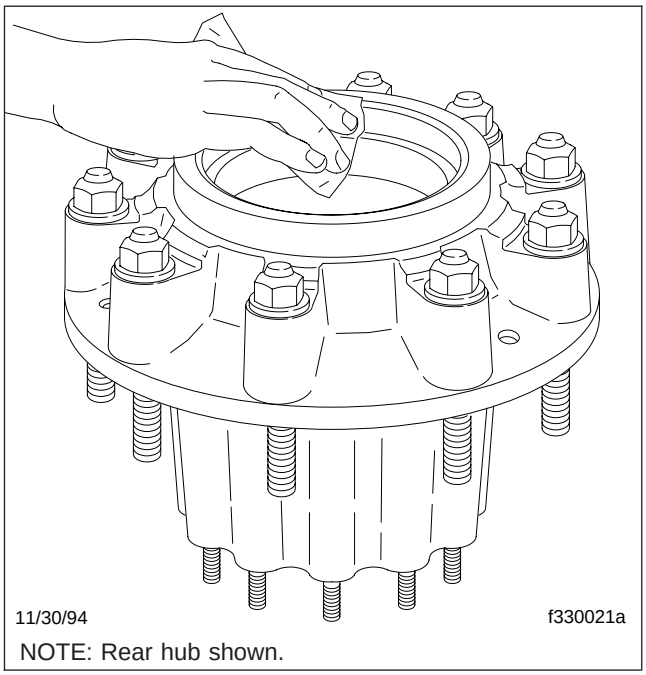
   4.2 Wipe the hub area with a clean shop cloth.

   4.3 After removing the hub, inspect the spindle. Remove any sharp edges and burrs from the leading edges and the shoulder area. Repair deep gouges with filler and smooth with an emery cloth. See **Fig. 2**.

   4.4 Wipe the seal and shoulder area with a clean shop cloth.

⚠ CAUTION

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.



NOTE: Rear hub shown.

Fig. 1, Clean and Inspect the Hub Bore

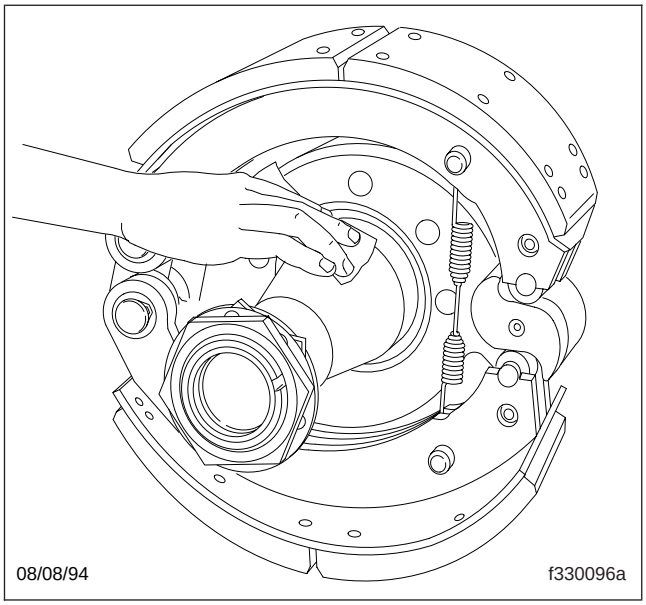


Fig. 2, Clean and Inspect the Axle Spindle

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Seal Replacement, Dana Spicer

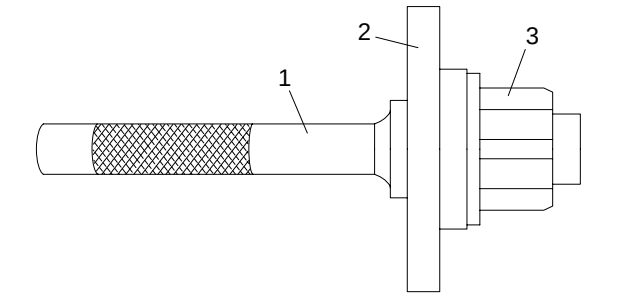
4.5 Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.

4.6 Coat the wheel bearing cones with oil.

5. Install the inner wheel bearing cone in the inner wheel bearing cup.

IMPORTANT: Use the Dana Spicer Outrunner installation tool *with the centering tool* when installing the seal. See **Fig. 3**.

6. Install the oil seal in the hub bore.



1. Outrunner Handle
2. Outrunner Adapter Plate
3. Bearing Centering Tool

Fig. 3, Dana Spicer Outrunner Installation Tool

⚠ CAUTION

Do not use any silicone or permatex type bore sealant with this seal. The Dana Spicer Corporation recommends a light coating of bearing oil on the outer circumference of the seal.

Do not mix lubricants of different grades. Do not mix mineral and synthetic lubricants. Do not pack the bearings with grease when using an oil bath system. Failure to follow these installation guidelines will result in less than desired performance of the Outrunner seal, and installation-related failures are not covered under warranty.

6.1 Place the outrunner seal tool with the words "air side" facing the adaptor plate of the installation tool. See **Fig. 4**. Lubricate the seal outer circumference with wheel bearing oil.

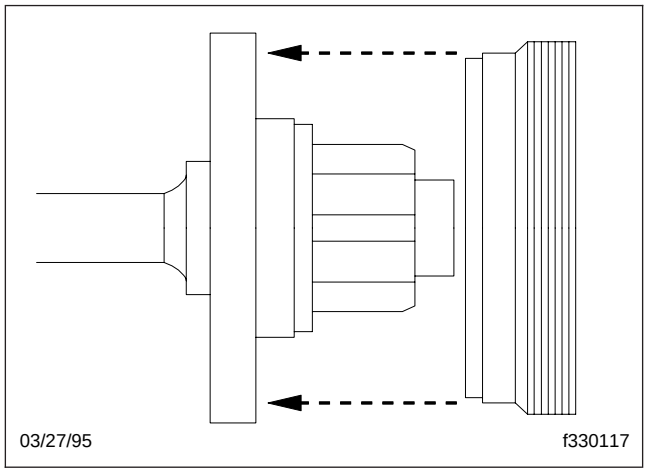


Fig. 4, Seal Placement on Tool

IMPORTANT: Install the seal in the hub bore with the hub laid flat. Do not install the seal with the hub in the vertical (upright) position.

6.2 With the hub and the wheel assembly laid flat on the floor, place the inner bearing cone in the cup.

6.3 Position the oil seal in the hub bore. Before striking the handle of the installation tool, tap the adaptor plate around the outer edge to position the seal. See **Fig. 5**.

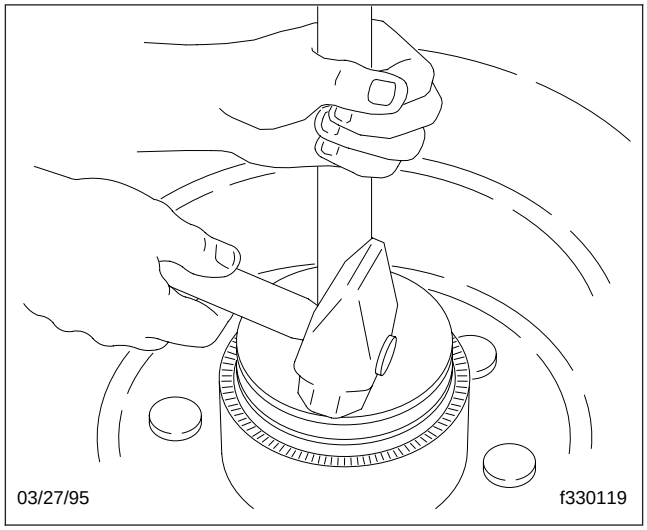


Fig. 5, Position the Seal

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6.4 Hit the handle of the installation tool *gently*. See **Fig. 6**.

Because of the rubber outer circumference, the Outrunner seal is easier to install than seals with metal outer circumferences. When the adaptor plate bottoms out on the hub surface, the seal is installed correctly. You will hear a metal-to-metal sound.

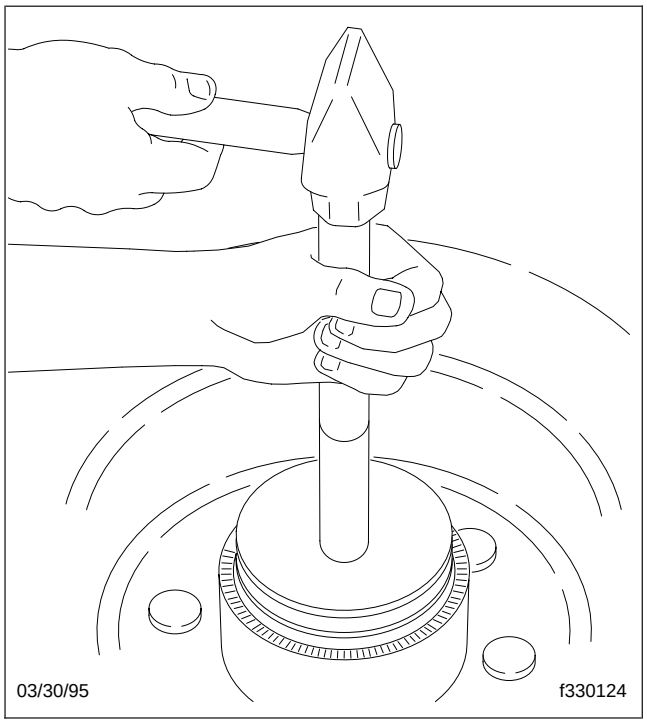


Fig. 6, Install the Seal

6.5 Check that the seal is not cocked, and that the unitized seal inner circumference and inner bearing turn freely.

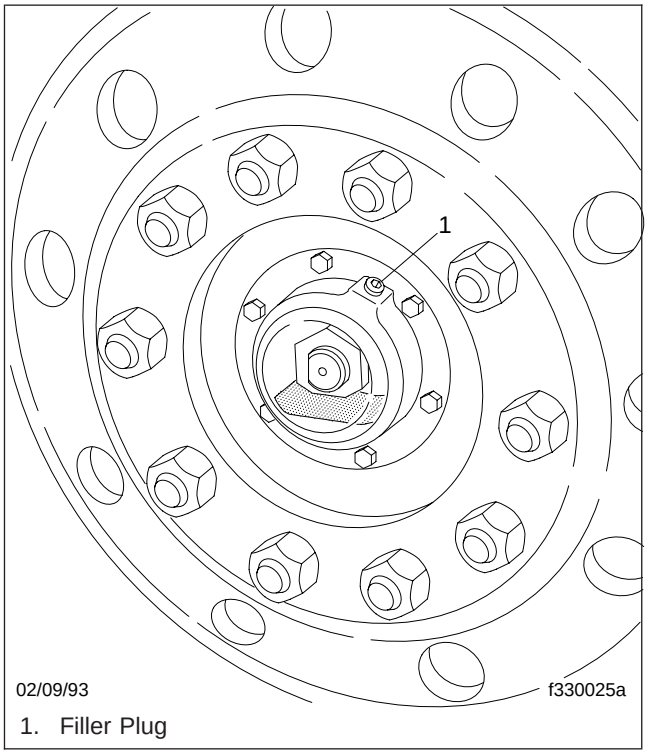
6.6 Lubricate the inner circumference of the seal with a light film of clean bearing oil.

7. Install the wheel hub on the axle, and adjust the wheel bearings. For instructions, see **Section 33.01**.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

8. Place the hubcap and a new gasket in position, then install the capscrews. Tighten the capscrews 15 lbf·ft (20 N·m).

9. Fill the hub with oil to the level shown on the hubcap. See **Fig. 7**. Do not overfill.



1. Filler Plug

Fig. 7, Fill the Hub with Oil

10. Spin the wheel and check the oil level.

11. Adjust the brake shoe-to-drum clearance. For instructions, see Group 42 of the *Acterra® Maintenance Manual*.

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Replacement

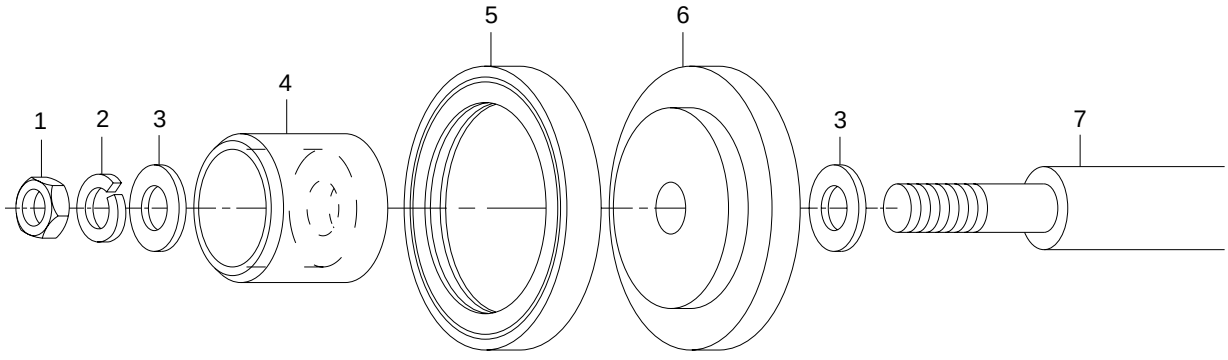
NOTE: This procedure applies to the National® oil seal.

1. If not already done, remove the hub from the axle spindle. For instructions, see **Section 33.01, Subject 100**.
2. Remove the old oil seal from the hub or axle spindle, as applicable. Be careful not to damage the axle spindle.
3. Inspect the hub chamfer and bore for burrs, nicks, roughness, deep scratches, and other imperfections. Clean any imperfections with an emery cloth. Wipe the surface clean.
4. If using a press, put the hub onto a centering fixture, inboard side up.

   If you are manually installing the oil seal, put the hub (inboard side up) on a firm, level surface.
5. Using approved gear oil, lubricate the inner bearing. For approved gear oil, see **Section 33.01, Specifications, 400**.
6. Install the inner bearing into the hub.
7. Put a light coating of gear oil on the inner and outer surfaces of the oil seal.
8. Install the adapter plate and bearing pilot on the steel handle, using the hexnut and washers provided. See **Fig. 1**.
9. Put the oil seal on the adapter plate, making sure the words "Air Side" on the oil seal are facing the adapter plate surface.
10. Making sure the oil seal is aligned straight with the hub bore, install it into the hub. See **Fig. 2**.

    If using a press, press the oil seal into the hub with 3000 to 5000 psi (20 684 to 34 474 kPa) of pressure.

    If manually installing the seal, strike the end of the installation tool with a heavy mallet. Continue striking until the sound changes.
11. Make sure the oil seal is correctly installed in the hub bore. The face of the seal (the side with the words "Air Side") should be flush with the face of the hub.
12. Wipe off any excess oil from the face of the oil seal.
13. Install the hub on the axle spindle. For instructions, see **Section 33.01, Subject 100**.
14. Check the other side of the vehicle for front-axle oil seal leakage. If needed, repeat the procedure on the other side of the vehicle.

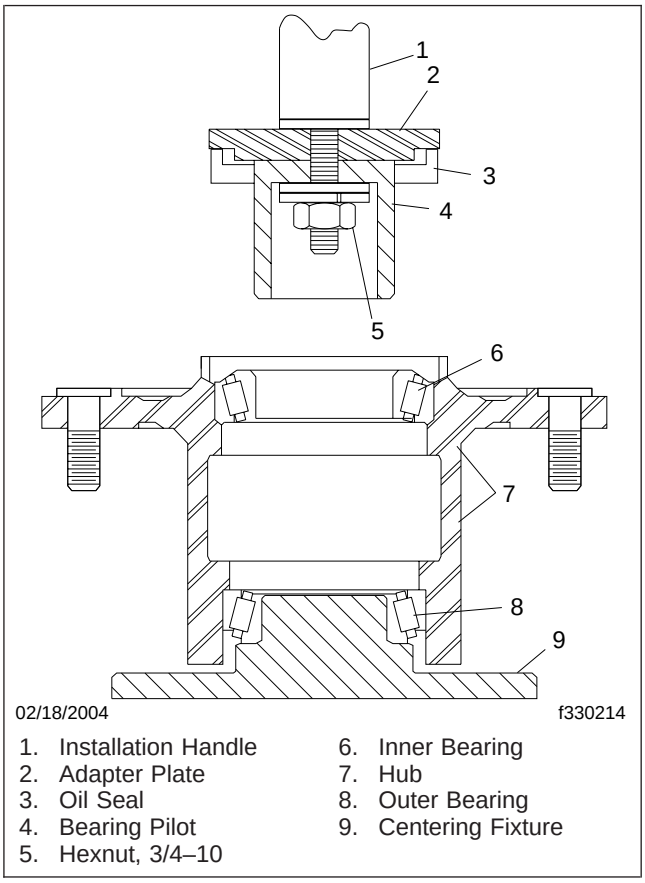


1. Hexnut, 3/4–10
2. Lockwasher
3. Flatwasher
4. Bearing Pilot
5. Oil Seal
6. Adapter Plate
7. Installation Handle

Fig. 1, Oil Seal and Installation Tools

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Seal Replacement, National



1. Installation Handle
2. Adapter Plate
3. Oil Seal
4. Bearing Pilot
5. Hexnut, 3/4–10
6. Inner Bearing
7. Hub
8. Outer Bearing
9. Centering Fixture

Fig. 2, Installing the Oil Seal Into the Hub (cross-sectional view)

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Specifications

National® Oil Seal Special Tool Guide, 8000-lb Steer Axles		
Vendor Part Number	**Description**	**Qty.**
NA RD296	Steel Installation Handle	1
NA RD421	Bearing Pilot	1
NA RD272	Adapter Plate	1
NA 370150A	National Oil Seal	As Needed

Table 1, National Oil Seal Special Tool Guide, 8000-lb Steer Axles

Bearing Centering Tool Interchange				
Spindle Type	**Bearing Cone**	**Centering Tool Number**		
		Dana® Spicer® Outrunner™	**Chicago Rawhide**	**National®**
—	641	BCT-6	706	RD-406
—	39581	BCT-2	702	RD-402
—	557A	BCT-3	703	RD-403
FL	6461A	BCT-8	708	RD-418
—	H715345	BCT-16	716	RD-407
—	HM212044	BCT-3	703	RD-403
—	HM212047	BCT-4	704	RD-404
FF	HM212049	BCT-6	706	RD-406

Table 2, Bearing Centering Tool Interchange

Adapter Plates		
Seal	**Adapter Plate**	**Color**
847	847-T	Blue
855	855-T	
857	857-T	
863	863-T	

Table 3, Adapter Plates

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General Information

Detroit front axles have a unique steering knuckle design that reduces vibration and wear. Low-friction, high-strength needle bearings roll on a large-diameter kingpin, replacing the conventional bushings.

They are compatible with all standard industry model brakes, hubs, and wheel bearings.

There are two basic models for the Detroit front axle on Acterra: Model 2 and Model 3. The basic model is indicated by the numbers on the axle's identification tag.

The following explains a typical model number.

Typical Model Number: AF-12-3.

- *AF* = front axle
- *12* = Weight Rating (times 1000 lbs.)
- *3* = Model Number

NOTE: Detroit axles are a proprietary product, though in some applications they may be referred to as "Sterling" or "Axle Alliance" axles or "MB components."

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Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the rear tires. Put the transmission in neutral.
2. At both ends of the front axle, loosen all the wheel nuts.

⚠ WARNING

Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, causing the vehicle to fall, which could result in serious injury or death.

3. Raise the front of the vehicle and support it with safety stands.
4. Drain the air system.
5. Remove the front wheel and tire assemblies. For instructions, see **Group 40**.
6. Remove the brake drums and front hubs from the axle. For instructions, see **Section 33.01, Subject 100**.
7. Remove the brake shoes. For instructions, see the applicable service brake section in **Group 42**.
8. Remove the ABS sensors and wiring from the brake spiders (anchor plates) and secure them and their wiring out of the way.
9. Remove the brake air chambers and the slack adjusters. For instructions, see the applicable sections in **Group 42**.
10. Remove the brake spiders from the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
11. Disconnect the drag link from the axle steering arm.
12. If so equipped, disconnect the sway bar from the axle brackets.
13. Using a suitable jack, support the front axle.
14. Remove the U-bolt nuts or remove the nuts that hold the axle beam to the leaf springs and the air bag brackets, as applicable.
15. Remove the U-bolts, if applicable.
16. Remove the axle from the vehicle.
17. If you are replacing the steering knuckles, put the axle on a suitable stand and secure it to prevent it from moving.

Installation

1. With the axle on a suitable jack, position it under the vehicle.
2. For vehicles with front air suspension, raise the axle so that the holes in the axle beam line up with the bolts that hold the air bags to the leaf springs. Install the nuts and washers and tighten the nuts 220 lbf·ft (298 N·m).

   For vehicles with a leaf-spring front suspension, install the U-bolts and nuts. For instructions on tightening U-bolt nuts, see the applicable section in **Group 32**.
3. If so equipped, connect the sway bar to the axle brackets. Tighten the sway bar fasteners 100 lbf·ft (136 N·m).
4. Connect the drag link to the steering arm. For instructions, see the applicable section in **Group 46**.
5. Install the brake spiders on the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
6. Install the brake air chambers and slack adjusters on the axle. For instructions, see the applicable sections in **Group 42**.
7. Install the ABS sensors.
8. Install the brake shoes. For instructions, see the applicable service brake section in **Group 42**.
9. Install the hubs and adjust the wheel bearings. For instructions, see **Section 33.01, Subject 100**.
10. Install the brake drums.
11. Adjust the slack adjusters. For instructions, see the applicable section in **Group 42**.
12. Install the tire and wheel assemblies. For instructions, see **Group 40**.
13. Raise the vehicle, remove the safety stands, and lower the vehicle.
14. Start the engine and build the air pressure.

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Axle Removal and Installation

15. If equipped with a front air suspension, check that the suspension air bags are inflating correctly.
16. Remove the chocks from the rear tires.

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Disassembly

NOTE: The following procedures can be done with the axle installed on the vehicle or with the axle removed from the vehicle.

1. If the axle has been removed, make sure it is securely mounted on a suitable stand. Go to the step for removing the tie rod from the tie-rod arm.

   If the axle is on the vehicle, park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the rear tires. Drain the air system.

2. If the axle is on the vehicle, do the following substeps to gain access to the steering knuckle.

   2.1 Remove the wheel and tire assembly from the applicable side of the vehicle.

   2.2 Remove the brake drum and hub. For instructions, see **Section 33.01, Subject 100**.

   2.3 Remove the brake shoes. For instructions, see the applicable service brake section in **Group 42**.

   2.4 If so equipped, remove the ABS sensor and wiring from the brake spider (anchor plate) and secure the sensor and the wiring out of the way.

   2.5 Disconnect the air line from the brake air chamber, then remove the air chamber and the slack adjusters. For instructions, see the applicable sections in **Group 42**.

   2.6 Remove the brake spider from the axle flange. For instructions, see the applicable service brake section in **Group 42**.

   2.7 Disconnect the drag link from the steering arm, if present.

   NOTE: On the driver's side of the vehicle, the steering arm connects to the steering knuckle. On the passenger's side, no steering arm is present.

3. If not already done, disconnect the tie rod from the tie-rod arm.

4. Remove the tie-rod arm from the steering knuckle. See **Fig. 1**.

5. If applicable, remove the steering arm. See **Fig. 1**.

6. Remove the steering knuckle and spindle assembly from the axle beam. See **Fig. 1**.

   6.1 Remove the upper and lower snap rings that hold the cover plates in place.

   6.2 Remove the upper and lower cover plates from the steering knuckle.

   6.3 Remove and discard the O-ring from the edges of each cover plate.

   6.4 Note the orientation of the draw keys and the kingpin, then remove the draw keys and nuts that hold the kingpin in place.

   6.5 Using a brass drift, remove the kingpin by driving it downward. Make a note of where the needle bearings were installed.

   6.6 Remove the spacer(s) and shim(s) from the upper surface of the axle beam bore.

   6.7 On the side with a steering arm, push down on the steering knuckle and spindle assembly to clear the lip on the thrust friction bearing and remove the assembly from the axle beam bore.

NOTE: The steering knuckle on the passenger's side (side without a steering arm) has a thrust roller bearing instead of a thrust friction bearing. Unlike the thrust friction bearing, the thrust roller bearing has no protruding lip at the top. When removing the thrust roller bearing from the axle beam bore, it is not necessary to push down on the steering knuckle.

7. Remove the grease seal from the upper steering-knuckle bore.

8. Remove the thrust friction bearing (driver's side) or the thrust roller bearing (passenger's side) from the top of the lower steering knuckle bore.

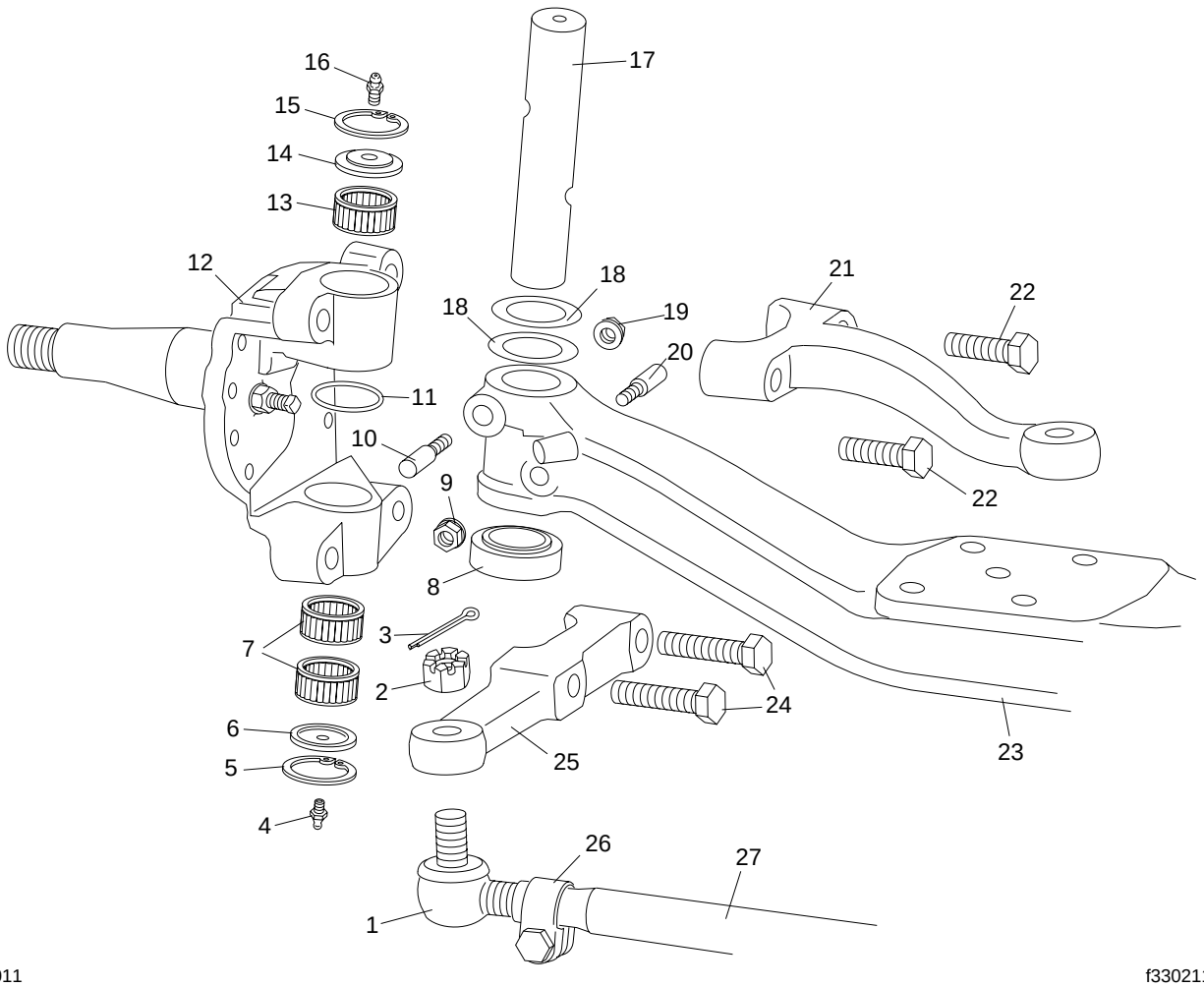
NOTE: If removing the thrust friction bearing (driver's side), note the orientation of the bearing for future reference.

9. Using a brass drift, drive out the needle bearings from the steering knuckle bores.

10. If needed, repeat the entire procedure for the other side of the axle assembly.

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Steering Knuckle Disassembly and Assembly



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NOTE: The number of upper and lower needle bearing sets may vary, depending on the axle model.

1. Tie-Rod Ball Joint
2. Castle Nut
3. Cotter Pin
4. Lower Grease Fitting
5. Lower Snap Ring
6. Lower Cover Plate
7. Lower Needle Bearings (may be one or two sets)
8. Thrust Friction Bearing (thrust roller bearing on the passenger side)
9. Lower Draw Key Nut
10. Upper Draw Key
11. Grease Seal
12. Steering Knuckle
13. Upper Needle Bearing (may be one or two sets)
14. Upper Cover Plate
15. Upper Snap Ring
16. Upper Grease Fitting
17. Kingpin
18. Shim
19. Upper Draw Key Nut
20. Lower Draw Key
21. Steering Arm
22. Steering Arm Capscrew
23. Axle Beam
24. Tie-Rod Arm Capscrews
25. Tie-Rod Arm
26. Tie-Rod Clamp
27. Tie-Rod Tube

Fig. 1, Front Axle Components (driver side shown)

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Assembly

IMPORTANT: If replacing the kingpin, use a complete rebuild kit with all new components.

1. Clean the steering knuckle bores and the axle beam bores. Check for damage such as grooves, scratches, and pitting.

   If any bores show significant damage, replace the component.

2. Install the grease seal—with the grooved side down (toward the road)—into the top of the upper steering knuckle bore. Carefully drive the seal down into the bore until the outer edge of the seal is flush with the bottom edge of the bore. Make sure the seal is not cocked.

3. Install new needle bearings into the bores of one of the steering knuckles. Install the same number of bearings as was removed.

NOTE: Install the needle bearings just far enough into the bores so that the cover plates can be installed.

4. Install a new thrust friction bearing (driver's side) or thrust roller bearing (passenger's side) into the top of the lower steering knuckle bore. Install the thrust friction bearing (or thrust roller bearing) with the sealed side up.

NOTE: The thrust friction bearing has a protruding lip at the top. The thrust roller bearing has no such protruding lip.

5. Partially install the steering knuckle on the axle beam.

   5.1 Making sure the flats on the kingpin are aligned with the draw-key holes in the axle beam, put the new kingpin into the top bore of the steering knuckle. Note that the top of the new kingpin is clearly marked. Push the kingpin through the axle beam bore until the upper end of the kingpin is flush with the upper surface of the axle beam bore.

   5.2 Align the steering knuckle with the axle beam, then check the clearance between the axle beam bore and the upper steering knuckle bore. Clearance is to be a maximum of 0.003 inch (0.08 mm).

   IMPORTANT: To correctly check the clearance, the thrust friction or thrust roller bearing must be installed correctly, and upward pressure must be applied to the steering knuckle.

   5.3 If needed, install sufficient spacers to reduce the clearance to 0.002 to 0.003 inch (0.05 to 0.08 mm).

6. Install the kingpin fully into the steering knuckle bores, making sure the flats on the kingpin are still aligned with the draw-key holes in the axle beam.

7. Install new upper and lower draw keys and nuts. See **Fig. 1**.

   7.1 Install the upper draw key from the back of the axle, and the lower one from the front of the axle.

   IMPORTANT: Make sure the new draw keys are the same length as those removed. On some axle models the lower draw key is longer than the upper one.

   7.2 Tighten the draw-key nuts 30 to 55 lbf·ft (40 to 75 N·m).

8. Install new grease fittings and cover plates.

   8.1 Install the new upper cover plate (with a new O-ring) and the snap ring. Install the new grease fitting into the cover plate.

   8.2 Install the new lower cover plate (with a new O-ring) and the snap ring. Install the new grease fitting into the cover plate.

9. Install the steering arm. Apply Loctite® 277 to the threads and tighten the steering arm capscrews: if M20 capscrews are used, tighten them 425 lbf·ft (575 N·m); if M24 capscrews are used, tighten them 664 lbf·ft (900 N·m).

10. Attach the tie-rod arm to the steering knuckle. Apply Loctite® 277 to the threads and tighten the tie-rod arm capscrews: if M20 capscrews are used, tighten them 425 lbf·ft (575 N·m); if M24 capscrews are used, tighten them 664 lbf·ft (900 N·m).

11. Attach the tie-rod arm to the tie rod. Tighten the castle nut 120 to 170 lbf·ft (163 to 230 N·m) plus a maximum of one-sixth of a turn to align a slot in the castle nut with the cotter pin hole in the tie

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Steering Knuckle Disassembly and Assembly

rod stud. Insert the cotter pin and bend the tangs to secure it.

12. If removed, install the axle.
13. If removed, connect the drag link to the steering arm.
14. Install the brake spider on the axle flange. For instructions, see the applicable service brake section in **Group 42**.
15. Install the brake air chambers and slack adjusters on the axle. For instructions, see the applicable sections in **Group 42**.
16. Install the ABS sensor.
17. Install the brake shoes. For instructions, see the applicable service brake section in **Group 42**.
18. Install the hub and adjust the wheel bearings. For instructions, see **Section 33.01**.
19. Install the brake drum.
20. Install the tire and wheel assembly. For instructions, see **Group 40**.
21. If necessary, repeat the entire procedure for the other side of the vehicle.
22. Raise the vehicle, remove the safety stand, then lower the vehicle.
23. Remove the chocks from the tires.

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Specifications

Torque Values			
Application	**Size**	**Class**	**Torque: lbf·ft (N·m)**
Air Bag-to-Leaf Spring Nuts	—	—	220 (298)
Draw-Key Nuts	—	—	30–55 (40–75)
Sway Bar Fasteners	—	—	100 (136)

Table 1, Torque Values

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General Information

Rear axle alignment should be checked whenever rear axle or suspension components are replaced. It should also be checked when there is excessive front or rear tire wear or hard or erratic steering.

Manufacturers of axle alignment equipment offer a variety of systems to precisely measure and correct rear axle alignment. Alignment specifications for Hunter and Bee Line alignment equipment, and for manual measurement, are in **Specifications, 400**.

If alignment equipment is not available, the basic tools needed for checking rear axle alignment on tandem axles are a straightedge (which is nonflexible and at least as long as the axle), a steel tape rule, and a center point bar. On single axle vehicles, a straightedge, trammel bar and steel tape rule are needed.

The straightedge is used to see if a single axle, or the rearmost rear axle of a tandem axle installation, is in alignment with the frame. The distance from the straightedge to the center of the wheel hub is measured on each side of the vehicle. Any difference in the measurements means that the axle is out of alignment.

The center point bar is used to see if the forward rear axle and rearmost axle of a tandem installation are aligned with each other (parallel). See **Fig. 1**. The center point bar has adjustable pointers at each end which are inserted into the axle cap holes of each axle. By comparing the distance between the two axles on one side to the distance on the other side it can be determined if the axles are parallel.

Instructions and a list of materials for making the center point bar are in **Subject 120**.

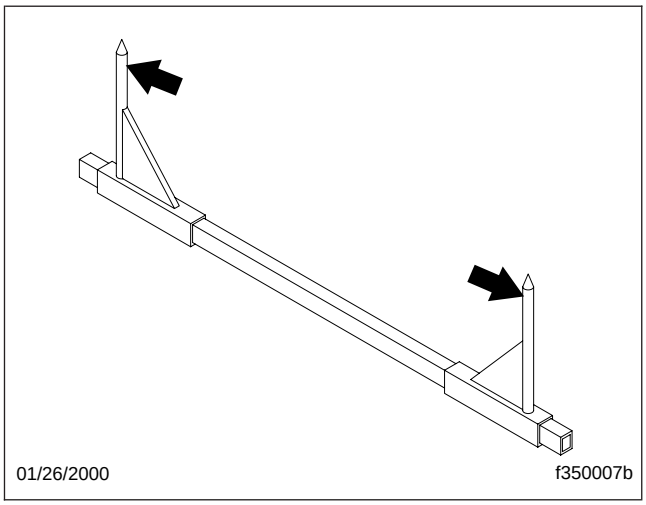


Fig. 1, Center Point Bar Adjustable Pointers

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Thrust Angle (Perpendicularity) Check

NOTE: Before checking the axle alignment, make sure the wheel bearings are adjusted. For instructions, see the appropriate subject in this group. Make sure the wheel rims are not bent and that all rims are correctly seated. See **Group 31** for frame rail alignment instructions. Correct the frame rail alignment if necessary.

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turnplates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Acterra dealers must have proof of this calibration history.

1. Park the vehicle on a level surface. Relieve internal stresses in the suspension by driving the vehicle back and forth in a straight line or by jacking the axle up and letting it down.
2. Chock the front tires and place the transmission in neutral. Release the parking brakes.

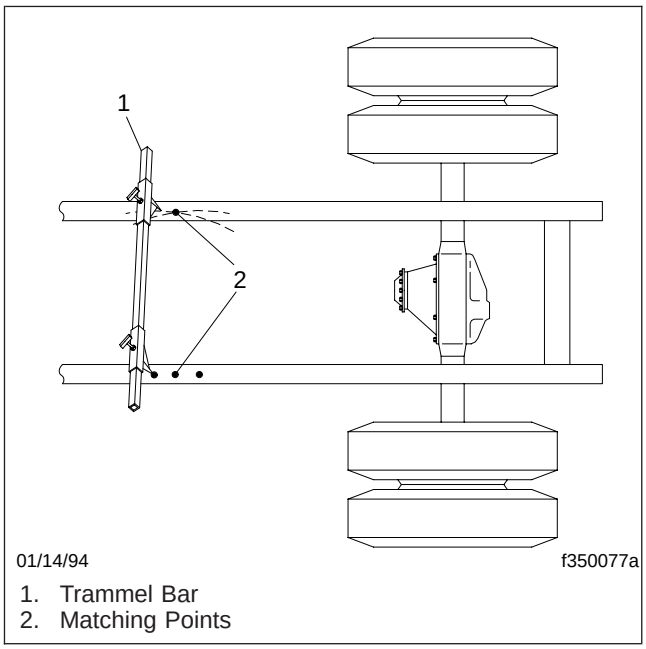
⚠ CAUTION

Do not use scribe lines for marking on frame rails. Scribe lines which cut or scratch the metal can develop into starting points for structural damage to the frame.

3. Select a point on the frame rail forward of the rear axle. Using a pencil or soapstone, mark two other points, about 4 inches (102 mm) forward and to the rear of the original point.

IMPORTANT: The distance from the original point to the forward and to the rear point does not have to be exactly 4 inches (102 mm) but the distance from the original point to the forward point *must* exactly equal the distance from the original point to the rear point.

4. Make sure that all three marks are aligned and of equal distance from the outside edge of the frame rail. Using a trammel bar, place one trammel pointer on the forwardmost point and make an arc with a pencil or soapstone on the opposite frame rail. Place the trammel pointer on the rearmost point and make an arc on the opposite frame rail intersecting the first arc. See **Fig. 1**. The point where the two arcs intersect and the original (or middle) point on the opposite frame rail have matching locations.



1. Trammel Bar
2. Matching Points

Fig. 1, Marking an Arc With the Trammel Bar

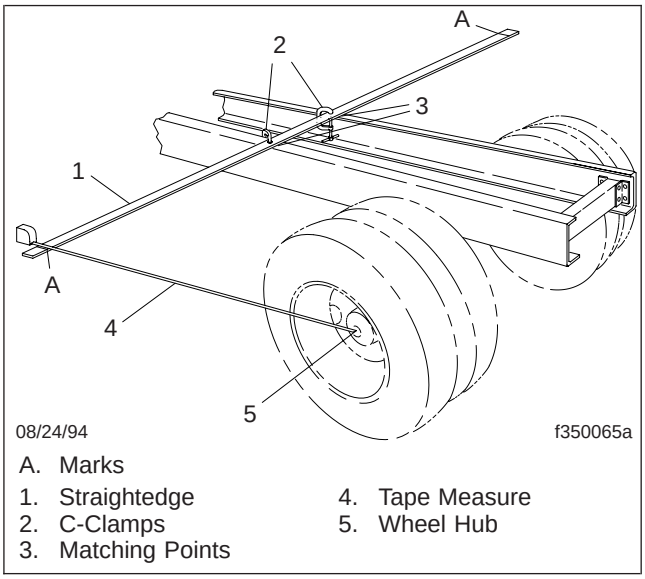
5. Line up the straightedge with the two matching points. Check that the straightedge extends out about the same distance on each side of the frame rail. Using C-clamps, clamp the straightedge to the frame. See **Fig. 2**. The straightedge must line up exactly with the points.
6. Measuring from the outside edge of each frame rail, mark the straightedge on both sides of the frame. The marks must be of equal distance from the frame and as far from the frame rail as the tires are at their farthest point from the frame. See **Fig. 2**.

IMPORTANT: The distance between the mark on the straightedge and the frame rail must be equal on both sides of the vehicle.

7. On each side of the vehicle, measure the distance from the mark on the straightedge to the center of the wheel hub. See **Fig. 2**. The difference between these measurements should be 3/8 inch (9 mm) or less. If the difference is more

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Alignment Check, Single Axle



A. Marks
1. Straightedge
2. C-Clamps
3. Matching Points
4. Tape Measure
5. Wheel Hub

Fig. 2, Straightedge to Wheel Hub Measurement

than 3/8 inch (9 mm), adjust the axle alignment. For instructions, see **Group 32** in this manual or the suspension manufacturer's service literature.

8. Remove the chocks from the tires.

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Alignment Check, Tandem Axle

Check

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turnplates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Acterra dealers must have proof of this calibration history.

A straightedge and a center point bar are needed to align a tandem axle. A straightedge and trammel bar are used to check and, if needed, align the rearmost axle. The center point bar is used to check and, if needed, align the forward-rear axle.

Use the instructions in **Subject 100** to check and align the rearmost axle. Check the alignment of the forward-rear axle as follows:

IMPORTANT: Align the rearmost axle before checking the forward-rear axle.

1. Using the center point bar, set the two points into the axle cap holes as shown in **Fig. 1**. Lock them in place by tightening the setscrews.

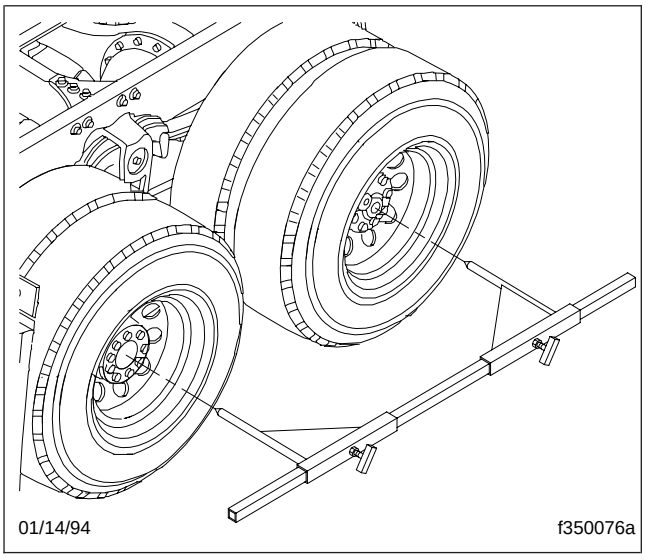


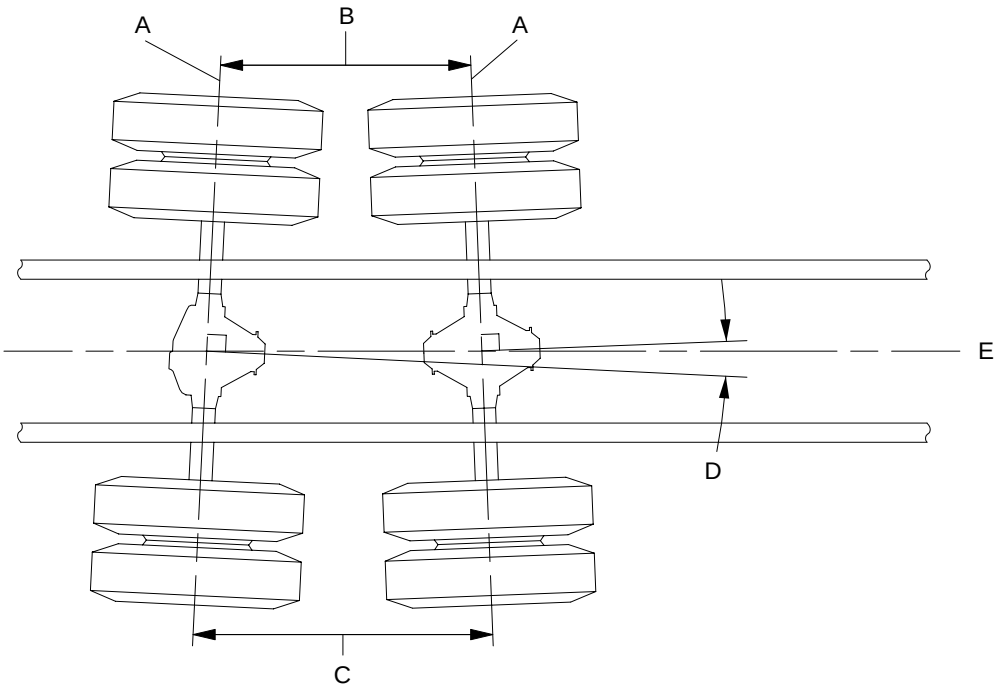
Fig. 1, Position of Center Point Bar to Axle Cap Holes

2. With the points still locked in place, move the center point bar to the other side of the vehicle, set the two points into the axle cap holes and compare the axle spacing. If there is a difference of 1/8 inch (3 mm) or less between the spacing on one side of the vehicle compared to the other, no further action is necessary.

   If the difference is more than 1/8 inch (3 mm), adjust the forward-rear axle alignment. See **Fig. 2**. For instructions, see **Group 32** in this manual or the suspension manufacturer's service literature.

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Alignment Check, Tandem Axle



A. Axle Centerline
B. Left-Hand Axle End Spacing, Measured Manually or with Bee Line Alignment Tools
C. Right-Hand Axle End Spacing, Measured Manually or with Bee Line Alignment Tools
D. Maximum Tolerance as Measured with Hunter Alignment Tools = ±0.08 degree
E. Vehicle Centerline

Fig. 2, Centerline Measurements

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Center Point Bar Construction

Materials Required

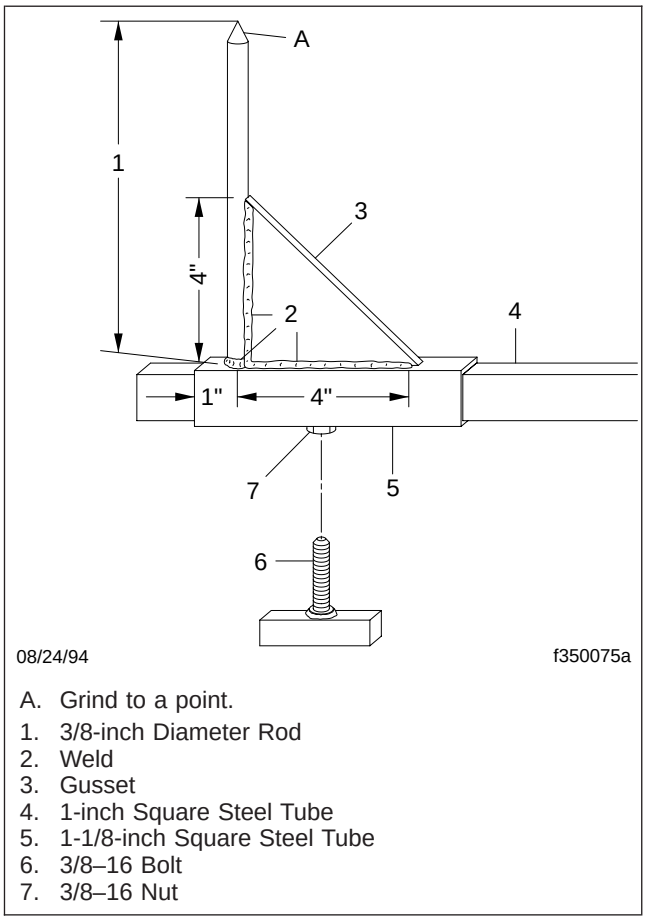
NOTE: To obtain metric conversions (millimeters), multiply the number of inches by 25.4.

Required materials are listed below:

- 62 inches of square steel tube (1-inch o.d.)
- 12 inches of square steel tube (1-1/8-inch i.d.)
- 20 inches of 3/8-inch steel rod
- two 1/2-inch x 3-inch pieces of steel square-bar stock
- one 4-inch x 4-inch steel plate, 1/8-inch thick
- two 3/8–16 capscrews (grade 5), 2 inches long
- two 3/8–16 hexnuts (equivalent to grade 5)

Construction Procedures

1. Cut the 1-1/8-inch i.d. square steel tube in half to obtain two pieces 6 inches long. These will be the sliding members (slides) of the center point bar.
2. Cut the 4-inch x 4-inch steel plate diagonally into two pieces (gussets). Weld one gusset to each slide. See **Fig. 1**.
3. Cut the steel rod in half to obtain two 10-inch rods. Grind one end of each to form a point.
4. Weld the pointed steel rods to the slides and gussets, as shown in **Fig. 1**.
5. Drill a 1/2-inch (12.7 mm) hole in the center of each slide, on the side opposite where the pointer was welded. Drill through only one side of the tube.
6. Directly over each hole drilled in the step above, weld a 3/8–16 nut (equivalent to grade 5).
7. Weld a piece of steel stock, about 1/2-inch wide x 3-inch long, over the head of each of two 3/8–16 x 2-inch long capscrews.
8. Place a slide over each end of the 60-inch piece of steel tube, with the pointed rods to the outside. Screw the handscrews (made in the step above) into the slides until they are clamped tightly to the cross tube.



A. Grind to a point.
1. 3/8-inch Diameter Rod
2. Weld
3. Gusset
4. 1-inch Square Steel Tube
5. 1-1/8-inch Square Steel Tube
6. 3/8–16 Bolt
7. 3/8–16 Nut

Fig. 1, Center Point Bar Construction

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Specifications

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turnplates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Dealers must have proof of this calibration history.

Maximum Tolerance from Perpendicular	
Method	**Maximum Tolerance ± from Perpendicular**
Manual	1/4 inch (6 mm)
Hunter *	0.18 degree

* To use Hunter alignment equipment, see the applicable Hunter service literature.

Table 1, Maximum Tolerance from Perpendicular

Maximum Tolerance from Perpendicular at Target, Bee Line Equipment	
Distance from the Forward or Rear Drive Axle to Target inches (mm)	**Maximum Tolerance± from Perpendicular inches (mm)**
100 (2540)	5/16 (8)
120 (3048)	3/8 (10)
140 (3556)	7/16 (11)
160 (4064)	1/2 (13)
180 (4572)	9/16 (14)
200 (5080)	5/8 (16)
220 (5588)	11/16 (17)
240 (6096)	3/4 (19)
260 (6604)	13/16 (21)

Table 2, Maximum Tolerance from Perpendicular at Target, Bee Line Equipment

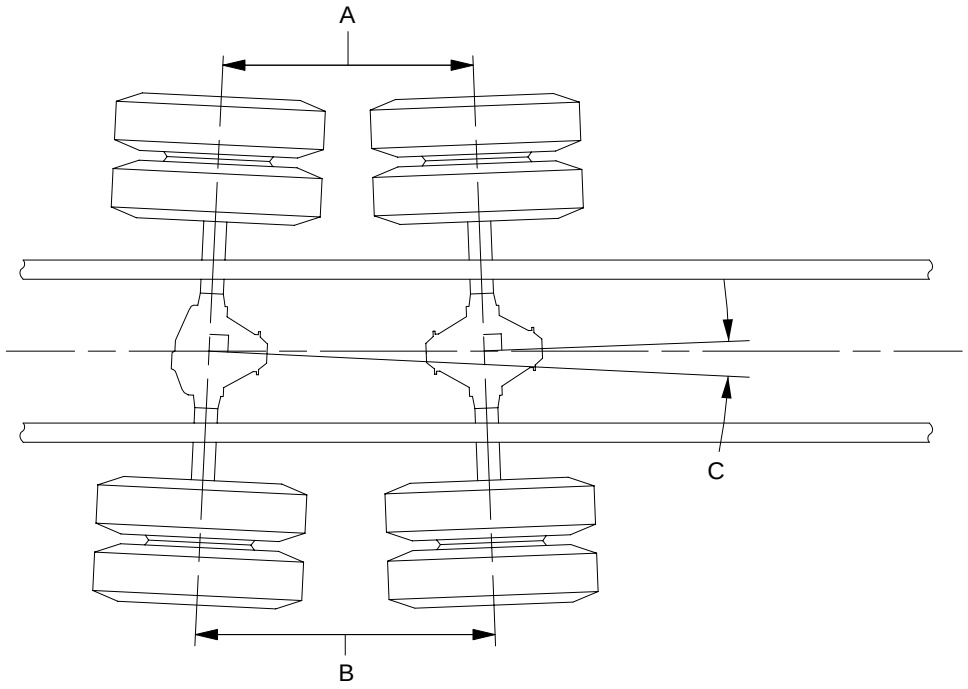
Rear Axle Parallelism Specifications	
Method	**Maximum Tolerance**
Hunter	±0.08 degree maximum axle-to-axle difference; reference "C" in **Fig. 1**.

Rear Axle Parallelism Specifications	
Method	**Maximum Tolerance**
Bee Line or Manual	±1/8-inch max. difference in axle-end spacing; reference "B" minus "A" in **Fig. 1**.

Table 3, Rear Axle Parallelism Specifications

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Specifications



B minus A equals axle-end spacing.
C equals axle-to-axle difference.

Fig. 1, Tandem Axle Measurements

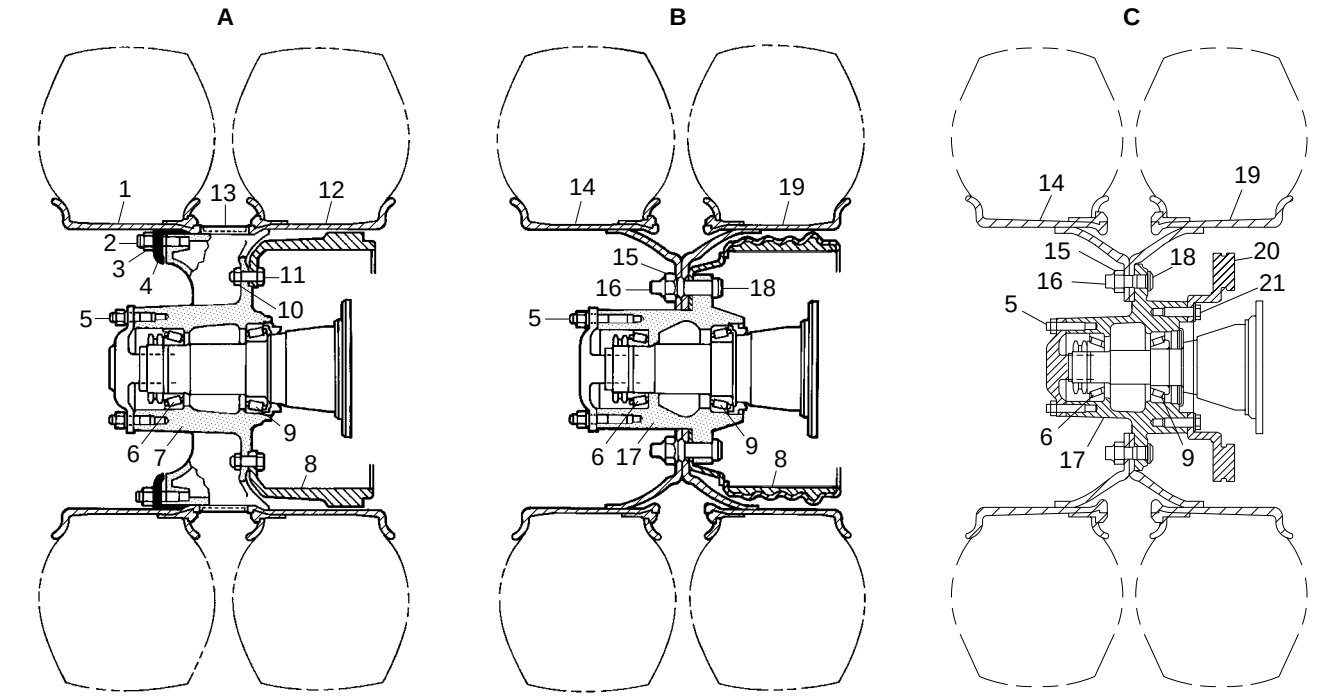
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General Information

The rear axle full-floating wheel hub assembly is made up of five major components: inner and outer tapered wheel bearings, the drive axle spindle assembly, the wheel hub, the brake drum, and the wheel studs. See **Fig. 1**.

Each hub has a set of inner and outer tapered wheel bearing assemblies. The bearing setting is locked in place on the axle spindle by an adjusting nut, lockring, and jam nut. See **Fig. 3**.

DRIVE AXLE SPINDLE ASSEMBLY



A. Spoke Wheel and Brake Drum Assembly
B. Disc Wheel, Wheel Hub, and Brake Drum Assembly
C. Disc Wheel, Wheel Hub, and Brake Rotor Assembly

1. Outer Rim
2. Rim Stud
3. Rim Stud Nut
4. Rim Clamp
5. Drive Axle Stud
6. Outer Wheel Bearing
7. Spoke Wheel
8. Brake Drum
9. Inner Wheel Bearing
10. Brake Drum Nut
11. Brake Drum Bolt
12. Inner Rim
13. Rim Spacer
14. Outer Wheel
15. Outer Wheel Nut
16. Inner Wheel Nut
17. Wheel Hub
18. Wheel Stud
19. Inner Wheel
20. Brake Rotor
21. Rotor Bolt

Fig. 1, Wheel Hub Assemblies

TAPERED WHEEL BEARINGS

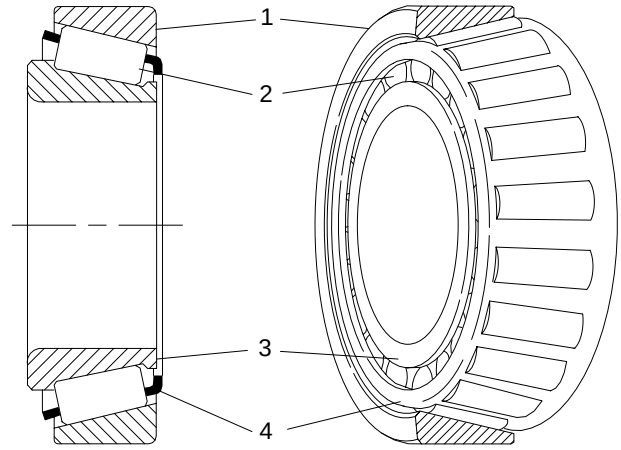
A typical tapered wheel bearing assembly consists of a cone, tapered rollers, a roller cage, and a separate cup that is press-fit in the hub. See **Fig. 2**. All components carry the load, with the exception of the cage, which spaces the rollers around the cone.

The drive axle spindle assembly is made up of a drive axle flange and shaft, drive axle studs and stud nuts, a flange gasket, an axle spindle, an oil seal, and the nut/lockring assembly described above. See **Fig. 4**.

The surfaces of the spindle and the nut threads are machined. When these surfaces become damaged,

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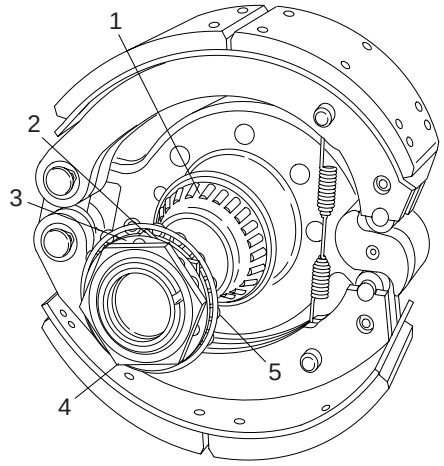
General Information



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1. Cup
2. Tapered Roller
3. Cone
4. Roller Cage

Fig. 2, Tapered Wheel Bearing Assembly



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1. Inner Wheel Bearing
2. Wheel Bearing Inner Adjusting Nut
3. Lockring
4. Axle Spindle Jam Nut
5. Outer Wheel Bearing

Fig. 3, Drive Axle Bearings and Spindle Assembly

repairs are necessary. There are standard methods for performing those repairs that preserve the proper alignment of the axle spindle assembly. Refer to the axle manufacturer for instructions.

⚠ CAUTION

The National Highway Traffic Safety Administration (NHTSA) has warned against repairs that involve cutting off a portion of a damaged spindle and welding on a replacement part. The heat of welding can reduce the strength of spindles made with heat-treated materials and lead to spindle failure. After the cutting and welding operations, the replacement part may not be correctly aligned on the spindle. This can cause damage to the spindle nut.

WHEEL HUB

The inner disc wheel and/or brake drum is mounted on an aluminum or iron wheel hub. Both the inner and outer bearing cups and certain types of wheel studs are press-fit in the hub. The hub is also the interconnecting point for the drive axle shaft and wheels. See **Fig. 4**.

Each spoke wheel combines both wheel and hub into a single unit. See **Fig. 4**.

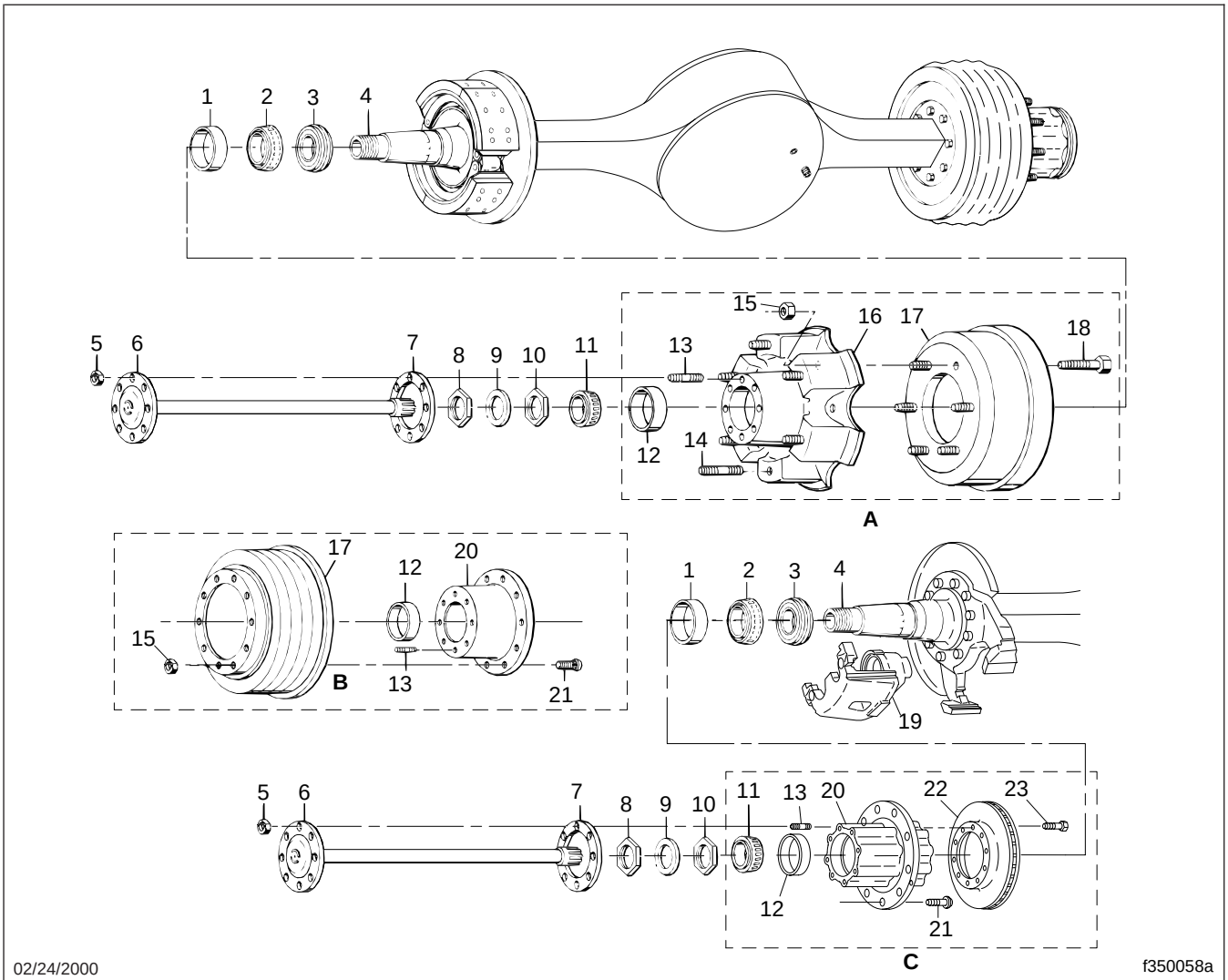
WHEEL STUDS

A headed wheel stud is used on rear axle disc wheel hub assemblies and has either serrations on the stud body or a flat area on the stud's head to prevent the stud from turning in the wheel hub. See **Fig. 5**.

The end of the stud that faces away from the vehicle is stamped with an "L" or "R," depending on which side of the vehicle the stud is installed. Studs stamped with an "L" are left-hand threaded and are installed on the driver's side of the vehicle. Studs stamped with an "R" are right-hand threaded and are installed on the passenger's side of the vehicle.

Spoke wheels have rim studs. Rim studs are threaded on both ends, with a nonthreaded section midway along the shaft of the stud. The studs are coated with an anaerobic locking compound.

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A. Spoke Wheel and Drum Assembly
B. Disc Wheel, Hub, and Drum Assembly
C. Disc Wheel, Hub, and Rotor Assembly

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Lockring
10. Wheel Bearing Inner Adjusting Nut
11. Outer Wheel Bearing
12. Outer Wheel Bearing Cup
13. Drive Axle Stud
14. Rim Stud
15. Brake Drum Nut
16. Spoke Wheel
17. Brake Drum
18. Brake Drum Bolt
19. Brake Caliper
20. Wheel Hub
21. Wheel Stud
22. Brake Rotor
23. Rotor Bolt

Fig. 4, Typical Drive Axle (exploded view)

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General Information

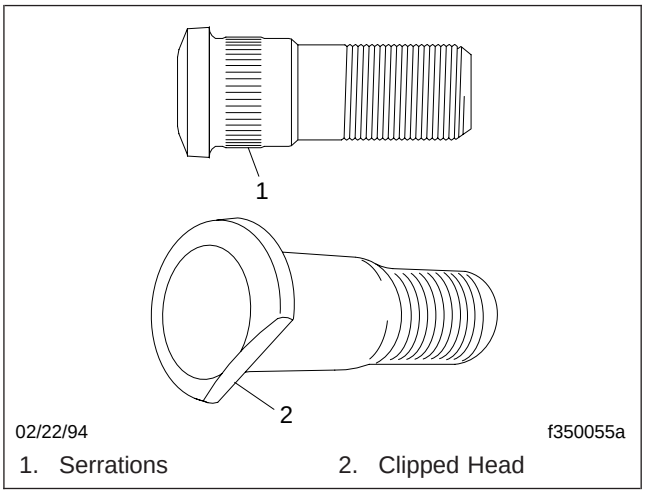


Fig. 5, Typical Headed Wheel Studs

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Hub Assembly Removal and Installation

IMPORTANT: Make sure the required tools are available before beginning these procedures. See the "Bearing Centering Tool Interchange" and "Adapter Plates" tables in **Specifications, 400**.

Removal

See **Fig. 1** for this procedure.

NOTE: Spoke wheel assemblies with inboard drums do not need to be completely disassembled for brake component maintenance. The tires and rims can remain attached to the wheel, and the wheel to the brake drum. The assembly is then removed from the axle as a single unit to expose brake components. See **Group 42** for brake assembly service information.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires. Release the parking brakes.
2. Raise the rear of the vehicle until the tires clear the ground. Place safety stands under the axle to be serviced. Position a jack or wheel-and-tire dolly under the tires.
3. If the vehicle is equipped with air brakes, back off the slack adjuster to release the rear axle brake shoes. For instructions, see the applicable slack adjuster section in **Group 42**.
4. Remove both wheel and tire assemblies. For instructions, see **Group 40**.

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

5. On all types of wheels, to minimize the possibility of creating airborne brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Using a rag soaked in water and wrung until nearly dry, remove any remaining dust. Do not use compressed air or dry brushing to clean the brake assembly.
6. If equipped with outboard drums (disc wheels), remove the brake drum (air brakes), or brake caliper (disc brakes). For instructions, see **Group 42**.

NOTE: On vehicles equipped with oil-lubricated bearings, oil will spill as the drive axle shaft and wheel hub are removed. Place a suitable container under the axle spindle to catch any spilled oil. Dispose of the oil properly.

7. Remove the drive axle stud nuts and washers. See **Fig. 2**.
8. Using a hammer and a soft drift, such as one made of brass, sharply tap the center portion of the drive axle flange. See **Fig. 2**. The shaft will usually spring slightly outward after the seal has broken. Remove the drive axle shaft.

NOTICE

When tapping the drive axle flange, avoid striking the drive axle studs. If struck, the studs may bend or break, or the stud threads can be damaged. Replace damaged studs.

NOTE: Even if the drive axle shaft does not spring outward, the seal may have loosened enough to allow the shaft to be pulled from the axle spindle. If the seal has not broken, repeat the step above.

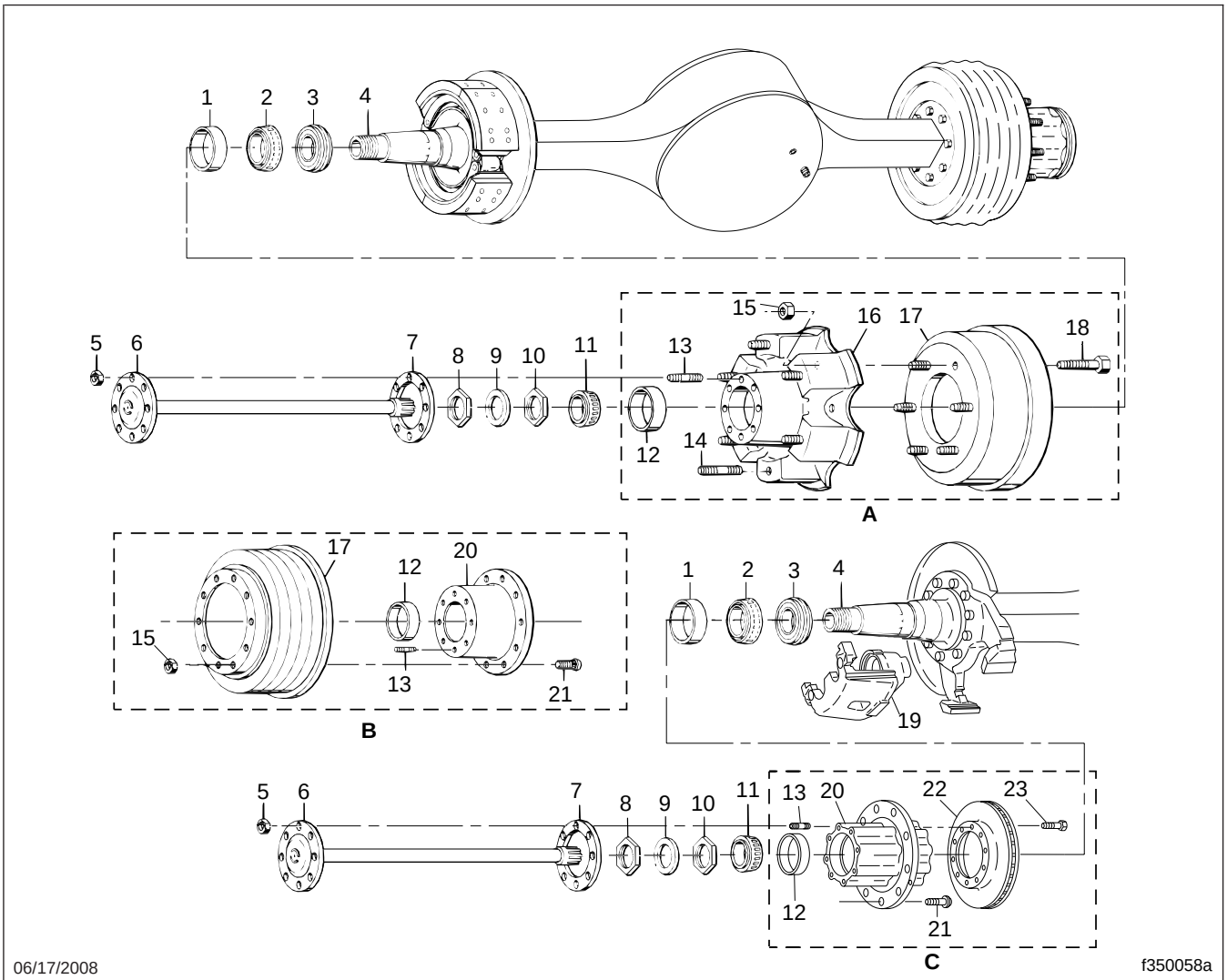
9. If equipped, remove the tapered dowels and washers from the drive axle flange.
10. Remove and discard the gasket.
11. Remove the wheel bearing locking device, as equipped. See **Fig. 3** and **Fig. 4**. If the axle is equipped with ConMet PreSet hubs, see **Subject 160**.

NOTICE

Be careful not to let the outer wheel bearing drop from the axle spindle. Dropping the bearing can warp the cage or damage the rollers, ruining the bearing. On vehicles equipped with WABCO ABS, use care when working with the hubs. To prevent damage to the tone wheel, do not drop the hub,

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Hub Assembly Removal and Installation



A. Spoke Wheel and Drum Assembly
B. Disc Wheel Hub and Drum Assembly
C. Disc Wheel Hub and Rotor Assembly

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Lockring
10. Wheel Bearing Adjusting Nut
11. Outer Wheel Bearing
12. Outer Wheel Bearing Cup
13. Drive Axle Stud
14. Rim Stud
15. Brake Drum Nut
16. Spoke Wheel
17. Brake Drum
18. Brake Drum Bolt
19. Brake Caliper
20 Wheel Hub
21. Wheel Stud
22. Brake Rotor
23. Rotor Bolt

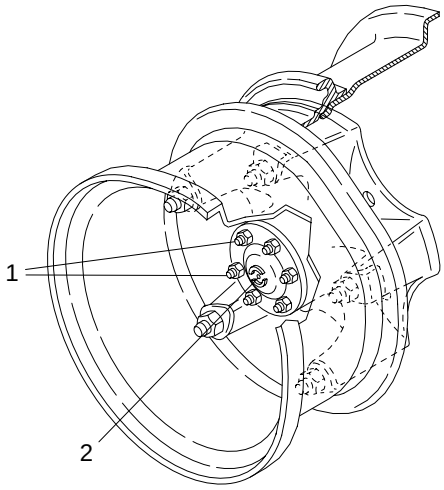
Fig. 1, Typical Rear Drive Axle Assemblies

or lay it down in a way that would damage the tone wheel.

12. Move the hub about 1/2 inch (13 mm) to jar loose the outer wheel bearing (allow the hub-only

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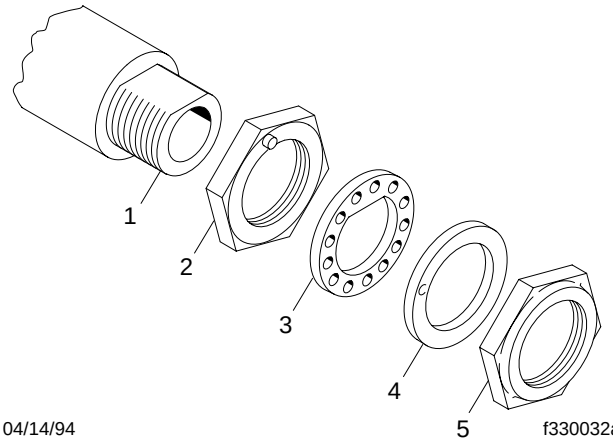
Hub Assembly Removal and Installation



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1. Drive Axle Studs and Nuts
2. Center of Drive Axle Flange

Fig. 2, Wheel Assembly and Hub



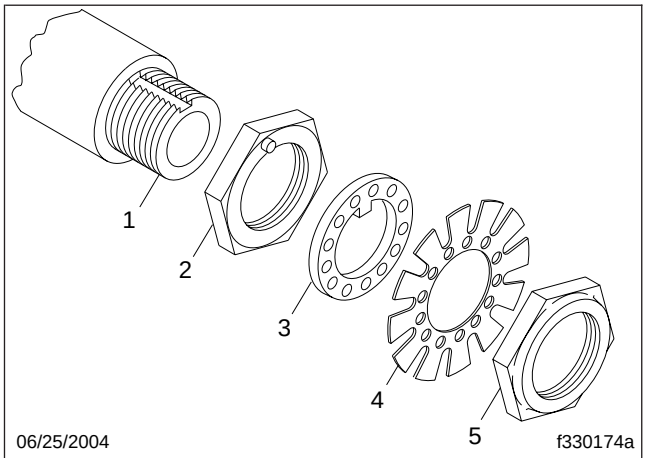
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1. Axle Spindle
2. Adjusting Nut
3. Pierced Lockring
4. Lockwasher
5. Jam Nut

Fig. 3, Wheel Bearing-Lock System with Pierced Lockring

assembly to rest on the axle spindle; be careful not to damage the axle spindle threads).

13. Carefully remove the outer wheel bearing; handle the bearings with clean, dry hands. Wrap them in either clean oil-proof paper or lint-free rags.



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1. Axle Spindle
2. Adjusting Nut
3. Tanged Nut-Lock
4. Lockwasher
5. Jam Nut

Fig. 4, Wheel Bearing-Lock System with Tanged Nut-Lock

NOTICE

Do not spin the bearing rollers at any time. Dirt or grit can scratch their surfaces and cause rapid wear of the bearing assembly. Treat good used bearings as carefully as new ones.

14. Remove the hub. Be careful not to damage the axle spindle threads as the assembly is removed.

    If equipped with inboard drums (spoke wheels), remove the wheel hub, then detach the brake drum from the hub. See **Fig. 1**.

    If equipped with disc brakes, remove the wheel hub, then detach the rotor from the hub. See **Fig. 1**.

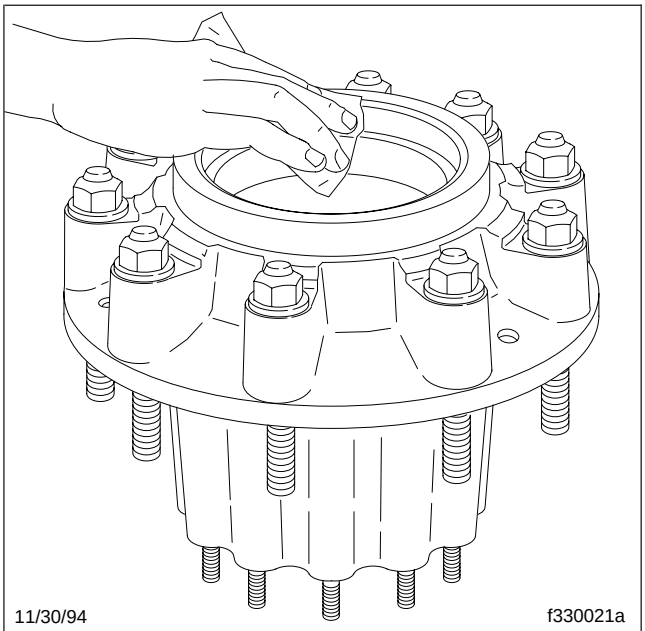
15. Using a seal removal tool, remove the oil seal, if not already removed.

16. Remove the inner wheel bearing from the hub. If the bearings are not easily removed, place a protective cushion where it will catch them. Use a hardwood drift and a light hammer to gently tap the bearings (and seal, if needed) out of the cup. Handle the bearings with clean, dry hands. Wrap them in either clean oil-proof paper or lint-free rags.

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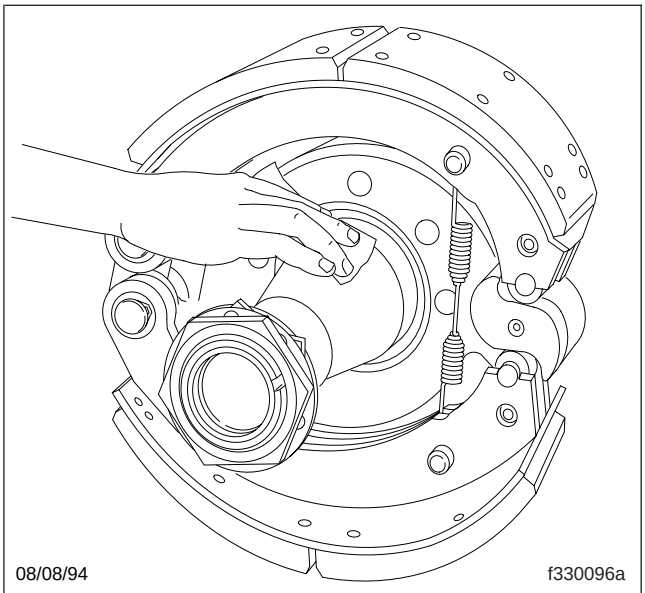
Hub Assembly Removal and Installation

17. Remove all burrs from the shoulder and the seal bore, using an emery cloth or a file. See **Fig. 5** and **Fig. 6**. Clean any metal filings from the parts.



NOTE: Typical application.

Fig. 5, Cleaning the Hub



NOTE: Typical application shown.

Fig. 6, Cleaning the Spindle

IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle. Dirt, metal filings, or other debris can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

Installation

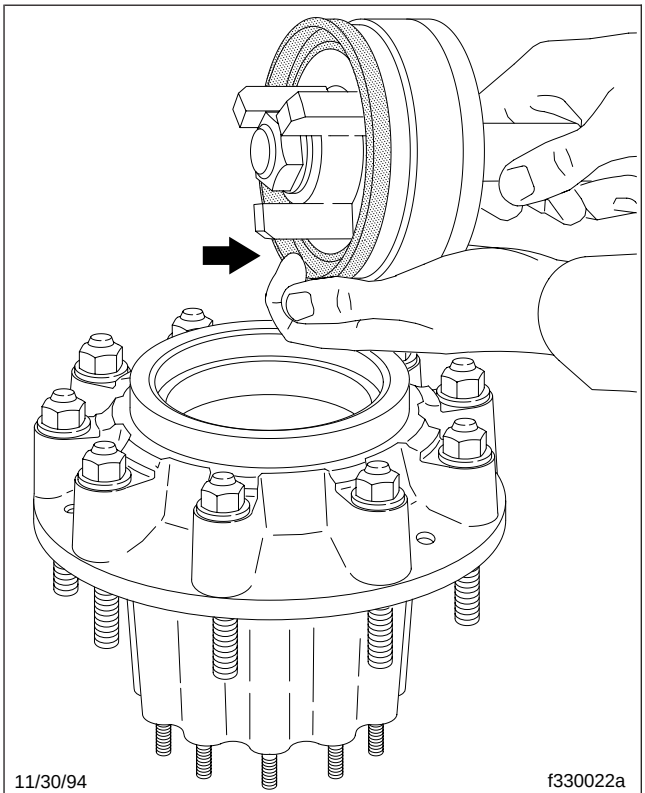
1. Using cleaning solvent, remove the old oil from the axle spindle and the disassembled parts. Inspect and clean the wheel hub cavity and the wheel bearings as instructed under **Subject 110**. Allow the parts to dry, or dry them with a clean, absorbent, and lint-free cloth or paper. Wrap a protective layer of friction tape on the axle spindle threads.
2. On inboard drums, attach the brake drum or rotor to the wheel. Install the brake drum or rotor bolts and nuts. Tighten the nuts to the torque values in the table in **Specifications, 400**. See **Group 42** for additional instructions.

NOTICE

Use only fresh oil on the bearing assemblies; old oil could be contaminated with dirt or water (both are corrosives) and could cause damage to both wheel bearing assemblies and the wheel hub.

3. Handling the bearings with clean, dry hands, coat both bearing assemblies with fresh oil. For lubricant specifications, see **Specifications, 400**.
4. Install the inner wheel bearing assembly.
5. Inspect a new seal for damage (such as cuts or being out of round) and contamination. If damage is evident, discard it and use a suitable seal.
6. Install the oil seal as follows.
   - 6.1 Seat the small outer diameter of the seal in the recess of the tool adapter. See **Fig. 7**. The correct adapter is identified on the box.
   - 6.2 Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 8**. The plug prevents cocking of the seal in the bore.

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NOTE: Typical application shown.

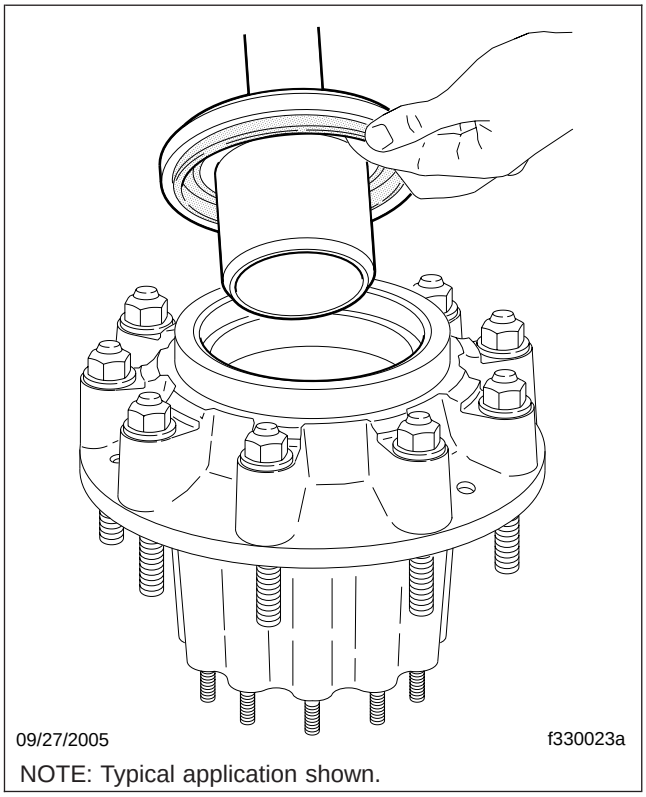
Fig. 7, Seating the Seal in the Tool

6.3 To avoid bounce or unseating of the seal, hold the tool handle firmly, and strike it until the seal is bottomed in the bore. See **Fig. 9**.

6.4 After the seal is bottomed in the bore, check for freedom of movement by manually moving the interior rubber part of the seal back and forth. A slight movement indicates a damage-free installation. If any damage is visible, remove the seal and install a new one.

7. If the axle is equipped with ConMet PreSet hubs, see **Subject 160** for installation and adjustment procedures.

8. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.



NOTE: Typical application shown.

Fig. 8, Inserting the Tool

NOTICE

On vehicles equipped with WABCO ABS, use care when installing the hubs. To prevent damage to the tone wheel, do not drop the hub or lay it down in a way that would damage the tone wheel.

9. Carefully mount the hub and inner wheel bearing assembly on the axle spindle. Be careful not to unseat the inner wheel bearing or seal.

10. Fill the hub cavity with oil, and install the outer wheel bearing; handle the bearings with clean, dry hands. Use care not to damage the bearings as they are seated in the bearing cups. Remove the friction tape from the axle spindle threads.

11. Install the wheel bearing adjusting nut as follows. See **Fig. 3** for assemblies with a pierced lockring, or **Fig. 4** for assemblies with a tanged nutlock.

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Hub Assembly Removal and Installation

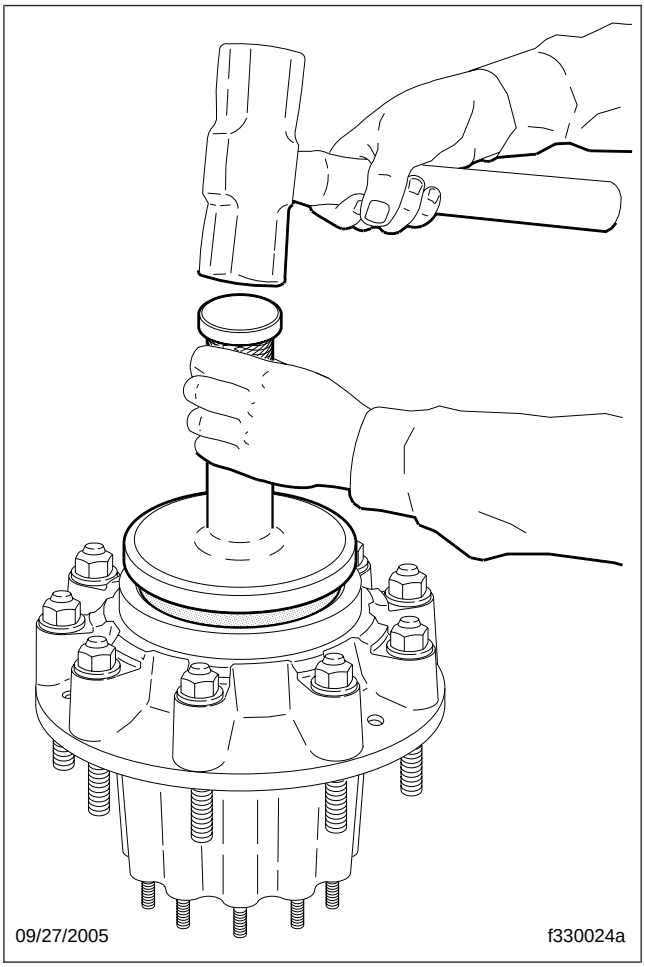


Fig. 9, Striking the Tool

11.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner adjusting nut finger-tight.

NOTE: On brakes with inboard drums only, be sure there is sufficient clearance between the brake shoes and the brake drum, so brake shoe drag will not interfere with bearing adjustment.

11.2 While rotating the hub, tighten the inner adjusting nut 100 lbf·ft (136 N·m).

11.3 Back off the adjusting nut completely.

11.4 Tighten the adjusting nut 20 lbf·ft (27 N·m) while rotating the hub.

11.5 Back off the adjusting nut one-third turn.

12. Install the locking device and jam nut, as follows.

NOTE: If securing the wheel bearings with a pierced lockring and no hole in the lockring aligns with the dowel on the adjusting nut, remove the lockring, turn it over and install it again. If a hole still does not align with the dowel, loosen the adjusting nut, but only enough to align the dowel with a hole in the lockring.

12.1 Install the locking device (tanged nut-lock, lockring, lockwasher with a lockring, or nut-lock with a lockring).

12.2 Install the jam nut and tighten it to the applicable torque in **Table 1**.

13. If using standard (non-PreSet) wheel bearings, adjust the wheel bearings as follows.

IMPORTANT: Do not adjust the wheel bearings with the wheel mounted on the hub. Bearing end play cannot be accurately adjusted or measured with the wheel mounted on the hub.

13.1 Attach a dial indicator to the hub and set the point of the indicator in line with the end of the axle spindle.

If using aluminum hubs, it may be necessary to install the brake drum on the hub to provide a steel base for the magnet of the dial indicator. Mount the drum on the hub's drum pilot. Adjust the brake or have someone apply the brakes to hold the drum securely while securing the drum using the stud at the 12 o'clock position, then the studs at about the 4 o'clock and 8 o'clock positions.

NOTE: If using a stud-piloted hub and a steel drum, install 1-1/4 inch washers between the nuts and the drum.

13.2 Release the brakes, if you used them to hold the drum while installing it.

13.3 Grip the sides of the hub at the three o'clock and nine o'clock positions. Push in on the hub (and drum, if applicable), to seat the inboard bearing set. Zero the dial indicator.

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13.4 Once again, grip the sides of the hub at the three o'clock and nine o'clock positions. This time, pull out on the hub. Read the dial indicator and note the end play.

Jam Nut Torque Values	
Size	**Torque: lbf·ft (N·m)**
1-1/8	Target: 175 (235) Permissible Range: 150–225 (205–305)
1-1/2 to 2-1/2	Target: 250 (340) Permissible Range: 200–300 (270–405)
2-5/8 or Larger	Target: 325 (440) Permissible Range: 250–400 (340–540)

Table 1, Jam Nut Torque Values

13.5 Push the hub back in to confirm that the needle of the dial indicator returns to zero.

14. The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm). If the end play is not within this range, adjust the end play as follows.

14.1 Remove the jam nut and locking device, and back off or tighten the inner adjusting nut.

IMPORTANT: *If using a nut-lock,* turning the adjusting nut 1/4 turn will change the end play about 0.014 inch (0.36 mm).

If using a lockring, turning the adjusting nut one lockring hole will change the end play about 0.005 inch (0.13 mm). If you take the lockring off and reverse it, then turn the adjusting nut to the next hole, this will change the end play about 0.0025 inch (0.064 mm).

14.2 Install the locking device and jam nut as described earlier, and measure the end play. If the end play is not between 0.001 and 0.005 inch (0.03 and 0.13 mm), turn the inner adjusting nut again.

14.3 Once the end play is correct, bend the nut-lock or lockwasher, as applicable. This will lock the jam nut and/or adjusting nut in place.

14.4 Rotate the hub in both directions. It should turn freely with no dragging or binding.

15. Install a new gasket on the drive axle studs.

16. Install the drive axle shaft. The splined end of the axle shaft must seat before the drive axle flange will fit over the studs.

17. If equipped, install the dowels and washers on the drive axle studs. Install the drive axle stud nuts. Following the sequence shown in **Fig. 10**, tighten the nuts to the torque values in **Specifications, 400**.

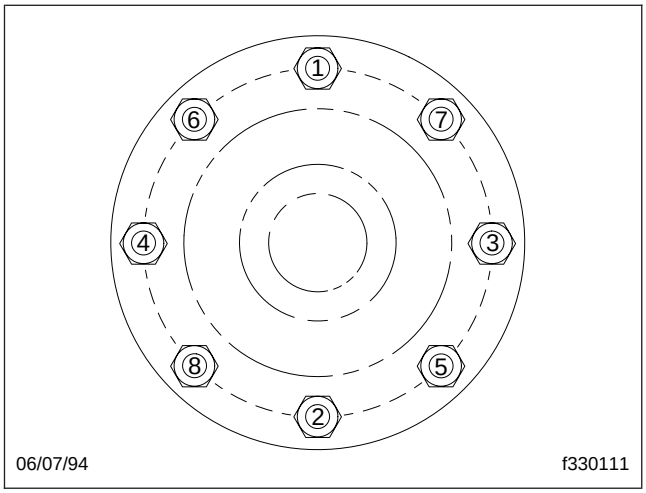


Fig. 10, Tightening Sequence, Drive Axle Stud Nut

18. Install the brake caliper, if removed. See **Group 42** for instructions.

19. If equipped with outboard drums, install the brake drum on the wheel hub.

20. Install the inner and outer wheel and tire assemblies. For instructions, see **Group 40**.

⚠ WARNING

If the inner wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking action, and the hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when the conditions described above exist, could result in loss of a wheel or loss of vehicle control, and possible personal injury.

21. Fill the axle with lubricant as follows.

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Hub Assembly Removal and Installation

⚠ WARNING

Failure to add oil to the axle housing bowl or the wheel hub after the drive axle shaft and wheel hub have been serviced will damage the wheel bearings and cause them to seize during vehicle operation. See Fig. 11. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury.

21.1 Pour the recommended drive axle lubricant through the axle housing filler hole (**Fig. 12**) until the lubricant is level with the bottom of the hole. See **Fig. 13**.

21.2 For Meritor axles, tighten the oil filler plug 35 lbf·ft (47 N·m). For Sterling axles, tighten the plug 37 lbf·ft (50 N·m). For Dana® Spicer® axles, tighten the plug 40 to 60 lbf·ft (54 to 81 N·m).

21.3 Tilt the axle to the left and right, by jacking the opposite side. Hold the tilted position for one minute on each side, to allow oil to run into the wheel end.

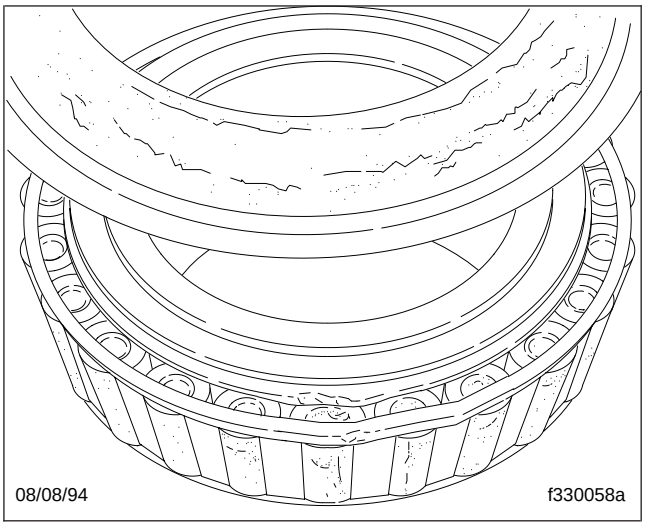
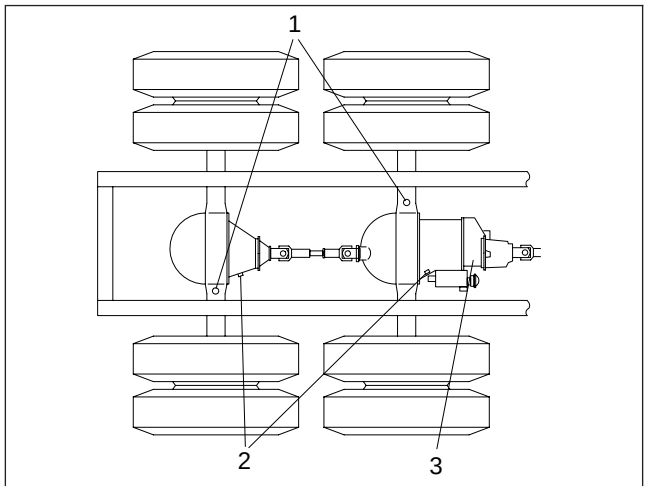


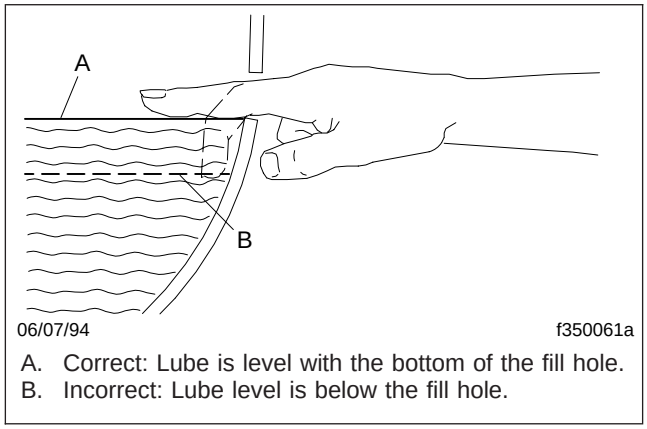
Fig. 11, Bearing Damage Resulting from Inadequate Lubrication

21.4 Return the axle to a level position, and add oil through the axle housing fill hole. About two extra pints (1 liter) of lubricant will be needed to bring the oil level even with the base of the fill hole.



1. Axle Housing Breathers
2. Oil Filler Plugs
3. Interaxle Differential

Fig. 12, Axle Filler Holes



A. Correct: Lube is level with the bottom of the fill hole.
B. Incorrect: Lube level is below the fill hole.

Fig. 13, Checking Lubricant Level

NOTE: Drive axle wheel bearings are lubricated by oil drawn from the axle housing bowl section. This method ensures good exchange of heat, prevents stagnation, and minimizes the maintenance required on bearings and hub assemblies.

22. Turn the wheels, and check the lubricant level.

23. If the vehicle is equipped with air brakes, adjust the rear axle brakes at the slack adjusters. For instructions, see the applicable service brake section in **Group 42**.

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24. Remove the safety stands, then lower the vehicle.
25. Set the parking brakes.
26. Remove the chocks from the front tires.

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Wheel Hub Assembly and Drive Axle Inspection

1. Inspect the wheel hub flange. A loose wheel assembly will cause the flange to be worn, jagged, or warped. See **Fig. 1**. Replace the wheel hub if any of these conditions exist.

   Inspect the flange surface around the wheel studs. Improperly torqued wheel nuts will cause worn or cracked stud grooves on the hub. See **Fig. 2**. If wear spots or cracks appear anywhere on the hub, or if the hub is otherwise damaged, replace it with a new one.

2. Remove all the old oil from the spoke wheel or hub cavity. Inspect the inner surface of the wheel or hub for cracks, dents, wear, or other damage. Replace the wheel or hub if damaged.

3. Remove all the old grease or oil from the surfaces of the wheel bearing cups. Inspect the cups for cracks, wear, spalling, or flaking. See **Fig. 3**. Replace the cups if damaged in any way. For instructions, see **Subject 120**.

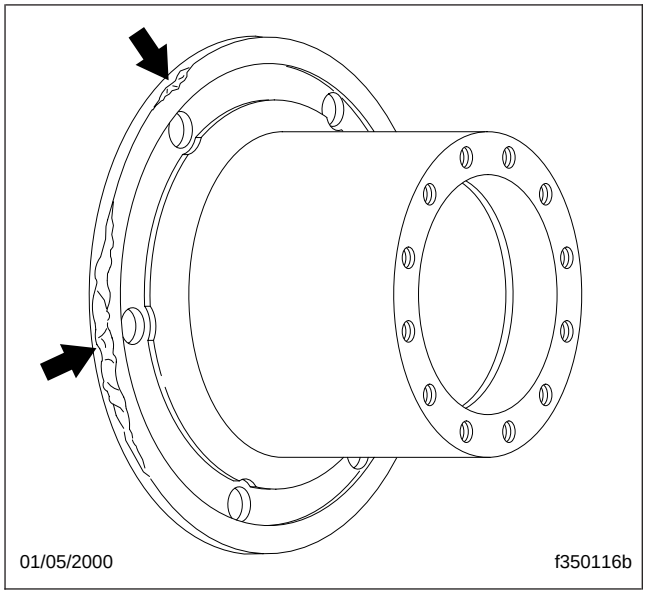


Fig. 1, Wear Spots

4. Inspect the wheel nuts on disc wheel installations, or the rim nuts on spoke-wheel installations. Damaged nuts, usually caused by inadequate tightening, must be replaced with new ones. See **Fig. 4**.

   Inspect the wheel studs or rim studs. Replace studs that are stripped, broken, bent, or otherwise damaged See **Fig. 5**. For instructions, see **Subject 130** for disc wheels or **Subject 140** for spoke wheels.

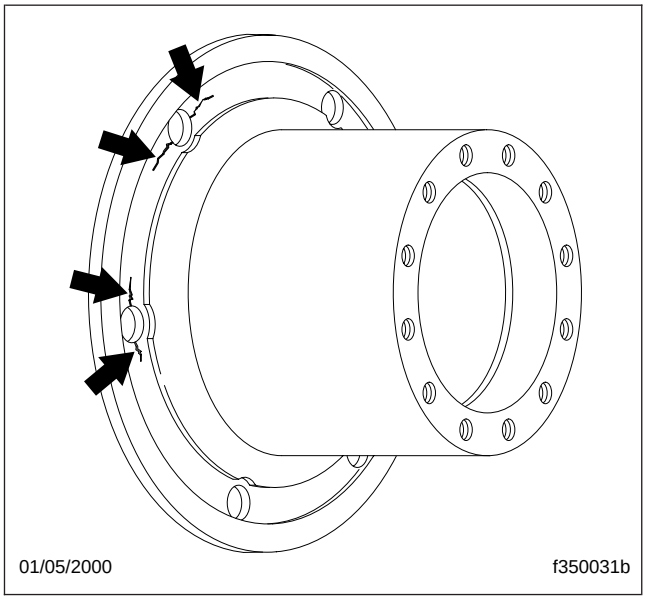
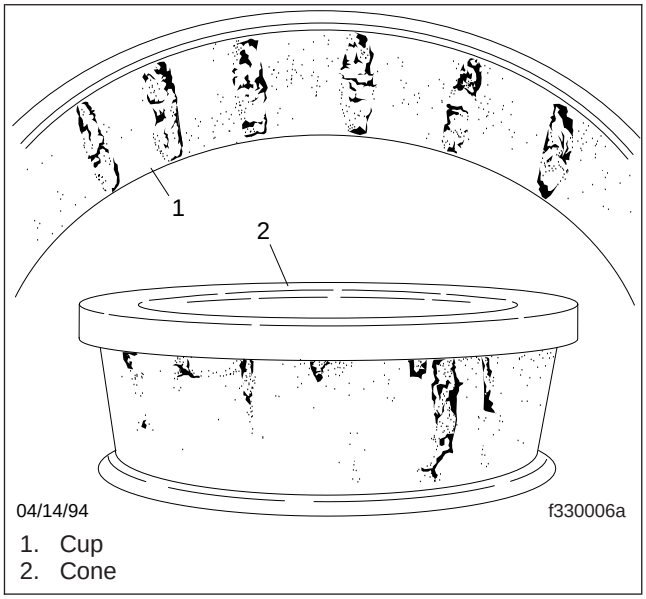


Fig. 2, Cracked Stud Grooves



1. Cup
2. Cone

Fig. 3, Spalling (Flaking) of Wheel Bearing Assembly

5. Inspect the drive axle studs. Replace the studs that have stripped threads or are broken. Also,

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Axle Components Cleaning and Inspection

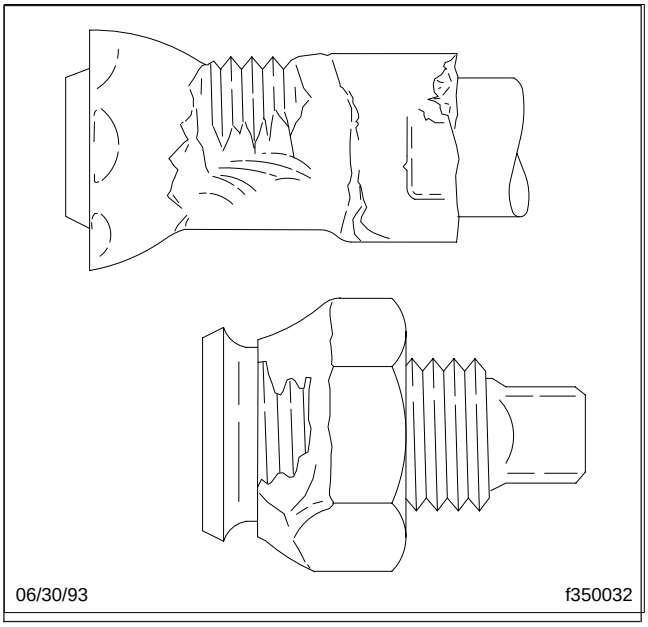


Fig. 4, Damaged Wheel Stud Nuts

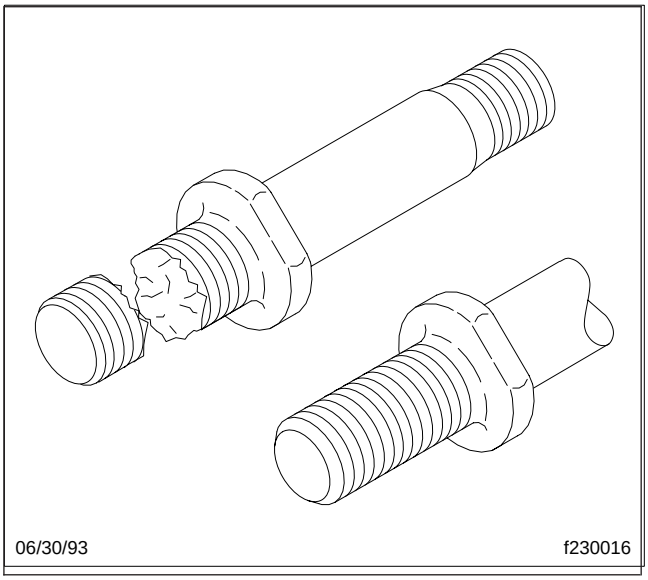


Fig. 5, Damaged Wheel Studs (shouldered type)

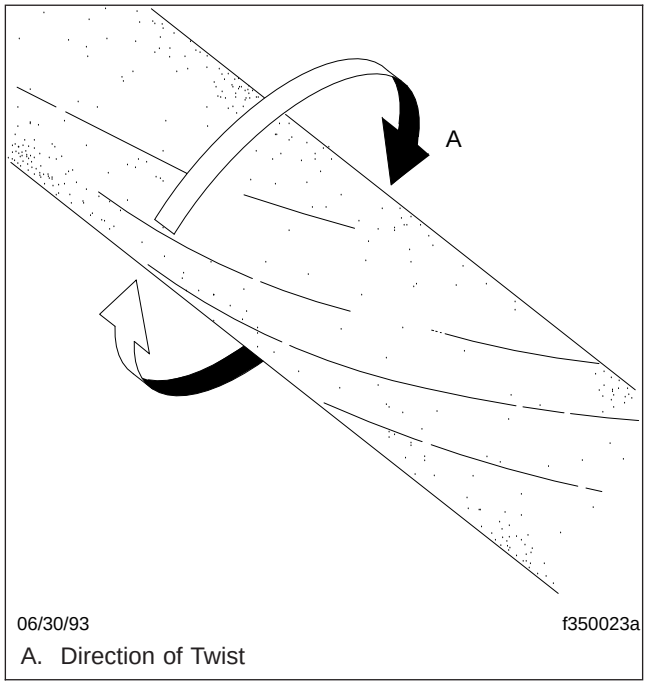
replace bent or otherwise damaged studs. For instructions, see **Subject 150**.

6. Inspect the drive axle shaft. If the vehicle has been overloaded, or used under severe or improper operations, the drive axle shaft may be twisted, bent, or otherwise damaged. See **Fig. 6**. Replace the drive axle shaft and flange assembly if damaged.

CAUTION

If the drive axle shaft and flange assembly is not replaced once the shaft is twisted or otherwise damaged, it will continue to twist until fracture occurs. With complete fracture of the shaft, other axle parts may be damaged which will increase the cost of repairs. Whenever a drive axle assembly is damaged, the drive axle shaft and flange on the opposite side of the axle should also be carefully examined, and replaced if damaged.

7. Inspect the drive axle shaft-to-flange surface. Loose wheel bearings can lead to progressive fatigue fractures where the shaft and flange meet. See **Fig. 7**. Replace the drive axle assembly if damaged.

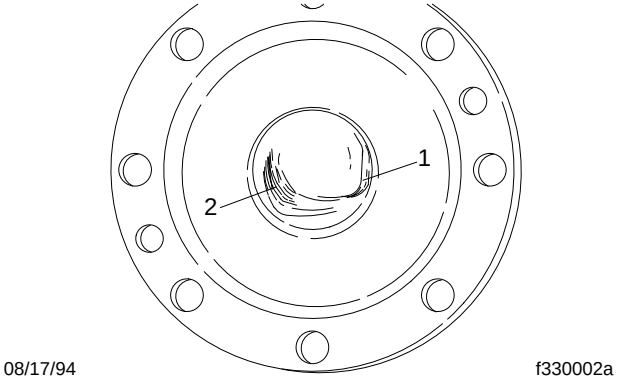


A. Direction of Twist

Fig. 6, Damaged Drive Axle Shaft

8. Inspect the inboard portion of the drive axle flange. Minor burrs or rough spots can adversely affect the sealing action of the oil or grease seals. Remove the burrs or rough spots using fine-grit emery cloth. If they cannot be removed, replace the drive axle shaft.

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1. Sudden Fracture Surface (dark area)
2. Area of Progressive Fracture

Fig. 7, Fracture Areas

9. Inspect the drive axle flange around the stud holes. Replace the drive axle shaft and flange assembly if any of the following conditions exist:
   - cracks on the flange surface;
   - metal build-up around the stud holes (a result of wear);
   - out-of-round stud holes.

Wheel Bearing Cleaning and Inspection

CLEANING

⚠ WARNING

To prevent skin irritation, wear chemical resistant gloves when working with diesel fuel or kerosene. Also, do not expose these fluids to flames or heat exceeding 100°F (38°C); both are combustible, and could cause personal injury if ignited.

Do not spin the bearing rollers at any time. Dirt or grit can scratch the roller surface and cause premature wear of the bearing assembly. Treat a used bearing as carefully as a new one.

Wheel bearings should be very closely inspected at the time of disassembly. The best inspection conditions are possible only after the bearings have been thoroughly cleaned using kerosene or diesel fuel oil, and a stiff brush See **Fig. 8**. Before inspecting, clean the bearings as follows:

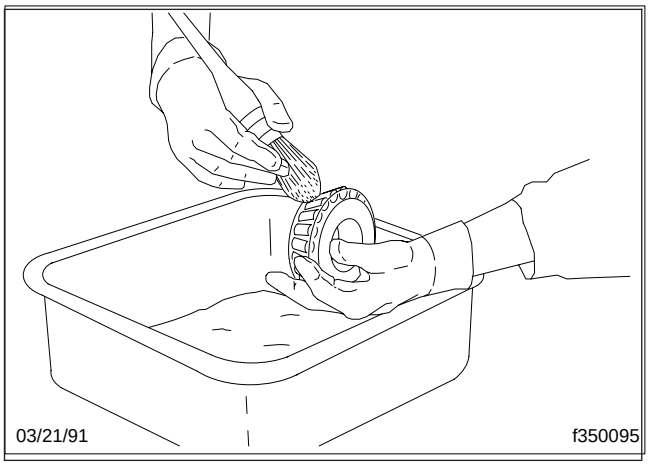


Fig. 8, Cleaning Oil from Bearings, Hub Cavities

1. Clean all old oil from the bearings and hub cavities, with kerosene or diesel fuel and a stiff brush. Do not use gasoline or heated solvent.
2. Allow the cleaned parts to dry, or dry them with a clean absorbent cloth or paper. Clean and dry your hands and all tools used in the maintenance operation. Oil will not stick to a surface that is wet with kerosene or diesel fuel, and the kerosene or diesel fuel may dilute the lubricant.

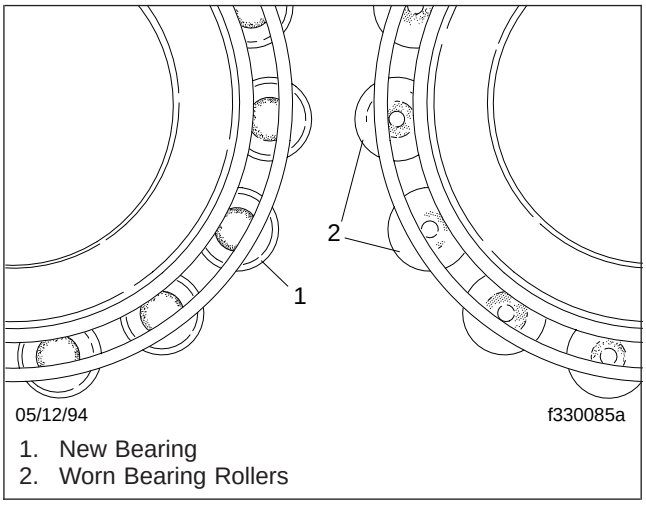
INSPECTION

After the bearings are cleaned, inspect the assemblies, which include the rollers, cones, cups, and cages. If any of the following conditions exist, replace the bearing assemblies:

1. The large ends of the rollers are worn flush to the recess; the radii at the large ends of the rollers are worn sharp. These are signs of advanced wear. See **Fig. 9**.
2. Visible step wear, especially at the small end of the roller track, or deep indentations, cracks, or breaks in the cone surfaces. See **Fig. 10**.
3. Bright rubbing marks on the dark phosphate surfaces of the bearing cage. See **Fig. 11**.
4. Water etch on any bearing surface. Water etch appears as gray or black stains on the steel sur-

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Axle Components Cleaning and Inspection



1. New Bearing
2. Worn Bearing Rollers

Fig. 9, Wear on Rollers

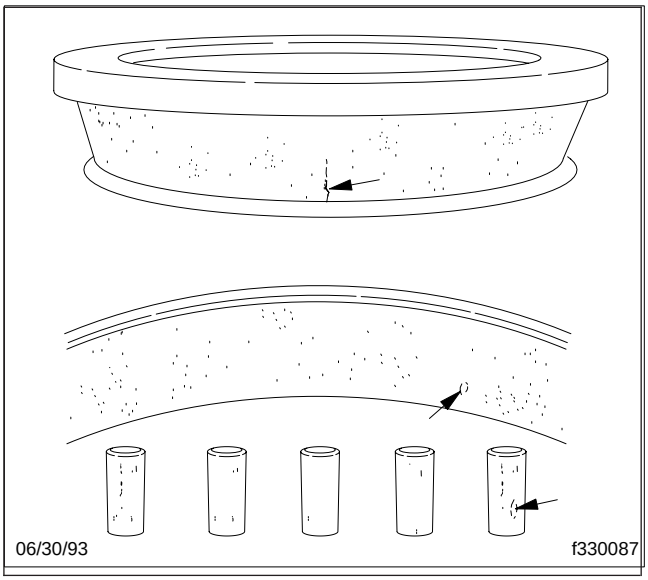


Fig. 10, Indentations, Cracks, or Breaks in Bearing Surfaces

face, and it greatly weakens the affected area. If water etch is present, check the oil seal sealing surfaces.

5. Etching or pitting on functioning surfaces. See **Fig. 12**.
6. Spalling (flaking) of the bearing cup, roller, or cone surfaces. See **Fig. 3.**

After inspection, brush the bearings with fresh axle lubricant.

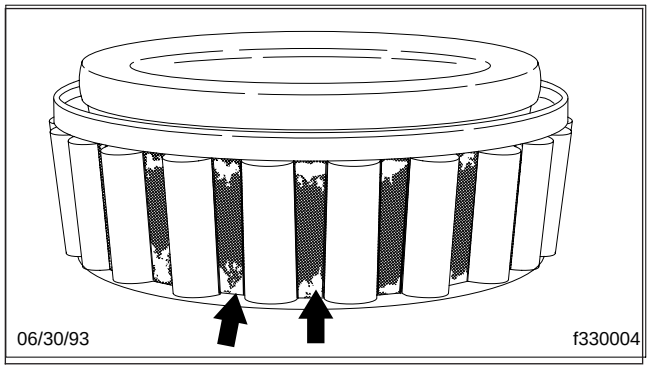


Fig. 11, Rubbing Marks on Bearing Cage

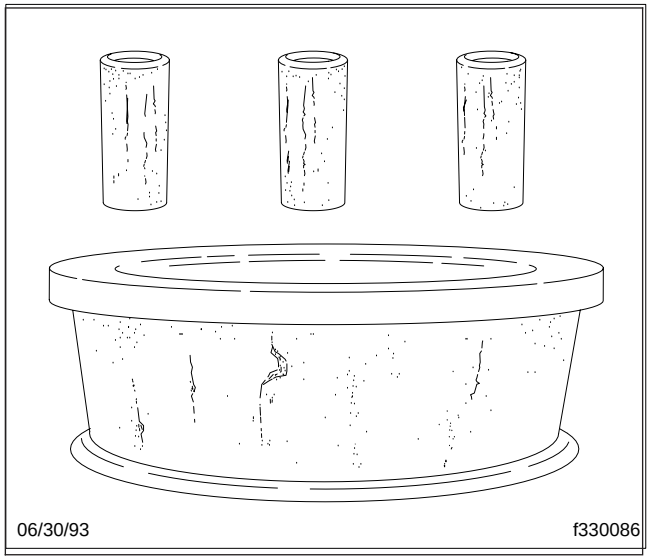


Fig. 12, Etching (Pitting) on Bearing Surfaces

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Wheel Bearing Cup Removal and Installation, Ferrous Hubs

Removal

IMPORTANT: Wheel bearing cups are removed from ferrous hubs by driving them out; there is no need to first heat the hubs.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly.
2. Using a mild steel rod through the opposite end of the hub, drive against the inner edge of the bearing cup. Alternately drive on opposite sides of the cup to avoid cocking the cup and damaging the inside of the hub.

Installation

IMPORTANT: Wheel bearing cups are installed in ferrous hubs by pressing them in; there is no need to first heat the hubs.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Coat the hub-contact surface of the replacement bearing cup with a film of grease.
4. Position the cup in the hub and press it into place, using a suitable tool against the outer edge of the cup. The cups must seat against the shoulder in the hub.

⚠ WARNING

To prevent skin irritation, wear chemical resistant gloves when working with diesel fuel or kerosene. Also, do not expose these fluids to flames or heat exceeding 100°F (38°C); both are combustible, and could cause personal injury if ignited.

5. Wipe off the accumulation of grease left after the bearing cup has been seated. Using a clean lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

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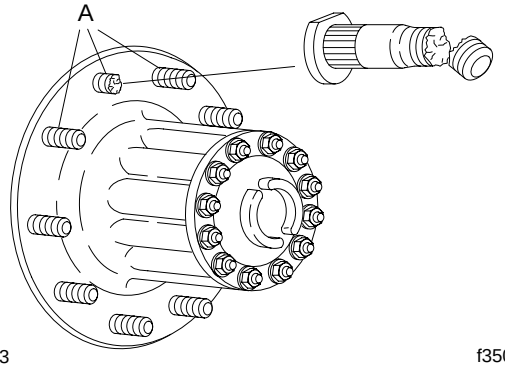
Wheel Stud Replacement, Disc Wheels

Replacement

WARNING

If a wheel stud breaks, the remaining studs are subjected to undue strain and could fail due to fatigue. When a broken stud is replaced, replace the stud on each side of it (Fig. 1). If more than one stud is broken, replace all of the studs. Failure to replace the studs could result in the loss of a wheel or loss of vehicle control, possibly resulting in personal injury.

1. Remove the wheel hub from the axle. For instructions, see **Subject 100**.
2. If a bent portion of a wheel stud will have to pass through the wheel stud bore, cut off the bent portion before removing the wheel stud.
3. Place the wheel hub on a suitable press; make sure the hub flange is evenly supported around and next to the stud being removed. With steady movement, press the damaged stud out of the hub.



A. Replace all three studs.

Fig. 1, Broken Studs on Hub

CAUTION

Do not use a drift and hammer or concentrated heat to remove or install the wheel studs. Constant, smooth movement of the wheel stud is necessary to ensure the least amount of metal removal from the wheel stud bore. Concentrated heat will damage the hub. If the hub is damaged during wheel stud removal or installation, replace it.

4. Apply a coat of clean axle grease to the entire shaft on headed studs.
5. With the hub on a suitable press, make sure the hub flange is evenly supported around and next to the stud being installed.
6. Position the stud in its hole.

CAUTION

Position the teeth of the serrated portion in the notches carved by the original wheel studs during factory installation. If additional metal is scraped from the wheel stud bores, the locking action provided by the serrations will be greatly weakened. Loss of locking action will prevent achieving final torque of the wheel nuts during wheel installation. If final wheel nut torques during wheel installation cannot be achieved, replace the wheel hub assembly.

IMPORTANT: For installations that use hub-piloted wheels, the studs are right-hand thread on both sides of the vehicle. See **Fig. 2**. The replacement stud and inner wheel nut must be stamped with an "R" (right-hand threaded) and the nut's face must be stamped "Right."

7. With steady movement, press the new stud all the way into the hub.
8. Make sure the stud is fully seated and that its head (flange) is not embedded in the hub. If the head of the stud is embedded in the hub, replace the hub.

WARNING

Wheel studs with heads embedded in the wheel hub will weaken the wheel hub flange. Weakness in the wheel hub can result in the loss of a wheel or loss of steering control, possibly resulting in personal injury.

9. Wipe off any grease on the wheel studs and wheel hub. Install wheel nuts on dry wheel studs only.
10. Install the wheel hub on the axle. For instructions, see **Subject 100**.

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Wheel Stud Replacement, Disc Wheels

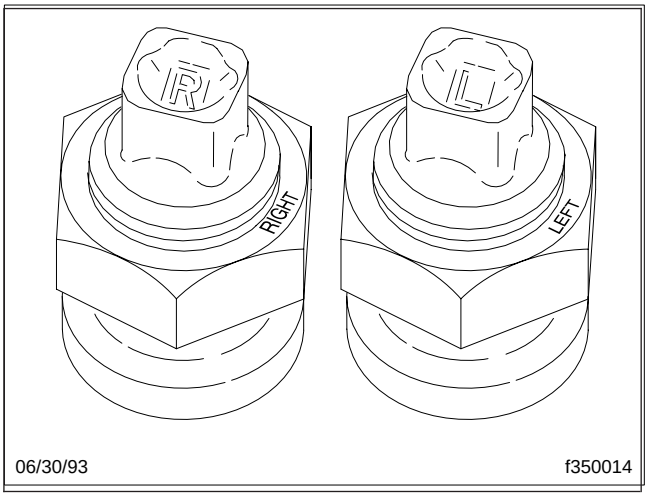


Fig. 2, Wheel Nuts

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Rim Stud Replacement, Spoke Wheels

Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front and rear tires.
2. Remove the rim and tire assemblies from the spoke wheel. For instructions, see **Group 40**.
3. If enough threads remain on the damaged stud, remove it by double-nutting the stud. Turn the inner nut with a wrench in order to remove the stud. Go to the step for tapping out the rim stud hole.

   If the rim stud is broken near the surface of the wheel, the stud should be center-drilled using a high-speed drill, and removed with an easy-out tool. If needed, grind off a flat surface on the damaged stud, then centerpunch the surface as a starting point for drilling. Remove the stud.

   3.1 Determine the correct drill diameter by referring to the easy-out tool manufacturer's guidelines. At no time should it be large enough to penetrate the threads of the stud; if the stud threads in the wheel are damaged, replace the wheel.

   3.2 Do not drill more than 1-1/4 inches (32 mm) into the broken stud, as measured at the stud's entrance into the wheel. Drilling through the bottom of the rim stud could damage the wheel. If the wheel is drilled into, replace it.

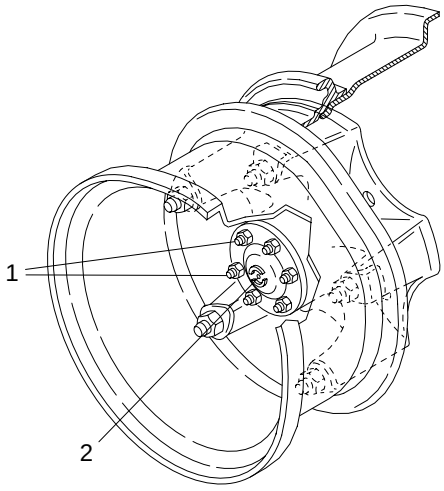
   3.3 While drilling, keep the cutting surfaces of the drill well lubricated with oil, which acts as a coolant. Allow the drill and drill bit to cool frequently.
4. After the damaged stud is removed, tap out the rim stud hole in the wheel to rid the threads of old stud-locking compound. Use an appropriate sized tap, depending on the original rim stud installation size.
5. Be sure the threads of the new stud are clean and dry. Coat the insertion end of the rim stud with an anaerobic thread-lock compound.
6. Using double nuts on the fine thread portion of the stud, install the new stud. Seat the rim stud using the torque values in the torque table in **Specifications, 400**.
7. Allow enough time for the thread-lock compound to set, as suggested by the manufacturer.
8. Install the rim and tire assemblies. For instructions, see **Group 40**.

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Replacement

NOTE: If the hub has been removed from the axle, go to the step for removing the stud.

1. Park the vehicle on a level surface and set the parking brake.
2. Oil will spill as the drive axle shaft is removed. Place a suitable container inside the wheel and under the drive axle flange. Safely discard the lubricant after removal.
3. Remove the drive axle shaft.
   - 3.1 Remove the drive axle stud nuts and the washers. See **Fig. 1**.



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1. Drive Axle Studs and Nuts
2. Center Portion of Drive Axle Flange

Fig. 1, Wheel Assembly and Hub

   - 3.2 Using a hammer and a soft drift, such as one made of brass, sharply tap the center portion of the drive axle flange. See **Fig. 1**. The shaft will usually spring slightly outward after the seal has broken.

⚠ CAUTION

When tapping the drive axle flange, avoid striking the drive axle studs. If struck, the studs may bend or break, or the stud threads can be damaged. Replace damaged studs.

   - 3.3 If the drive axle shaft does not spring outward, the seal may have loosened enough to allow the shaft to be manually pulled from the axle housing. Try to manually remove the drive axle shaft from the housing. If the seal has not broken, repeat steps as required.
4. If equipped, remove the tapered dowels and washers from the drive axle flange.
5. Remove and discard the gasket.
6. If enough threads remain on the damaged stud, remove it by double-nutting the stud. Turn the inner nut with a wrench in order to remove the stud. Go to the step for tapping out the drive axle stud hole.

   If the drive axle stud is broken near the surface of the hub, the stud should be center-drilled using a high-speed drill, and removed with an easy-out tool. If needed, grind off a flat surface on the damaged stud. Centerpunch the surface as a starting point for drilling.

   - 6.1 Determine the correct drill diameter by referring to the easy-out tool manufacturer's guidelines. At no time should it be large enough to penetrate the threads of the stud; if the stud threads in the wheel hub are damaged, replace the hub.
   - 6.2 Do not drill more than 1-1/4 inches (32 mm) into the broken stud, as measured at the stud's entrance into the wheel hub. Drilling through the bottom of the drive axle stud could damage the hub. If the wheel hub is drilled into, replace it.
   - 6.3 While drilling, keep the cutting surfaces of the drill well lubricated with oil, which acts as a coolant. Allow the drill and drill bit to cool frequently.
7. After the damaged stud is removed, tap out the drive axle stud hole in the wheel to rid the threads of old stud-locking compound. Use an appropriate sized tap, depending on the original drive axle stud installation size.
8. Be sure the threads of the new stud are clean and dry. Then, coat the insertion end of the drive axle stud (the coarse threads) with an anaerobic thread-lock compound.

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Drive Axle Stud Replacement

9. Using double nuts on the fine-thread portion of the stud, install the new stud. Seat the drive axle stud using the torque values in the torque table in **Specifications, 400**.
10. Allow sufficient time for the thread-lock compound to set, as suggested by the manufacturer.
11. If the hub was removed from the axle, proceed to **Subject 100** for installation instructions. If the hub was not removed from the axle, install the drive axle shaft.

    11.1 Install a new axle flange gasket over the drive axle studs.

    11.2 Install the drive axle shaft in the axle housing. The splined end of the shaft must seat before the drive axle flange will fit over the drive axle studs.

    11.3 If equipped, install the dowels and washers on the drive axle studs. Install the drive axle nuts. Using the sequence shown in **Fig. 2**, tighten the nuts to the torque values in the torque table in **Specifications, 400**.

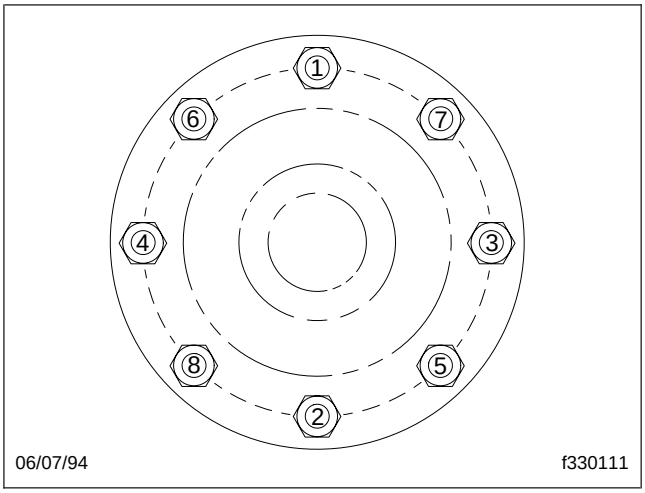


Fig. 2, Axle Shaft Flange Nut-Tightening Sequence

    11.4 Add fresh oil to the wheel hub. For instructions, see **Subject 100**.

⚠ WARNING

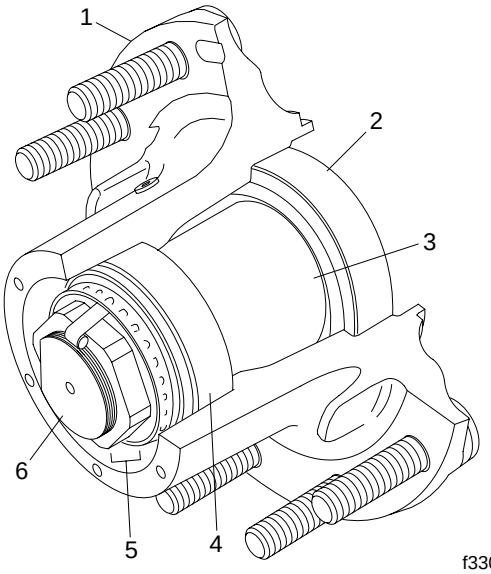
Failure to add oil to the wheel hub after the drive axle shaft has been serviced will damage the wheel bearings and cause them to seize during vehicle operation. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury.

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ConMet PreSet® Hub Installation and Adjustment

General Information

ConMet PreSet® drive axle hubs are equipped with a special tubular spacer inside the hub, between the inner and outer bearings. See **Fig. 1**.



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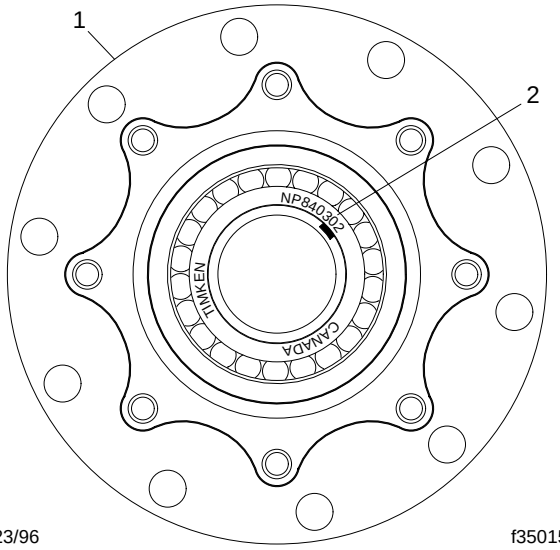
NOTE: Front axle hub shown.

1. Hub
2. Inner Bearing
3. Bearing Spacer
4. Outer Bearing
5. Axilok Retaining Nut
6. Axle Spindle

Fig. 1, ConMet PreSet Hub (cut-away view)

Wheel bearing adjustment is unnecessary when installing these hubs, because the spacer, together with specially toleranced bearings, automatically sets the bearing end-play. Rear axle PreSet hubs can be identified by the part number NP840302 stamped on the outer bearing cone. The outer bearing cone is visible when the retaining nut is removed. See **Fig. 2**.

NOTE: If you are replacing the bearings for a PreSet hub, and the required bearings are not available, use standard wheel bearings. Remove the bearing spacer and adjust the bearings manually. See the installation instructions for "Using Standard Bearings," under "Installation and Adjustment."



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1. Rear Axle Hub
2. Outer Bearing Cone and Part Number

Fig. 2, Identifying a ConMet PreSet Hub

NOTICE

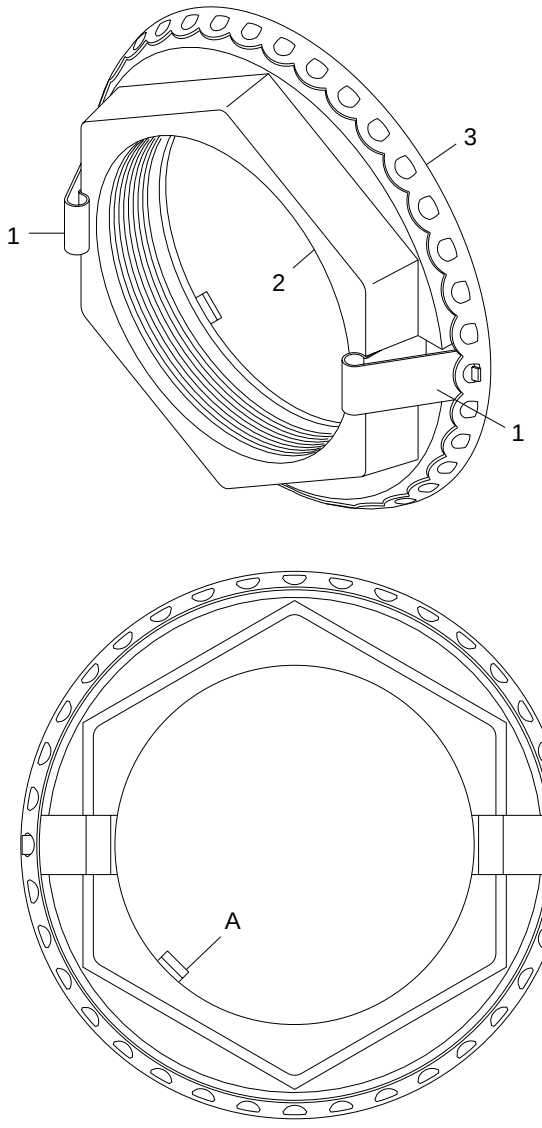
Do not use the bearing spacer with standard wheel bearings. To do so may result in too much bearing end-play, which could damage the wheel bearings, oil seals, the axle spindle, and the hub.

ConMet PreSet hubs use Axilok® retaining nuts. See **Fig. 3**. Axilok retaining nuts can be damaged if they are not removed or installed correctly. Use the following guidelines when removing and installing Axilok retaining nuts.

- Use only the correct size, *six-point* socket to remove or install Axilok spindle nuts. Do not use a worn or loose-fitting socket. *Do not use a 12-point socket.*
- Do not use hammers, chisels, pliers, wrenches, or power tools to remove or install Axilok nuts.
- Do not use an Axilok nut if the locking clips are damaged or missing, or if the retainer cage tab or D-flat is damaged or missing.
- Never try to repair a damaged Axilok nut; always replace it with a new one.
- Always start an Axilok installation by hand. A good-fitting six-point socket will completely disengage the nut's locking clips, allowing it to

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ConMet PreSet® Hub Installation and Adjustment



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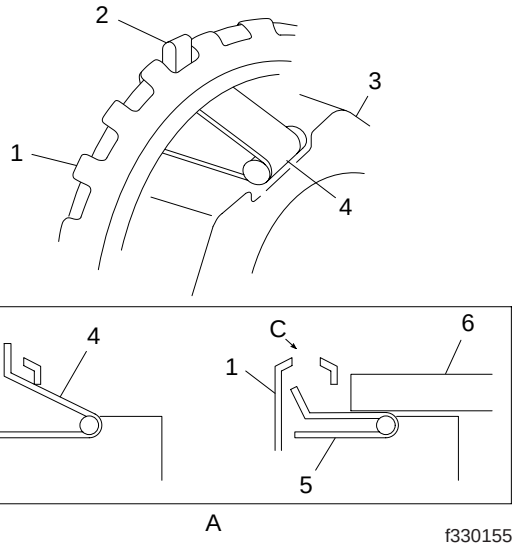
A. The retainer tab must engage the keyway of the axle spindle.

1. Locking Clip
2. Nut
3. Retainer

Fig. 3, Rear Axle Axilok Nut

spin freely by hand. See **Fig. 4**. Use an accurately calibrated torque wrench to tighten the nut to its final torque value.

- After the nut is installed, always make sure that both locking clips are present and engaged in the retainer cage. See **Fig. 4**. If the locking clips are not engaged, the nut is not locked in position and can rotate freely.



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A. Cross-Section View
B. The tab is engaged.
C. The tab is disengaged.

1. Retainer Cage
2. Locking Clip Tab
3. Nut
4. Locking Clip
5. Locking Clip (compressed)
6. Six-Point Socket

Fig. 4, Axilok Nut, Checking the Position of the Locking Clip

Installation and Adjustment

Using Preset Bearings

1. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.
2. If present, remove the temporary plastic bearing cover from the front of the hub.
3. Install the PreSet hub assembly all the way onto the axle spindle. A temporary plastic alignment sleeve may be installed in the center of a new hub. It will be pushed out when the hub is installed on the axle spindle. If it is present, remove and discard this sleeve.

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ConMet PreSet® Hub Installation and Adjustment

NOTICE

Do not remove the outer wheel bearing once the hub is installed on the axle. Removing the outer bearing could cause the oil seal to become misaligned, which could cause damage to the wheel bearings, the hub, and the axle spindle.

⚠ WARNING

Follow the guidelines at the beginning of this subject when installing an Axilok nut. Axilok retaining nuts secure the hub assemblies on the axle. If the Axilok nut is not correctly installed, the hub could separate from the axle, resulting in severe personal injury or death.

4. Apply a few drops of oil through one of the holes in the Axilok retainer cage to reduce friction between the retainer cage and nut. Then, install the Axilok retaining nut onto the axle spindle. See **Fig. 3**.
5. Tighten the retaining nut 250 lbf·ft (339 N·m). The nut should lock in place when you remove the wrench. If it does not, advance the nut until it does. **Do not back off the retaining nut**.
6. Ensure that both locking clips are present and engaged in the retainer cage. See **Fig. 4**. If the locking clips are not engaged, the nut is not locked in position and can rotate freely.
7. Install a new gasket and the axle shaft. See **Subject 100** for instructions.

⚠ WARNING

Add oil to the axle housing bowl or the wheel hub after the drive axle shaft and wheel hub have been serviced. Failure to add oil will damage the wheel bearings and cause them to seize during vehicle operation. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury.

8. Pour the recommended drive axle oil through the axle housing filler hole.

Using Standard Bearings

1. If not already done, remove the tubular spacer from inside the hub. Save it for future use to convert the hub back to the PreSet system.
2. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.
3. Ensure the inner wheel bearing assemblies and oil seal are installed per the instructions given in **Subject 100**.
4. Install the hub with the inner bearing and oil seal onto the axle spindle. Be careful not to unseat the inner bearing or oil seal.
5. Fill the hub cavity with oil, and install the outer wheel bearing.

NOTICE

Do not remove the outer wheel bearing once the hub is installed on the axle. Removing the outer bearing could cause the oil seal to become misaligned, which could cause damage to the wheel bearings, the hub, and the axle spindle.

⚠ WARNING

Follow the guidelines at the beginning of this subject when installing an Axilok nut. Axilok retaining nuts secure the hub assemblies on the axle. If the Axilok nut is not correctly installed, the hub could separate from the axle, resulting in severe personal injury or death.

6. Adjust the wheel bearings as follows.
   - 6.1 Install the Axilok nut and turn it against the bearing while spinning the hub. See **Fig. 3**.
   - 6.2 Tighten the nut 90 to 110 lbf·ft (122 to 149 N·m) while spinning the hub in both directions.
   - 6.3 Loosen the nut to zero torque and spin the hub a few turns.
   - 6.4 Tighten the nut 50 lbf·ft (68 N·m) while spinning the hub in both directions. Back off the nut one-eighth to one-sixth turn.
   - 6.5 Remove the wrench from the nut. The Axilok nut should automatically lock in place. If it does not, advance it until it does.
7. Using a dial indicator, measure the end play as follows.

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ConMet PreSet® Hub Installation and Adjustment

IMPORTANT: Do not measure the wheel bearings with the wheel mounted on the hub. You cannot accurately measure or adjust bearing end play with the wheel mounted on the hub.

7.1 Attach a dial indicator to the hub, and set the point of the indicator in line with the end of the axle spindle. The point of the indicator should be parallel to the spindle axis.

If equipped with aluminum hubs and air brakes, it may be necessary to install the brake drum onto the hub to provide a steel base for the magnet of the dial indicator. Mount the drum on the hub's drum pilot. Adjust the brake or have someone apply the brakes to hold the drum secure. Secure the drum using the stud at the 12 o'clock position. Then secure the studs at about the 4 o'clock and 8 o'clock positions.

If using a stud-piloted hub and a steel drum, install 1-1/4-inch washers between the nuts and the drum.

7.2 Grip the sides of the hub at the three o'clock and nine o'clock positions. Push in on the hub (and drum, if applicable) to seat the inboard bearing set. Zero the dial indicator.

7.3 Again, grip the sides of the hub at the three o'clock and nine o'clock positions. This time, pull out on the hub. Read the dial indicator, and note the end play.

7.4 Push the hub back in to confirm that the needle of the dial indicator returns to zero.

⚠ WARNING

The wheel-bearing end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm). Correct end play is crucial: if the wheel-bearing end play is not correct, the wheel bearings could fail. This could cause the loss of the wheel and hub assembly, resulting in an accident causing serious injury or property damage. Use the dial indicator to measure the end play.

8. **The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm)**. If it is not within this range, remove the Axilok nut, and repeat the tightening sequence as described earlier in this procedure. Once the end play is correct, go to **Subject 100**, and complete the hub assembly installation.

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Troubleshooting Tables

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals	
Possible Cause	**Remedy**
Not enough oil on bearings, wrong type of oil	Clean then inspect the bearings for wear. Replace worn seals. Coat the bearing assemblies with fresh oil. For lubricant specifications, see **Specifications, 400**.
Foreign matter or corrosive agents entered bearing assembly, dirt or metallic debris from bearings not removed	Clean then inspect the bearings for wear. Replace worn seals. Also clean the wheel hub, the axle spindle, and any other part in contact with the bearing lubricant.
Incorrect adjustment of wheel bearings causing noise and wear	Adjust the wheel bearings following the instructions in **Subject 100**.
Flat spots, dents on roller surface caused by skidding of roller or improper handling of wheel bearing during installation	Clean and inspect the bearing rollers. Replace the bearing if damaged. Coat the replacement bearings with fresh oil. For lubricant specifications, see **Specifications, 400**.

Problem—Broken Wheel or Rim Studs

Problem—Broken Wheel or Rim Studs	
Possible Cause	**Remedy**
Overtightened wheel or rim nuts	Replace the wheel or rim studs. For instructions, see **Group 40** for the wheel or rim tightening sequence.
Overloaded vehicle	Do not exceed the maximum load-carrying capacity of the vehicle.

Problem—Damaged Hub

Problem—Damaged Hub	
Possible Cause	**Remedy**
Bent flange; wheel studs installed incorrectly (a hammer and drift were used, the hub flange not fully supported on press during wheel stud replacement)	Replace the hub assembly. Replace the wheel studs as instructed in **Subject, 130**.
Insufficient tightening of wheel nuts to wheel hub	Replace the hub assembly and tighten the wheel nuts to the values in the torque table in **Specifications, 400**.

Problem—Loss of Lubricant From the Wheel Hubs

Problem—Loss of Lubricant From the Wheel Hubs	
Possible Cause	**Remedy**
Loose drive axle studs	Tighten the nuts to the torque values in the torque table in **Specifications, 400**. Add lubricant to the axle housing or to the wheel hub.
Worn or damaged seals or gaskets	Replace worn or damaged parts.
Minor burrs or rough spots on inboard portion of drive axle flange	Use fine-grit emery cloth to remove the burrs or rough spots. If they can't be removed, replace the drive axle shaft.

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Specifications

Torque Values		
Description	**Size (grade 8)**	**Torque: lbf·ft (N·m)**
Drive Axle Stud Nuts (with or without dowels)	5/8–18	150–170 (203–230)
Drive Axle Studs (to hub)	1/2–13	70 (95)
	5/8–11	135 (185)
Hub Cap Capscrews	5/16–18	15 (20)
Oil Filler Plug (Dana® Spicer® axles)	—	40–60 (54–81)
Oil Filler Plug (Meritor axles)	—	35 (47)
Spoke Wheel Brake Drum Nuts	3/4–10	240 (325)
Spoke Wheel Rim Studs	3/4–10	240 (325)
Rotor Capscrews	9/16–12	130 (175)
Dual-Nut Wheel Bearing Lock Assembly		
Adjusting Nut	—	Stage 1: Tighten to 100 (136)
		Stage 2: Back Off Completely
		Stage 3: Tighten to 20 (27) While Rotating Hub
		Stage 4: Back Off 1/3 Turn
Jam Nut (with Tanged Nut-Lock or Lockring)	All Sizes	200–300 (271–407)
Jam Nut (with Nut-Lock and Lockring, or Lockwasher and Lockring)	1-1/8 to 2-1/2	200–300 (271–407)
	2-5/8 or larger	250–400 (339–542)

Table 1, Torque Values

Meritor Drive Axle Lubricant Capacities, Single Axles*			
Axle Model	**Capacity in pints (liters)†**	**Axle Model**	**Capacity in pints (liters)†**
RS-13-120	16 (7.6)	RS-19-220	31 (14.7)
RS-15-120	16 (7.6)	RS-21-145	32 (15.1)
RS-15-210	16 (7.6)	RS-21-160	39.5 (18.7)
RS-17-140	31 (14.7)	RS-21-230	39 (18.5)
RS-17-145	33.6 (15.9)	RS-23-160	42 (19.9)
RS-17-220	31 (14.7)	RS-23-240	45 (21.3)
RS-19-145	34.4 (16.3)		

* Single drive axles equipped with traction equalizers may require a "friction modifier" to correct a slip-stick condition, as described in the vehicle driver's manual. Meritor's experience shows that the following additives perform adequately: Add Elco No. 2 Friction Modifier (1 ounce [30 ml] of additive for each 1 pint [0.5 liter] of lube capacity) or Lubrizol No. 797 or 762 (1 ounce [30 ml] of additive for each 1 pint [0.5 liter] of lube capacity).

† Quantities listed are approximate and include 1 pint (0.5 liter) for each wheel end and with the drive pinion at 3 degrees.

Table 2, Meritor Drive Axle Lubricant Capacities, Single Axles

Dana® Spicer® Drive Axle Lubricant Capacities, Tandem Axles	
Axle Model	**Capacity in pints (liters)***
RT-34-135	Forward 29.8 (14.1)
	Rear 34.0 (16.1)

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Specifications

Dana® Spicer® Drive Axle Lubricant Capacities, Tandem Axles	
Axle Model	**Capacity in pints (liters)***
RT-40-145	Forward 30.4 (14.4)
	Rear 34.4 (16.3)

* Quantities listed are approximate and include 1 pint (0.5 liter) for each wheel end and with the drive pinion at 3 degrees.

Table 3, Dana Spicer Drive Axle Lubricant Capacities, Tandem Axles

Meritor Drive Axle Recommended Lubricant			
Recommended Lubricant Type	**Ambient Temperature**	**Lubricant SAE Viscosity Grade**	**Meritor Specification**
Hypoid Gear Oil API Service Classification GL-5	–12.2°C (+10°F) and up*	85W–140	0-76-A
	–26.1°C (–15°F) and up*	80W–140	0-76-B
	–26.1°C (–15°F) and up*	80W–90	0-76-D
	–40°C (–40°F) and up*	75W–90	0-76-E
	–40°C (–40°F) to +2°C (+35°F)	75W	0-76-J
	–40°C (–40°F) and up*	75W–140	0-76-L
Synthetic Gear Oil	–40°C (–40°F) and up*	75W–90	0-76-N
	–40°C (–40°F) and up*	75W–140	0-76-M

* There is no upper limit on these ambient temperatures, but axle sump temperature must never exceed 121°C (250°F).

Table 4, Meritor Drive Axle Recommended Lubricant

Bearing Centering Tool Interchange				
Spindle Type	**Bearing Cone**	**Centering Tool Number**		
		Dana Spicer Outrunner™	**Chicago Rawhide**	**National®**
—	580	BCT-10	710	RD-410
—	582	BCT-10	710	RD-410
—	594	BCT-15	715	RD-416
—	595	BCT-10	710	RD-410
—	598	BCT-14	714	RD-415
—	663	BCT-10	710	RD-410
—	665	BCT-11	711	RD-411
—	759	BCT-12	712	RD-412
—	5760	BCT-8	708	RD-418
15K	33287	BCT-7	707	RD-408
—	47678	BCT-8	708	RD-418
L	47686	BCT-10	710	RD-410
—	495AX	BCT-8	708	RD-418
R	594A	BCT-15	715	RD-416

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Specifications

Bearing Centering Tool Interchange				
Spindle Type	Bearing Cone	Centering Tool Number		
		Dana Spicer Outrunner™	Chicago Rawhide	National®
—	598A	BCT-14	714	RD-415
—	HM516449	BCT-10	710	RD-410

Table 5, Bearing Centering Tool Interchange

Adapter Plates		
Seal	Adapter Plate	Color
848	848-T	Gold
849	849-T	
852	852-T	
854	854-T	
856	856-T	
858	858-T	
860	860-T	
861	861-T	

Table 6, Adapter Plates

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General Information

Wheel oil seals (also called "oil bath seals" or "hub seals") work as a dam to keep oil in the hub cavity so that it constantly "bathes" the wheel bearings. The seals also protect the wheel bearings by keeping dirt, dust, and water out of the hub.

The oil seal fits between the hub bore and the axle spindle, and the sealing element either turns with the wheel (*hub-mounted seals*) and seals against the axle spindle, or the sealing element stays stationary with the axle spindle (*spindle-mounted seals*) and seals against the turning hub.

Most wheel oil seals consist of four basic parts:

- The outside edge (also called the outer "cup" or "case")
- The inside edge (also called the inner "cup" or "case")
- The sealing element
- The garter spring

The outside edge is usually metal coated with rubber or another sealing agent so that it grips the hub bore tight enough to prevent oil escaping between the outer edge of the seal and the hub bore.

The inside edge is usually metal or rubber with a metal ring within it to prevent the sealing element from wearing a groove in the axle spindle.

The sealing element is usually molded rubber, leather, or a synthetic such as nitrile or silicone. The element is molded into lips which will seal against the axle spindle or against the outside or inside edge described above. The innermost lip, called the "primary lip," keeps the oil inside the hub cavity. The outermost lip, called the "secondary lip," keeps dirt out of the hub cavity.

The garter spring is a coiled wire spring with its ends connected to make a loop. On hub-mounted seals, the spring runs around the outside of the sealing element to press the element inwards against the sealing surface. On spindle-mounted seals, the spring runs around the inside of the sealing element to press the element outward against the sealing surface.

Freightliner uses two brands of axle oil seals:

- Chicago Rawhide (Scotseal® and Scotseal Plus XL®)
- Dana Spicer (Outrunner™)

Chicago Rawhide

The Chicago Rawhide Scotseal is a unitized, one-piece design consisting of a sealing element (packing) that is assembled between metal outer and inner cups. See **Fig. 1**. The sealing element consists of three sealing lips; a spring-loaded primary sealing lip that is factory pre-lubed and two dirt exclusion lips. The seal is press fit into the hub bore using Scotseal service installation tools. *Do not install the Scotseal directly onto the axle spindle.*

Although you install the Scotseal into the hub bore, the seal's element grips the axle spindle tightly enough that the sealing element stays stationary with the spindle and seals against the outer cup which turns with the hub.

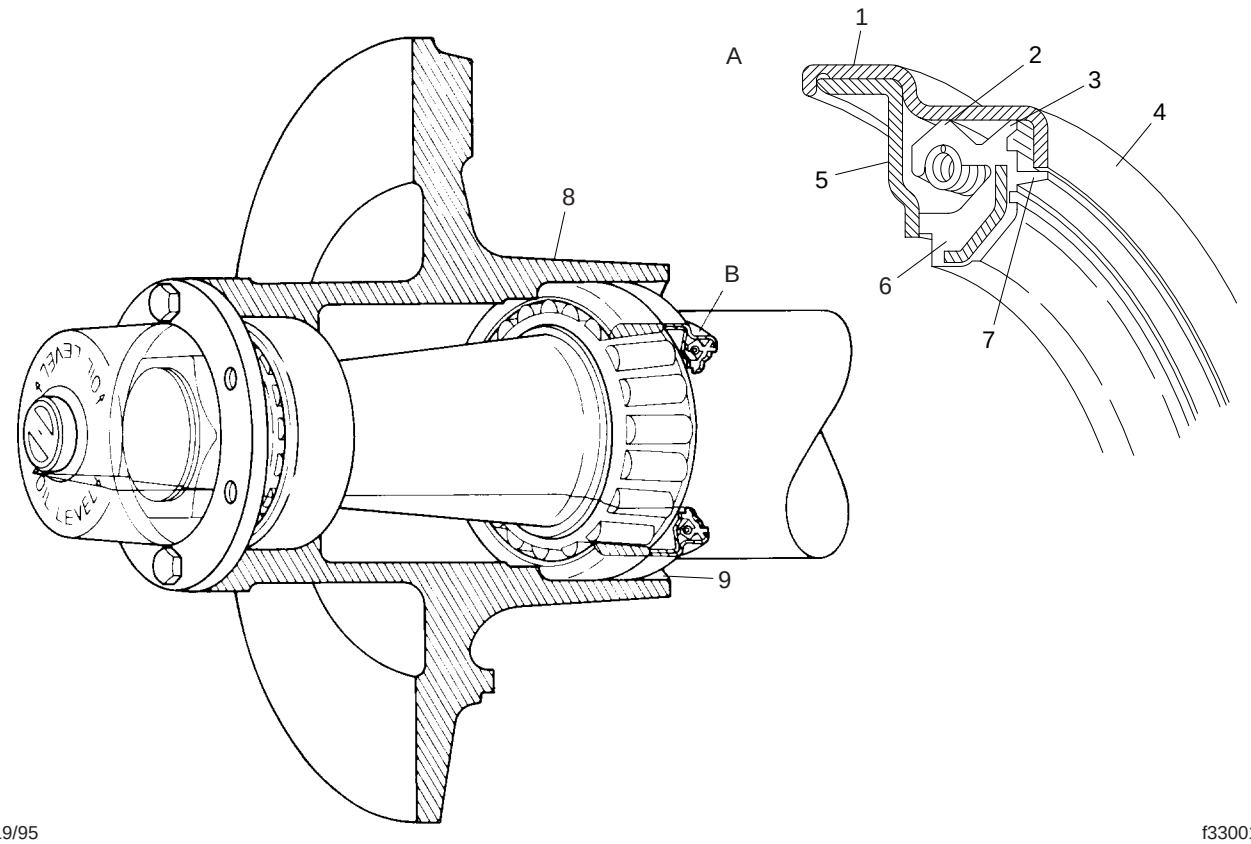
The Chicago Rawhide Scotseal maintains a metal-to-metal contact between the outer cup and the hub bore surface as well as a metal-to-metal contact between the sealing element inside edge and the axle spindle.

Dana Spicer

The Dana Spicer Outrunner has a rubber-coated outside edge and is installed in the hub bore using Dana Spicer installation tools. See **Fig. 2**.

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General Information

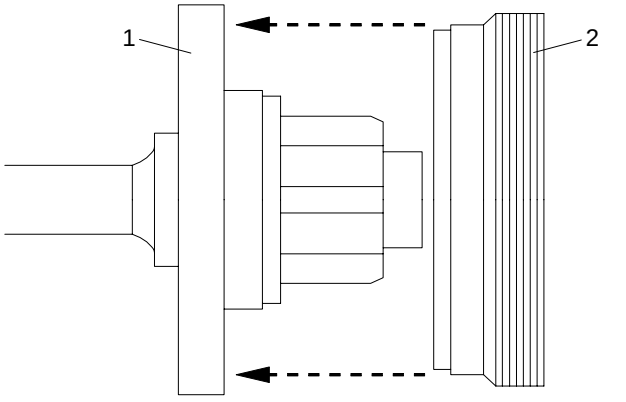


A. Detail A
B. Oil Seal (See detail A)

1. Bore-Tite® Coating
2 Primary Sealing Lip
3. Dirt Lip
4. Outer Cup
5. Inner Cup
6. Sealing Element (Packing)
7. Bumper Lip
8. Hub
9. Hub Bore

Fig. 1, Chicago Rawhide Scotseal

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1. Dana Spicer Outrunner Installation Tool
2. Dana Spicer Outrunner Seal

Fig. 2, Dana Spicer Outrunner Seal

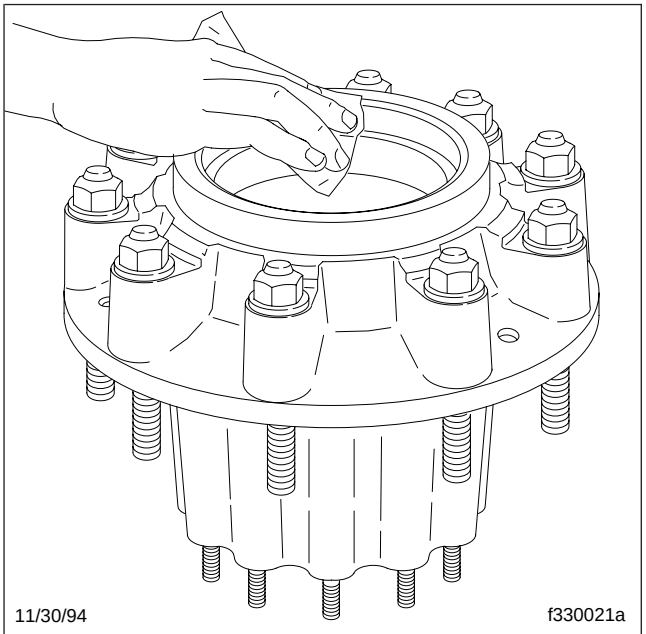
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Seal Replacement, Chicago Rawhide

Replacement

NOTE: This procedure applies to the Chicago Rawhide Scotseal®.

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 35.01**.
2. Remove the oil seal from the hub.
3. Remove the inner wheel bearing assembly from the hub. Handling the bearings with clean dry hands, wrap the bearings in clean oil-proof paper or lint-free cloths. Occasionally, the inner wheel bearing cone assembly will remain in the hub after the seal is removed. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing out of the inner wheel bearing cup.
4. Clean the spindle, spindle threads, seal bore, and the hub cavity. See **Fig. 1** and **Fig. 2**.
5. Remove all burrs from the shoulder and the seal bore with an emery cloth or a file. Clean any metal filings from the components.



NOTE: Rear hub shown.

Fig. 1, Clean the Hub

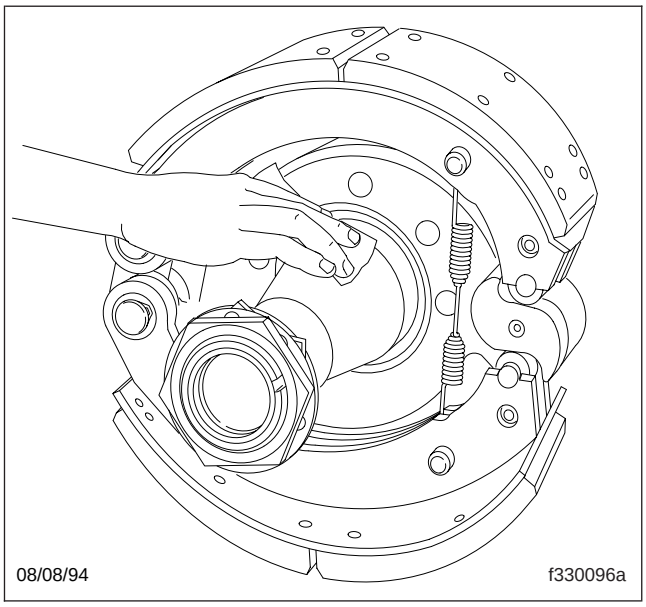


Fig. 2, Clean the Spindle

⚠ CAUTION

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

6. Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.
7. Coat the wheel bearing cones with oil.
8. Install the inner wheel bearing cone in the inner wheel bearing cup.
9. Seat the small outside edge of the seal in the recess of the tool adaptor. See **Fig. 3**. The correct adaptor is identified on the box.
10. Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 4**. The plug prevents cocking of the seal in the bore.
11. Hold the tool handle firmly, and strike it until the sound of the impact changes as the seal bottoms

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Seal Replacement, Chicago Rawhide

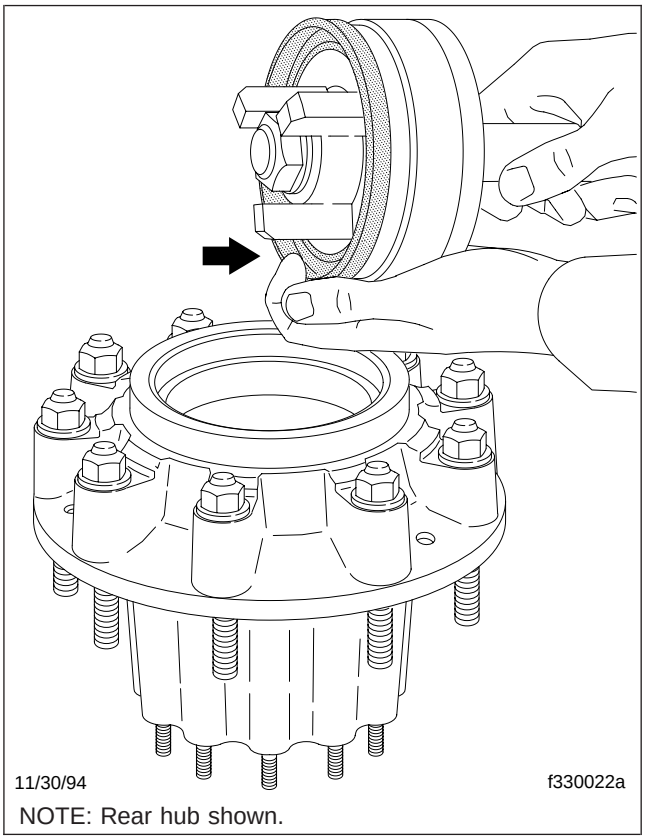


Fig. 3, Place the Seal on the Installation Tool

out. See **Fig. 5**. Hold the tool firmly to avoid bounce or unseating of the seal from the adaptor.

12. After the seal is bottomed in the bore, check for freedom of movement by manually moving the interior rubber part of the seal back and forth. A slight movement indicates a damage-free installation.
13. Install the wheel hub on the axle, and adjust the wheel bearings. For instructions, see **Section 35.01**.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

14. Place the hubcap and a new gasket in position, then install the capscrews. Tighten the capscrews 15 lbf·in (20 N·m).
15. Fill the hub with oil to the level shown on the hubcap. See **Fig. 6**. Do not overfill.

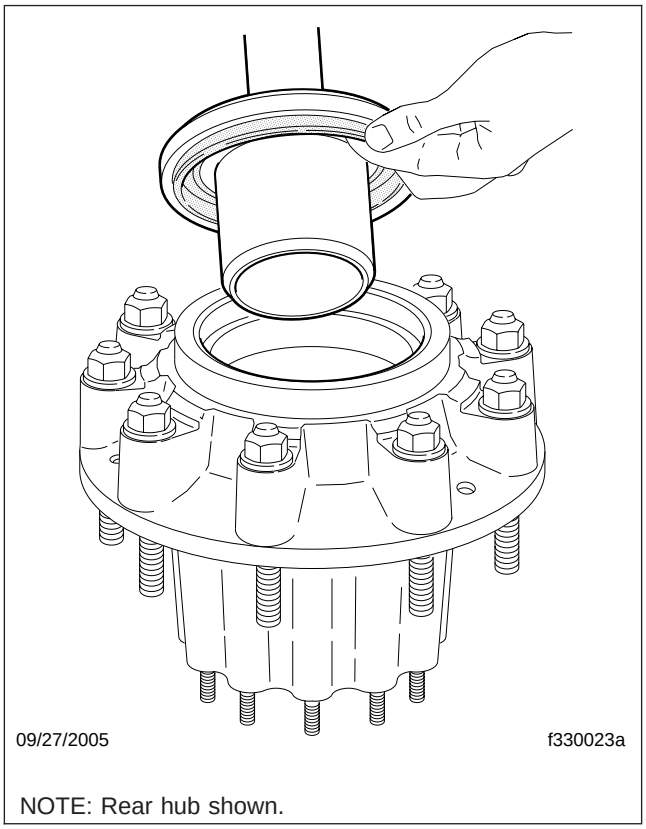
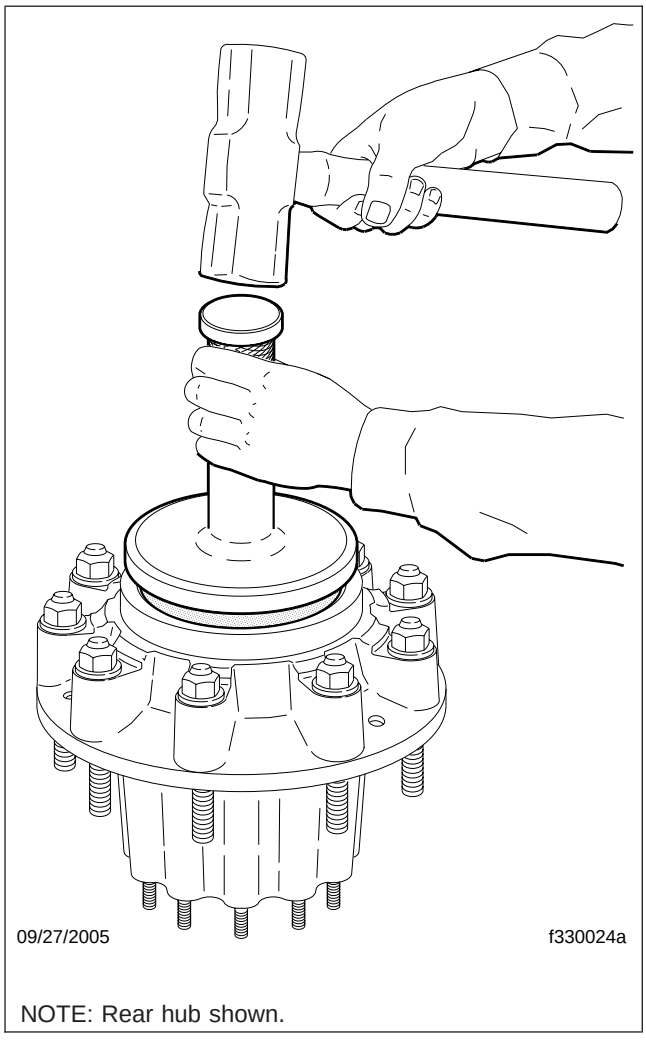


Fig. 4, Insert the Tool in the Hub Bore

16. Spin the wheel and check the oil level.
17. Adjust the brake shoe-to-drum clearance. For instructions, see Group 42 of the *Acterra® Maintenance Manual*.

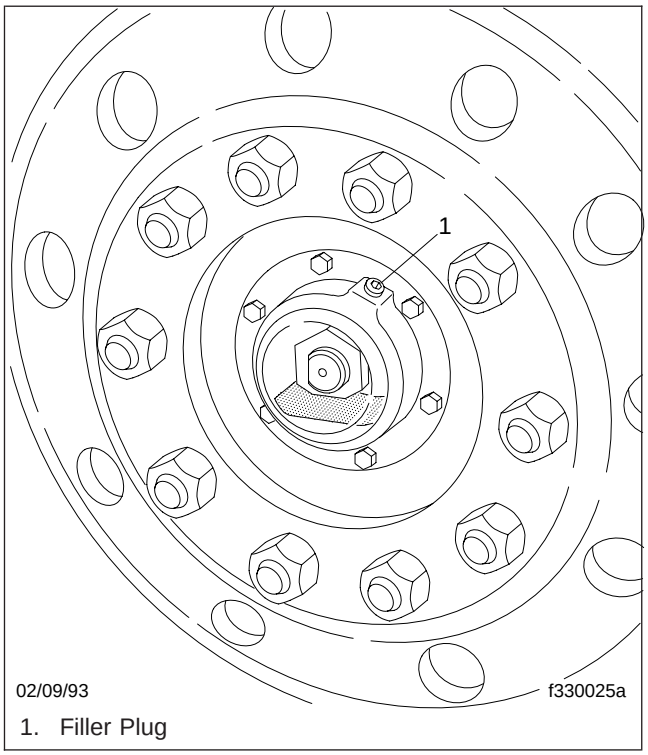
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Seal Replacement, Chicago Rawhide



NOTE: Rear hub shown.

Fig. 5, Strike the Tool



1. Filler Plug

Fig. 6, Fill the Hub With Oil

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Replacement

NOTE: This procedure applies to the Dana Spicer Outrunner™ seal.

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 35.01**.
2. Remove the oil seal from the hub.
3. Remove the inner wheel bearing assembly from the hub. Handling the bearings with clean dry hands, wrap the bearings in clean oil-proof paper or lint-free cloths. Occasionally, the inner wheel bearing cone assembly will remain in the hub after the seal is removed. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing out of the inner wheel bearing cup.
4. Clean and inspect the bearings, the spindle, spindle threads, seal bore, and the hub cavity.

   IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

   4.1 Inspect the inner hub bore. Remove dirt and contaminants from all recesses and corners. Smooth any sharp edges with emery cloth, and fill in any grooves with filler. See **Fig. 1**.

   4.2 Wipe the hub area with a clean shop cloth.

   4.3 After removing the hub, inspect the spindle. Remove any sharp edges and burrs from the leading edges and the shoulder area. Repair deep gouges with filler and smooth with an emery cloth. See **Fig. 2**.

   4.4 Wipe the seal and shoulder area with a clean shop cloth.

⚠ CAUTION

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

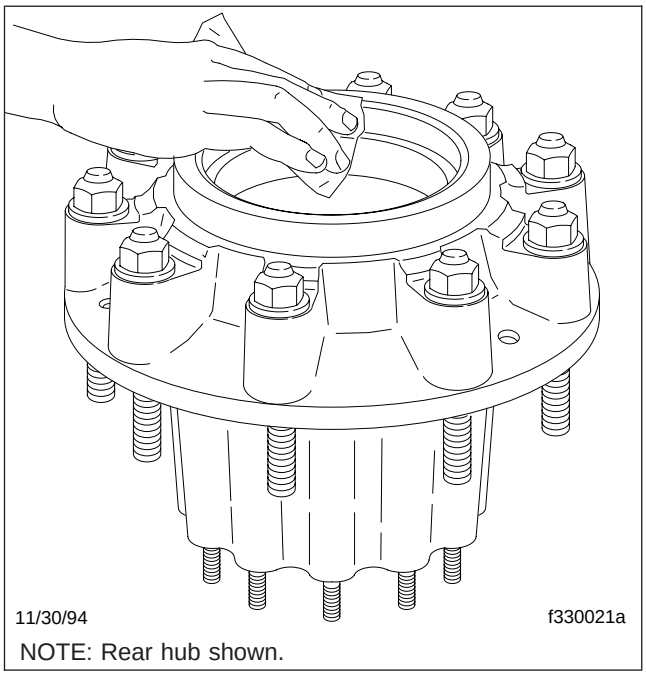


Fig. 1, Clean and Inspect the Hub Bore

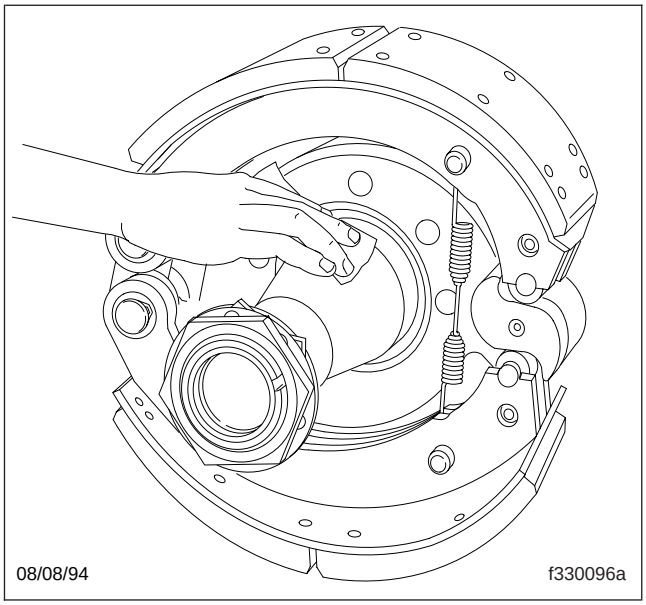


Fig. 2, Clean and Inspect the Axle Spindle

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Seal Replacement, Dana Spicer

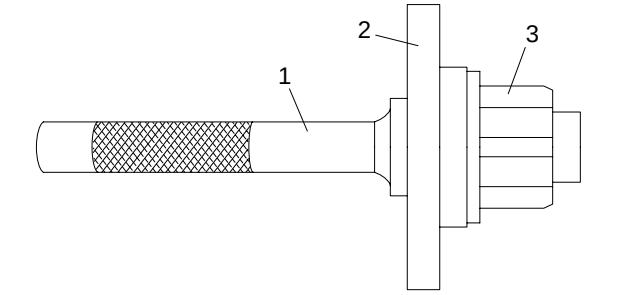
4.5 Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.

4.6 Coat the wheel bearing cones with oil.

5. Install the inner wheel bearing cone in the inner wheel bearing cup.

IMPORTANT: Use the Dana Spicer Outrunner installation tool *with the centering tool* when installing the seal. See **Fig. 3**.

6. Install the oil seal in the hub bore.



1. Outrunner Handle
2. Outrunner Adapter Plate
3. Bearing Centering Tool

Fig. 3, Dana Spicer Outrunner Installation Tool

⚠ CAUTION

Do not use any silicone or permatex type bore sealant with this seal. The Dana Spicer Corporation recommends a light coating of bearing oil on the outer circumference of the seal.

Do not mix lubricants of different grades. Do not mix mineral and synthetic lubricants. Do not pack the bearings with grease when using an oil bath system. Failure to follow these installation guidelines will result in less than desired performance of the Outrunner seal, and installation-related failures are not covered under warranty.

6.1 Place the Outrunner seal tool with the words "air side" facing the adaptor plate of the installation tool. See **Fig. 4**. Lubricate the seal outer circumference with wheel bearing oil.

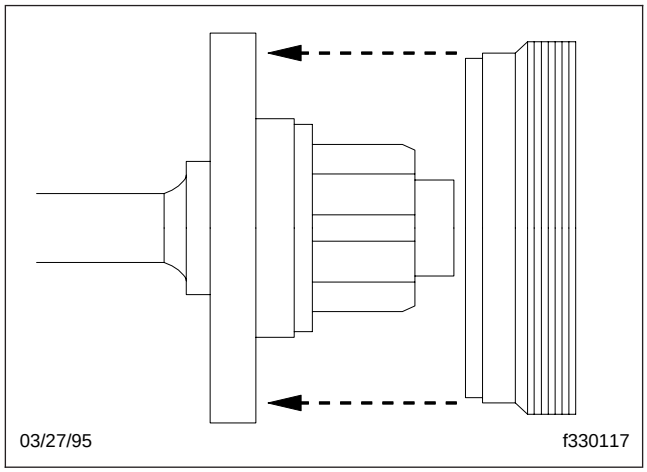


Fig. 4, Seal Placement on Tool

IMPORTANT: Install the seal in the hub bore with the hub laid flat. Do not install the seal with the hub in the vertical (upright) position.

6.2 With the hub and the wheel assembly laid flat on the floor, place the inner bearing cone in the cup.

6.3 Position the oil seal in the hub bore. Before striking the handle of the installation tool, tap the adaptor plate around the outer edge to position the seal. See **Fig. 5**.

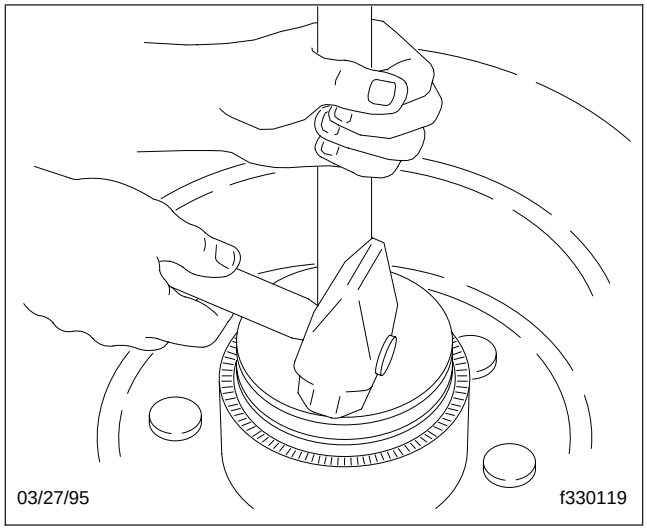


Fig. 5, Position the Seal

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6.4 Hit the handle of the installation tool *gently*. See **Fig. 6**.

Because of the rubber outer circumference, the Outrunner seal is easier to install than seals with metal outer circumferences. When the adaptor plate bottoms out on the hub surface, the seal is installed correctly. You will hear a metal-to-metal sound.

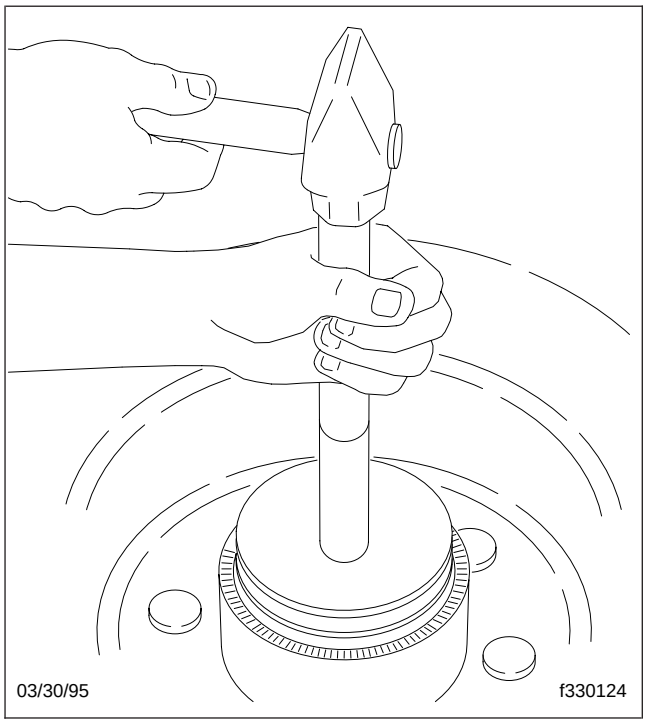


Fig. 6, Install the Seal

6.5 Check that the seal is not cocked, and that the unitized seal inner circumference and inner bearing turn freely.

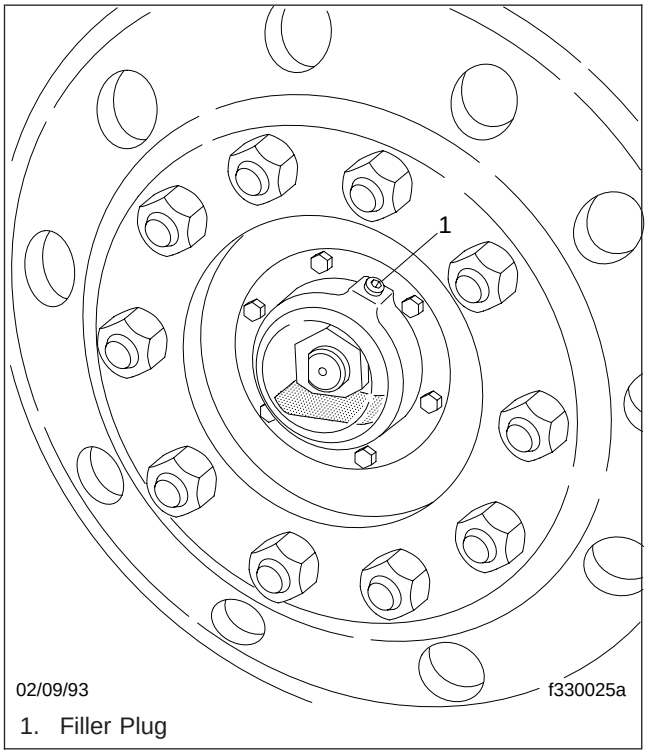
6.6 Lubricate the inner circumference of the seal with a light film of clean bearing oil.

7. Install the wheel hub on the axle, and adjust the wheel bearings. For instructions, see **Section 35.01**.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

8. Place the hubcap and a new gasket in position, then install the capscrews. Tighten the capscrews 15 lbf·ft (20 N·m).

9. Fill the hub with oil to the level shown on the hubcap. See **Fig. 7.** Do not overfill.



1. Filler Plug

Fig. 7, Fill the Hub With Oil

10. Spin the wheel and check the oil level.

11. Adjust the brake shoe-to-drum clearance. For instructions, see Group 42 of the *Acterra® Maintenance Manual*.

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General Information

Detroit rear axles are compatible with industry-standard brakes, hubs, and wheel bearings.

The following explains an example of the number found on a Detroit rear axle identification tag, which is located on the carrier. See **Fig. 1**.

Typical Model Number: ART-40.0-4

- *ART* = tandem rear axle
- *40.0* = weight rating (times 1000 lb)
- *4* = basic model number

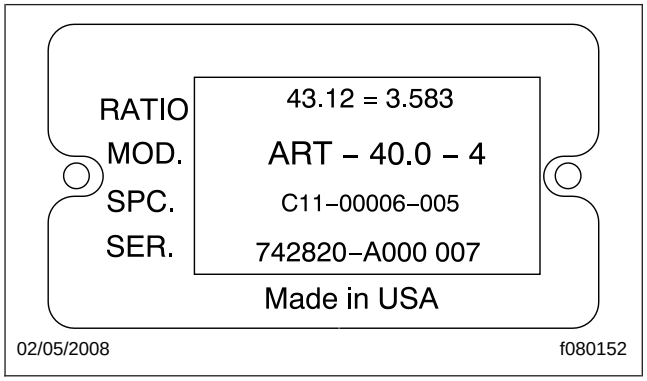


Fig. 1, Rear Axle ID Tag

Detroit rear axles may have a main differential lock, which is commonly known as the "DCDL" (Driver-Controlled Differential Lock). The DCDL is an optional feature that can lock the differential assembly. When the differential lock is engaged, the clutch collar completely locks the differential case, gearing, and axle shafts together to maximize traction of both wheels and protect against spinout. Each part of the DCDL is replaceable; see **Subject 180** for Model 2 axles, and **Subject 190** for Model 4 axles.

On tandem axles there are three possible differential lock options: forward-rear carrier only, rear-rear carrier only, or both rear carriers.

NOTE: Detroit axles are a proprietary product, though in some applications they may be referred to as "Sterling" or "Axle Alliance" axles or "MB components."

Warranty

To assist in the determination of warrantable and non-warrantable failures for these axles, warranty evaluation guides are available through WarrantyLit on **www.accessfreightliner.com**. These guides help determine whether or not pre-approval is needed for a repair. The following evaluation guides are available:

- **Warranty Evaluation Guide**
- **Submission Guidelines - Differential Cross Failure**
- **Submission Guidelines - Pinion Bearing Cage Damage**
- **Submission Guidelines - Pinion Nut Failure**
- **Submission Guidelines - Thrust Bearing Failure**
- **Submission Guidelines - Yoke (Pinion) End Play**

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Single or Rearmost Axle Removal and Installation

Removal

For rear axle components, see **Fig. 1**.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires. Put the transmission in neutral.
2. Using a suitable jack, raise the vehicle enough to take the weight off the axles, but not enough to raise the tires off the ground.
3. At both ends of the axle, loosen all the wheel nuts.
4. Continue to raise the vehicle evenly until there is room to fit a stand underneath the axle housing.

⚠ WARNING

Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, allowing the vehicle to fall, which could result in serious injury or death.

5. Support the vehicle with safety stands.
6. Remove the tire and wheel assemblies. For instructions, see **Group 40**.
7. Remove the oil drain plug from the bottom of the axle housing and drain the oil. Install the drain plug after emptying.
8. Disconnect the driveshaft from the differential carrier. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
9. Release the parking brakes.
10. Cage the parking brake springs to prevent the parking brakes from engaging. For instructions, see **Group 42**.
11. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being removed.

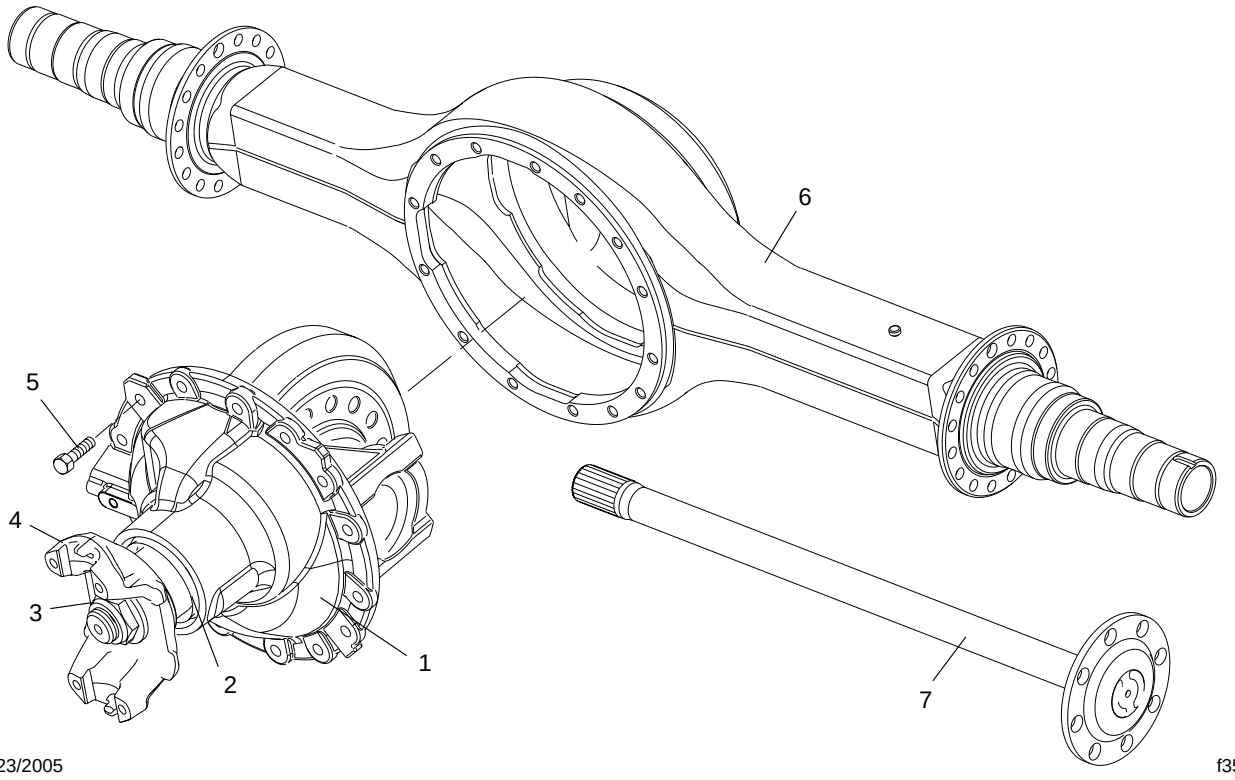
12. Drain the air system, if installed.
13. Place a basin under the axle shaft flanges to catch any oil, then remove the axle shafts. For instructions, see **Subject 120**.
14. If installed, disconnect the DCDL air line from the carrier housing.
15. If necessary, back off the slack adjusters. Remove the brake drums.
16. Remove the hubs from the axle spindles. For instructions, see **Section 35.01, Subject 100**.
17. Remove the brake shoes. For instructions, see the applicable service brake section in **Group 42**.
18. If applicable, disconnect the leveling valve rod(s) from the suspension.
19. If installed, disconnect the air lines from the rear brake chambers. Then remove the brake air chambers and the slack adjusters from the axle housing. For instructions, see **Group 42**.
20. Remove the brake spiders from the axle flanges.
    - 20.1 At the frame rail or crossmember, disconnect the wiring for the ABS sensors. Remove any tie straps that hold the wires to the frame rails.
    - 20.2 Remove the ABS sensors and wiring.
    - 20.3 Remove the fasteners that hold the brake spiders to the axle flanges. Remove the spiders from the axle.
21. Using a suitable jack, support the axle housing.
22. If applicable, remove the hexnuts that hold the bottom of each suspension air bag to its suspension bracket.
23. Remove the suspension components that attach the axle to the vehicle. If applicable, remove the U-bolt nuts from the U-bolts. Discard the U-bolt nuts and U-bolts.
24. Lower the axle enough to clear the suspension components.
25. Remove the axle from the vehicle.
26. If you are going to replace the differential carrier, place the axle on a secure axle stand.

Installation

1. Position the axle underneath the vehicle.

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Single or Rearmost Axle Removal and Installation



1. Differential Carrier
2. Radial Shaft Seal
3. Yoke Nut
4. Carrier Yoke
5. Carrier Capscrew
6. Rear Axle Housing
7. Axle Shaft

Fig. 1, Single or Rearmost Axle Components

2. Install the suspension components that attach the axle to the vehicle, as follows.

   NOTE: U-bolts and U-bolt nuts cannot be reused.

   2.1 On vehicles with conventional suspensions, install the upper U-bolt brackets, new U-bolts, lower U-bolt brackets, and new U-bolt nuts.

   On vehicles with air suspensions, in addition to the U-bolts, install the hexnuts that attach the air springs to the suspension brackets. For torque values, see **Group 32**.

   On vehicles without U-bolts, install the walking beams.

   2.2 If applicable, tighten the new U-bolt nuts in a diagonal pattern. For torque values, see **Group 32**.

3. Connect the driveshaft to the differential carrier yoke. For instructions, see **Section 41.00, Subject 120**.
4. Install the brake spiders on the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
5. Install the ABS sensors and connect the wiring at the frame rail. Secure the wiring with tie straps as needed.
6. Install the brake air chambers (if removed) and slack adjusters on the axle housing brackets. For instructions, see **Group 42**.
7. Connect the air lines to the brake air chambers.

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8. Install the brake shoes, as removed. For instructions, see the applicable service brake section in **Group 42**.
9. Fill each hub with approved axle oil until you can see a small amount of oil trickling out of the back of the hub (fill with about 0.8 quart, or 0.75 liter). Install the hubs on the axle spindles, and adjust the wheel bearings. For instructions, see **Section 35.01, Subject 100**.

NOTE: See **Table 1** for approved axle oils.

10. If DCDL is installed on the vehicle, connect the DCDL air line, fill the air system, and use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged.

Approved Single Rear Axle Oil Type and Capacity				
Model	Oil Type		Capacity: quarts (liters)	
	Mineral	Synthetic	Hubs Full	Hubs Dry
2	80W-90	75W-90	5.8 (5.5)	7.4 (7.0)
4			10.6 (10.0)	12.2 (11.5)

Table 1, Approved Single Rear Axle Oil Type and Capacity

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being installed.

11. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.
12. Install the brake drums on the hubs.
13. Install the tire and wheel assemblies. For instructions, see **Group 40**.
14. Adjust the brakes. For instructions, see the applicable service brake section in **Group 42**.
15. Uncage the parking brake springs.
16. Using approved axle oil, fill the axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.
17. If the hubs are dry, raise one side of the vehicle about 8 inches (20 cm) to let the oil flow into the hub on the opposite side, then raise the other side in the same manner. On each side, hold the tilted position for three minutes to allow oil to run into the wheel end.

NOTICE

Make sure the hubs are filled. Driving with the hubs dry will cause bearing damage.

18. Turn the wheels, wait one minute, and check the lubricant level.
19. Raise the vehicle, remove the safety stands, then lower the vehicle.
20. If applicable, connect the suspension leveling valve(s). Start the engine, build the air pressure, and make sure the suspension air bags inflate correctly. Make sure the ride height is correct. For instructions, see **Group 32**.
21. Check the operation of the wheel lock, if installed.
22. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.
23. Set the parking brake.

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Single or Rearmost Axle Differential Carrier Removal and Installation

When the wheel lock is removed, inspect the carrier for damage and replace it if damage is found. If no damage is found, install the carrier again.

Removal

NOTE: The differential carrier can be removed either with the rear axle installed on the vehicle or with the rear axle removed from the vehicle.

Axle Installed on Vehicle

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires. Put the transmission in neutral.
2. If applicable, release the suspension air pressure.
3. Using suitable jacks, raise the vehicle evenly until there is room to fit a stand underneath the axle housing.
4. Remove the tire and wheel assemblies. For instructions, see **Group 40**.
5. Remove the oil drain plug from the bottom of the rear axle housing and drain the oil. Install the drain plug after emptying.
6. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.
7. Disconnect the driveshaft from the carrier input yoke. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
8. Place a basin under the axle shaft flanges, then remove the axle shafts. For instructions, see **Subject 120**.
9. Do the steps under the heading, "Axle Removed from Vehicle."

Axle Removed from Vehicle

WARNING

The differential carrier is heavy. Do not try to move it without a suitable support. To do so could result in the carrier falling, which could cause serious personal injury and component damage. Support the carrier with a suitable jack and chain it to the jack, or use a hoist if the axle has been removed from the vehicle.

1. Using a suitable jack, support the differential carrier. Chain the differential carrier to the jack.
2. If DCDL is installed on the vehicle, ensure the lock is engaged. Turn the appropriate wheels to verify it is fully engaged.
3. Remove the carrier capscrews that hold the differential carrier to the axle housing. See **Fig. 1**.
4. With the differential carrier securely supported, remove it from the axle housing.

Installation

IMPORTANT: If you replace the yoke on the differential carrier, use a *new* nut when installing the new yoke.

NOTE: Use a cleaning solvent and clean rags to remove dirt. Blow dry the cleaned areas with air.

1. Remove any old sealant material from the mating surfaces of the axle housing. Clean the inside of the rear axle housing and the forward carrier mating surface.
2. Inspect the axle housing for damage. Repair or replace the axle housing as necessary.
3. Apply a thin bead of Loctite® 5900 sealant all the way around the mating surface of the axle housing, and around each bolt hole.

WARNING

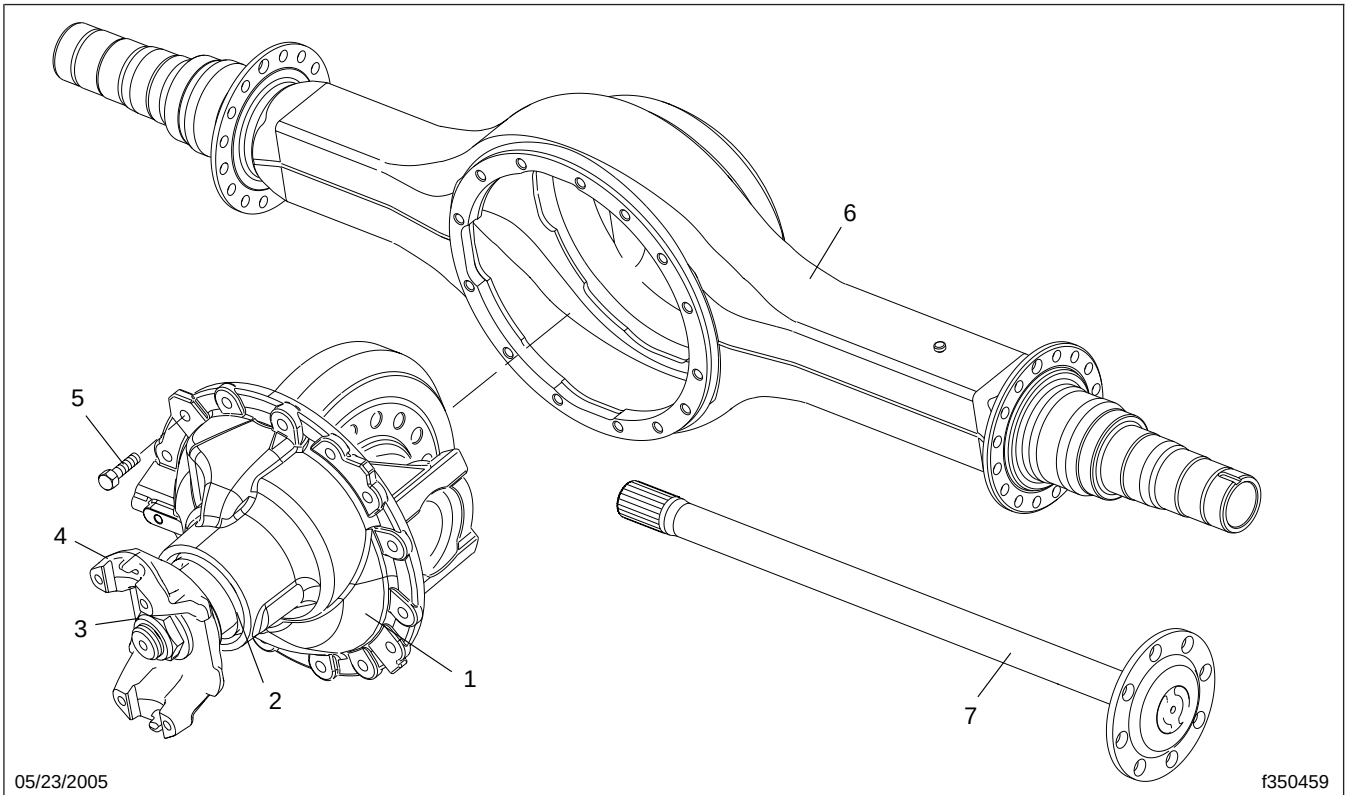
The differential carrier is heavy. Do not try to move it without a suitable support. To do so could result in the carrier falling, which could cause serious personal injury and component damage. Support the carrier with a suitable jack and chain it to the jack, or use a hoist if the axle has been removed from the vehicle.

4. If equipped with a wheel lock, engage the lock with air. This will help the carrier assembly join the axle housing.

NOTE: Alignment dowels for installing the differential carrier can be made by sawing off the heads of two M12 x 1.5 x 100 mm bolts (for

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Single or Rearmost Axle Differential Carrier Removal and Installation



1. Differential Carrier
2. Radial Shaft Seal
3. Yoke Nut
4. Carrier Yoke
5. Carrier Capscrew
6. Rear Axle Housing
7. Axle Shaft

Fig. 1, Single or Rearmost Axle Components

Model 2 axles) or M16 x 1.5 x 100 mm bolts (for Model 4 axles).

5. Install alignment dowels 180 degrees apart at the 3 o'clock and 9 o'clock positions on the axle housing flange.

NOTICE

Make sure the differential carrier is centered and straight on the axle housing before you install the mounting capscrews. Attempting to install the carrier when it is not centered or straight may cause damage to the carrier.

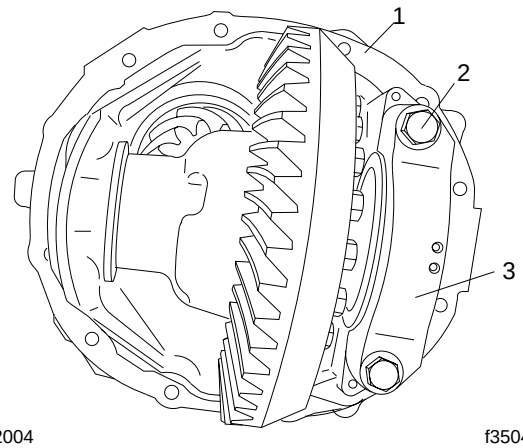
6. Using a hoist (if the axle is removed from the vehicle) or a suitable transmission jack, install the differential carrier into the axle housing. Use the alignment dowels to center the carrier on the axle housing.
7. Install the end caps on the sides of the carrier into the corresponding slots in the axle housing. See **Fig. 2**.
   - 7.1 For the last 3/4 inch (19 mm) or so of travel, walk the carrier slowly into the housing.

   IMPORTANT: The end caps fit tightly into the axle housing. Be very careful not to cock the carrier.

   - 7.2 Install the carrier capscrews finger-tight. Make sure the carrier capscrews turn easily in the axle housing.
   - 7.3 In a star pattern, gradually tighten the carrier capscrews to the values given.
     - M12 capscrews: 115 lbf·ft (156 N·m)
     - M16 capscrews: 200 lbf·ft (270 N·m)

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Single or Rearmost Axle Differential Carrier Removal and Installation



1. Differential Carrier
2. End Cap Bolt
3. End Cap

Fig. 2, Carrier End Caps

8. If removed, install the axle on the vehicle. For instructions, see **Subject 100**.

   If the axle is already on the vehicle, go to the next step.

9. Connect the driveshaft to the carrier input yoke. For instructions, see **Section 41.00, Subject 120**.
10. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.
11. Install the tire and wheel assemblies. For instructions, see **Group 40**.
12. Using approved axle oil, fill the axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.

Approved Single Rear Axle Oil Type and Capacity				
Model	Oil Type		Capacity: quarts (liters)	
	Mineral	Synthetic	Hubs Full	Hubs Dry
2	80W-90	75W-90	5.8 (5.5)	7.4 (7.0)
4			10.6 (10.0)	12.2 (11.5)

Table 1, Approved Single Rear Axle Oil Type and Capacity

13. Raise one side of the vehicle about 8 inches (20 cm) to let the oil flow into the hub on the opposite side, then raise the other side in the same manner. On each side, hold the tilted position for three minutes to allow oil to run into the wheel end.

NOTICE

Make sure the hubs are filled. Driving with the hubs dry will cause bearing damage.

14. Turn the wheels, wait one minute, and check the lubricant level.
15. Raise the vehicle, remove the safety stands, then lower the vehicle.
16. Start the engine, build the air pressure, and check that the suspension air bags inflate evenly and correctly. Make sure the ride height is correct. For instructions, see **Group 32**.
17. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.

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Removal

1. Chock the front tires.
2. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.
3. Raise the rear of the vehicle with a suitable jack high enough to clear the axle. Support the axle with jack stands.
4. Place a basin under the axle shaft flanges to catch any oil. Dispose of used oil properly.
5. If necessary, remove the rear wheels and tires. For procedures, see **Group 40**.

NOTE: This procedure can be done with the wheels and tires installed or with the wheels and tires removed.

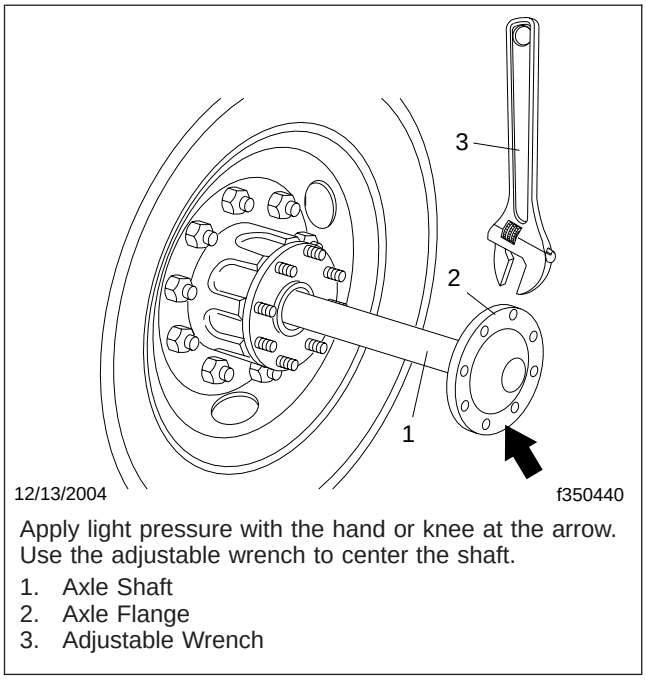
6. Remove the drive axle stud nuts that attach the axle shaft to the wheel hub.
7. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.
8. Tap the axle shaft flange if necessary to loosen it and slide the axle shaft out of the axle. Remove and discard the gasket.

Installation

1. Position a new gasket on the axle shaft flange.
2. If DCDL is installed on the vehicle, ensure it is engaged.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being installed.

3. Install the axle shaft, as follows. See **Fig. 1**.
   - 3.1 Carefully raise the axle with the floor jack, and support the axle with jack stands. Slide the axle shaft into the axle.
   - 3.2 Apply light pressure with the hand or knee to the axle flange.



Apply light pressure with the hand or knee at the arrow. Use the adjustable wrench to center the shaft.

1. Axle Shaft
2. Axle Flange
3. Adjustable Wrench

Fig. 1, Installing the Axle Shaft

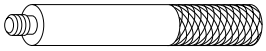
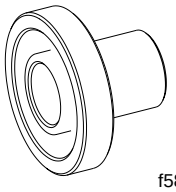
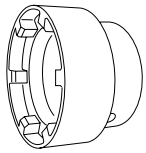
   - 3.3 Use an adjustable wrench to center the shaft. Turn the shaft with a slight rotating motion.
   - 3.4 Install the drive axle stud nuts and tighten them to the values given.
     - 1/2–20 nuts: 75 to 115 lbf·ft (102 to 156 N·m)
     - 5/8–18 nuts: 150 to 170 lbf·ft (203 to 230 N·m)
4. If removed, install the rear wheels and tires. Tighten the wheel nuts according to the procedures in **Group 40**.
5. Remove the supports and lower the vehicle.
6. As needed, replace any oil that was drained from the hub when the axle shaft was removed.

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Single or Rearmost Axle Yoke and Seal Replacement, Model 4 Axles

Special Tools

Special tools are required for this procedure. See **Table 1**.

Special Tools			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580406	Rear Pinion Seal Installer*	Kent-Moore	J-47354
 f580450	Yoke Nut Socket†	Daimler	MBA 742589020700

* To order Kent-Moore tools call 1-800-328-6657.

† The yoke nut socket is needed to remove the round, slotted yoke nut installed on some vehicles. It can be ordered through Paragon.

Table 1, Special Tools

Replacement

1. Disconnect the driveshaft from the differential carrier. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
2. Remove the yoke nut from the center of the carrier yoke. If the yoke nut is round and slotted, use the yoke nut socket shown in **Table 1**. See **Fig. 1**. Be careful not to damage the seal bore.
3. Remove the carrier yoke from the input shaft.
4. Pry up the seal, using a prybar or large screwdriver. Clean any old sealant from the axle housing. Do not allow dirt or grease to contaminate the seal bore or shaft bearings. See **Fig. 2**.
5. Install the rear pinion seal on the rear input shaft, as follows. See **Fig. 3**.

   5.1 Inspect the area around the seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

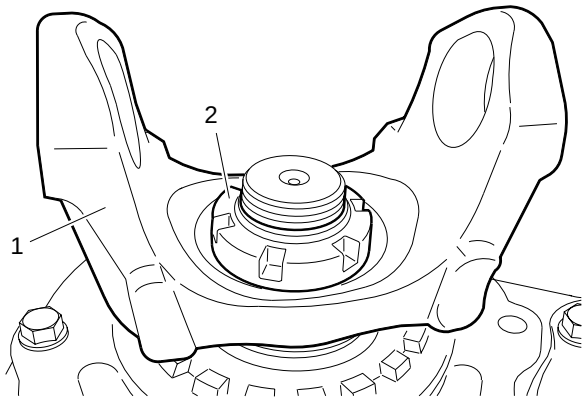
   5.2 Assemble the rear pinion seal installer onto the threaded end of the universal handle. See **Table 1**.

   IMPORTANT: Be careful not to cock the seal during installation.

   5.3 Using the rear pinion seal installer assembly, press the seal into the bore until the seal surface is flush with the bottom surface of the counterbore.

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Single or Rearmost Axle Yoke and Seal Replacement, Model 4 Axles

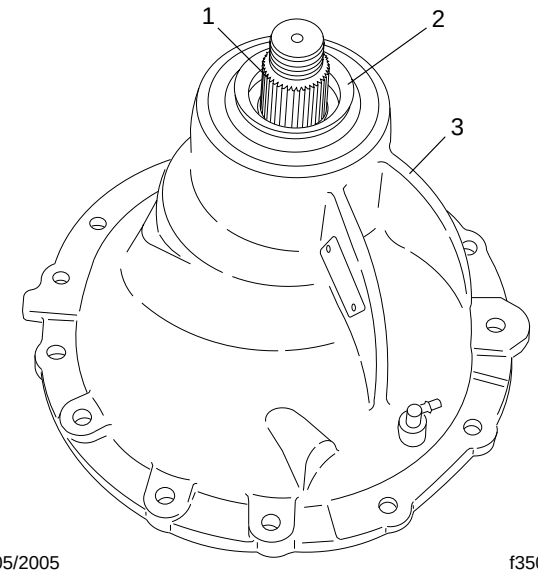


04/01/2008 f350496

NOTE: The yoke nut may be a hexnut rather than the round, slotted nut shown here.

1. Yoke
2. Yoke Nut

Fig. 1, Yoke Nut on the Carrier



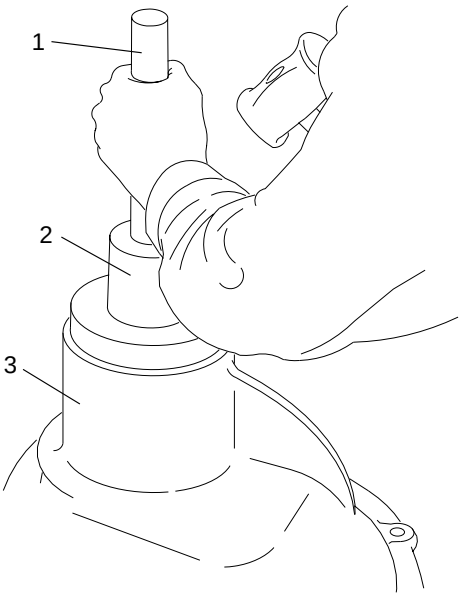
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1. Input Shaft
2. Rear Pinion Seal
3. Carrier Housing

Fig. 2, Rear Pinion Seal

6. Install the carrier yoke on the input shaft. If the yoke is damaged or worn, install a new yoke.

NOTE: It is not necessary to replace the yoke when replacing the seal.



05/12/2005 f350448

1. Universal Handle
2. Rear Pinion Seal Installer
3. Carrier Housing

Fig. 3, Installing the Rear Pinion Seal

7. Install a new M45 x 1.5 yoke nut on the carrier yoke, and tighten it 627 lbf·ft (850 N·m).
8. Punch in the cylindrical area at the pinion groove to lock the nut in place.

IMPORTANT: The bent area has to reach the bottom of the pinion groove.

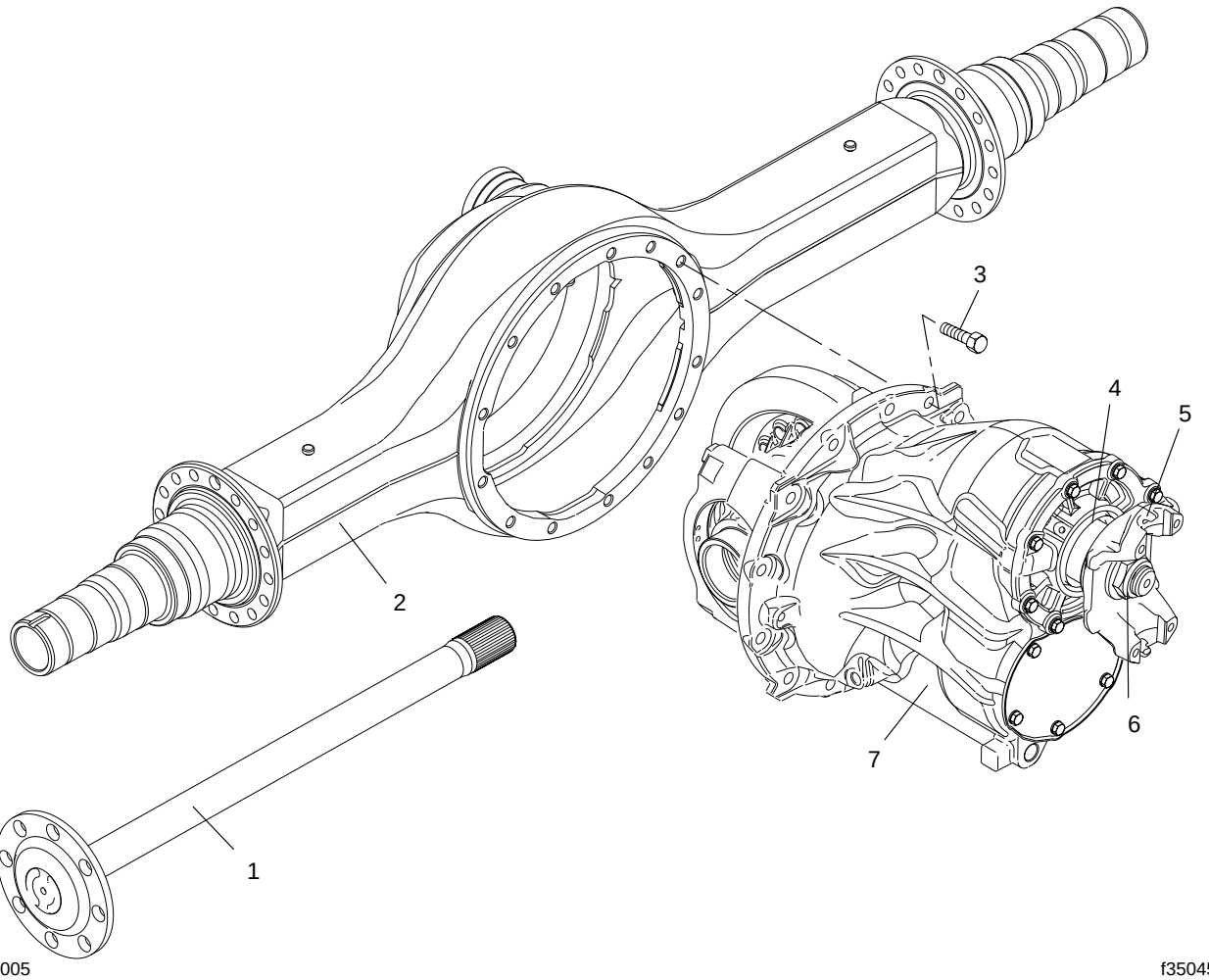
9. Connect the driveshaft. For instructions, see **Section 41.00, Subject 120**.

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Removal

For forward-rear axle components of a tandem installation, see **Fig. 1**.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires. Put the transmission in neutral.
2. Using a suitable jack, raise the vehicle enough to take the weight off the axles, but not enough to raise the tires off the ground.
3. At both ends of the axle, loosen all the wheel nuts.
4. Using a suitable jack, continue to raise the vehicle evenly until there is room to fit a stand underneath the axle housing.



1. Axle Shaft
2. Forward-Rear Axle Housing
3. Carrier Capscrew
4. Input Seal
5. Carrier Yoke
6. Input Yoke Nut
7. Forward Differential Carrier

Fig. 1, Forward-Rear Axle Components

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Forward-Rear Axle Removal and Installation

⚠ WARNING

Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, allowing the vehicle to fall, which could result in serious injury or death.

5. Support the vehicle with safety stands.
6. Remove the oil drain plug from the bottom of each axle housing and drain the oil. Install the drain plug after emptying.
7. Remove the tire and wheel assemblies. For instructions, see **Group 40**.
8. Release the parking brakes.
9. If necessary, back off the slack adjusters. Then remove the brake drums.
10. If installed, make sure the optional DCDL (main differential lock) has been shifted into the engaged (locked) position.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being removed.

11. Drain the air system. Disconnect the air lines at the interaxle lock and the wheel lock (if installed).
12. Disconnect the main driveshaft from the forward differential carrier. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
13. Disconnect the interaxle driveshaft from the output yoke of the forward-rear axle and the input yoke of the rearmost axle. For instructions, see **Section 41.00, Subject 120**.
14. Cage the parking brake springs to prevent the parking brakes from engaging. For instructions, see **Group 42**.
15. Place a basin under the axle shaft flanges to catch any oil; then remove the axle shafts. For instructions, see **Subject 120**.
16. Remove the hubs from the axle spindles. For instructions, see **Section 35.01, Subject 100**.
17. Remove the brake shoes. For instructions, see the applicable service brake section in **Group 42**.
18. Remove the ABS sensors and wiring, and the fasteners that hold the brake spiders to the axle flanges. Remove the spiders from the axle.
19. If applicable, disconnect the leveling valve rod(s) from the suspension.
20. At the frame rail or crossmember, disconnect the wiring for he ABS sensors. Remove any tie straps that hold the wires to the frame ails.
21. Disconnect the air lines from the rear brake chambers. Remove the brake air chambers and the slack adjusters from the axle housings. For instructions, see **Group 42**.
22. Using suitable jacks, support the axle housing.
23. If applicable, remove the hexnuts that hold the bottom of each suspension air bag to its suspension bracket.
24. Remove the suspension components that attach both axles to the vehicle. If applicable, remove the U-bolt nuts from the U-bolts. Discard the U-bolt nuts and U-bolts.
25. Lower the axles enough to clear the suspension components.
26. Remove the axle from the vehicle.
27. If you are going to replace the differential carrier, place the axle on a secure axle stand

Installation

1. Position the axle underneath the vehicle.
2. Install the suspension components that attach both axles to the vehicle, as follows.

   NOTE: U-bolts and U-bolt nuts cannot be reused.

   2.1 On vehicles with conventional suspensions, install the upper U-bolt brackets, new U-bolts, lower U-bolt brackets, and new U-bolt nuts.

   On vehicles with air suspensions, in addition to the U-bolts, install the hexnuts that attach the air springs to the suspension brackets. For torque values, see **Group 32**.

   On vehicles without U-bolts, install the walking beams.

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2.2 If applicable, tighten the new U-bolt nuts in a diagonal pattern. For torque values, see **Group 32**.

3. Connect the interaxle driveshaft to the output yoke of the forward carrier and the input yoke of the rear carrier. For instructions, see **Section 41.00, Subject 120**.
4. Install the brake spiders on the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
5. Install the ABS sensors and connect the wiring at the frame rail. Secure the wiring with tie straps as needed.
6. Install the brake air chambers and slack adjusters on the axle housing brackets. For instructions, see **Group 42**.
7. Connect the air lines to the brake air chambers.
8. Install the brake shoes, as removed. For instructions, see the applicable service brake section in **Group 42**.
9. If equipped with a wheel lock, engage the lock with air.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being installed.

10. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.
11. Connect the main driveshaft to the forward carrier input yoke. For instructions, see **Section 41.00, Subject 120**.
12. Connect the air hoses to the air cylinder for the interaxle lock and (if installed) the wheel lock.
13. Connect the electrical connector of the sensor unit for axles equipped with a wheel lock.
14. Fill each hub with approved axle oil until you can see a small amount of oil trickling out of the back of the hub (fill with about 0.8 quart, or 0.75 liter). Install the hubs on the axle spindles, and adjust the wheel bearings. For instructions, see **Section 35.01, Subject 100**. See **Table 1** for approved axle oils.
15. Install the brake drums on the hubs.
16. Install the tire and wheel assemblies. For instructions, see **Group 40**.
17. Adjust the brakes. For instructions, see the applicable service brake section in **Group 42**.
18. Uncage the parking brake springs.
19. Using approved axle oil, fill the forward-rear axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.

Forward-Rear Axle Oil Type and Capacity		
Approved Oil Type	**Capacity: quarts (liters)**	
	Hubs Full	**Hubs Dry**
80W-90 Gear Oil	14.3 (13.5)	15.9 (15.0)
75W-90 Synthetic Gear Oil		

Table 1, Forward-Rear Axle Oil Type and Capacity

20. Raise one side of the vehicle about 8 inches (20 cm) to let the oil flow into the hub on the opposite side, then raise the other side in the same manner. On each side, hold the tilted position for three minutes to allow oil to run into the wheel end.
21. Raise the vehicle, remove the safety stands, then lower the vehicle.
22. If applicable, connect the suspension leveling valve(s). Start the engine, build the air pressure, and make sure the suspension air bags inflate correctly. Make sure the ride height is correct. For instructions, see **Group 32**.
23. Check the operation of the wheel lock, if installed.
24. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.
25. Set the parking brake.

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Forward-Rear Axle Differential Carrier Removal and Installation

For forward-rear axle components of a tandem installation, see **Fig. 1**.

When the wheel lock is removed, inspect the carrier for damage and replace it if damage is found. If no damage is found, install the carrier again.

Forward-Rear Axle Differential Carrier

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires. Put the transmission in neutral.
2. If applicable, release the suspension air pressure.
3. Using suitable jacks, raise the vehicle evenly until there is room to fit a stand underneath the axle housing.
4. Remove the tire and wheel assemblies. For instructions, see **Group 40**.
5. Remove the oil drain plug from the bottom of the axle housing and drain the oil from the axle housing. Install the drain plug after emptying.
6. Disconnect the driveshaft from the carrier yoke. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
7. Place a basin under the axle shaft flanges to catch any oil; then remove the axle shafts. For instructions, see **Subject 120**.

⚠ WARNING

The differential carrier is heavy. Do not try to move it without a suitable support. To do so could result in the carrier falling, which could cause serious personal injury and component damage. Support the carrier with a suitable jack and chain it to the jack, or use a hoist if the axle has been removed from the vehicle.

8. Using a suitable jack, support the differential carrier. Chain the differential carrier to the jack.

NOTICE

When using a pry bar, be careful not to damage the carrier or housing flange. Damage to these surfaces will cause oil leaks.

9. Remove the differential carrier from the axle housing, as follows. See **Fig. 1**.
   - 9.1 If equipped with a wheel lock, engage the lock with air. This will help separate the carrier from the axle housing.
   - 9.2 Remove all but the top two carrier capscrews.
   - 9.3 Loosen and back off, but do not remove, the top two carrier capscrews. The capscrews will hold the carrier in the housing.
   - 9.4 Using a pry bar, separate the mating surfaces of the forward differential carrier and axle housing.

   NOTE: Use a pry bar that has a round end to help separate the carrier from the housing.

   - 9.5 When the surfaces are separated, remove the top two capscrews.
   - 9.6 With the carrier on the jack, slide the carrier away from the axle housing.
   - 9.7 Lift the carrier assembly onto a suitable stand.

Installation

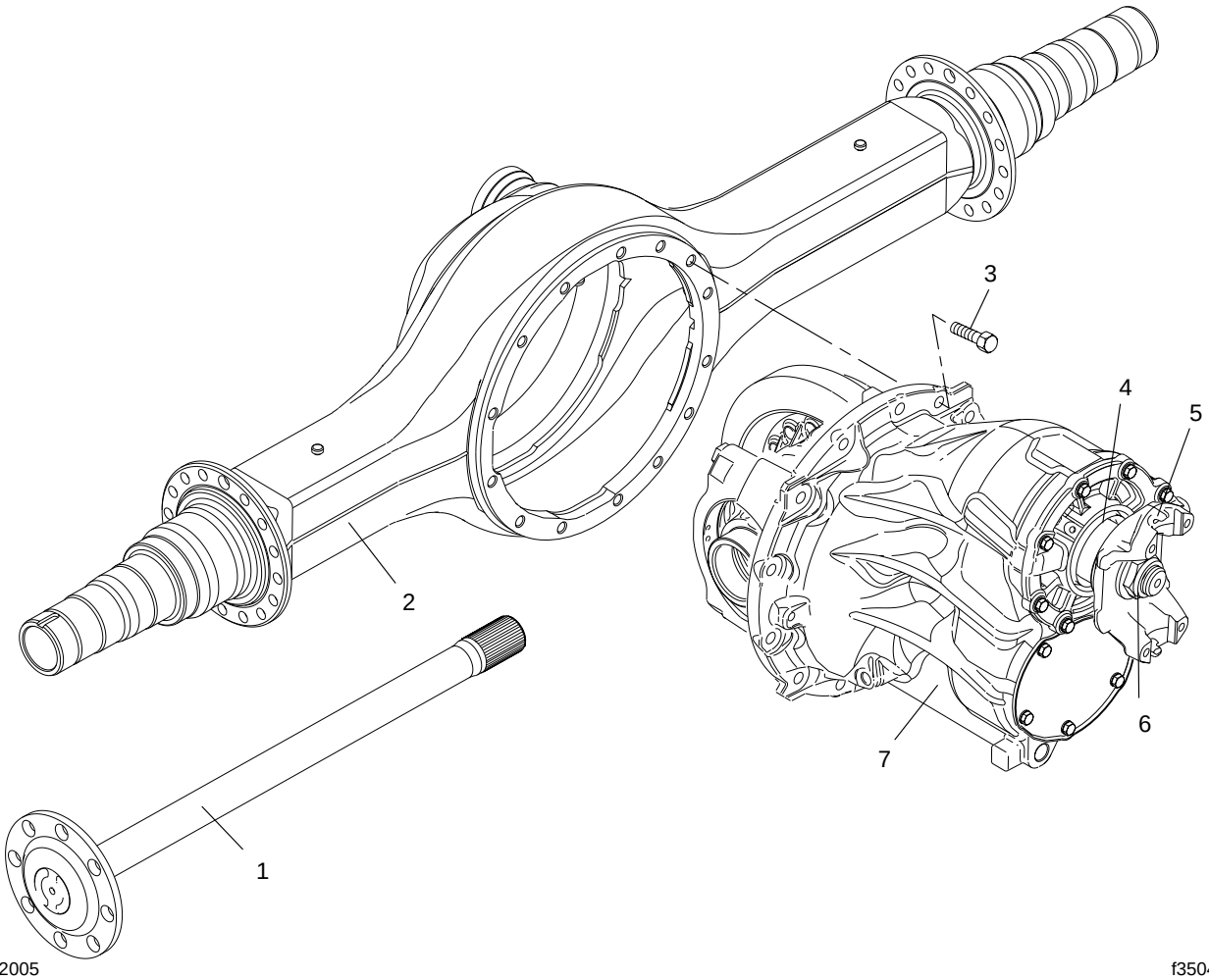
NOTE: Use a cleaning solvent and clean rags to remove dirt. Blow dry the cleaned areas with air.

1. Remove any old sealant material from the mating surfaces of the axle housing. Clean the inside of the axle housing and the carrier mating surface.
2. Inspect the axle housing for damage. Repair or replace the axle housing as necessary.
3. Apply a thin bead of Loctite® 5900 sealant all the way around the mating surface of the axle housing, and around each bolt hole.

NOTE: Alignment dowels for installing the differential carrier can be made by sawing off the heads of two M16 x 1.5 x 100 mm bolts.

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Forward-Rear Axle Differential Carrier Removal and Installation



1. Axle Shaft
2. Forward-Rear Axle Housing
3. Carrier Capscrew
4. Input Seal
5. Carrier Yoke
6. Input Yoke Nut
7. Forward Differential Carrier

Fig. 1, Forward-Rear Axle Components

4. Install alignment dowels 180 degrees apart at the 3 o'clock and 9 o'clock positions on the axle housing flange.

⚠ WARNING

The differential carrier is heavy. Do not try to move it without a suitable support. To do so could result in the carrier falling, which could cause serious personal injury and component damage. Support the carrier with a suitable jack and chain it to the jack, or use a hoist if the axle has been removed from the vehicle.

5. Position the forward differential carrier in front of the axle housing, using an axle jack or other suitable lifting tool.
6. If equipped with a wheel lock, engage the lock with air. This will help the carrier assembly join the axle housing.

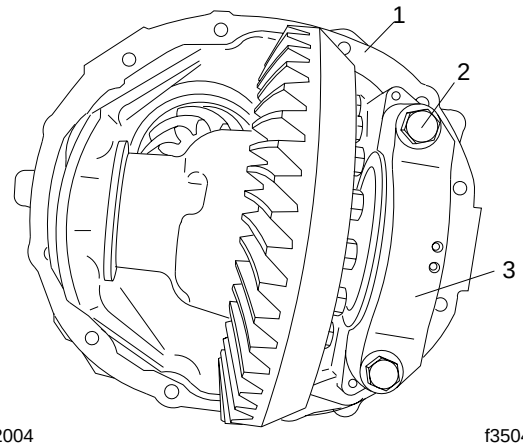
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Forward-Rear Axle Differential Carrier Removal and Installation

NOTICE

Do not use a hammer or a mallet to install the differential carrier. A hammer or a mallet will damage the mounting flange of the carrier and cause oil leaks.

7. Install the end caps at the sides of the forward differential carrier into the corresponding slots in the axle housing. See **Fig. 2**.



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1. Differential Carrier
2. End Cap Bolt
3. End Cap

Fig. 2, Carrier End Caps

7.1 For the last 3/4 inch (19 mm) or so of travel, walk the carrier slowly into the housing.

IMPORTANT: The end caps fit tightly into the axle housing. Be very careful not to cock the carrier.

7.2 Install the carrier capscrews finger-tight. Make sure the carrier capscrews turn easily in the axle housing.

7.3 In a star pattern, gradually tighten the capscrews 200 lbf·ft (270 N·m).

8. Connect the driveshaft to the forward input yoke. For instructions, see **Section 41.00, Subject 120**.
9. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.
10. Install the tire and wheel assemblies. For instructions, see **Group 40**.
11. Using approved axle oil, fill the axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.

Forward-Rear Axle Oil Type and Capacity		
Approved Oil Type	Capacity: quarts (liters)	
	Hubs Full	Hubs Dry
80W-90 Gear Oil	14.3 (13.5)	15.9 (15.0)
75W-90 Synthetic Gear Oil		

Table 1, Forward-Rear Axle Oil Type and Capacity

12. If the hubs are dry, raise one side of the vehicle about 8 inches (20 cm) to let the oil flow into the hub on the opposite side, then raise the other side in the same manner. On each side, hold the tilted position for three minutes to allow oil to run into the wheel end.

NOTICE

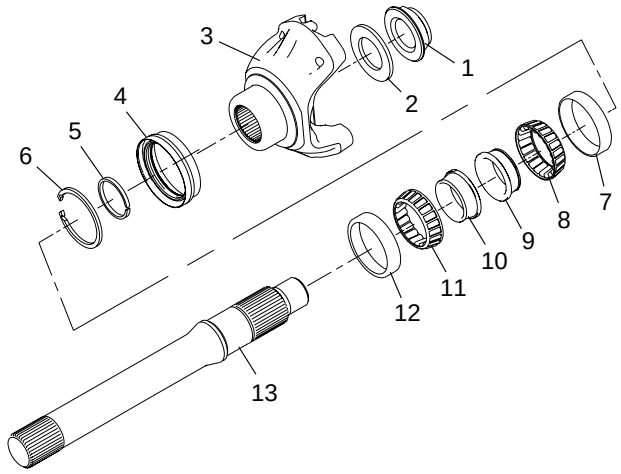
Make sure the hubs are filled. Driving with the hubs dry will cause bearing damage.

13. Turn the wheels, wait one minute, and check the lubricant level.
14. Raise the vehicle, remove the safety stands, then lower the vehicle.
15. Start the engine, build the air pressure, and check that the suspension air bags inflate evenly and correctly. Make sure the ride height is correct.
16. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.
17. Remove the chocks.

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Repair

1. Remove the output yoke nut, washer, and output yoke; see **Subject 170**.
2. Remove the output oil seal from the thru-shaft bore; see **Subject 170**.
3. Remove the snap ring and spacer from the thru-shaft. See **Fig. 1**.



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1. Output Yoke Nut
2. Washer
3. Output Yoke
4. Output Oil Seal
5. Spacer
6. Snap Ring
7. Outer Bearing Race
8. Outer Bearing
9. Outer Bearing Cup
10. Inner Bearing Cup
11. Inner Bearing
12. Inner Bearing Race
13. Thru-Shaft

Fig. 1, Thru-Shaft Components

4. Using a suitable shaft puller, draw the thru-shaft out of the bore.
5. Using a suitable bearing puller on the outer races, remove both the inner and outer bearings from the thru-shaft.
6. Inspect the bearings for wear and damage. Replace both bearings if any damage is found.
7. Install the inner bearing race in the thru-shaft bore.
8. Using an arbor press or other suitable pressing tool, press the bearings and bearing cups onto the thru-shaft.
9. Insert the thru-shaft into its bore.
10. Install the outer bearing race onto the thru-shaft and bore.
11. Install the snap ring and spacer. Use the next thicker snap ring from the snap ring pack supplied with the bearings.
12. Install the output oil seal; see **Subject 170**.
13. Install the output yoke, nut, and washer; see **Subject 170**. Make sure the output yoke nut is firmly tightened, but do not tighten the nut to specifications at this time.
14. Attach a dial indicator to the flat surface of the output yoke.
15. Using a pry bar or other lever, apply force to the base of the output yoke. If the dial indicator shows a deflection of 0.0012 to 0.0024 inches (0.03 to 0.06 mm), the end play is correct.

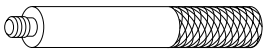
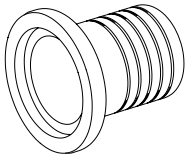
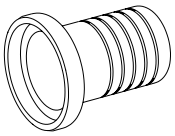
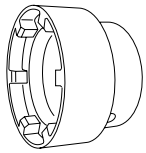
    If the deflection is too large, use a thicker snap ring. If the deflection is too small, use a thinner snap ring.
16. Coat the threads of the nut with Loctite® 577. Tighten the output yoke nut 516 lbf·ft (700 N·m).

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Forward-Rear Axle Yoke and Seal Replacement

Special Tools

Special tools are required for this procedure. See **Table 1**.

Special Tools for Forward-Rear Axle Yoke and Seal Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580410	Input Seal Installer*	Kent-Moore	J-47369
 f580408	Output Seal Installer*	Kent-Moore	J-47368
 f580450	Yoke Nut Socket†	Daimler	MBA 742589020700

* To order Kent-Moore tools call 1-800-328-6657.

† The yoke nut socket is needed to remove the round, slotted yoke nut installed on some vehicles. It can be ordered through Paragon.

Table 1, Special Tools for Forward-Rear Axle Yoke and Seal Replacement

Replacement

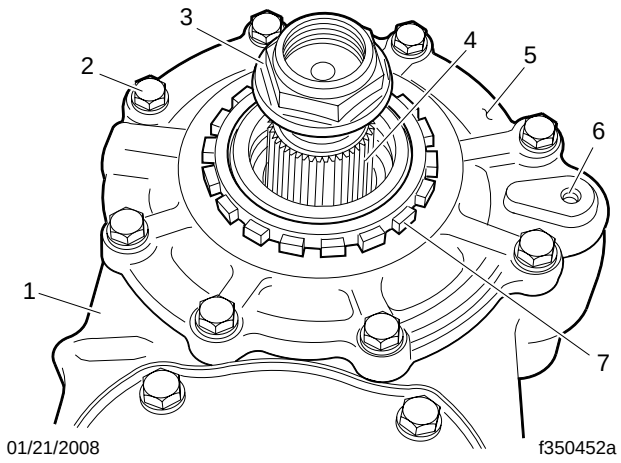
Forward Carrier Input Yoke and Seal

1. Disconnect the main driveshaft from the forward carrier input yoke. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
2. Remove the input yoke nut and washer from the center of the forward carrier input yoke.
3. Remove the old forward carrier input yoke from the forward input shaft.
4. If there is an oil leak at the threaded ring, repair it; for instructions, see **Subject 200**.

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Forward-Rear Axle Yoke and Seal Replacement

5. If there is a leak between the bearing cage and the carrier housing, remove the bearing cage, as follows. See **Fig. 1**.



1. Forward Carrier Housing
2. Bearing Cage Mounting Capscrew
3. Input Yoke Nut
4. Input Shaft
5. Bearing Cage
6. Interaxle Lock Bore
7. Threaded Ring

Fig. 1, Bearing Cage

5.1 Remove the bearing cage capscrews from the bearing cage.

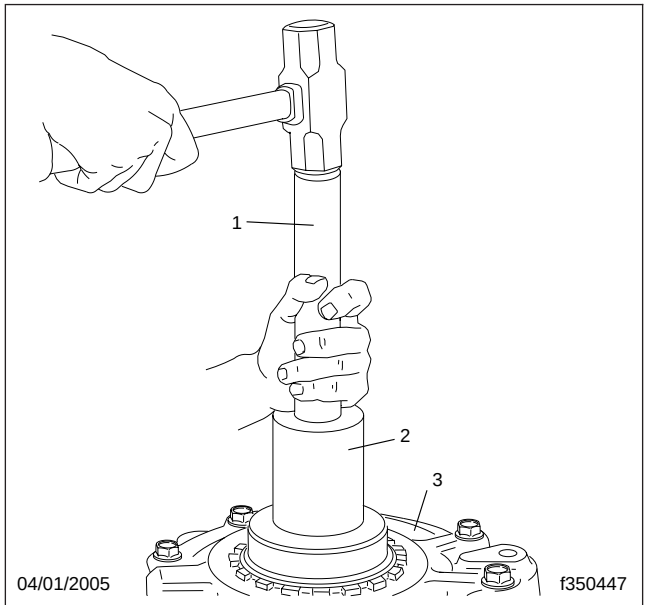
5.2 Pry the bearing cage from the forward carrier housing. Clean any remnants of sealant clinging to the mating surfaces of the carrier housing and the bearing cage.

6. Pry up the input seal, using a prybar or large screwdriver. Clean any old sealant from the axle housing. Do not allow dirt or grease to contaminate the seal bore or shaft bearings.

7. Install the seal in the input shaft bore, as follows. See **Fig. 2**.

7.1 Inspect the area around the seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

7.2 Assemble the input seal installer onto the threaded end of the universal handle. See **Table 1**.



1. Universal Handle
2. Input Seal Installer
3. Carrier Housing

Fig. 2, Installing the Forward Carrier Input Seal

7.3 Using the input seal installer assembly, press the seal into the bore until the seal surface is flush with the threaded ring.

8. On the mating surface of the bearing cage, lay down a bead of Loctite® 5900 sealant, or equivalent. Go around all of the bolt holes and other openings in the inside cover of the bearing cage. See **Fig. 3**.

IMPORTANT: Do not allow sealant to get into the interaxle lock bore. See **Fig. 4**. Do not attempt to repair the interaxle differential lock (IAD). No repairs to this component are possible.

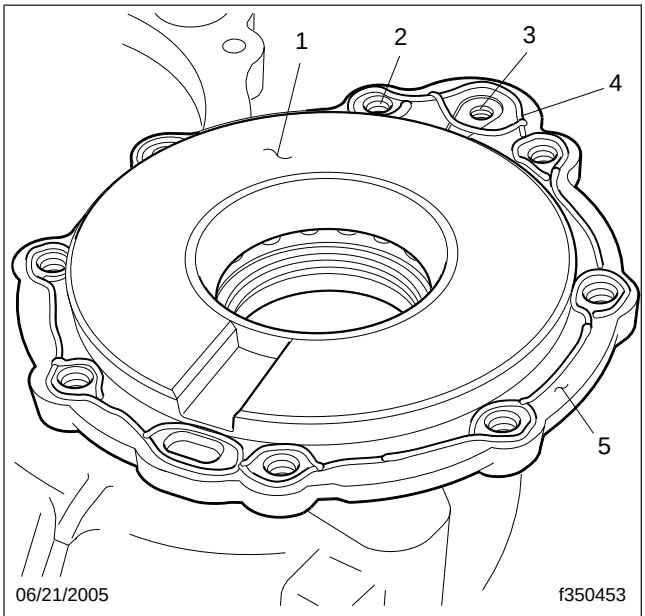
9. Install the bearing cage onto the forward carrier housing. Tighten the M12 bearing cage capscrews 107 lbf·ft (145 N·m).

10. Install the forward carrier input yoke on the forward input shaft. If the yoke is damaged or worn, install a new yoke.

NOTE: It is not necessary to replace the yoke when replacing the seal.

11. Coat the threads of a new M45 x 1.5 input yoke nut with Loctite® 277. Install the new washer and

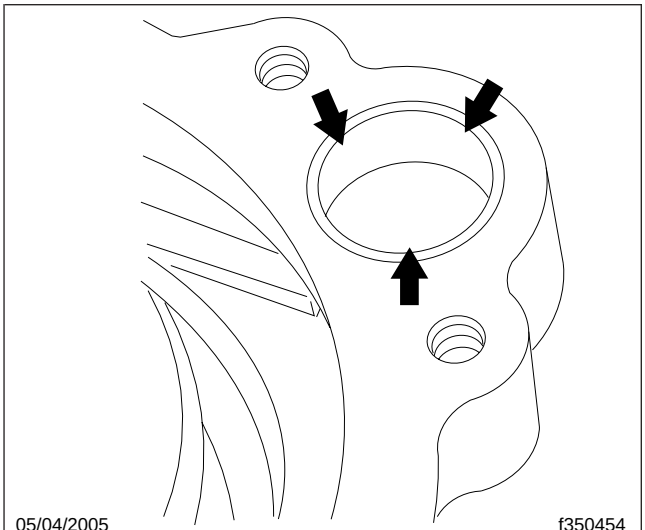
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Apply a bead of sealant to the inner mating surface as shown.

1. Inside Cover
2. Mounting Capscrew Hole
3. Interaxle Lock Bore
4. Sealant
5. Mating Surface

Fig. 3, Sealant Application



Keep sealant away from this bore.

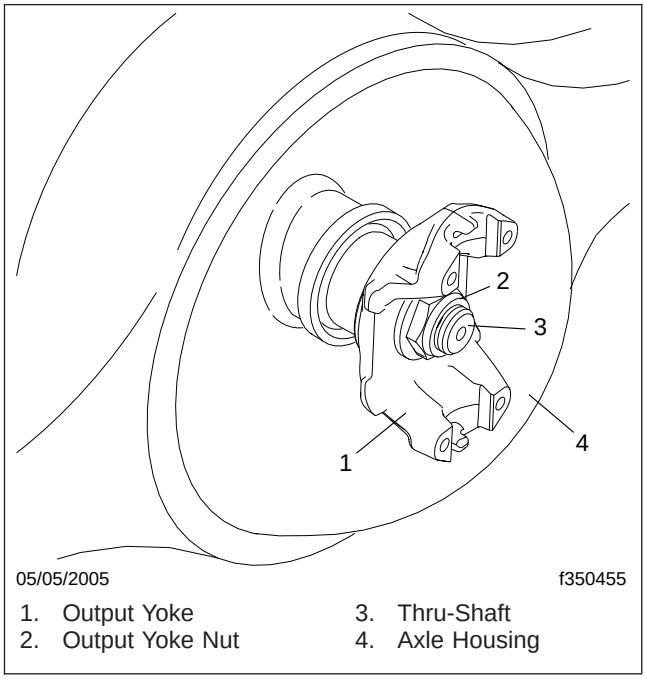
Fig. 4, Interaxle Lock Bore

input yoke nut on the forward carrier input yoke. Tighten the nut 627 lbf·ft (850 N·m).

12. Connect the main driveshaft; see **Section 41.00, Subject 120**.

Output Yoke and Seal

1. Disconnect the interaxle driveshaft from the output yoke; see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
2. Remove the output yoke nut and washer from the center of the output yoke.
3. Remove the output yoke from the thru-shaft. See **Fig. 5**.



1. Output Yoke
2. Output Yoke Nut
3. Thru-Shaft
4. Axle Housing

Fig. 5, Output Yoke

4. Pry up the output oil seal, using a prybar or large screwdriver. Clean any old sealant from the axle housing. Do not allow dirt or grease to contaminate the seal bore or thru-shaft bearings.
5. Install the seal on the thru-shaft, as follows.

   5.1 Inspect the area around the output oil seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

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Forward-Rear Axle Yoke and Seal Replacement

5.2 Assemble the output seal installer onto the threaded end of the universal handle. See **Table 1**.

5.3 Using the output seal installer assembly, press the seal into the bore until the seal surface is flush with the thru-shaft receptacle.

6. Install the output yoke on the thru-shaft. If the yoke is damaged or worn, install a new yoke.

NOTE: It is not necessary to replace the yoke when replacing the seal.

7. Coat the threads of a new M39 x 1.5 output yoke nut with Loctite® 577. Install the new washer and output yoke nut on the forward carrier output yoke. Tighten the nut 516 lbf·ft (700 N·m).
8. Connect the interaxle driveshaft; see **Section 41.00, Subject 120**.

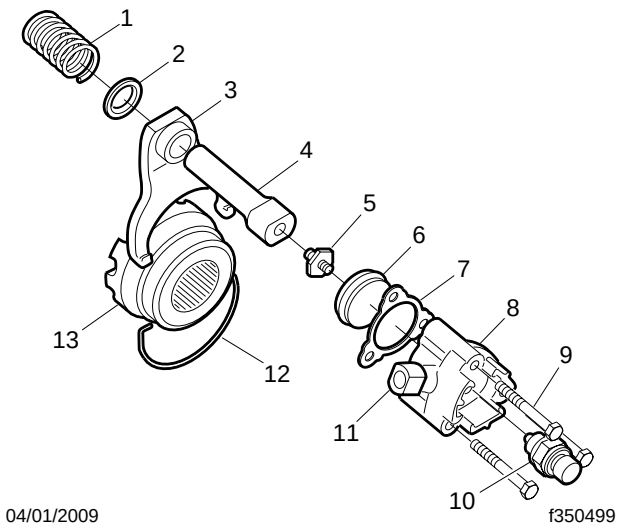
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Main Differential Lock Disassembly and Assembly, Model 2 Axles

General Information

Commonly known as DCDL (Driver-Controlled Differential Lock), a main differential lock is available on single and tandem rear axles. The following procedures only apply to Model 2 rear axles equipped with the optional DCDL.

Each part of the main differential lock is replaceable. See **Fig. 1**.



1. Spring
2. Spacer
3. Shift Fork
4. Shift Shaft
5. Adjustment Screw (with locknut)
6. Piston (with O-Ring)
7. Gasket
8. Differential Lock Cover
9. Capscrew
10. DCDL Control Switch
11. Air Interface Connection
12. Retaining Clip
13. Clutch Collar

Fig. 1, DCDL Components, Model 2 Axles

Disassembly

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires.
2. Remove the differential carrier, and place it on a work stand.

   To remove a Model 2 axle differential carrier, see **Subject 110**.
3. Remove the capscrews that attach the differential lock cover to the carrier housing. See **Fig. 1**.
4. Remove the DCDL control switch.
5. Remove the differential lock cover (including the air interface connection).
6. Remove the gasket, piston, and adjustment screw.
7. Unlatch the retaining clip, and remove it.
8. Remove the clutch collar.
9. Carefully remove the shift shaft from the bore in the carrier housing.
10. Due to spring tension, carefully remove the shift fork, spacer, and spring from the carrier housing.

Assembly

1. Install the spring in the carrier housing, and compress it to install the spacer and shift fork in the housing. Ensure that the spring is centered in the bore.
2. Install the shift shaft into the bore in the carrier housing and through the shift fork, spacer, and spring, being careful to properly align it in the bore. Do not force the shift shaft into the bore.
3. Install the clutch collar, and secure it by installing the retaining clip on the shift fork.
4. Install the adjustment screw as follows.

   4.1 Press the shift shaft in until the clutch collar teeth are fully engaged with the ring gear.

   4.2 Install the adjustment screw, and tighten it until the outer end of it is 0.02 – 0.06 inch (0.5 – 1.5 mm) below the top of the bore in the carrier housing. The screw advances 0.04 inch (1.0 mm) per full revolution, so one complete turn should be sufficient. Use an inside micrometer or depth micrometer to measure the gap.

   4.3 Hold the shift shaft and adjustment screw in a fixed position, and tighten the locknut on the adjustment screw to 18 lbf·ft (24 N·m).
5. Grease the o-ring on the piston.
6. Place the gasket on the differential lock cover, and press the flat side of the piston into the differential lock cover.

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Main Differential Lock Disassembly and Assembly, Model 2 Axles

7. Place the differential lock cover over the capscrew bores in the carrier housing, and install the DCDL control switch. Tighten the nut 21 lbf·ft (28 N·m).
8. Install the differential lock cover, and in a regular sequence that seats the cover evenly, tighten the capscrews 18 lbf·ft (24 N·m).
9. Connect the DCDL air line, and engage the DCDL. Ensure the teeth of the lock fully engage the teeth of the gear inside the carrier housing.
10. Install the differential carrier; for instructions, see **Subject 110**.

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Main Differential Lock Disassembly and Assembly, Model 4 Axles

Special Tool

A special tool is required for this procedure. See **Table 1**.

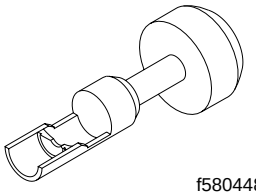
Special Tool for Main Differential Lock Disassembly and Assembly			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580448	Spring Compression Tool	Axle Alliance Special Tool	W742 589 00 16 00

Table 1, Special Tool for Main Differential Lock Disassembly and Assembly

General Information

Commonly known as DCDL (Driver-Controlled Differential Lock), a main differential lock is available on single and tandem rear axles. On tandem rear axles DCDL is available for the forward, rear, or both axles. The following procedures only apply to Model 4 rear axles with optional DCDL.

Each part of the main differential lock is replaceable. See **Fig. 1**.

Disassembly

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires.
2. Remove the differential carrier, and place it on a work stand.

   To remove a single or rearmost axle differential carrier, see **Subject 110**.

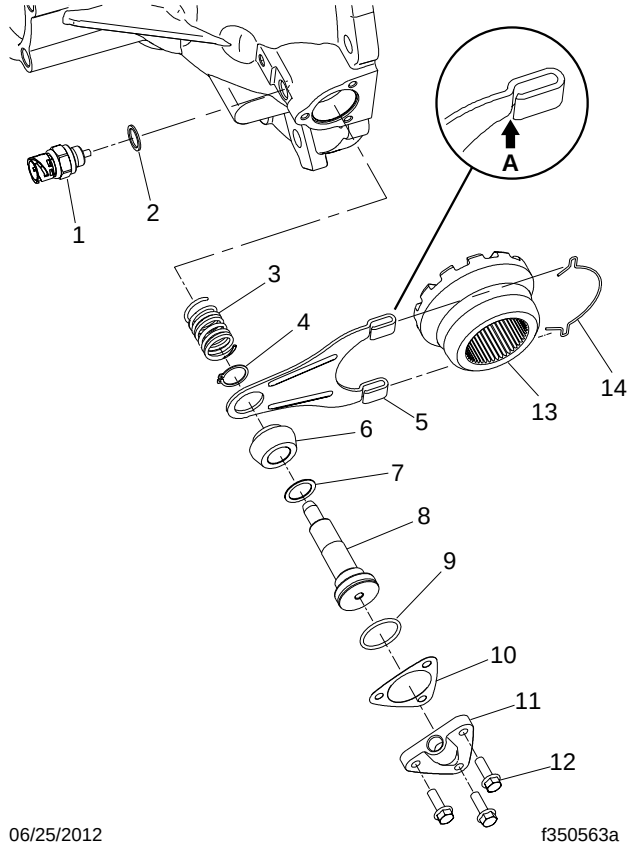
   To remove a forward-rear differential carrier, see **Subject 150**.
3. Unlatch the retaining clip, and remove it. See **Fig. 1**.
4. Remove the clutch collar.
5. Remove the DCDL sending unit from the carrier housing.
6. Remove the three bolts that attach the air interface to the carrier housing.
7. Remove the air interface and gasket.
8. Remove the shift shaft piston from the bore in the carrier housing, and note the number of shims found on the piston. There should be at least one shim, and a maximum of three.
9. Using the spring compression tool (see **Table 1**), compress the spring and pull the shift fork from the carrier housing.
10. Remove the spring from the carrier housing.

Assembly

1. Install the spring in the carrier housing, and, using the spring compression tool, compress it to install the shift fork in the housing. Ensure that the spring is centered in the bore.
2. Ensure the O-ring on the shift shaft piston is properly installed and lubricated. Then install the piston, being careful to properly align it in the bore. Do not force the piston into the bore.
3. Place the air interface and gasket over the air interface bore, and insert the three capscrews that attach the air interface to the carrier housing. Tighten the capscrews in a regular sequence that ensures it seats evenly. Tighten the capscrews 19 lbf·ft (25 N·m).
4. Install the clutch collar.

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Main Differential Lock Disassembly and Assembly, Model 4 Axles



A. Opening in fork loop faces away from the clutch collar as shown.

1. Sending Unit
2. Sending Unit Seal
3. Spring
4. Snap Ring
5. Shift Fork
6. Alignment Boss
7. Shim(s)
8. Shift Shaft Piston
9. O-Ring
10. Air Interface Gasket
11. Air Interface
12. Capscrew
13. Clutch Collar
14. Retaining Clip

Fig. 1, DCDL Components, Model 4 Axles

5. Install the retaining clip on the shift fork.
6. Install the DCDL sending unit in the carrier housing, as removed.
7. Connect the DCDL air line, and engage the DCDL. Ensure the teeth of the lock fully engage the teeth of the gear inside the carrier housing.
8. The clearance between the clutch collar and ring gear must be between 0.4 and 1.4 mm. Engage the DCDL, and use a feeler gauge to measure the gap.

   If the gap between the clutch collar and ring gear measured between 0.4 and 1.4 mm, ensure the same number of shims are on the shift shaft piston (as when it was removed).

   If the gap between the clutch collar and ring gear was not between 0.4 and 1.4 mm, add or remove shims to vary the gap until it measures within the acceptable range. The acceptable maximum number of shims is three, and the minimum is one.
9. Install the differential carrier.

   For instructions on installing a single or rearmost axle differential carrier, see **Subject 110**.

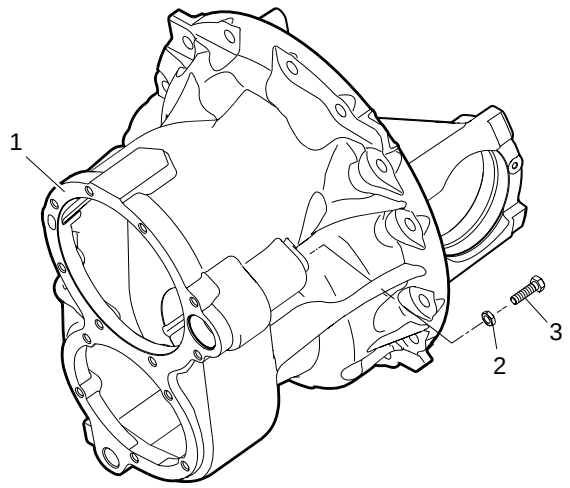
   For instructions on installing a forward-rear axle differential carrier, see **Subject 150**.
10. Remove the chocks.

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Adjustment

The Interaxle Differential (IAD) has an adjustment screw that can become loose or even fall out, causing an oil leak, and malfunction of the IAD. To ensure the adjustment screw is properly tightened and secured, follow the steps below. The IAD is sometimes called the power divider. See **Fig. 1**.

1. Chock the front tires.
2. Use the IAD switch in the cab to engage the lock.
3. Using a suitable jack, raise the vehicle until the tires are off the ground.
4. Support the vehicle with safety stands.
5. At the forward-rear axle, rotate one of the wheels to ensure the teeth of the lock fully engage the teeth of the gear inside the carrier housing.
6. Remove the adjustment screw, and using a suitable solvent (such as brake cleaner), clean the threads of the screw and bore. Dry the surfaces completely, making sure no cleaning solvent remains.
7. Coat the threads of the adjustment screw with Loctite® 577, install it, and hand-tighten it until it hits the shaft.
8. Disengage the IAD to relieve the air pressure exerted on the adjustment screw.
9. Hand-tighten the adjustment screw one quarter turn, then tighten the locknut 30 lbf·ft (41 N·m).
10. Raise the vehicle, remove the safety stands, then lower the vehicle.



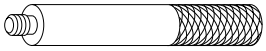
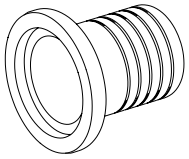
1. Carrier Housing
2. Lock Nut
3. Adjustment Screw

Fig. 1, Interaxle Differential and Adjustment Screw

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Special Tools

Special tools are required for this procedure. See **Table 1**.

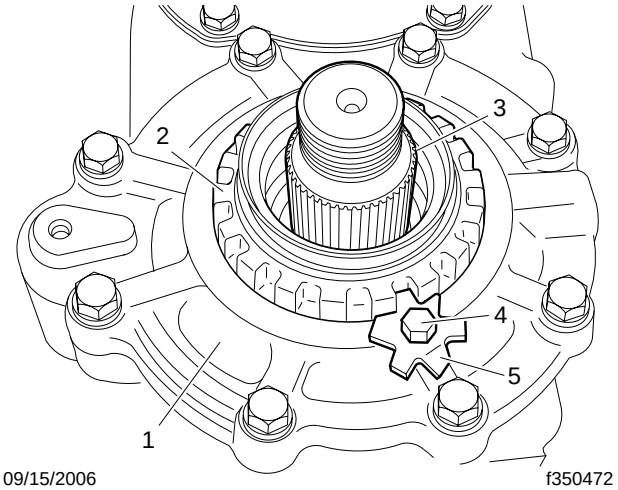
Special Tools for Threaded Ring Repair			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580410	Input Seal Installer*	Kent-Moore	J-47369

* To order Kent-Moore tools call 1-800-328-6657.

Table 1, Special Tools for Threaded Ring Repair

Repair

1. Apply the parking brakes, shut down the engine, and chock the tires.
2. Disconnect the main driveshaft from the forward carrier input yoke. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
3. Remove the yoke nut and washer from the input shaft of the forward differential carrier, then remove the yoke.
4. Remove the capscrew and the locking plate from the bearing cage on the front of the differential carrier. See **Fig. 1**.
5. Using a spanner wrench, remove the threaded ring to expose the bearing cavity. See **Fig. 2**.
6. Using a suitable solvent, such as brake cleaner, clean the surface of the bearing cavity. See **Fig. 2**. Dry the surface, making sure no cleaning solvent remains.
7. Coat the threads of the threaded ring with Loctite® 577 sealant. Apply a 1/8-inch (3-mm) diameter bead all the way around the bottom thread, then spread the sealant evenly over the threads, so that all threads are thoroughly covered with the sealant.

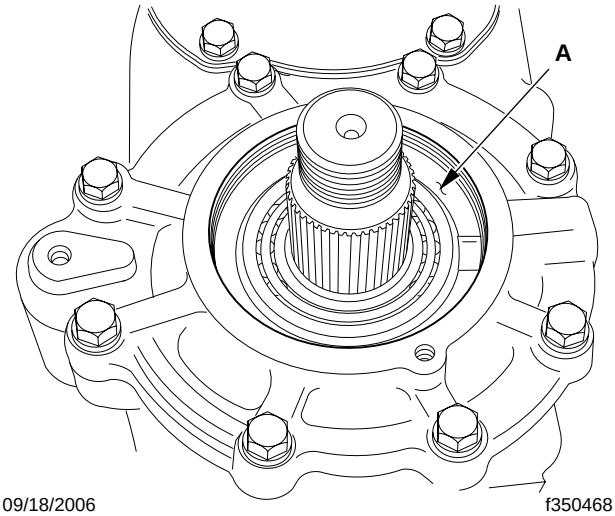


1. Bearing Cage
2. Threaded Ring
3. Input Shaft (yoke removed)
4. Capscrew
5. Locking Plate

Fig. 1, Forward-Rear Axle Differential Housing

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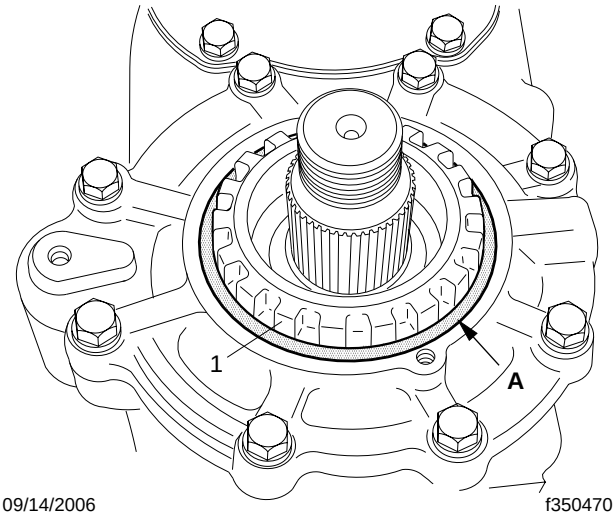
Threaded Ring Repair



A. Clean and dry this entire surface.

Fig. 2, Bearing Cavity Exposed

8. Install the threaded ring (without the new input-shaft seal) and turn it clockwise (tighten it) enough to form a uniform bead of sealant all the way around the threaded ring. See **Fig. 3**.

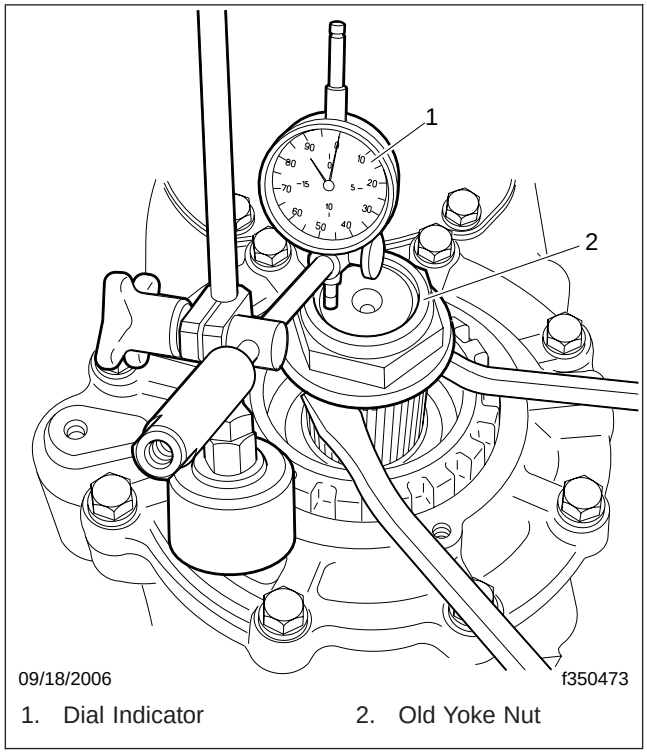


A. Loctite Bead from the Threads

1. Threaded Ring

Fig. 3, Preliminary Installation of the New Threaded Ring

9. Install the old yoke nut on the input shaft to protect the threads, then strike the nut sharply with a brass mallet to unseat the bearing.
10. Adjust the initial bearing preload to 0.002 inch (0.05 mm), as follows:
    10.1 Install a dial indicator on the bearing cage, and using two pry bars, pry up evenly on the yoke nut (and the input shaft) to determine the bearing preload. See **Fig. 4**.



1. Dial Indicator
2. Old Yoke Nut

Fig. 4, Measuring Bearing Preload

    10.2 Tighten the threaded ring until the dial indicator reads 0.002 inch (0.05 mm).
11. Using a suitable marker or paint, mark the center of one of the teeth on the threaded ring and the surface of the bearing cage. See **Fig. 5**.

IMPORTANT: The next step is critical. Tightening the threaded ring by advancing it one tooth will set the bearing preload to 0.00 to 0.0012 inch (0.00 to 0.03 mm). If you tighten the threaded ring beyond this tolerance, you cannot back it off; you will need to remove the threaded ring and repeat the entire installation procedure.

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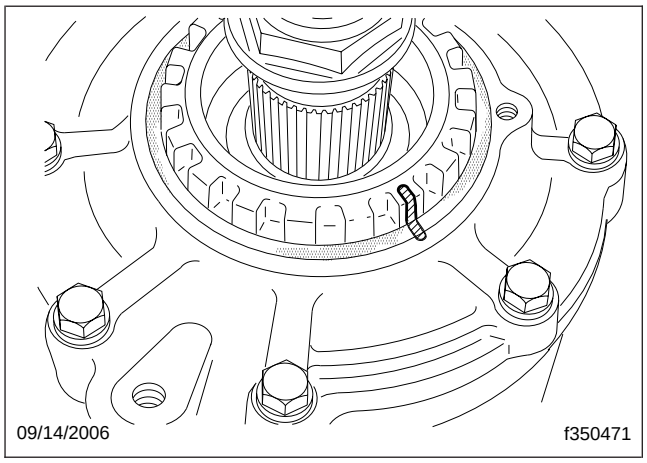


Fig. 5, Marking the Tooth and Bearing Cage

12. Very carefully advance the threaded ring one tooth while checking the paint mark. Stay close to a one-tooth advancement when making the final adjustment. Bear in mind that the new locking plate must fit into place once the correct tightness is achieved. The locking tab should fit in place either slightly before or slightly past a one-tooth advancement of the threaded ring. *You cannot back off the threaded ring once it is tightened.*

    Try fitting the new locking plate in place by turning and flipping it over as you slowly tighten the threaded ring. Tighten the threaded ring so the bearing preload is 0.00 to 0.0012 inch (0.00 to 0.03 mm). When the correct tolerance is reached, the mark on the surface of the bearing cage should line up with the center of the next tooth. See **Fig. 6**. Do not tighten the threaded ring any further.

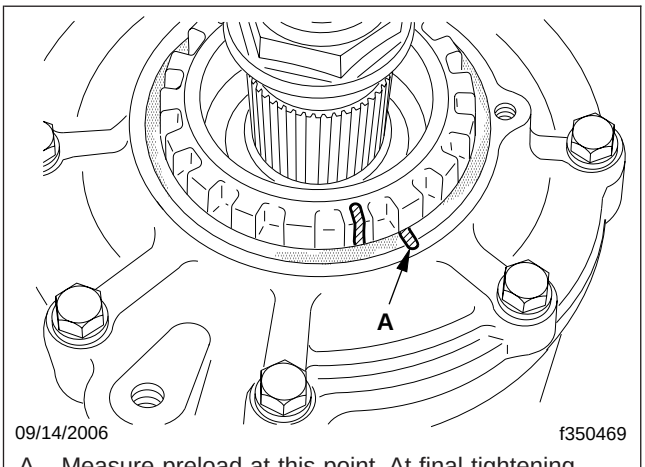
13. When the bearing preload is correct, install the new locking plate and capscrew. Tighten the capscrew 18 lbf·ft (24 N·m).

14. Install the new input-shaft seal as follows (see **Fig. 7**):

    14.1 Inspect the area around the seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

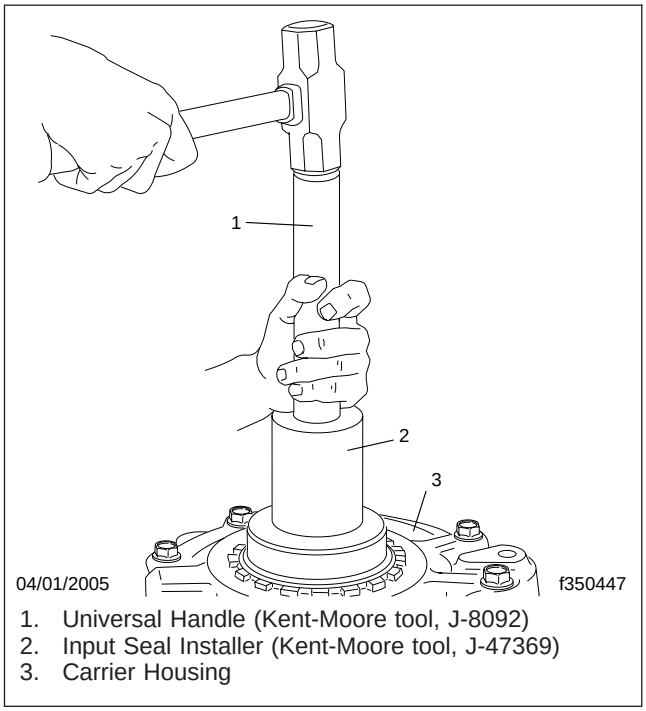
    14.2 Apply a light coating of axle oil to the seal bore.

    14.3 Coat the mating surfaces of the new seal with Loctite® 5900 sealant, or equivalent.



A. Measure preload at this point. At final tightening, this mark should be opposite the center of the next tooth, but no further.

Fig. 6, Advancing the Threaded Ring



1. Universal Handle (Kent-Moore tool, J-8092)
2. Input Seal Installer (Kent-Moore tool, J-47369)
3. Carrier Housing

Fig. 7, Installing the Forward Carrier Input Seal

14.4 Assemble the input shaft seal installer onto the threaded end of the universal handle. See **Fig. 7**.

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Threaded Ring Repair

14.5 Using the input shaft seal installer assembly, press the seal into the bore until the seal surface is flush with the threaded ring.

15. Apply Loctite 242 to the threads of the new yoke nut, then using it and a new washer, install the existing yoke on the input shaft. Tighten the yoke nut 628 lbf·ft (850 N·m).
16. Connect the main driveshaft to the input shaft. For instructions, see **Section 41.00, Subject 120**.
17. Remove the chocks.

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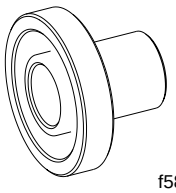
Specifications

Torque Values		
Application	**Size**	**Torque: lbf·ft (N·m)**
Detroit Axles (all models)		
Carrier Capscrews	M12	115 (156)
	M16	200 (270)
Drive Axle Stud Nuts	1/2–20	75–115 (102–156)
	5/8–18	150–170 (203–230)
Pinion Nut (Model 2 axles)	M40 x 1.5	370 (500)
Pinion Nut (Model 4 axles)	M45 x 1.5	627 (850)
Tandem Forward Axles (Model 4 only)		
Bearing Cage Capscrews	M12	107 (145)
Input Yoke Nut	M45 x 1.5	627 (850)
Output Yoke Nut	M39 x 1.5	516 (700)

Table 1, Torque Values

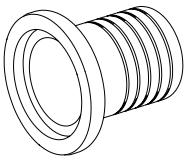
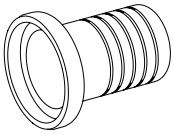
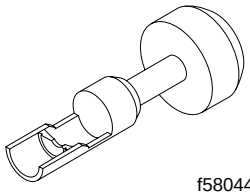
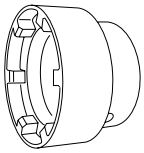
Single Rear Axle Oil Type and Capacity				
Model	**Approved Oil Type**		**Capacity: quarts (liters)**	
	Mineral	**Synthetic**	**Hubs Full**	**Hubs Dry**
Model 2	80W-90	75W-90	5.8 (5.5)	7.4 (7.0)
Model 4			10.6 (10.0)	12.2 (11.5)

Table 2, Single Rear Axle Oil Type and Capacity

Special Tools for Detroit Rear Axles			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580406	Rear Pinion Seal Installer*	Kent-Moore	J-47354

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Specifications

Special Tools for Detroit Rear Axles			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580410	Input Seal Installer*	Kent-Moore	J-47369
 f580408	Output Seal Installer*	Kent-Moore	J-47368
 f580448	Spring Compression Tool	Axle Alliance Special Tool	W742 589 00 16 00
 f580450	Yoke Nut Socket†	Daimler	MBA 742589020700

* To order Kent-Moore tools call 1-800-328-6657.

† The yoke nut socket is needed to remove the round, slotted yoke nut installed on some vehicles. It can be ordered through Paragon.

Table 3, Special Tools for Detroit Rear Axles

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General Information

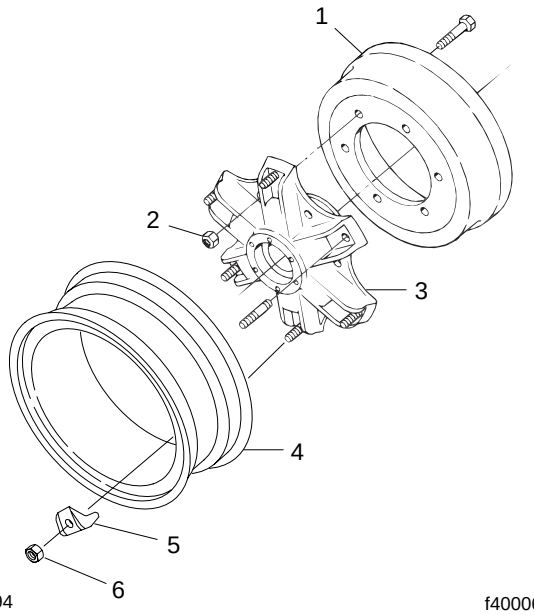
WHEELS AND TIRES

The tires support the weight of the vehicle, and are integral parts of the drivetrain and braking systems. The wheels serve as load carrying members between the tires and the axle.

There are two types of wheels: spoke and disc.

Spoke wheels consist of a wheel and brake drum assembly installed on the axle and a tire and rim assembly that mounts on the wheel. See **Fig. 1**. Rim clamps and rim nuts hold the tire and rim assembly in place.

Disc wheels consist of a rim and disc. The rim, the portion of the wheel on which the tire is mounted and supported, is welded to the disc. See **Fig. 2**. After the tire is mounted on the wheel, the assembly is held in place on the hub with wheel studs and nuts.

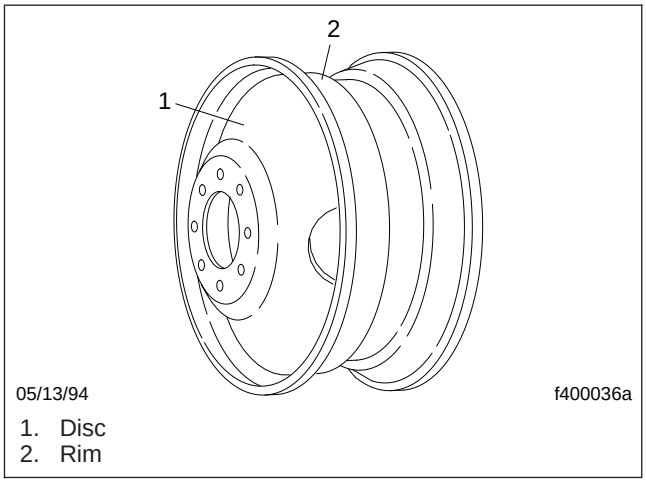


1. Brake Drum
2. Brake Drum Nut
3. Spoke Wheel
4. Rim Base
5. Rim Clamp
6. Rim Nut

Fig. 1, Spoke Wheel and Brake Drum Assembly

Eight-hole and ten-hole (single and dual) disc wheels are centered by pilot pads and are held in place on the hub with two-piece flange nuts.

Tires are constructed of radial plies. Radial tires have ply cords that run from bead to bead, and at a right angle to the belt plies and tire tread See **Fig. 3**. The belt plies constrict the radial ply cords and give rigidity to the tread.



1. Disc
2. Rim

Fig. 2, Disc Wheel

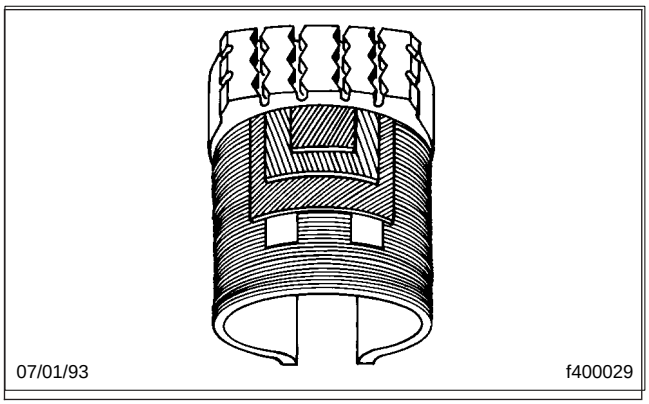


Fig. 3, Radial Ply Tire Construction

Tire body plies, breakers, and belts are made of polyester, rayon, nylon, fiberglass, steel, or aramids (fibrous reinforcements). In radial ply tires, these materials are used in various combinations, including steel body/steel belt, polyester body/fiberglass belt, or nylon body/steel belt.

Wheels and tires operate either with or without tubes. Tube-type tires require a tube and flap for correct assembly on a two-or three-piece rim See **Fig. 1**. Tubeless tires require only the tire and a one-piece drop-center wheel or rim. See **Fig. 2**.

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General Information

TIRE MATCHING AND MIXING

IMPORTANT: Review and follow these requirements for matching and mixing tires, before installing any tire and wheel or rim assembly on a vehicle.

Before changing wheels and tires, consider the effect that the change may have on the Gross Vehicle Weight Rating (GVWR) of the vehicle. At the time of vehicle certification, the GVWR is calculated by adding the vehicle's Gross Axle Weight Ratings (GAWR). The GVWR and each of the GAWRs are shown on a certification label (U.S.-purchased vehicles) or "Statement of Compliance" label (Canadian-purchased vehicles) attached to the left rear door post. See **Fig. 4**.

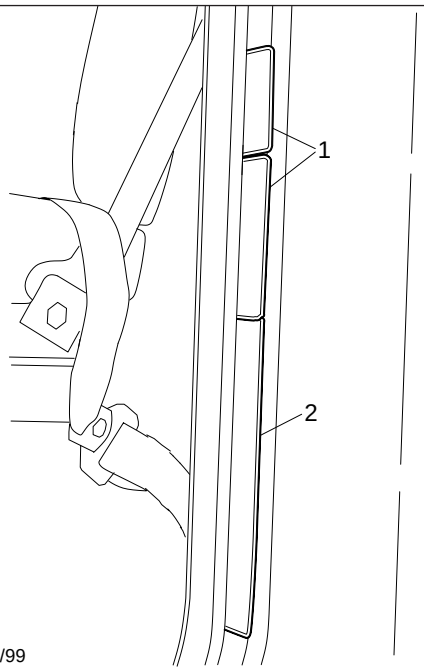
Tire and rim labels certify the minimum tire and rim combinations that can be installed on the vehicle for the given GAWRs. See **Fig. 4** and **Fig. 5**. Each GAWR is determined by considering each component of the axle system, including suspension, axle, wheels, and tires. The lowest component's capacity is the value used for the system. Therefore, the tires and rims installed on the vehicle at the time of vehicle manufacture may have a higher load capacity than that certified by the tire and rim label. Tires and rims of the minimum capacity can be installed without changing the load limitations. If tires and rims are installed that have a lower load capacity than that shown on the tire and rim label, then the tires and rims determine the load limitations (the GAWRs and GVWR will be lower).

When pairing tires in a dual assembly, the tire diameters must not differ by more than 1/4 inch (6.4 mm), or the tire circumference by more than 3/4 inch (19 mm).

CAUTION

Mismatching dual tires overloads the larger diameter tire, causing it to overdeflect and overheat. The smaller diameter tire, lacking proper road contact, wears faster and unevenly. Tread or ply separation, tire body breaks and blowouts can occur from mismatched duals.

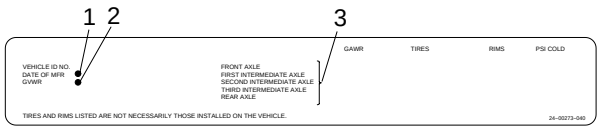
With an endless pi tape (**Fig. 6**) or square (**Fig. 7**), measure the diameter of the tires 24 hours after inflation. A matching stick (**Fig. 8**), string gauge (**Fig. 9**) or tire straight edge (**Fig. 10**) can also be used to determine the difference in tire radius, which is then doubled to calculate the diameter difference.



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1. Tire and Rim Labels
2. Certification Label

Fig. 4, Labels Location



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NOTE: Example only. Actual specifications may vary from vehicle to vehicle.

1. Date of manufacture by month and year.
2. Gross vehicle weight rating; developed by taking the sum of all the vehicle's gross axle ratings.
3. Gross axle weight ratings; developed by considering each component in an axle system, including suspension, axle, wheels, and tires. The lowest component capacity is the value for the system.

Fig. 5, Tire and Rim Label

When pairing tires of unequal diameters (but within the above limits), mount the larger tire on the outside.

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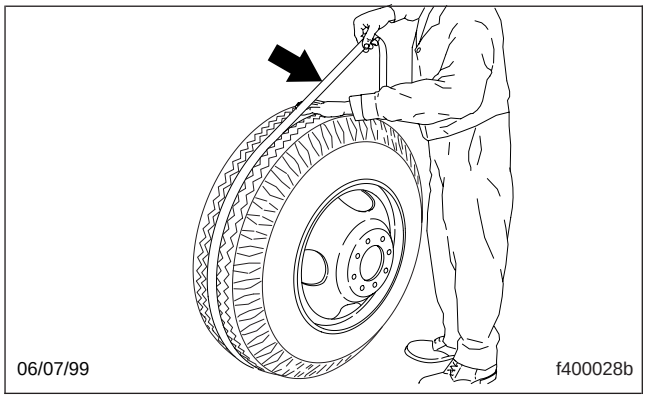


Fig. 6, Endless Pi Tape

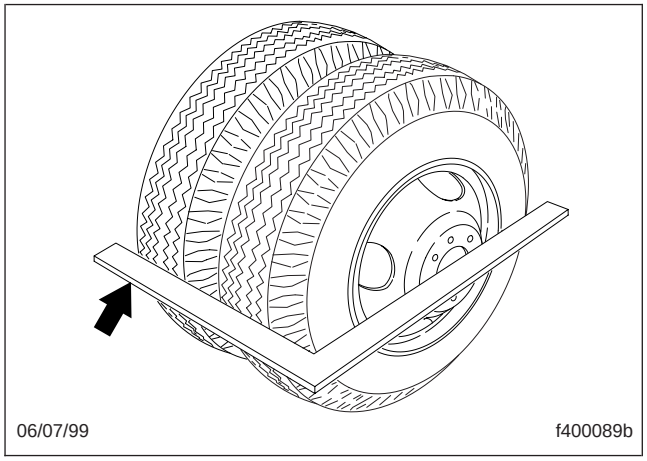


Fig. 7, Square

CAUTION

Driving a vehicle on one tire of a dual assembly dangerously exceeds the carrying capacity of the single tire and wheel. Operating in this manner can cause damage to the wheel and tire.

Inflate all tires on an axle to within 5 psi (35 kPa) of one another. For tire inflation specifications, see the applicable tables in **Specifications, 400**.

There must be sufficient space between dual tires for air to flow and cool the tires, and to prevent them from rubbing against one another. Rims and wheels of the same size, but of different makes and types, can have different offsets, which would affect dual spacing. If there is sidewall contact between tires, or between the inside tire and the chassis, see the tire manufacturer’s catalog to determine the minimum dual spacing. See the rim or wheel manufacturer’s catalog to determine the correct offset.

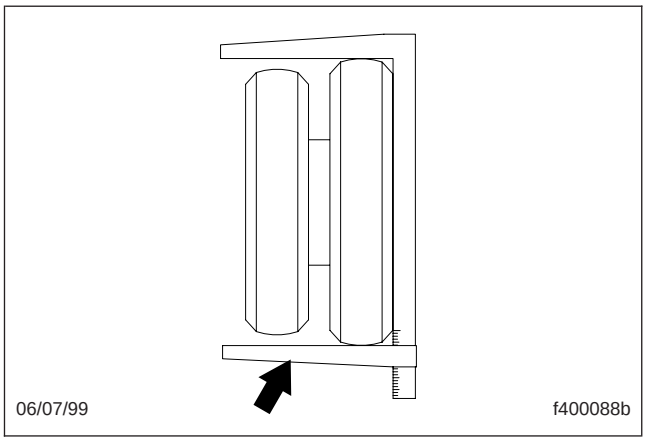


Fig. 8, Matching Stick

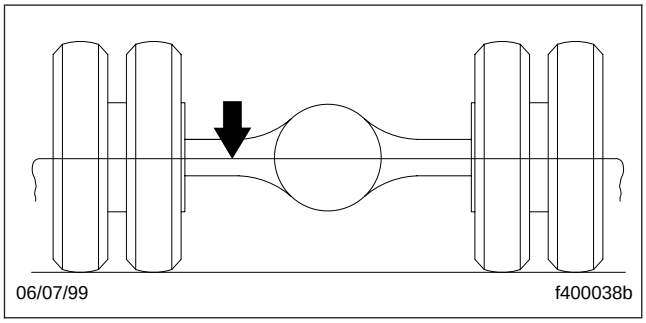


Fig. 9, String Gauge

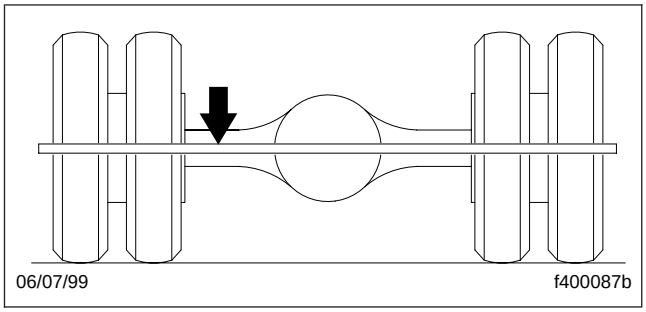


Fig. 10, Tire Straight Edge

Federal Motor Carrier Safety regulations require the removal of all tires with less than 4/32-inch (3-mm) remaining groove depth on a front axle and tires with less than 2/32-inch (1.5-mm) remaining groove depth on a rear axle. However, tires with the word "Re-groovable" on the sidewall may be regrooved.

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Disc Wheel Removal and Installation

Removal

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock all tires that will not be serviced.
2. If removing wheels and tires from the front axle, raise the front of the vehicle until the tires clear the floor. Place safety stands under the front axle.

   If removing wheels and tires from the rear axle, raise the rear of the vehicle until the tires clear the floor. Place safety stands under the axle being serviced.
3. If any of the following conditions apply, deflate the tire being serviced by removing the valve core. On a dual assembly, deflate both tires.
   - the wheel or tire is damaged
   - there is suspected damage
   - the tire has been run at 80 percent or less of its recommended operating pressure
4. Turn the hub until one hub-pilot pad is in the top-center position.
5. Place a jack or wheel-and-tire dolly under the wheel assembly being serviced.

CAUTION

Keep the wheel square to the hub during removal. The wheel center hole and hub pilot have close tolerances. If the wheel is not kept square to the hub, it could bind during removal and damage the stud threads or hub-pilot pads.

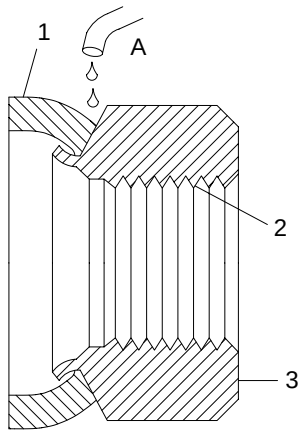
IMPORTANT: On both sides of the vehicle, the two-piece flange nuts have right-hand threads.

6. Leaving one top and one bottom nut to keep the wheel straight, remove the other eight two-piece flange nuts from the wheel. Then, remove the top and bottom nuts.
7. Remove the wheel. Do not let it drop on, or drag across, the stud threads.

Installation

NOTE: Before installing a wheel and tire assembly, inspect it using the instructions in **Subject 140**. Follow the tire matching and mixing requirements in **Subject 050**.

1. Clean the hub and wheel mounting surfaces, and all disc faces of dual wheels. Make sure the tire is correctly inflated. For instructions, see **Subject 160**.
2. Apply a few drops of light engine oil to the wheel studs and the area between the body and the flange of each two-piece flange nut. See **Fig. 1**. Wipe off any excess oil.



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NOTE: Apply oil here.
1. Flange
2. Nut Threads
3. Nut Body

Fig. 1, Lubricating a Two-Piece Flange Nut

CAUTION

Keep the wheel square to the hub during installation. The wheel center hole and hub pilot have close tolerances. If the wheel is not kept square to the hub, it could bind during installation and damage the stud threads or hub-pilot pads.

IMPORTANT: Before installing the wheels, make sure the drum is positioned on the raised step of the pilot pad. One of the hub's pilot pads must be at the top location. To help keep the drum in place, it may be necessary to adjust the brakes before installing the wheels.

3. Turn the hub until one hub-pilot pad is in the top-center position. Using a jack or wheel-and-tire

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Disc Wheel Removal and Installation

dolly, position the wheel assembly (inner wheel on a dual wheel assembly) on the hub. Make sure the wheel is square to the hub. Be careful not to damage the threads or hub-pilot pads. On rear axles, mount the outer wheel against the inner wheel using the same procedure.

4. Make sure the hub-pilot pad is still centered at the top.

IMPORTANT: Install the wheel assembly so that the balance weight(s) on the wheels are 180 degrees opposite the balance weight(s) on the brake drum. If this causes the valve stems to be in the same wheel hole on the rear wheel assemblies, mount the outer wheel so that the outer wheel balance weight(s) is on the same side as the brake drum balance weight(s).

5. Install and hand-tighten a two-piece flange nut on the top and bottom studs.

CAUTION

The two-piece flange nuts have right-hand metric threads. Do not try to install a similar size SAE nut on a stud or the stud and nut will be damaged.

6. Install and hand-tighten the remaining two-piece flange nuts. Tighten the nuts 50 lbf·ft (68 N·m) following the sequence in **Fig. 2** or **Fig. 3**.

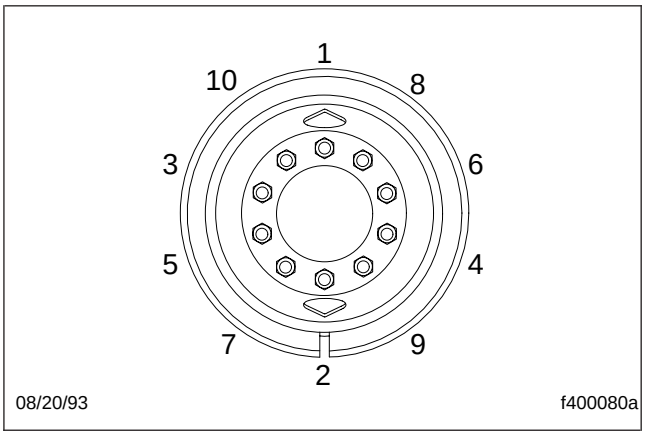


Fig. 2, 10-Stud Disc Wheel Tightening Sequence

7. Check that the wheel is correctly seated against the hub and on the hub-pilot pads.

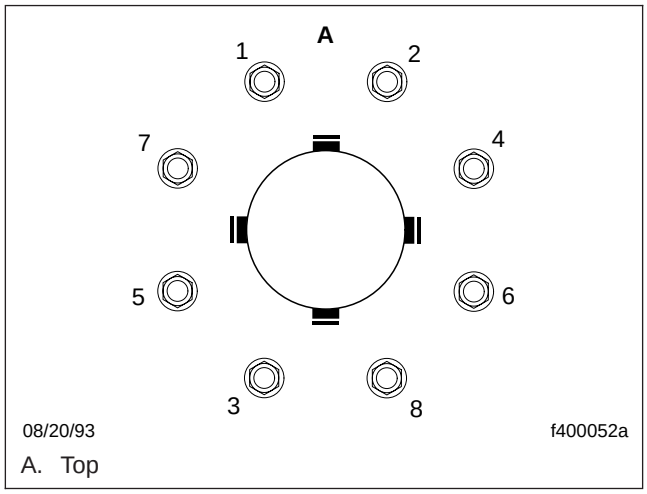


Fig. 3, 8-Stud Disc Wheel Tightening Sequence

8. Following the sequence in **Fig. 2** or **Fig. 3**, tighten the two-piece flange nuts 450 to 500 lbf·ft (610 to 678 N·m).

WARNING

If the wheel nuts cannot be tightened to minimum torque values, the studs could be turning in the hub flange, having lost their locking ability. In this case, the wheel hub assembly is damaged and must be replaced with a new assembly.

Failure to reach minimum torque values could also be caused by stripped threads on the wheel studs or wheel nuts. Damaged parts must be replaced with new parts. Failure to replace damaged parts could result in the loss of a wheel or loss of vehicle control, causing property damage or personal injury.

IMPORTANT: Replace damaged parts following the instructions in **Group 33** or **Group 35** in this manual.

NOTE: Nuts on double-threaded wheel studs should be tightened 390 to 450 lbf·ft (529 to 610 N·m).

9. Remove the safety stands, lower the vehicle, and remove the chocks from the tires.

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CAUTION

Too little wheel nut torque can cause wheel shimmy, wheel damage, stud breakage, and extreme tire tread wear. Too much wheel nut torque can break studs, damage threads, and crack discs in the stud hole area.

IMPORTANT: The two-piece flange nuts seat during vehicle operation. It is necessary to periodically tighten the wheel nuts to the specified torque. Tighten the two-piece flange nuts to the specified torque 50 to 100 miles (80 to 160 km) after service work and check the torque every 10,000 miles (16 000 km).

10. After operating the vehicle for 50 to 100 miles (80 to 160 km), retighten the wheel nut to the original specification. Follow the sequence in **Fig. 2** or **Fig. 3**.

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Spoke Wheel, Tire and Rim Assembly Removal and Installation

Removal

1. Park the vehicle on a level surface. Shut down the engine.
2. Chock all tires that will not be serviced, to prevent vehicle movement. If removing tire and rim assemblies from the front axle, apply the parking brake.
3. Raise the end of the vehicle being serviced until the tires clear the floor. Place safety stands under the axle being serviced.
4. Deflate the tire(s) being serviced by removing the valve core(s).
5. Place a jack or wheel-and-tire dolly under the tire and rim assembly being serviced (outer tire and rim assembly on rear axle). Remove the rim nuts and clamps. Slide the tire and rim (outer tire and rim on rear axle) off the wheel.
6. On rear axles only, remove the rim spacer. Place a jack or wheel-and-tire dolly under the inner tire and rim assembly and slide it off.

Installation

NOTE: Before installing a wheel and tire assembly, inspect it using the instructions in **Subject 140**. Also, follow the tire matching and mixing requirements in **Subject 050**.

1. Clean the wheel, rim spacer and rim mounting surfaces. The mounting surface of the wheel is the 28-degree taper on the inboard side of each spoke. See **Fig. 1**.

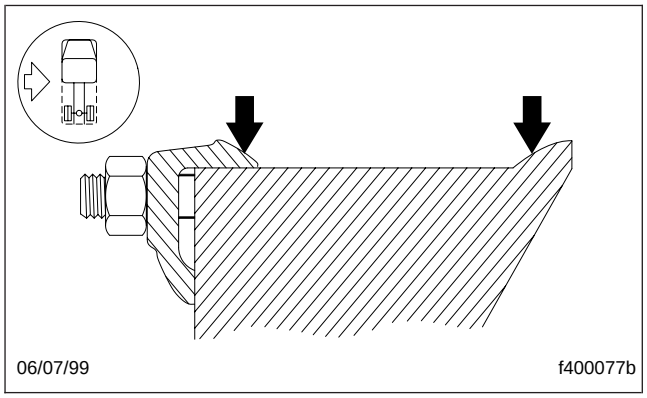
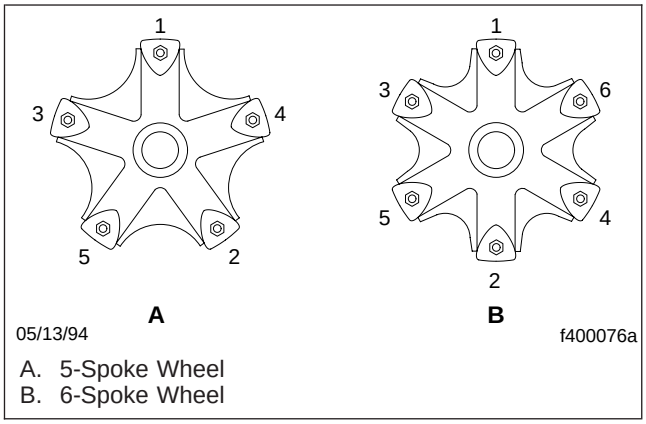


Fig. 1, 28-Degree Tapered Rim Mounting Surfaces

2. Make sure the tire and rim assembly is inflated using the procedures in **Subject 160**.
3. Slide the assembly over the wheel and push it into place against the tapered mounting surface. It should fit snugly against all the tapers. Be sure that the valve stem faces out and is centered between two spokes.
4. Install the rim clamps and nuts. Run the nuts up until the end of each wheel stud is flush with the face of its nut. Rotate the wheel a half turn to seat the parts.
5. Tighten the rim nuts a quarter turn at a time, following the star pattern shown in **Fig. 2**. Continue until all the rim nuts are tightened to the required torque value. See the applicable torque table in **Specifications, 400**.



A. 5-Spoke Wheel
B. 6-Spoke Wheel

Fig. 2, Spoke Wheel Tightening Sequence

WARNING

If the wheel nuts cannot be tightened to minimum torque values, the studs could be turning in the hub flange, having lost their locking ability. In this case, the wheel hub assembly is damaged and must be replaced with a new assembly.

Failure to reach minimum torque values could also be caused by stripped threads on the wheel studs or wheel nuts. Damaged parts must be replaced with new parts, as described in Group 33 or Group 35 in this manual. Failure to replace damaged parts could result in the loss of a wheel and loss of vehicle control, causing property damage or personal injury.

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Spoke Wheel, Tire and Rim Assembly Removal and Installation

CAUTION

Failure to tighten the nuts in the sequence shown and to the correct torque could cause misalignment of the tire and chording of the rim. See Fig. 3. This would result in excessive vehicle vibration and permanent damage to the rim and wheel.

IMPORTANT: On rear tire and rim assemblies, the clamps must not bottom out until at least 80 percent of the recommended torque is reached. If the clamps do bottom out, make sure the correct clamps and rim spacers are being used. Make sure the rim edges contact the spacer edges.

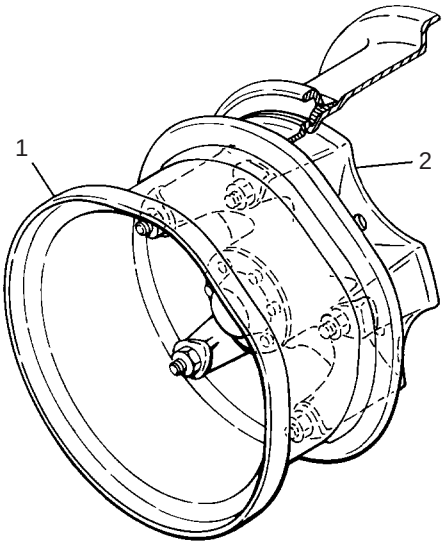
NOTE: When replacing a spoke wheel, contact the wheel manufacturer for the correct torque value for the brake drum nuts attaching the spoke wheel to the brake drum.

6. Check the wheel alignment by placing a block of wood or any other point of reference on the floor next to the tire. Rotate the tire and note any variations in the space between the tire and the block. If the variation exceeds 1/16 inch (1.5 mm) for front rims, or 1/8 inch (3 mm) for rear duals, the rim is not correctly mounted.

   To correct any misalignment, loosen the rim nuts where the largest gap occurs, and tighten the nuts on the opposite side. Recheck and correct until the variation is corrected. Make sure the rim nuts are tightened to the correct. See the applicable torque table in **Specifications, 400**.

7. Remove the safety stands, lower the vehicle and remove the chocks.

8. After operating the vehicle for 50 to 100 miles (80 to 160 km), retighten the rim nuts to the torque specified in the applicable table in **Specifications, 400**. Follow the sequence shown in **Fig. 2**.



1. Rim
2. Spoke Wheel

Fig. 3, Out-of-Round Rim (Rim Chording)

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Tire Demounting and Mounting Service Precautions

Safety Precautions

IMPORTANT: Do not mount or demount tires without proper training as required in Occupational Safety and Health Administration (OSHA) Rules and Regulations 1910.177, *Servicing Multi-Piece and Single Piece Rim Wheels*. Service information containing mounting and demounting instructions are available through your rim supplier. Charts detailing service procedures are available through OSHA area offices. The address and telephone number of the nearest OSHA area office can be obtained by looking in the local telephone directory under U.S. Government, Labor Department of Occupational Safety and Health Administration.

Use the information from the above sources with the following precautions before and during the demounting and mounting of tires:

- Examine all wheel and tire parts as explained in **Subject 140** and **Subject 150**. Replace damaged, rusted or worn parts.
- Since wheels and rims are under stress and are dangerous if improperly assembled, be sure all parts of an assembly match in size, manufacturer and classification within a manufacturer's line. Before assembling the wheel or rim, check the catalog issued by the wheel or rim manufacturer for the correct part numbers and sizes of approved parts. Never use a part that does not bear clear, legible and correct numbers and manufacturer's identification, even if that part appears to fit.
- Make sure that tires are stored indoors or outdoors under cover to prevent water collecting inside the tire.
- Use special tools, as recommended by tire suppliers, for mounting and demounting tires. These tools must be smooth and used with care to avoid gouging the rim.
- Loosening tire beads may be difficult, since considerable force may be needed. The use of a machine designed for loosening tire beads is recommended.
- Handle the wheels and rims on a wooden floor or rubber mat to prevent nicking or gouging the wheel or rim.
- Do not use a duck-bill hammer or any steel hammer on wheel or rim parts. Use rubber, leather-faced or plastic mallets to tap parts together, if necessary.
- Lubricate the tire with an approved tire-mounting lubricant. Never use antifreeze, silicones, petroleum-based lubricants or any flammable material (ether/starting fluid).
- When lubricating a tire prior to mounting, make sure excess lubricant does not run into the tire.
- Michelin Tire Corporation recommends applying lubricant to the valley of the tire, formed by the tire and rim, before using tools to break the bead.
- Michelin also recommends applying a sufficient but sparing amount of lubricant to the entire rim face when mounting a tire on a rim to ensure correct bead seating and ease of mounting.
- Balance the tire and wheel or rim assembly before installing the assembly on a vehicle.
- Do not reinflate a tire that has been run flat or has been run at 80 percent or less of its recommended operating pressure. Use your spare. Before removing the low tire from the vehicle, make sure it is completely deflated. Have the assembly taken apart and all the parts checked for damage, including the side or lockrings.
- The air pressure contained in a tire is dangerous. When servicing a tire, stay out of any potential path or route that a rim wheel component may travel during an explosive separation.

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Demounting and Mounting Tubeless Tires

Demounting

⚠ WARNING

Read the information in Subject 120. Failure to follow the precautions before and during tire demounting and mounting could cause tire or rim damage while servicing or in use. An incorrectly mounted tire can burst causing equipment damage and personal injury.

1. Deflate the tire being serviced by removing the valve core. Check the valve stem by running a piece of wire through the stem to make sure it is not plugged.
2. Loosen both beads from the rim by driving the flat end of the tire tool between the tire bead and the rim flange. Holding the tool upright, hammer on the neck to free the tire bead from the rim. See **Fig. 1**. Repeat at 8-inch (20-cm) intervals around the flanges until both beads are free from the rim.
3. Place the wide side of the rim down. Lubricate the tire bead and the rim. Insert the curved end of two tire tools between the bead and the rim, and just to one side of the tire valve. Step on the side of the tire, opposite from the valve, to force the first bead into the rim well. See **Fig. 2**. Hold one of the tools in place with your foot and pry with the second tool, forcing the bead over the rim flange. Continue to work the first bead off of the rim.
4. When the first bead is off the rim, and the second bead is in the rim well, stand the assembly upright with the valve stem near the top. Lubricate the second bead and rim. Insert the straight end of the tool between the tire bead and the back rim flange, hooking the tool over the second flange. Lean the tire assembly toward the tool and use a rocking or bouncing action to pry the rim out of the tire. See **Fig. 3**.
5. Clean and inspect all parts. See **Subject 140** and **Subject 150** for procedures.

Mounting

1. Place the valve stem, with a rubber washer, through the valve hole from the tire side of the rim. Screw on the valve nut from the opposite side. Make sure the rubber bushing and metal collar or nut are centered and fit snugly in the valve hole. See **Fig. 4**. Tighten the nut securely.
2. Place the rim on the floor with the wide side down. Using a brush or swab, lubricate both bead seats (flanges) of the rim, and both tire beads, with an approved lubricant. Apply enough lubricant to enable correct bead seating, and to make mounting easier. Do not let excess lubricant run inside the tire.

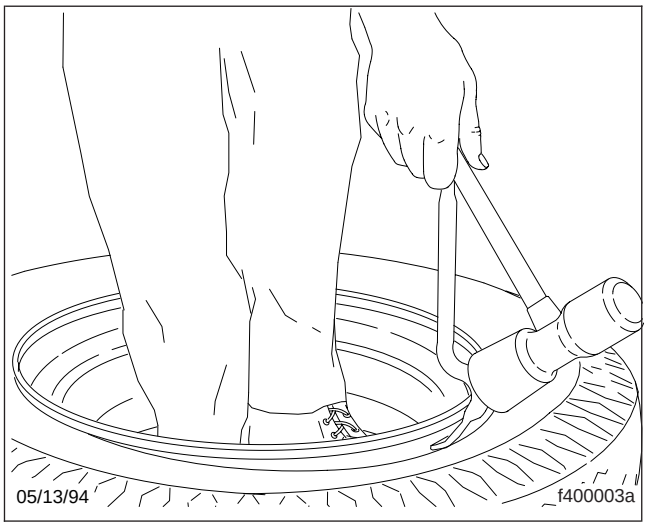


Fig. 1, Loosening the Beads

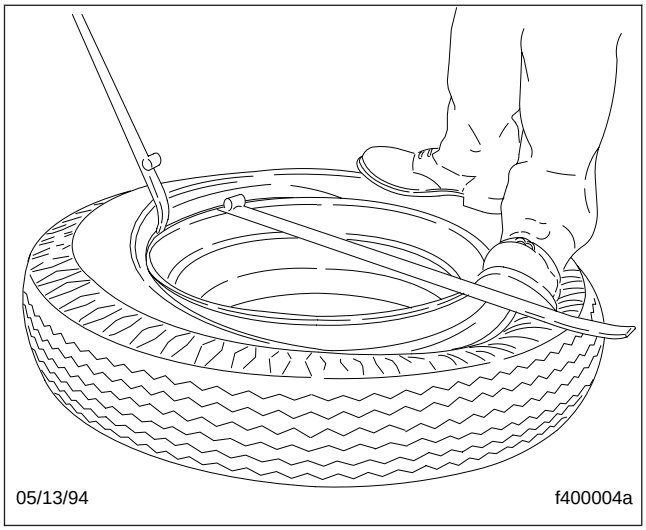


Fig. 2, Forcing the Bead into the Rim Well

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Demounting and Mounting Tubeless Tires

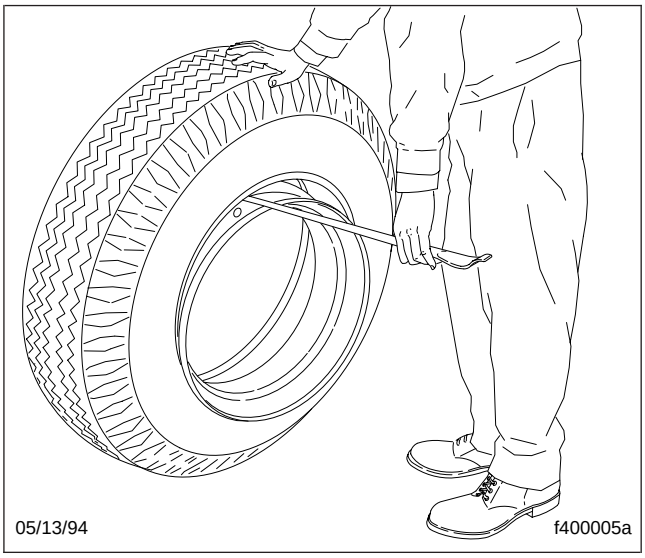


Fig. 3, Prying the Rim Out of the Tire

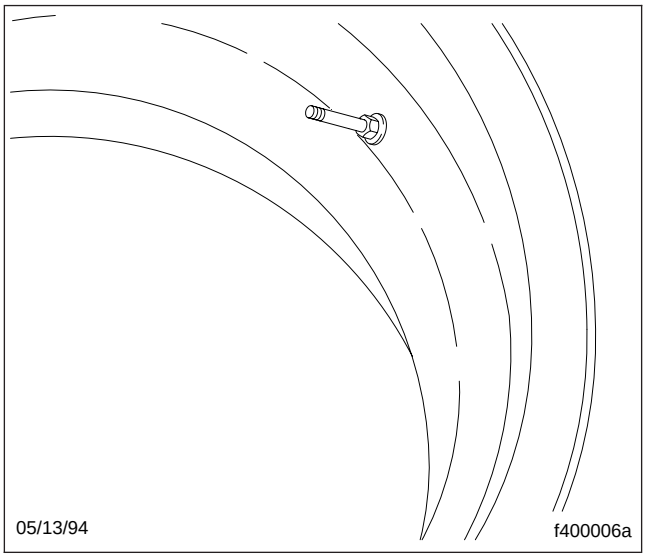


Fig. 4, Valve Stem Installation

3. Lay the tire on the rim. If there is a balance mark on the tire, line up this mark with the valve stem. Push the lower bead over the flange and into the rim well. Using the straight end of the tire tool (with the stop resting on the rim flange), take small bites to work the remaining section of the bead into the rim. See **Fig. 5**.
4. Start the upper bead over the rim flange and into the rim well by standing on the tire. If necessary, push a section of the bead into the rim well and anchor it by attaching Vise-Grip® pliers to the rim flange (snub side toward the tire). Using the spoon end of the tire iron, with the stop toward the rim, work around the bead. See **Fig. 6**. Use small bites until the bead slips over the flange and into the rim well. If necessary, insert a second tire iron and relubricate the last 8 inches (20 cm) of bead.
5. Inflate the tire. See **Subject 160** for procedures.

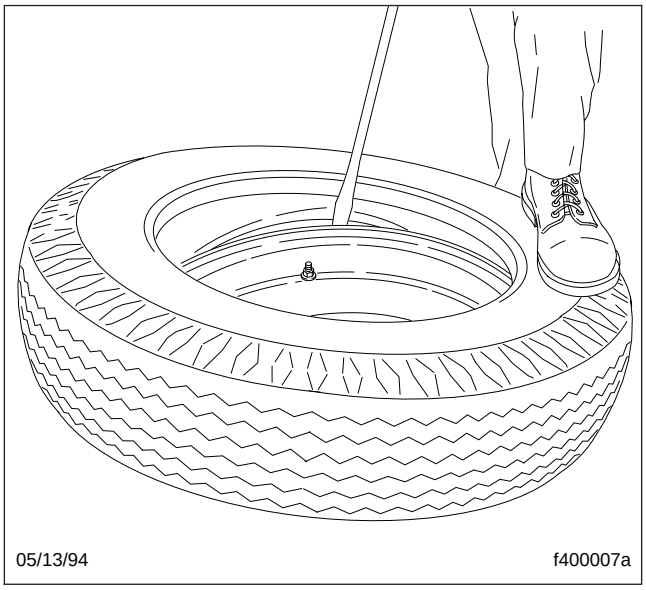


Fig. 5, Working the Lower Bead into the Rim

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Fig. 6, Working the Upper Bead into the Rim

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Inspection

⚠ WARNING

Failure to inspect the tires and wheels and correct any problems, could cause tire or rim damage while servicing or while in use. An incorrectly mounted tire can burst causing equipment damage and personal injury.

Examine the wheel or rim and all parts. Remove any grease, dirt or rust. Using a wire brush, remove any rubber from the bead seat. Use special care when cleaning the rim gutter. Rust or other foreign matter can prevent the correct fitting of side rings. Replace corroded parts. Paint the rim to prevent corrosion.

NOTE: Do not paint Alcoa aluminum disc wheels. If the wheels are corroded, contact the manufacturer for instructions.

A cracked brake drum, damaged inner or outer wheel nuts or an out-of-round wheel or rim makes the replacement of the damaged part necessary. See **Fig. 1**. Replace the wheel if it has out-of-round stud holes.

NOTE: See **Group 33** or **Group 35** for inspection and service procedures for the hub, wheel studs, wheel, and brake drum or disc rotor assemblies. When replacing the spoke wheel or the brake drum, contact the wheel manufacturer for the correct torque value for the brake drum nut that attaches the spoke wheel to the brake drum.

Inspect valve cores for cracks, bends and air retention. Replace damaged or leaky cores.

The most critical area of a spoke wheel is the 28-degree tapered rim mounting surface. See **Fig. 2**. Clean the surface and examine it for damage or excessive wear. Replace the wheel if the mounting surface is damaged or worn below the 28-degree taper.

Check the clamps, rim spacer, rim studs and spoke-wheel nuts for damage or wear. The clamps must not be excessively worn. The end of the wedge portion must be at least 1/16-inch (1.5-mm) thick. See **Fig. 3**. The rim spacer must not be bent, distorted or crushed. Replace all damaged or broken parts.

Do not attempt to rework, weld, heat or braze any rim or wheel parts that are cracked, broken or damaged. Use new parts or parts that are not cracked, broken or otherwise damaged, and that are of the same size and type.

Remove all foreign matter, such as grease and dirt, from the wheel mounting surface. Smooth any projections on the mounting surface to ensure even pressure when tightening the wheel nuts.

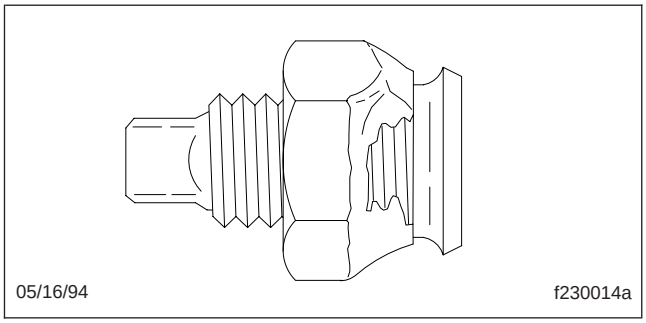


Fig. 1, Damaged Outer Wheel Nut

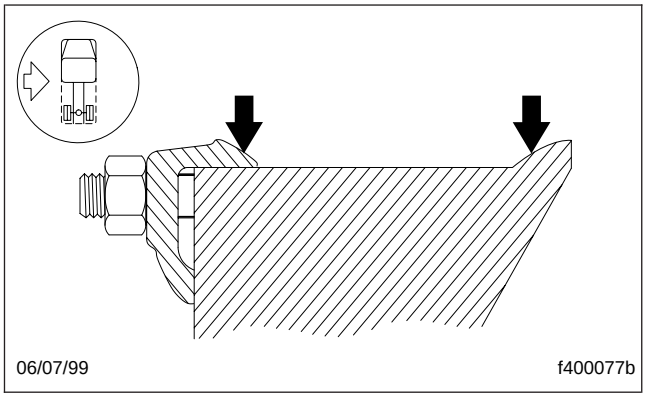


Fig. 2, 28-Degree Tapered Rim Mounting Surfaces

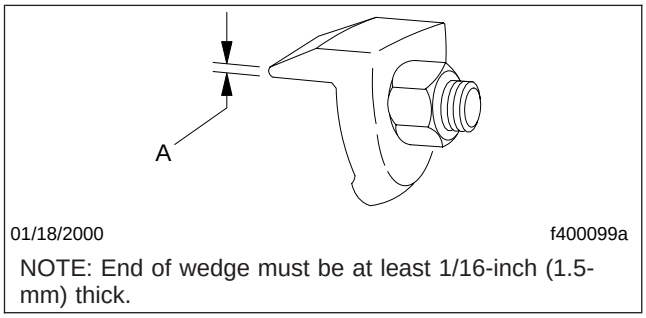


Fig. 3, Rim Clamp

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Inspection

⚠ WARNING

Inspect the tires and wheels, and correct any problems. Failure to do so could cause tire or rim damage while servicing or while in use. An incorrectly mounted tire can burst causing personal injury and equipment damage.

Inspect the inside and outside of the tire for out-of-roundness, loose cords, cuts, foreign objects, and other damage. Repair as needed. Contact the tire manufacturer for repair procedures.

Do not repair tires with:

- Cuts in the tread that are wire or breaker fiber deep;
- Tread worn to the wire or breaker fibers;
- Tread that is scalloped or otherwise worn unevenly;
- Visible, broken, deformed or otherwise damaged bead wires;
- Deteriorated rubber;
- Rubber cracked to the wire or cord;
- Separations in the casing;
- Exposed cord (for example, due to weather checking or sidewall scuffing).

Inspect the tread for abnormal or excessive wear. See **Troubleshooting, 300** for possible causes of abnormal wear. If the tires are wearing irregularly, they should be rotated. If the front axle tires become irregularly worn, they should be moved to the drive axle. The front-end alignment should be checked. In a dual assembly, if one tire wears faster than its mate, the position of the two tires should be reversed. See Group 40 in the *Acterra Maintenance Manual* for tire rotation procedures.

Government regulations require the removal of any tire with less than 2/32-inch (1.5-mm) tread remaining. Retread the tire (if possible), regroove it (only if marked " Regroovable " on the sidewall), or discard it.

Michelin Tire Corporation recommends using only new valve cores, caps and O-rings in a new mounting.

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Tire Inflation

⚠ WARNING

During initial tire inflation, there is the possibility of an explosion of the assembly. Observe the following safety rules to reduce the possibility of serious physical injury in the event of an explosion.

NOTE: Inflate tires in a safety cage or an approved portable restraining device. See **Fig. 1**. Always use a clip-on chuck with an inline valve and gauge. Make sure the inflation hose is long enough to permit standing to the side of the tire during inflation. Never sit on or stand in front of an assembly that is being inflated.

1. Check all parts to make sure they are correctly seated prior to inflation.

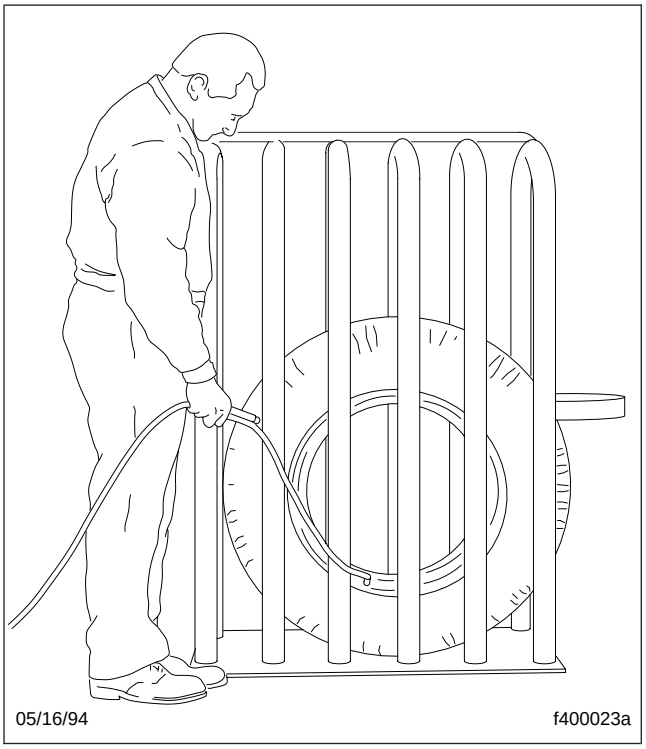


Fig. 1, Safety Cage

IMPORTANT: Inflate tires immediately after mounting, before the tire lubricant dries. Once the lubricant dries, bead positioning is not possible, even with increased inflation pressure.

2. Water in the tire can cause ply separation. During tire inflation, air tank reservoirs and lines must be dry. Use well-maintained air line moisture traps, and service them regularly.

   After placing the tire in a safety cage, or an approved portable restraining device, inflate the tire to 10 psi (69 kPa). Check the parts for correct seating. If the seating is not correct, completely deflate the tire and correct the problem. Never attempt to seat rings or other parts by hammering on an inflated or partially inflated tire.

3. If there are no problems with the assembly at 10 psi (69 kPa), continue to inflate the tire to the recommended pressure. See the applicable tables in **Specifications, 400** for correct cold inflation pressures. Michelin Tire Corporation recommends an initial inflation pressure of 90 to 100 psi (620 to 690 kPa) to correctly seat the tire beads.

IMPORTANT: Due to the different flex characteristics of radial sidewalls, it may be necessary to use an inflation aid to help seat tubeless tire beads:

- Metal rings, which use a blast of compressed air to seat the beads.
- Rubber rings, which seal between the tire bead and rim, allowing the bead to move out and seat correctly. A well-lubricated, heavy-duty bicycle tube can be used to help seal between the tire bead and rim.

4. After the initial inflation, completely deflate the tire by removing the valve core. This ensures correct bead seating. Inflate the tire to the applicable recommended cold inflation pressure listed in tables in **Specifications, 400**. Install valve caps and finger-tighten them.

⚠ WARNING

Tire underinflation or overinflation will damage wheels and tires, and could result in a blowout causing possible personal injury and property damage.

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Tire Inflation

CAUTION

Use tires of the same size, type, and capacity to carry the load at the recommended cold pressure. Attempting to increase the load capacity of a tire by overinflation will damage the tire assembly.

NOTE: Inflate the tires to the recommended pressure. Driving on overinflated tires will weaken the cords by reducing their ability to absorb road shocks, and will increase the danger of cuts, snags, and punctures. Overinflation will overstress and damage the rims. Driving on underinflated tires will generate excessive heat. This weakens the tire body and reduces tire strength.

5. Check the inflation pressure 24 hours after mounting new tires.

NOTE: When testing a vehicle on a dynamometer, severe tire damage can occur. Because the manufacturers differ in their recommendations for preventing tire damage, see the manufacturer's instructions for testing a vehicle on a dynamometer.

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General Information

Runout is side-to-side (lateral) or up-and-down (radial) movement when the tire/wheel assembly is rotated. Runout can be measured with a dial indicator, a tire runout gauge, or another instrument capable of measuring small movements of the tire/wheel assembly.

Lateral runout, shown in **Fig. 1**, is side-to-side movement of the rotating tire/wheel assembly. This may cause a perceived "shimmy" or "wobble".

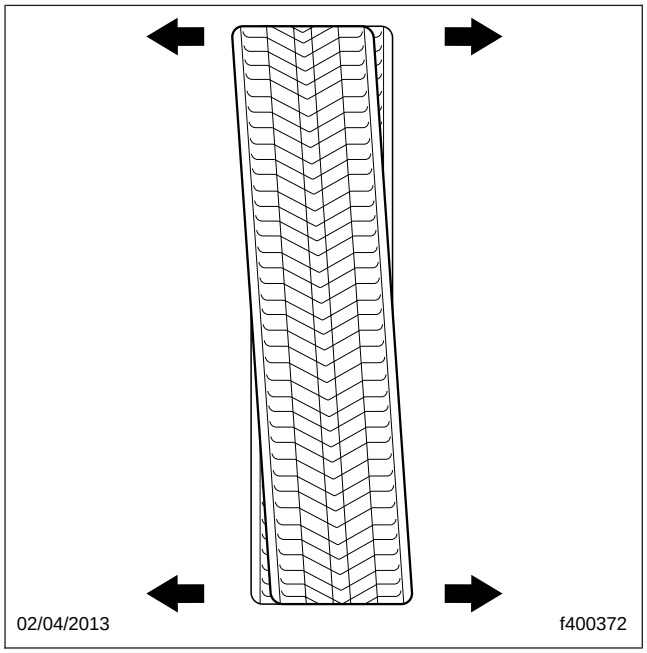


Fig. 1, Lateral Runout

Radial runout, shown in **Fig. 2**, is a changing radius of the rotating tire/wheel assembly. For a tire or wheel, its effect is to raise and lower the vehicle as it rolls along, giving the perception of a vertical "hop" or "bounce".

If a tire and wheel assembly shows visible up-and-down or side-to-side movement, it may have excessive runout. Use the inspection procedure that follows to measure runout.

Inspection

IMPORTANT: Before checking wheel runout, check the tires for proper:

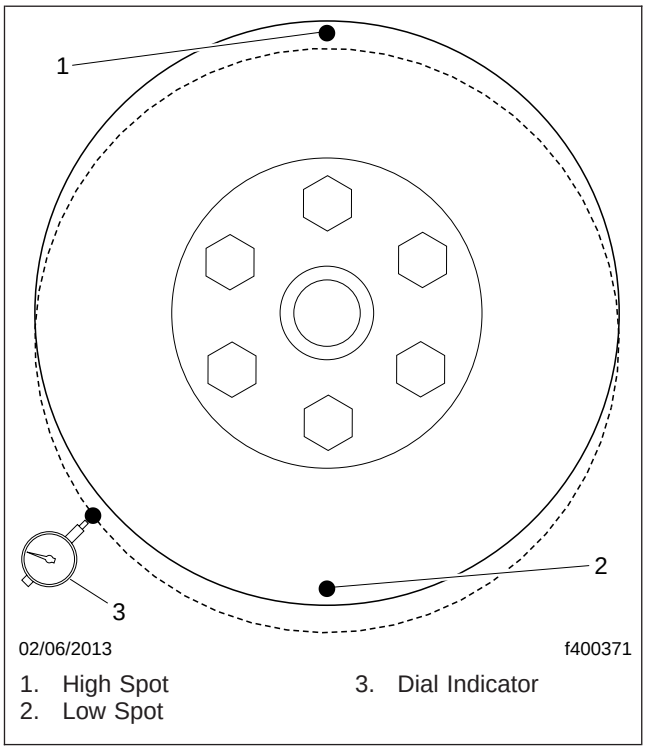


Fig. 2, Radial Runout

- inflation;
- wheel nut torque;
- bead seating on the rim.

Use a tire runout gauge, as shown in **Fig. 3**, to check lateral and radial runouts of the entire wheel end assembly.

Check radial runout on a smooth rib in the center of the tread. Check lateral runout on a smooth surface along the tire's mid-sidewall. If the wheel end assembly radial runout exceeds 0.060 inch (0.2 cm), or the lateral runout exceeds 0.150 inch (0.4 cm), the tire/wheel assembly should be removed to check the brake drum and hub runouts. Brake drum and hub runout tolerances are as follows:

- brake drum lateral runout—0.045 inch (0.11 cm)
- brake drum radial runout measured inside of the drum—0.020 inch (0.050 cm)
- hub lateral runout measured at the face of the hub—0.015 inch (0.38 cm)

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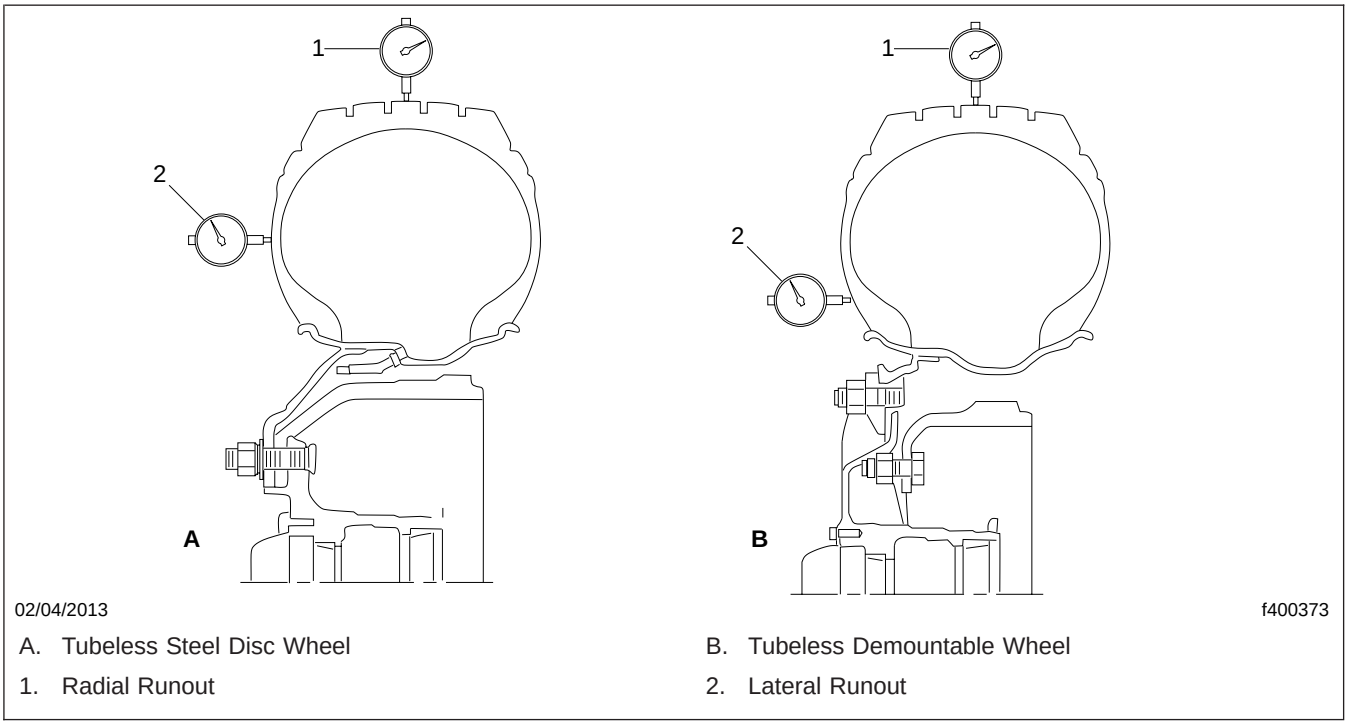
Wheel and Tire Runout Measurements

- hub radial runout measured near the hub pilots—0.015 inch (0.38 cm)

If hub and brake drum runouts are within specification, then the wheel runout will need to be checked. Demount the tire from the wheel and check lateral and radial runouts for the wheel as shown in **Fig. 4**. For tire demounting instructions, see **Section 40.00, Subject 130**. Make certain the wheel is properly fixed in a wheel balancer or remounted on the hub. See **Table 1** for wheel runout specifications.

Wheel Runout Specifications		
Wheel Type	**Lateral Runout: inches (cm)**	**Radial Runout: inches (cm)**
Aluminum	0.030 (0.08)	0.030 (0.08)
Steel	0.060 (0.15)	0.060 (0.15)

Table 1, Wheel Runout Specifications



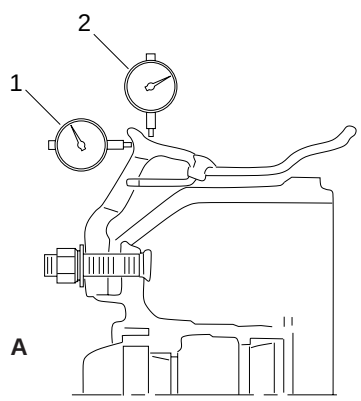
A. Tubeless Steel Disc Wheel
1. Radial Runout

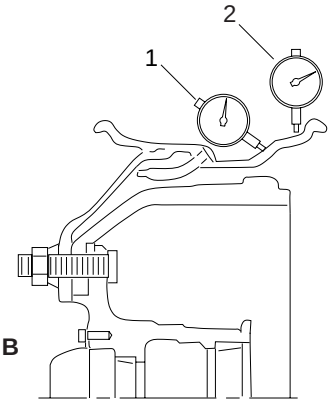
B. Tubeless Demountable Wheel
2. Lateral Runout

Fig. 3, Runout Check for Tires

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Wheel and Tire Runout Measurements





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A. Tubeless Aluminum Disc Wheel
B. Tubeless Steel Disc Wheel
1. Lateral Runout
2. Radial Runout

Fig. 4, Runout Check for Wheels

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Troubleshooting Tables

Problem—Abnormal Tire Wear

Problem—Abnormal Tire Wear	
Possible Cause	**Remedy**
Tires not inflated to correct pressure	Operate the tires at the recommended inflation pressure and use the proper size tires, wheels and rims for the load to be carried. See the applicable tables in **Specifications 400** for specifications.
Unequal inflation pressures in a dual assembly	Inflate all tires to a uniform pressure, within 5 psi (35 kPa). See the applicable tables in **Specifications 400** for the proper cold inflation pressures.
Mismatched dual tires	Examine all tires and match them according to the specifications in this section.
Severely vibrating vehicle	Determine the location of the vibration. Repair or replace the loose or worn components.
Grabbing brakes	Examine and adjust the brakes according to the instructions in **Group 42**.
Improperly aligned axles	Align the axles. For instructions, see **Group 33** and **Group 35**.
Loose or damaged wheel bearings or excessively worn bushings	Examine and repair or replace according to the instructions in **Group 33** and **Group 35**.
Uneven wear among tire sets	Rotate the tires according to the instructions in Group 40 of the *Acterra Maintenance Manual*.
Driver abusing equipment	Caution the driver.

Problem—Vehicle Vibration

Problem—Vehicle Vibration	
Possible Cause	**Remedy**
Improperly aligned axles	Align the axles. For instructions, see **Group 33** and **Group 35**.
Out-of-round, bent or distorted wheels, rims or tires	Replace damaged components.
Out-of-balance tires, wheels, rims or brake drums	Determine the out of balance component and balance.
Improperly seated tire beads	Demount and mount the tire. Make certain adequate lubrication is used and, if necessary, use an inflation aid to help seat tubeless tire beads.
Improperly installed tire and rim assembly on a spoke wheel	Remove the tire and rim assembly and inspect it for out-of-round or rim chording. Replace the rim if it is damaged. Follow closely the tightening sequence and torque values listed.
Worn or distorted rim spacers	Replace the rim spacers.
Loose or worn driveline, suspensions or steering components	Determine the location of the vibration. Repair or replace the loose or worn components.

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Troubleshooting

Problem—Excessive On-the-Road Tire Failures

Problem—Excessive On-the-Road Tire Failures	
Possible Cause	**Remedy**
Tires not inflated to correct pressure	Operate the tires at the recommended inflation pressure and use the proper size tires, wheels and rims for the load to be carried. See the applicable tables in **Specifications, 400** for specifications.
Mismatched dual tires	Examine all tires and match them according to the specifications in this section.
Water or foreign material inside casing	Clean and dry the tires prior to mounting. Make sure excess lubricant does not flow down into the tire. Store unmounted tires indoors, or under cover, to prevent moisture from collecting inside.
Oil contaminated tires	Clean the tires and inspect the engine seals, transmission seals, axle-end and drive axle seals, oil filters and oil lines for leakage. Make sure the lubricant used in mounting does not contain a petroleum derivative.
Severely vibrating vehicle	Determine the location of the vibration. Repair or replace the loose or worn components.
Mismatched wheel or rim components	Check the catalog issued by the applicable wheel or rim manufacturer for the proper part numbers and sizes of approved components. Make sure that all parts of an assembly match in size, manufacturer and classifications within a manufacturer's line. Never use a component which does not bear clear, legible and proper numbers and manufacturer's identification, even if it appears to fit.
Corroded, worn or otherwise damaged parts	Clean or replace parts as necessary.

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Tire Pressure

IMPORTANT: Do not reduce the pressure of a hot tire if it exceeds the specified pressure. In normal driving, tire temperature and inflation pressure increase. Increases of 10 to 15 psi (70 to 105 kPa) are common. Higher pressures may be signs of overloading, underinflation, excessive speed, improper tire size or any combination of these factors, and must be checked when the tire is cool.

IMPORTANT: The load and cold inflation pressure must not exceed the rim or wheel manufacturer's recommendations, even though the tire may be approved for a higher load or inflation. Some rims and wheels are stamped with a maximum load and maximum cold inflation rating. If they are not stamped, consult the rim or wheel manufacturer for the correct tire inflation pressure for the vehicle load. If the load exceeds the maximum rim or wheel capacity, the load must be adjusted or reduced.

For further information on rims and tires, and for inflation and load limits, see the "Tire and Rim Association Yearbook," or contact the tire manufacturer.

Wheel Fastener Torque Values

For torque values for disc wheel fasteners, see **Table 1**.

For torque values for spoke wheel rim clamp nuts, see **Table 2**.

NOTE: When using channel spacers (see **Fig. 1**), recommended torque for Gunite spoke-wheel rim clamp nuts is 190 to 210 lbf·ft (260 to 285 N·m); when using corrugated or corrugated-channel spacers (see **Fig. 2**), permitted torque is 240 to 260 lbf·ft (325 to 355 N·m).

Disc Wheel Fastener Torque			
Description	**Nut Size**	**Wheel Manufacturer**	**Torque: lbf·ft (N·m)**
*10-Hole and 8-Hole Hub-Piloted Disc Wheel With Two-Piece Flange Nuts**			
Front and Rear Wheel Nut	M22 x 1.5	All	450–500 (610–678)
Nuts on Double-Threaded Wheel Studs	M22 x 1.5	All	390–450 (529–610)
Double-Threaded Wheel Stud Retainer Nut	3/4–16	All	175–200 (235–270)
10-Hole Stud-Piloted Disc Wheel With Inner and Outer Nuts†			
Front Wheel Nut	1-1/8–16	All	450–500 (610–678)
Rear Wheel Inner Nut	3/4–16	All	450–500 (610–678)
Rear Wheel Outer Nut	1-1/8–16	All	450–500 (610–678)

* Torque values for hub-piloted wheels are given for lubricated threads. Lubricate threads with SAE 30W engine oil. Do not apply thread lubricant to ball seats of the nuts and wheels. Wipe it off if it is applied accidentally.

† Torque values for stud-piloted wheels are given for clean, dry threads.

Table 1, Disc Wheel Fastener Torque

Spoke Wheel Rim Clamp Nut Torque			
Description	**Nut Size**	**Manufacturer**	**Dry Threads: lbf·ft (N·m)**
Front and Rear Rim Clamp Nut, 5- and 6-Spoke	5/8–11	All	160–200 (215–270)
	3/4–10	All	200–260 (270–355)

Table 2, Spoke Wheel Rim Clamp Nut Torque

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Specifications

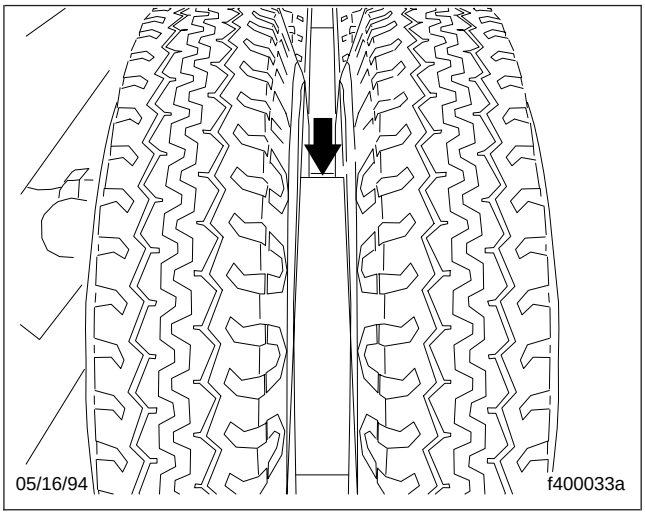


Fig. 1, Channel Spacer

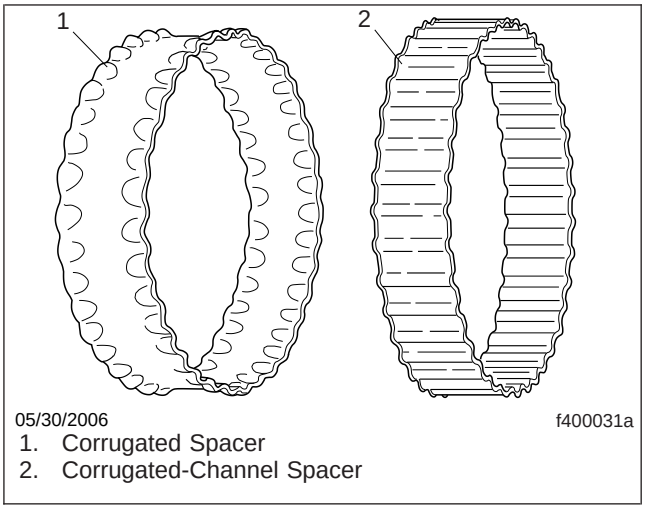


Fig. 2, Corrugated Spacers

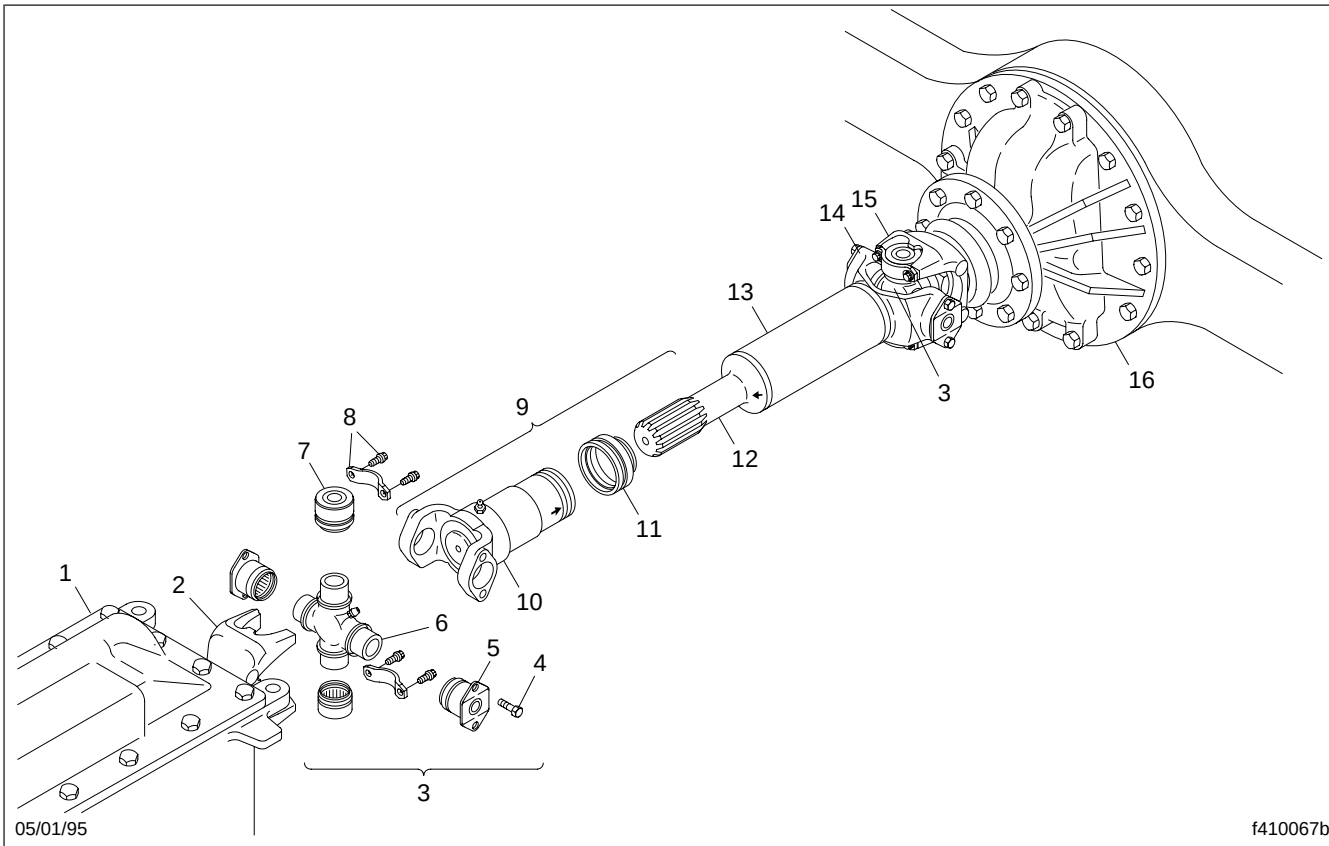
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General Information

The simplest driveline consists of a transmission output-shaft end-yoke, an axle input-shaft end-yoke, and a single slip-jointed driveshaft connecting the two end-yokes. See **Fig. 1**. The driveshaft is made up of a universal joint (U-joint), a sleeve-yoke, a splined stub shaft, a driveshaft tube, a tube-yoke, and a second U-joint.

DRIVELINE CONFIGURATIONS

The specific type and number of drivelines used on each vehicle depends on its number of transmissions, its number of drive axles and its wheelbase. See **Fig. 2**. A driveline is used between each driving and driven component. A driveline connecting a main transmission (or an auxiliary transmission) to a single drive axle or forward-rear axle of a dual-drive vehicle is always referred to as a No. 2 driveline. An inter-



NOTE: Not all fasteners are shown.

1. Transmission
2. Transmission Output-Shaft End-Yoke (half-round)
3. U-Joint Assembly
4. Bearing Plate Self-Locking Capscrew
5. Bearing Cup (for full-round yoke)
6. U-Joint Cross
7. Bearing Cup (for half-round yoke)
8. Bearing Strap and Bearing-Strap Capscrew
9. Slip-Joint Assembly
10. Sleeve-Yoke (full-round)
11. Dust Cap
12. Splined Stub Shaft
13. Driveshaft Tube
14. Tube-Yoke (full-round)
15. Axle Input-Shaft End-Yoke (half-round)
16. Rear Axle

Fig. 1, Components of a Basic Driveline

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axle driveline of a dual-drive vehicle is always called a No. 3 driveline. A driveline connecting a main transmission to an auxiliary transmission is always referred to as a No. 1 driveline. Acterra vehicles are not equipped with No. 1 drivelines or auxiliary transmissions.

A long driveshaft, supported only at its ends, will sag in the middle from its own weight. When turning at high rpm, it will flex, causing an out-of-balance vibration. Vehicles with a long wheelbase use a midship bearing, mounted on a frame crossmember, for additional support. See **Fig. 2**. This allows the No. 2 driveline to be separated into two, shorter shafts (a coupling shaft and a No. 2 driveshaft), improving balance and stability.

Vehicles with an even longer wheelbase use two crossmember-mounted midship bearings, allowing the No. 2 driveline to be separated into three short shafts, joined by four U-joints. See **Fig. 2**. The first shaft is the primary coupling shaft, the second is the intermediate coupling shaft and the third is the No. 2 driveshaft.

SLIP-JOINTS, U-JOINTS, AND YOKES

The basic function of the driveline is to send torque from the transmission to the axle in a smooth and continuous action. Because the vehicle axles are not attached directly to the frame, but are suspended by springs, they ride in an irregular, floating motion (when going over bumps or depressions), thus changing the distance between the transmission (or coupling shaft) and the rear axle, and the distance between the rear axles. The slip-joints of the No. 2 and No. 3 driveshafts, by expanding and contracting, allow for length changes between drivetrain components. Coupling shafts do not require a slip-joint.

Motion of the rear axle(s) also causes changes to the relative angles between drivetrain components. U-joints allow transfer of torque from an output shaft (or coupling shaft) to the driveshaft, and from the driveshaft to an input shaft, even though the angles between the shafts may be constantly changing.

Each U-joint consists of a cross with a close-tolerance ground cylindrical surface (trunnion) at the end of each of the four arms. Installed on each trunnion is a bearing cup lined with bearing needles. All bearing cups are sealed to retain lubricants, and to prevent entry of foreign material. See **Fig. 3**. In operation, the four bearing cups are held stationary in a pair of yokes, while the U-joint cross pivots on its trunnions.

Full-round yokes are installed at the front of coupling shafts and at both ends of the No. 2 and No. 3 driveshafts. All tube-yokes (yokes that are welded into driveshaft tubes) and all sleeve-yokes (yokes that are part of the internally splined half of slip-joints) are full-round yokes. See **Fig. 4**.

An end-yoke is an internally splined yoke, held on an externally splined shaft by a locknut. As standard equipment, all end-yokes used on Acterra vehicles are half-round; full-round end-yokes are optional. End-yokes are installed on the transmission output shaft, on each axle input and output shaft, and behind the midship bearing of most coupling shafts. See **Fig. 4**. A half-round flange-yoke is used with the driveline parking brake, and fastens with locknuts to the studs of a companion flange that installs on the transmission output shaft or the rear axle input shaft in the same manner as an end-yoke. See **Fig. 5**.

Spicer SPL90 (1590), 1610, 1710 and 1760 U-joints are coupled to half-round end-yokes and flange-yokes by capscrews inserted through semicircular bearing straps that hold the bearing cups in place under tabs in the yoke cross-holes. See **Fig. 6**.

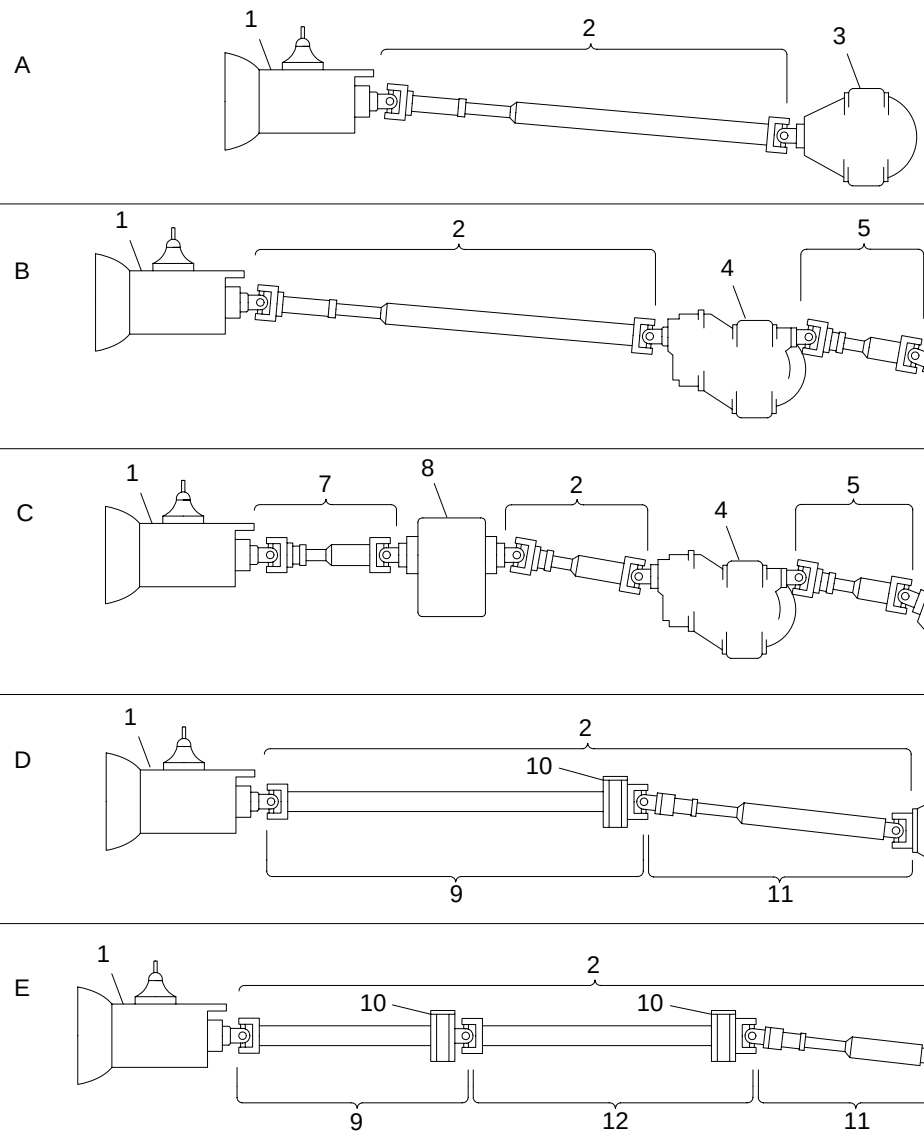
A Spicer SPL90 (1590) U-joint is installed in a full-round tube-yoke or sleeve-yoke by installing the cross and bearing cups into the yoke cross-holes, then installing a snap ring into a groove in each cross-hole. See **Fig. 7**.

Spicer 1610, 1710 and 1760 U-joints are installed in full-round tube-yokes, sleeve-yokes, and end-yokes, by inserting the cross through from the inside of both yoke cross-holes, then installing the bearing cups into the outsides of the yoke and over the ends of the trunnions. Capscrews, inserted through a bearing plate at the back of each cup, thread into the yoke to secure the cups. For Spicer U-joints, the capscrews are self-locking. See **Fig. 8**.

U-JOINT ANGLES, PHASING AND DRIVELINE BALANCE

Correct U-joint working angles, U-joint phasing and driveline balance are vital to maintaining a quiet-running drivetrain and long life of drivetrain components (including driveline components).

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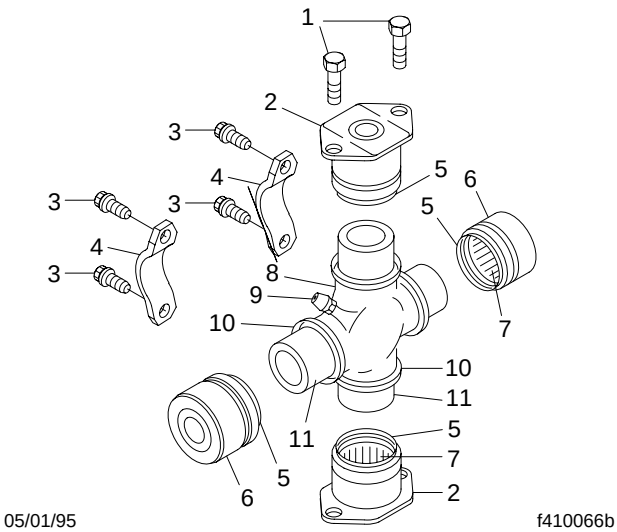
A. Main Transmission to a Single Drive Rear Axle
B. Main Transmission to a Dual-Drive Rear Axle
C. Main Transmission to an Auxiliary Transmission to a Dual-Drive Rear Axle
D. Main Transmission to a Single Drive Rear Axle with a Midship Bearing
E. Main Transmission to a Single Drive Rear Axle with Two Midship Bearings

1. Main Transmission
2. No. 2 Driveline
3. Rear Axle
4. Forward-Rear Axle
5. No. 3 Driveline
6. Rearmost Axle
7. No. 1 Driveline
8. Auxiliary Transmission
9. Primary Coupling Shaft
10. Midship Bearing
11. No. 2 Driveshaft
12. Intermediate Coupling Shaft

Fig. 2, Driveline Configurations

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General Information



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NOTE: Components shown are typical of all U-joints installed in vehicles with half-round end-yokes, except Spicer SPL90 (1590) U-joints.

1. Bearing-Plate Capscrews
2. Bearing Cup (for full-round yoke)
3. Bearing-Strap Capscrew
4. Bearing Strap
5. Bearing-Cup Seal
6. Bearing Cup (for half-round yoke)
7. Bearing Needles
8. U-Joint Cross
9. Grease Fitting
10. U-Joint Cross Slinger
11. Trunnion

Fig. 3, Typical U-Joint

The U-joint working angle is the angle formed by the intersection of the driveshaft centerline and the extended centerline of the shaft of any component (or other driveshaft) to which the U-joint connects. See **Fig. 9**. Because the double oscillating motion of a U-joint that connects angled shafts causes a fluctuating speed difference between the shafts, the effect created by the U-joint at one end of the shaft must cancel the effect created by the U-joint at the other end. This is done by making U-joint working angles at both ends of the driveshaft approximately equal, with the U-joints in phase. If the yoke lugs at both ends of the shaft are lying in the same plane (a plane which bisects the shaft lengthwise) the U-joints will be in phase. See **Fig. 10**.

After manufacture, each driveline yoke is statically balanced. After assembly, each driveshaft and coupling shaft is checked for out-of-roundness, straightened as necessary, then dynamically balanced.

AVOIDING DRIVELINE PROBLEMS

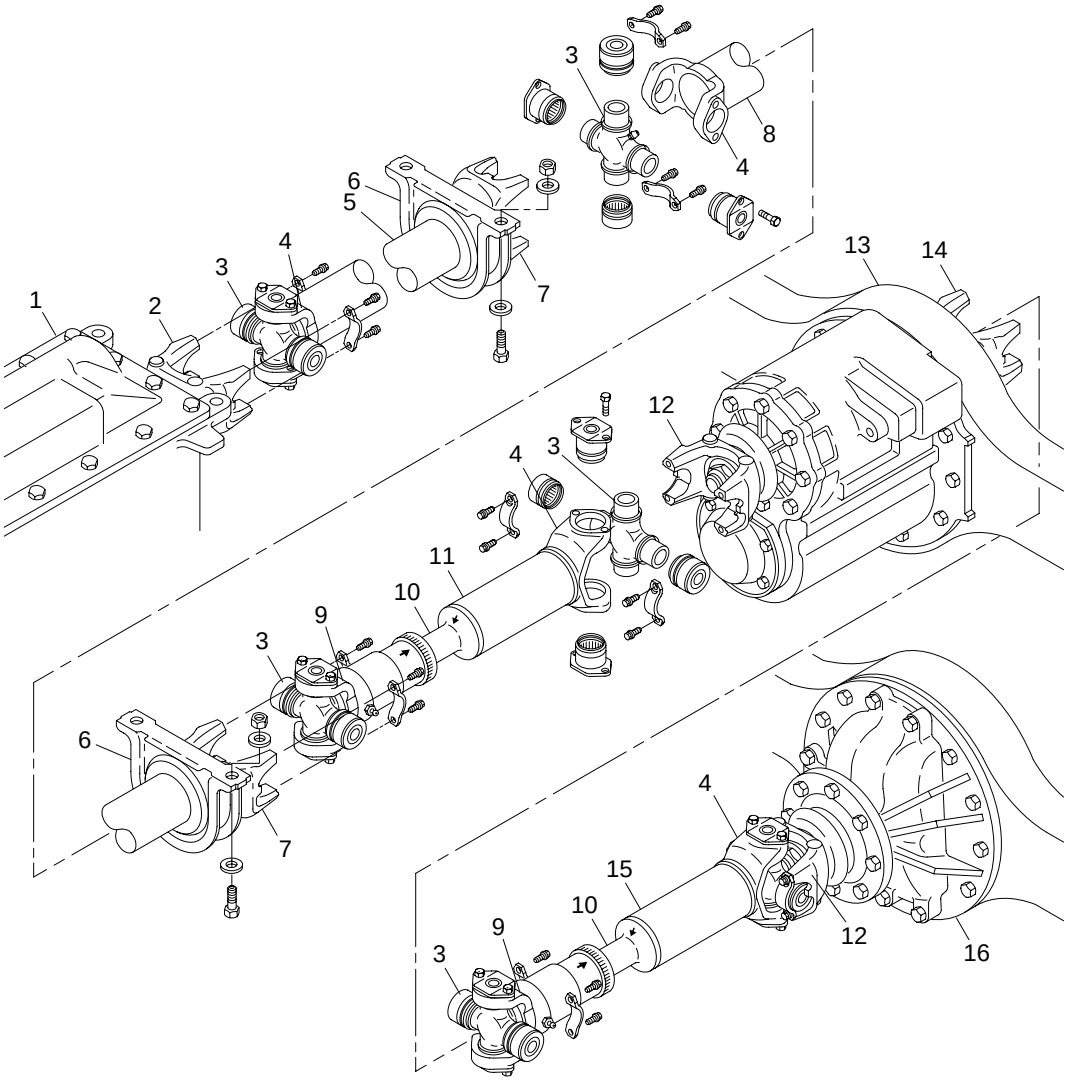
To ensure that U-joints turn in phase, sleeve-yokes, splined shafts, coupling shaft end-yokes, and coupling shafts, should be marked for assembly reference before disassembly. A misaligned slip-joint will seriously affect driveline balance (and U-joint phasing). Even if a slip-joint is assembled 180 degrees from its original position (which will keep the U-joints in phase), the dynamic balance of the driveshaft will be negatively affected.

A driveline can become unbalanced or greatly weakened if a driveshaft has been dented, bent, twisted, or otherwise damaged. Operating a vehicle at speeds which exceed the speed of the driveshaft's design specifications will cause an out-of-balance vibration. Any condition which allows excessive movement of a driveshaft will cause driveline imbalance: loose end-yoke nuts, loose midship bearing mounts, loose U-joint bearing cup retaining capscrews, worn U-joint trunnions and bearings and worn slip-joint splines.

Among the most common causes of U-joint and slip-joint damage is lack of lubrication.

To keep a vehicle operating smoothly and economically, the driveline must be carefully checked and lubricated at regular intervals. For inspection and lubrication intervals and procedures, see Group 41 of the *Acterra Maintenance Manual*.

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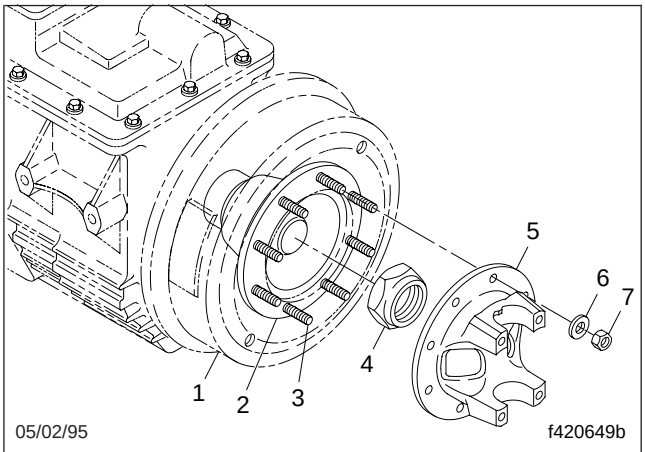
NOTE: Not all fasteners are shown.

1. Transmission
2. Transmission Output-Shaft End-Yoke (half-round)
3. U-Joint Assembly
4. Full-Round Tube-Yoke
5. Primary Coupling Shaft Tube
6. Midship Bearing Assembly
7. Coupling Shaft End-Yoke (half-round)
8. Intermediate Coupling Shaft Tube
9. Sleeve-Yoke (full-round)
10. Slip-Joint Assembly
11. No. 2 Driveshaft Tube
12. Axle Input-Shaft End-Yoke (half-round)
13. Forward-Rear Axle
14. Axle Output-Shaft End-Yoke (half-round)
15. No. 3 Driveshaft Tube
16. Rearmost Axle

Fig. 4, Dual-Drive Installation With Primary and Intermediate Coupling Shafts

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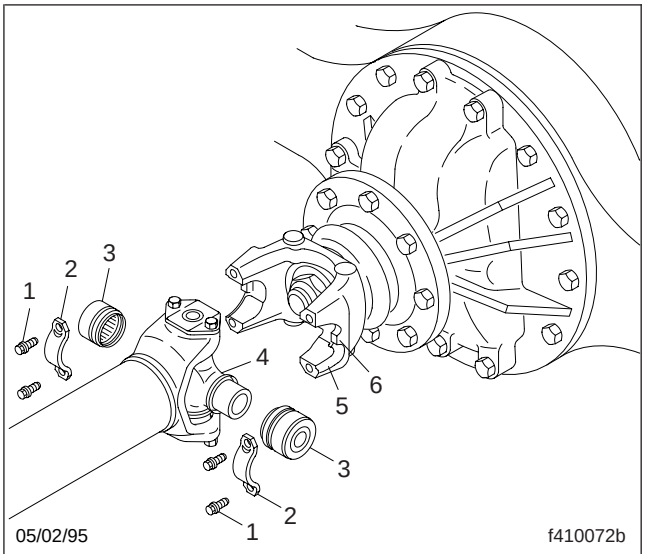
General Information



NOTE: Not all fasteners are shown.

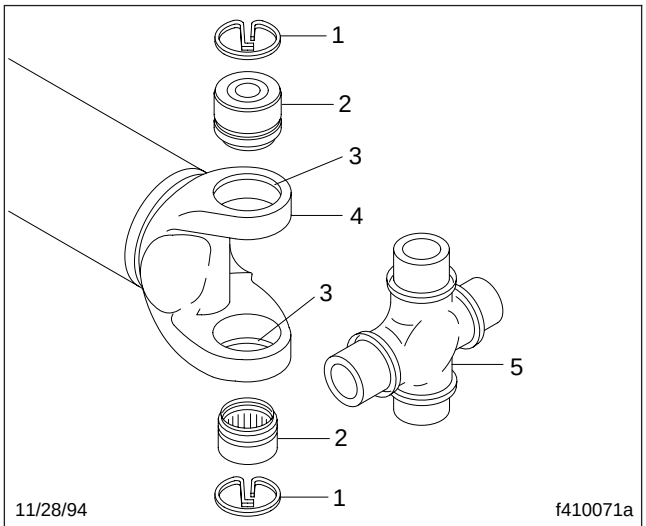
1. Parking Brake Drum
2. Companion Flange
3. 3/8–24 Threaded Stud
4. Companion-Flange Locknut
5. Half-Round Flange-Yoke
6. Bearing Washer
7. Flange-Yoke Locknut

Fig. 5, Companion Flange and Flange-Yoke Installation



1. Bearing-Strap Capscrew
2. Bearing Strap
3. Bearing Cup
4. U-Joint Cross
5. Half-Round Yoke
6. Yoke Cross-Hole Tab

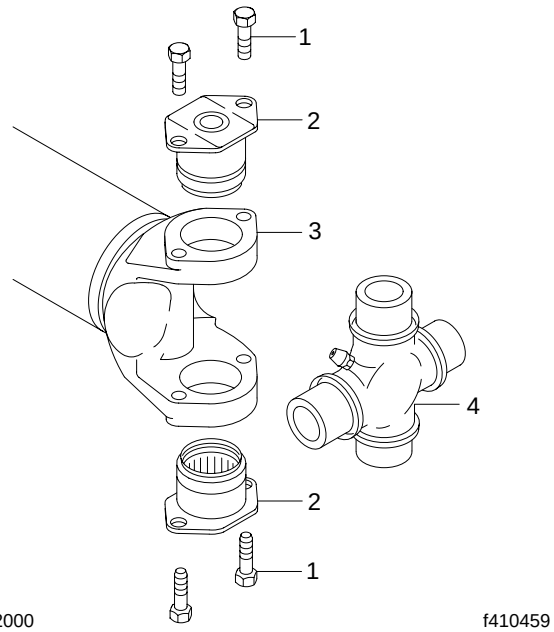
Fig. 6, Coupling of a Spicer U-Joint With a Half-Round End-Yoke



1. Snap Ring
2. Bearing Cup
3. Snap-Ring Groove
4. Full-Round Yoke
5. U-Joint Cross

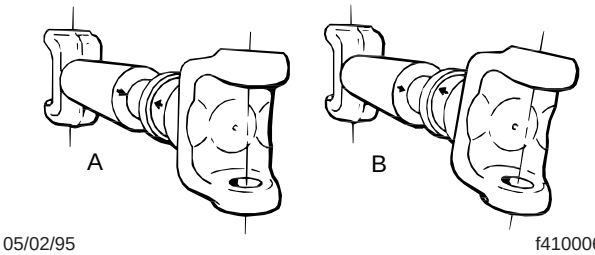
Fig. 7, Installation of a Spicer SPL90 (1590) U-Joint in a Full-Round Yoke

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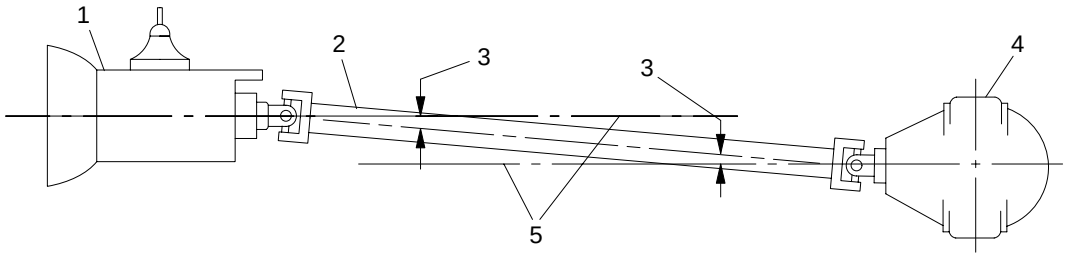
1. Bearing-Plate Self-Locking Capscrew
2. Bearing Cup (bearing-plate-type)
3. Full-Round Yoke
4. U-Joint Cross

Fig. 8, Installation of a Spicer 1610/1710/1760 U-Joint in a Full-Round Yoke



A. In Phase B. Out of Phase

Fig. 10, U-Joint Phasing



1. Transmission
2. No. 2 Driveshaft
3. U-Joint Working Angles
4. Rear Axle
5. Extended Centerlines

Fig. 9, U-Joint Working Angles

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U-Joint Uncoupling and Coupling With a Half-Round End-Yoke

NOTE: It is easier to check driveline parts and to replace a U-joint or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed and installed on a lathe or a balance machine. Removal is required for replacement of slip-joint parts, a driveshaft tube or a tube-yoke. To remove the driveshaft, see **Subject 120**.

NOTE: Many service operations do not require driveshaft removal from the vehicle: end-yoke or companion-flange nut tightening; drive component shaft seal, end-yoke or flange-yoke replacement; changing U-joint phasing at the slip-yoke; and transmission or axle removal (for overhaul, repair or replacement). To perform these operations, uncouple the U-joint at the applicable end of the appropriate driveshaft.

U-Joint Uncoupling

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front tires.
2. Turn the appropriate end-yoke (or flange-yoke) until the centerline through its cross-holes is horizontal. See **Fig. 1**. If the half-round bearing cups do not already have a retaining wire installed, install a bearing-cup retaining wire or install safety wire from the retaining-wire groove of one half-round bearing cup to the other.
3. Support the driveshaft with a nylon support strap.

   When uncoupling a coupling shaft, install two or three support straps, as needed. Remove the fasteners that attach the midship bearing(s) to its bracket(s). See **Fig. 1**.
4. Remove the capscrews that secure the bearing straps to the half-round yoke. Remove the bearing straps.
5. Compress the slip-joint to remove the U-joint from the yoke.

⚠ CAUTION

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

U-Joint Coupling

1. Check and clean the end-yoke.
   - 1.1 Check the torque on the end-yoke nut; see the applicable table in **Specifications, 400**.
   - 1.2 Check the end-yoke (or flange-yoke) cross-holes for burrs or raised metal. Using a half-round file, remove burrs or raised metal. See **Fig. 2**.
   - 1.3 Using fine emery cloth, smooth and clean the entire surface of the yoke cross-holes and bearing straps. See **Fig. 3**.
   - 1.4 Turn the end-yoke (or flange-yoke) until its cross-holes are horizontal. See **Fig. 1**.
2. Check, clean and lubricate the U-joint.
   - 2.1 Remove the bearing-cup retaining wire or safety wire. See **Fig. 1**.

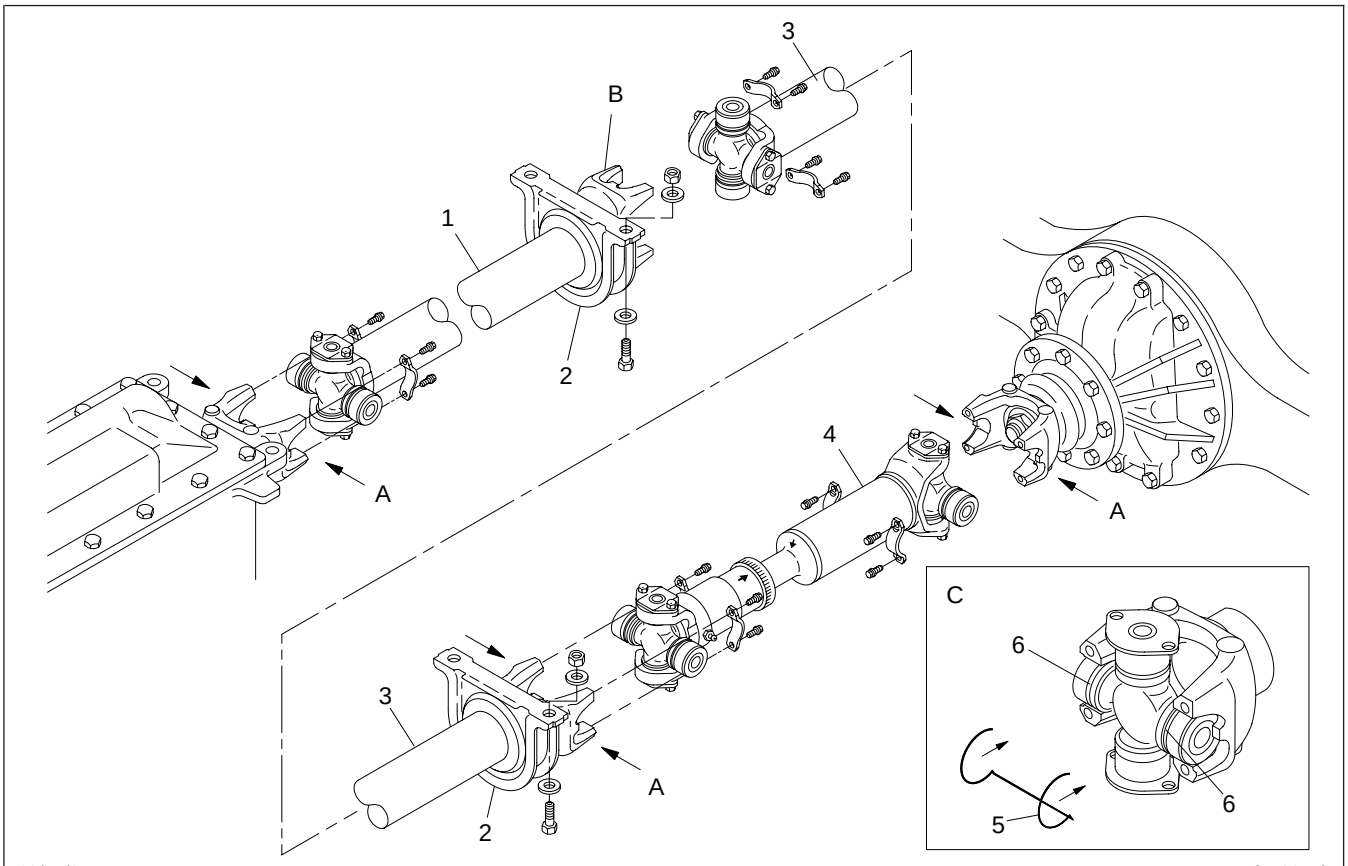
⚠ CAUTION

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

   - 2.2 Using fine emery cloth, smooth and clean the outside surfaces of both bearing cups. See **Fig. 4**.
   - 2.3 Check the U-joint trunnions and bearing cups for minute particles of dirt or grit. Clean if necessary; see **Subject 140**.
   - 2.4 Using NLGI grade 2 grease with EP additives, wipe a small amount of grease on the needles in the bearing cups.
   - 2.5 Using a light-weight oil, lubricate the lips of the bearing-cup seals. See **Fig. 5**.
   - 2.6 Install the bearing cups on the cross.
   - 2.7 Install a bearing-cup retaining wire. See **Fig. 1**. Or, install safety wire from the retaining-wire groove of one half-round bearing cup to the other.

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U-Joint Uncoupling and Coupling With a Half-Round End-Yoke



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NOTE: Not all fasteners are shown.

A. End-yoke cross-hole centerline is horizontal.
B. Before uncoupling/coupling the U-joint, turn the end-yoke until its cross-hole centerline is horizontal.
C. Install a half-round bearing-cup retaining wire (or safety wire) before removing the bearing straps.

1. Primary Coupling Shaft
2. Midship Bearing
3. Intermediate Coupling Shaft
4. No. 2 Driveshaft
5. Half-Round Bearing-Cup Retaining Wire
6. Retaining-Wire Groove

Fig. 1, U-Joint Uncoupling/Coupling for Drivelines With Half-Round End-Yokes

3. Extend the slip-joint, while pressing the cross and bearing cups into place in the yoke cross-holes. Using a rubber or plastic mallet, gently tap the bearing cups to seat them in the yoke. See **Fig. 6**.

⚠ CAUTION

Do not use the capscrews and bearing straps to seat the bearing cups in the yoke. Seating the cross by tightening the bearing straps can deform the bearing straps, allowing the bearing cups to spin, which will cause rapid wear and serious damage to the U-joint.

4. Place the bearing straps over the cups, and install the new strap capscrews finger-tight.

⚠ WARNING

The self-locking bearing-strap capscrews must not be reused. Replace the capscrews with new ones. Also, do not undertighten or overtighten the capscrews; use proper torque values. A loose or broken fastener at any point in the driveline

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U-Joint Uncoupling and Coupling With a Half-Round End-Yoke

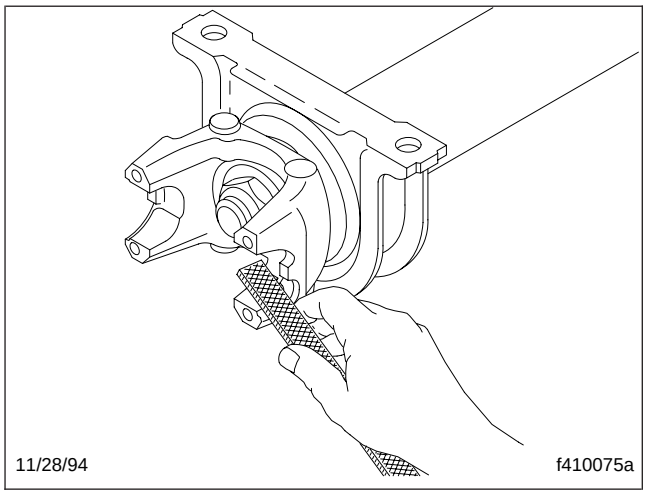
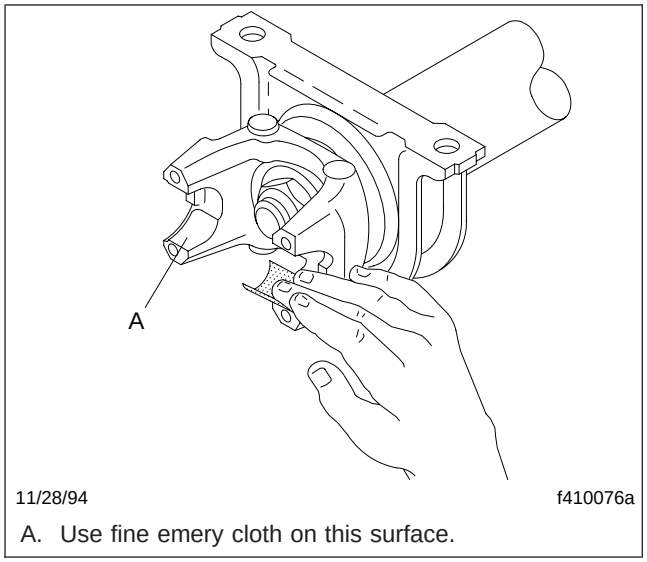


Fig. 2, Removing Burrs from a Half-Round End-Yoke Cross-Hole



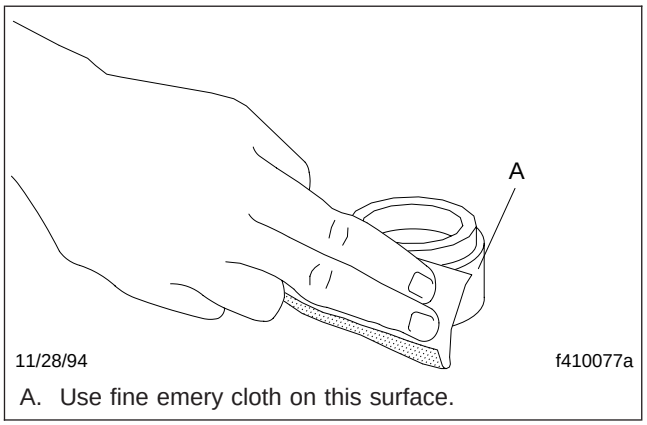
A. Use fine emery cloth on this surface.

Fig. 3, Smoothing a Half-Round End-Yoke Cross-Hole

weakens the driveline connection and can result in a driveshaft separating from the vehicle. Driveline separation can cause loss of vehicle control that could result in serious personal injury or death.

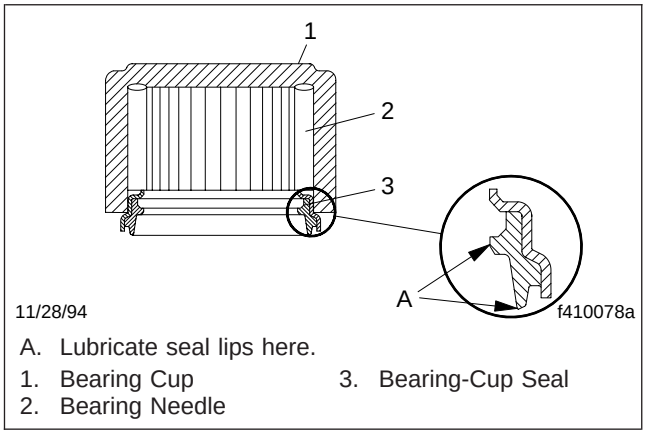
Separation of the driveline can also cause damage to the driveline, driveline components or other areas of the vehicle.

5. Alternately tighten the bearing-strap capscrews in increments of 20 lbf·ft (27 N·m) to the applicable torque value in **Specifications, 400**.



A. Use fine emery cloth on this surface.

Fig. 4, Smoothing a Half-Round End-Yoke U-Joint Bearing Cup



A. Lubricate seal lips here.
1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

Fig. 5, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup

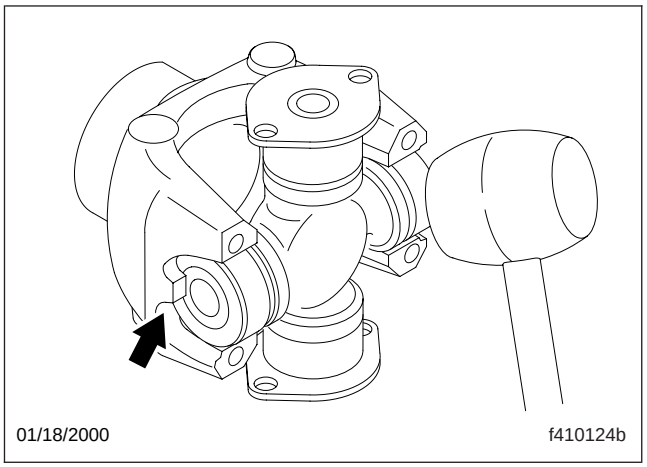


Fig. 6, Half-Round End-Yoke Retaining Tab

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U-Joint Uncoupling and Coupling With a Half-Round End-Yoke

6. If they were removed, install the fasteners that attach each midship bearing to its bracket; tighten the flanged locknuts 91 lbf·ft (123 N·m).
7. Lubricate the U-joint, following the procedure in Group 41 of the *Acterra Maintenance Manual*.
8. Remove the nylon support straps.
9. Remove the chocks from the front tires.

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U-Joint Uncoupling and Coupling With a Full-Round End-Yoke

NOTE: It is easier to check driveline parts, and to replace a U-joint or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed, and installed on a lathe or a balance machine. Removal is required for replacement of slip-joint parts, a driveshaft tube or a tube-yoke. To remove the driveshaft, see **Subject 120**.

NOTE: Many service operations do not require driveshaft removal from the vehicle: end-yoke or companion-flange nut tightening; drive component shaft seal, end-yoke, or flange-yoke replacement; changing U-joint phasing at the slip-yoke; and transmission or axle removal (for overhaul, repair, or replacement). To perform these operations, uncouple the U-joint at the applicable end of the appropriate driveshaft.

U-Joint Uncoupling

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front tires.
2. Turn the appropriate end-yoke until the centerline through its cross-holes is vertical. See **Fig. 1**.
3. Support the driveshaft with a nylon support strap.

   When uncoupling a coupling shaft, install two or three support straps, as needed. Remove the fasteners that attach the midship bearing(s) to its bracket(s).
4. Remove and discard all four bearing-cup-plate self-locking capscrews.
5. Using one of the U-joint pullers listed in **Specifications, 400**, remove both bearing assemblies from the end-yoke cross-holes. See **Fig. 2**.
6. Compress the slip-joint and pivot the end of the U-joint cross to remove it from the yoke. Install the bearing cups. Use tape to secure them to the U-joint cross.

CAUTION

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

U-Joint Coupling

1. Check and clean the end-yoke.
   - 1.1 Check the torque on the end-yoke nut; see the applicable table in **Specifications, 400**.
   - 1.2 Check the end-yoke cross-holes for burrs or raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3**.
   - 1.3 Using a mill file, and holding it flat against the machined surface of the yoke lug, remove any burrs or raised metal. See **Fig. 4**.
   - 1.4 Using fine emery cloth, smooth and clean the entire surface of the yoke cross-holes. See **Fig. 5**.
   - 1.5 Turn the end-yoke until the centerline through its cross-holes are vertical. See **Fig. 1**.
2. Check, clean and lubricate the U-joint.
   - 2.1 Using fine emery cloth, smooth and clean the outside surfaces of both bearing cups. See **Fig. 6**.
   - 2.2 Check the U-joint trunnions and bearing cups for minute particles of dirt or grit. Clean if necessary; see **Subject 140**.

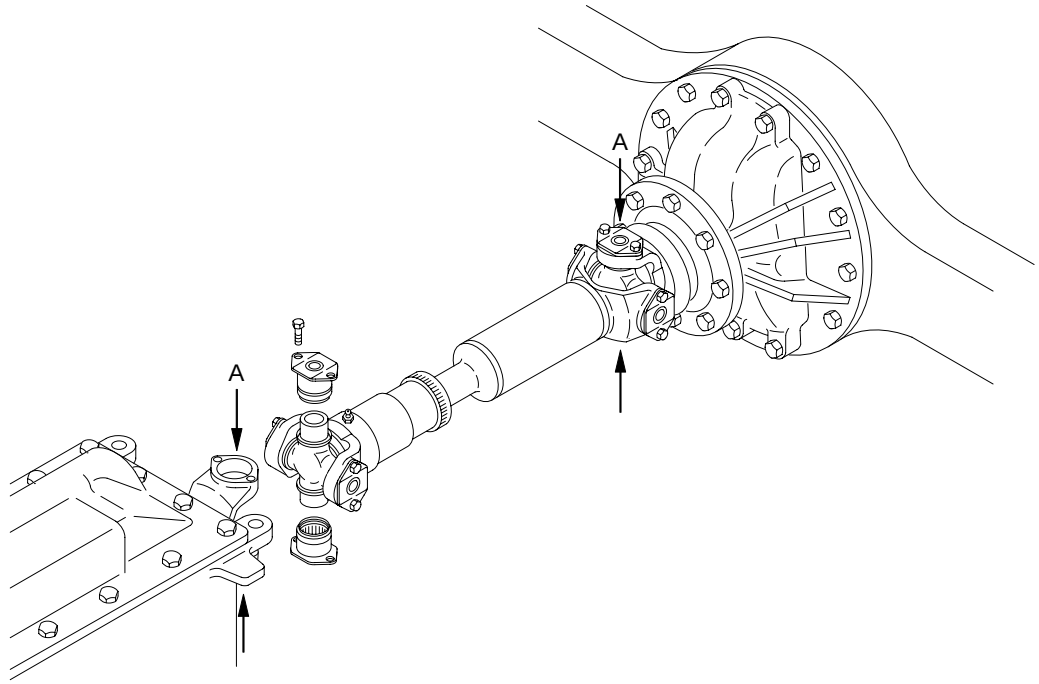
CAUTION

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

   - 2.3 Using NLGI grade 2 grease with EP additives, wipe a small amount of grease on the needles in the bearing cups.
   - 2.4 Using a light-weight oil, lubricate the lips of the bearing-cup seals. See **Fig. 7**.
3. Couple the U-joint cross to the end-yoke.
   - 3.1 Extend the slip-joint, while pivoting the U-joint cross into place in the yoke cross-holes.
   - 3.2 Move one end of the cross until a trunnion projects through the cross-hole, beyond

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U-Joint Uncoupling and Coupling With a Full-Round End-Yoke



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NOTE: Not all fasteners are shown.

A. End-yoke cross-hole centerline is vertical.

Fig. 1, U-Joint Uncoupling/Coupling of a Driveline With Full-Round End-Yokes

the outer machined face of the yoke lug. Using a Spicer trunnion (journal) locator (see **Specifications, 400**), hold the trunnions in alignment with the cross-holes, while placing a bearing assembly over the projected trunnion, and aligning it with the cross-hole. See **Fig. 8**.

IMPORTANT: A Spicer trunnion (journal) locator should be used, to prevent damage to the U-joint trunnions and slingers.

3.3 By hand, press the bearing assembly flush with the face of the yoke. If the bearing assembly binds in the cross-hole, tap the *center* of the bearing plate with a rubber or rawhide mallet; do not tap the outer edges of the bearing plate. See **Fig. 9**.

3.4 As equipped, install *new* bearing-cup-plate self-locking capscrews (**Fig. 10**), or the lockstrap and bearing-cup-plate (not self-locking) capscrews. Tighten the capscrews until all the parts are drawn down tight, with no gaps; do not tighten the capscrews to their final torque value.

⚠ WARNING

Self-locking bearing-cup-plate capscrews must not be reused; replace the capscrews with new ones. Also, do not undertighten or overtighten any bearing-cup-plate capscrews. A loose or broken fastener at any point in the driveline weakens the driveline connection, which could cause serious vehicle damage or could result in a driveshaft separating from the vehicle, possibly causing loss of vehicle control that could result in serious personal injury or death.

3.5 Move the cross until it projects beyond the machined surface of the opposite yoke lug. Repeat applicable substeps to install the opposite bearing.

3.6 Alternately tighten the bearing-cup-plate capscrews in increments of 60 lbf·ft (680

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U-Joint Uncoupling and Coupling With a Full-Round End-Yoke

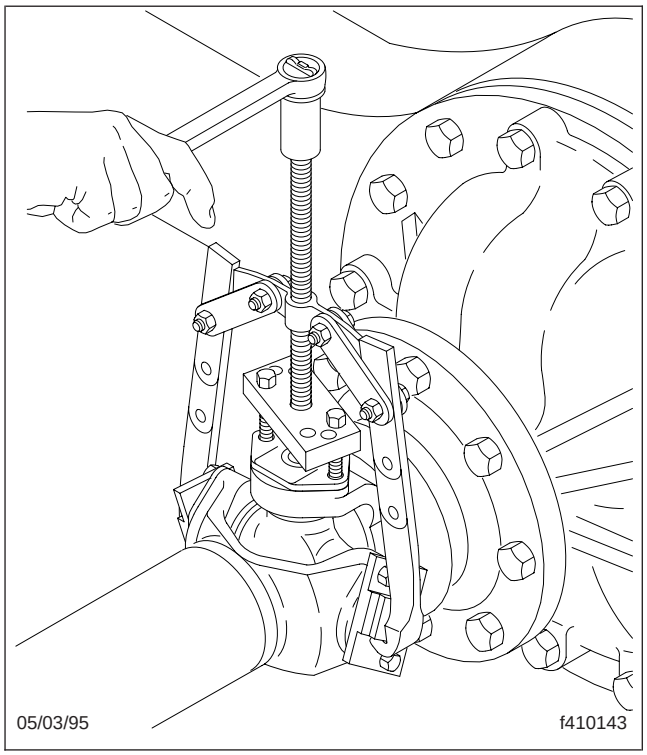


Fig. 2, Removing a Bearing Cup From a Full-Round End-Yoke

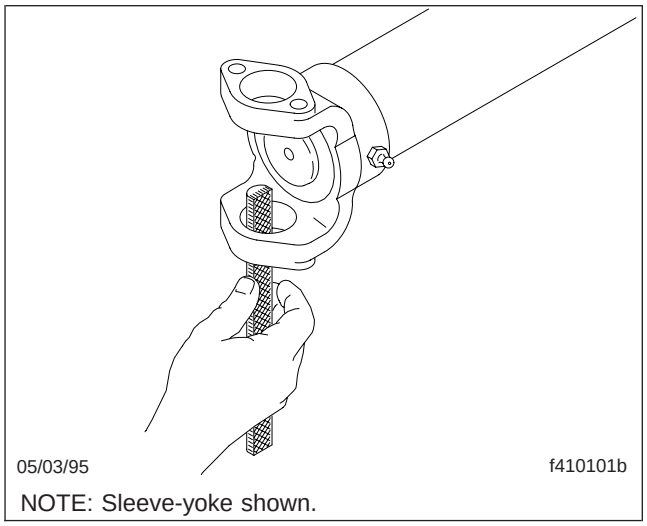


Fig. 3, Removing Burrs From a Full-Round Yoke Cross-Hole

N·m), to the torque value in **Specifications, 400**.

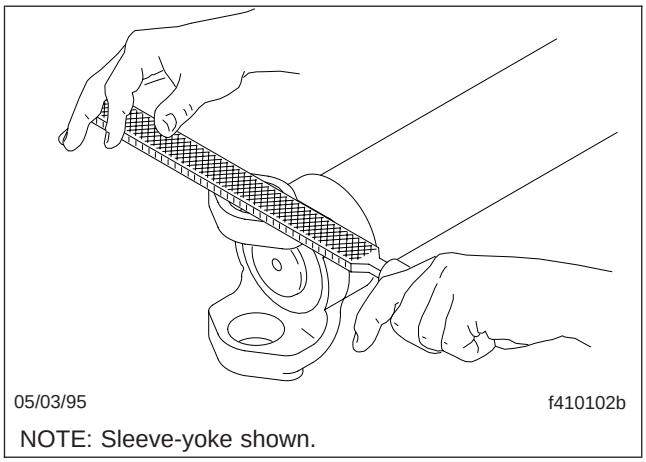


Fig. 4, Removing Burrs from the Machined Surface of a Full-Round Yoke Lug

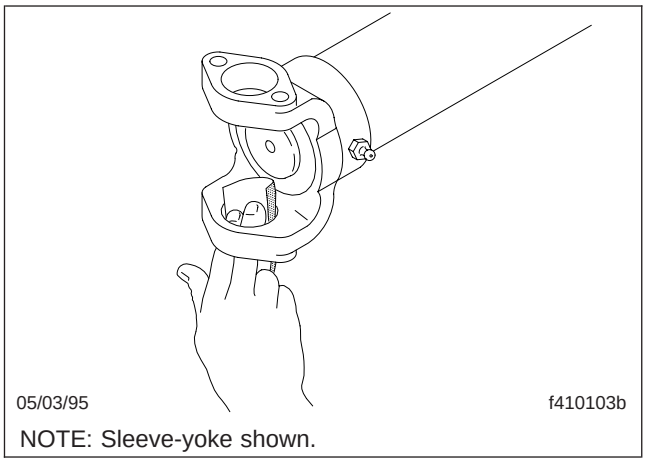


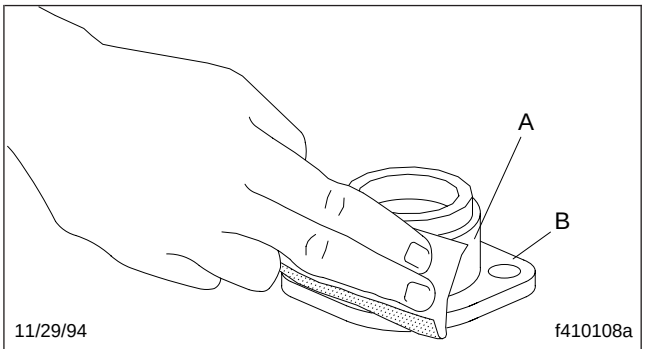
Fig. 5, Smoothing a Full-Round Yoke Cross-Hole

If equipped with lockplates, use a hammer and a pin punch to bend all four tabs of both lockplates upward until the tabs are firmly against a flat side of each capscrew. See **Fig. 11**.

4. If they were removed, install the fasteners that attach each midship bearing to its bracket; tighten the flanged locknuts 91 lbf·ft (123 N·m).
5. Lubricate the U-joint, following the procedure in Group 41 of the *Acterra Maintenance Manual*.
6. Remove the nylon support straps.
7. Remove the chocks from the front tires.

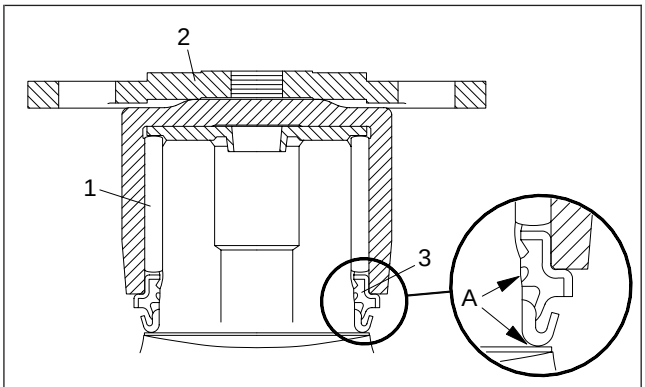
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U-Joint Uncoupling and Coupling With a Full-Round End-Yoke



A. Use fine emery cloth on this surface.
B. Use a mill file on this surface.

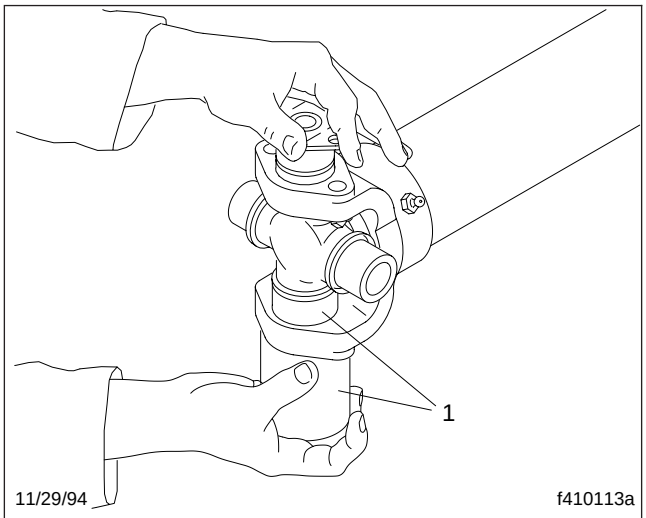
Fig. 6, Smoothing a Full-Round Yoke U-Joint Bearing Cup



A. Lubricate seal lips here.

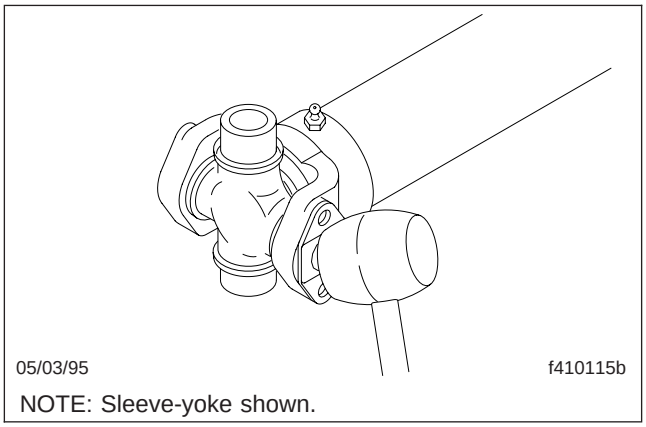
1. Bearing Needle
2. Bearing-Cup Plate
3. Bearing-Cup Seal

Fig. 7, Sectional View of a Full-Round Yoke U-Joint Bearing Cup



NOTE: Sleeve-yoke shown.
1. Trunnion Locator

Fig. 8, Using a U-Joint Trunnion Locator

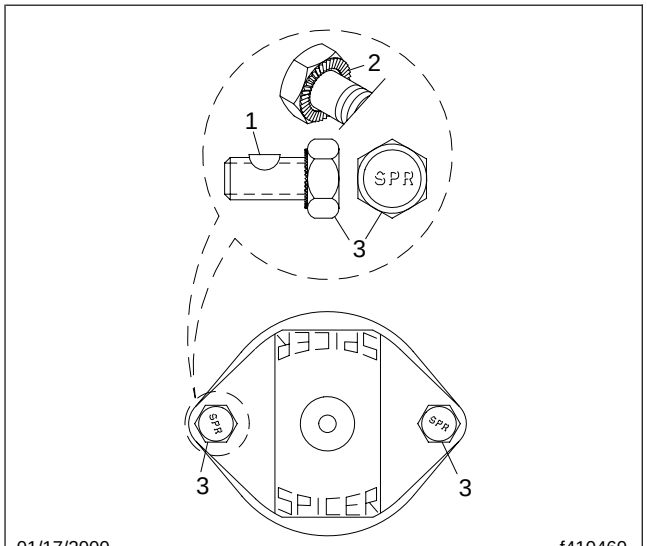


NOTE: Sleeve-yoke shown.

Fig. 9, Seating a U-Joint Bearing Cup in a Full-Round Yoke

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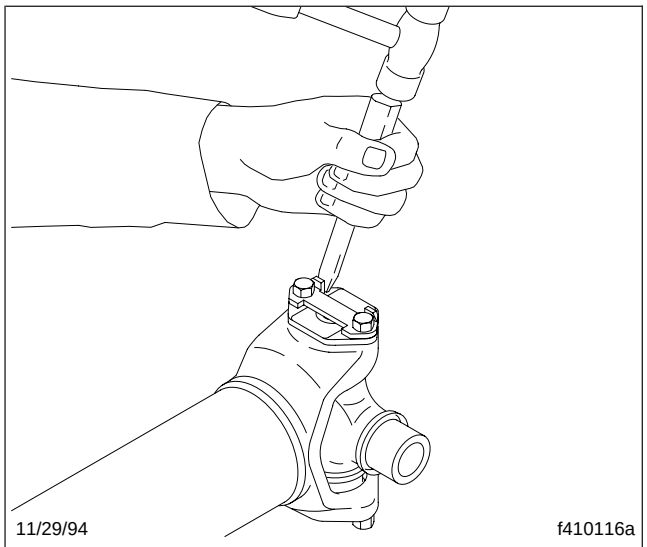
U-Joint Uncoupling and Coupling With a Full-Round End-Yoke



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1. Lock Patch
2. Serrations
3. Self-Locking Capscrew

Fig. 10, Spicer U-Joint Fasteners for Full-Round Yokes With Self-Locking Capscrews



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NOTE: Sleeve-yoke shown.

Fig. 11, Bending a Lockplate Tab Against a U-Joint Capscrew

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NOTE: Many service operations do not require driveshaft removal from the vehicle: end-yoke or companion-flange nut tightening; drive component shaft seal, end-yoke, or flange-yoke replacement; changing U-joint phasing at the slip-yoke; and transmission or axle removal (for overhaul, repair, or replacement). To perform these operations, uncouple the U-joint at the applicable end of the appropriate driveshaft; see **Subject 100**, for uncoupling from a *half-round* end-yoke, or see **Subject 110**, for uncoupling from a *full-round* end-yoke.

NOTE: It is easier to check driveline parts, and to replace a U-joint or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed, and installed on a lathe or balance machine. Removal is required for replacement of slip-joint parts, a driveshaft tube, or a tube-yoke.

No. 3 Driveshaft Removal

(See Fig. 1)

1. Uncouple the No. 3 driveshaft from the rearmost axle. If the No. 3 driveshaft is coupled to *half-round* end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 3 driveshaft is coupled to *full-round* end-yokes, follow the uncoupling procedure in **Subject 110**.
2. Uncouple the No. 3 driveshaft from the forward-rear axle. If the No. 3 driveshaft is coupled to half-round end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 3 driveshaft is coupled to full-round end-yokes, follow the uncoupling procedure in **Subject 110**.
3. Lift the No. 3 driveshaft out of the chassis.

No. 2 Driveshaft Removal

(See Fig. 2)

1. Uncouple the No. 2 driveshaft from the single or forward-rear axle. If the No. 2 driveshaft is coupled to *half-round* end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 2 driveshaft is coupled to *full-round* end-yokes, follow the uncoupling procedure in **Subject 110**.
2. For a vehicle with a Spicer SPL90 (1590) *coupling shaft*, use a marking stick or paint to mark the sleeve-yoke and coupling shaft with alignment marks, as shown in **Fig. 3**. Pull the driveshaft sleeve-yoke off of the midship bearing splined shaft.

   For all other installations, uncouple the No. 2 driveshaft from the transmission or coupling shaft. If the No. 2 driveshaft is coupled to half-round end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 2 driveshaft is coupled to full-round end-yokes, follow the uncoupling procedure in **Subject 110**.
3. Lift the No. 2 driveshaft out of the chassis.

Intermediate Coupling Shaft Removal **(See Fig. 4)**

1. If the No. 2 driveshaft is also being removed, remove it first.

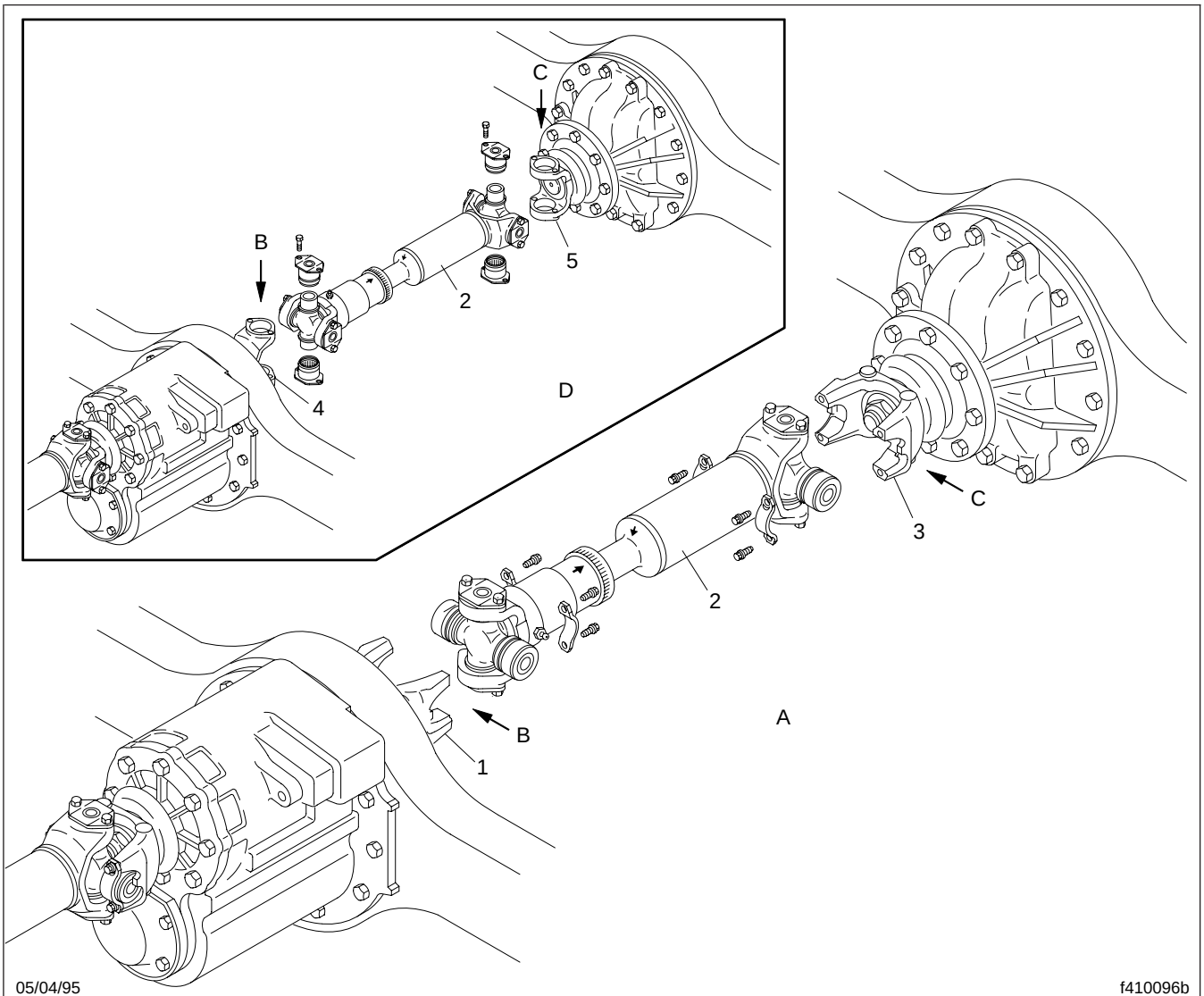
   If the No. 2 driveshaft is not being removed, use a nylon support strap to support its forward end.
2. For a vehicle with a Spicer SPL90 (1590) coupling shaft, use a marking stick or paint to mark the sleeve-yoke and coupling shaft with alignment marks, as shown in **Fig. 3**.

   For all other installations, uncouple the intermediate coupling shaft from the No. 2 driveshaft. If the intermediate coupling shaft has a *half-round* end-yoke, follow the uncoupling procedure in **Subject 100**. If the intermediate coupling shaft has a *full-round* end-yoke, follow the uncoupling procedure in **Subject 110**.
3. Uncouple the intermediate coupling shaft from the primary coupling shaft. See **Fig. 5**. If the primary coupling shaft has a half-round end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the uncoupling procedure in **Subject 110**.

NOTE: If the No. 2 driveshaft was not removed from a vehicle with a Spicer SPL90 (1590) driveline, pull the midship bearing splined shaft out of the No. 2 driveshaft sleeve-yoke. See **Fig. 3**.

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Driveshaft Removal and Installation



NOTE: Not all fasteners are shown.

A. No. 3 Driveshaft Coupled to Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
1. Forward-Rear Axle Output-Shaft Half-Round End-Yoke
2. No. 3 Driveshaft
C. Uncouple this end first; couple this end last.
D. No. 3 Driveshaft Coupled to Full-Round End-Yokes
3. Rearmost Axle Input-Shaft Half-Round End-yoke
4. Forward-Rear Axle Output-Shaft Full-Round End-Yoke
5. Rearmost Axle Input-Shaft Full-Round End-yoke

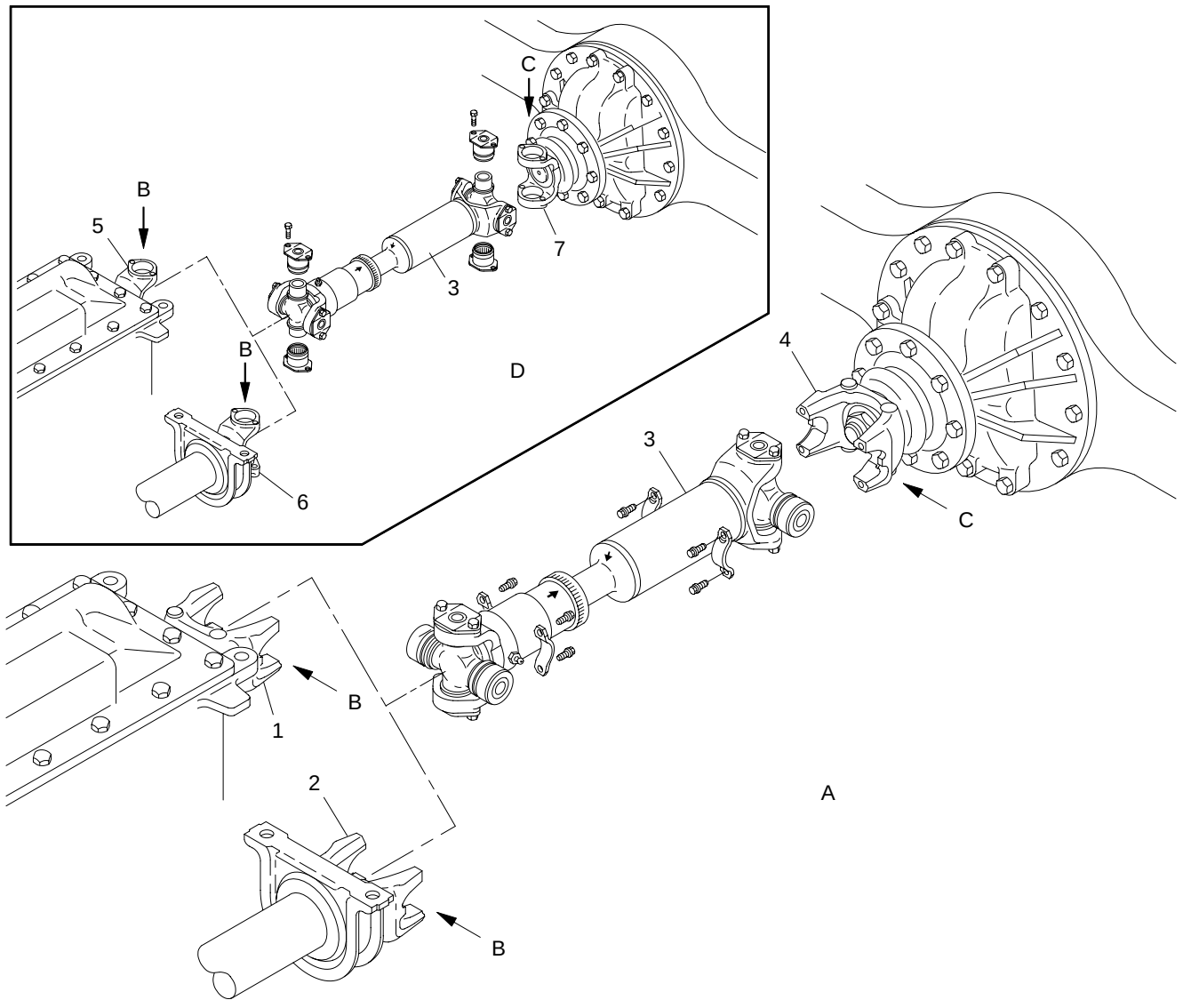
Fig. 1, Removal/Installation of a No. 3 Driveshaft

4. Lift the intermediate coupling shaft out of the chassis.

Primary Coupling Shaft Removal (See Fig. 5)

1. *For a vehicle with one coupling shaft:*

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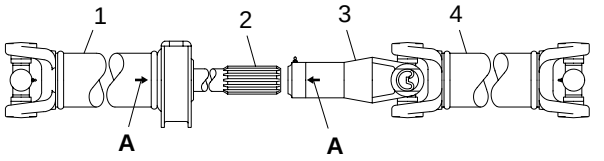
NOTE: Not all fasteners are shown.

A. No. 2 Driveshaft Coupled to Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
C. Uncouple this end first; couple this end last.
D. No. 2 Driveshaft Coupled to Full-Round End-Yokes
1. Transmission Output-Shaft Half-Round End-Yoke
2. Coupling Shaft Half-Round End-Yoke
3. No. 2 Driveshaft
4. Single Axle or Forward-Rear Axle Input-Shaft Half-Round End-Yoke
5. Transmission Output-Shaft Full-Round End-Yoke
6. Coupling Shaft Full-Round End-Yoke
7. Single Axle or Forward-Rear Axle Input-Shaft Full-Round End-Yoke

Fig. 2, Removal/Installation of a No. 2 Driveshaft

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Driveshaft Removal and Installation



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A. Add alignment marks at these locations before separating the parts of the slip-joint.
1. Spicer SPL90 (1590) Coupling Shaft
2. Splined Shaft
3. Sleeve-Yoke
4. No. 2 Driveshaft

Fig. 3, Spicer SPL90 (1590) Coupling Shaft Slip-Joint

If the No. 2 driveshaft is also being removed, remove it first.

If the No. 2 driveshaft is not being removed, use a nylon support strap to support its forward end. For a vehicle with a Spicer SPL90 (1590) coupling shaft, use a marking stick or paint to mark the sleeve-yoke and coupling shaft with alignment marks, as shown in **Fig. 3**.

For a vehicle with two coupling shafts:

If the No. 2 driveshaft is also being removed, remove it. Remove the intermediate coupling shaft.

If the intermediate coupling shaft is also being removed (but not the No. 2 driveshaft), remove the intermediate coupling shaft first.

If only the primary coupling shaft is being removed, use nylon support straps to support the forward end of the No. 2 driveshaft and both ends of the intermediate coupling shaft. Remove the fasteners that attach the intermediate coupling shaft midship bearing to its bracket. See **Fig. 5**.

2. If not already done, uncouple the primary coupling shaft from the No. 2 driveshaft or intermediate coupling shaft. If the primary coupling shaft has a *half-round* end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft has a *full-round* end-yoke, follow the uncoupling procedure in **Subject 110**.
3. Using two nylon support straps, support the primary coupling shaft. Remove the fasteners that attach the primary coupling shaft midship bearing to its bracket. See **Fig. 5**.
4. Uncouple the primary coupling shaft from the transmission. If the primary coupling shaft is coupled to a half-round end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft is coupled to a full-round end-yoke, follow the uncoupling procedure in **Subject 110**.

NOTE: If the No. 2 driveshaft was not removed from a vehicle with a Spicer SPL90 (1590) single-coupling-shaft driveline, pull the midship bearing splined shaft out of the No. 2 driveshaft sleeve-yoke. See **Fig. 3**.

5. Lift the primary coupling shaft out of the chassis.

Primary Coupling Shaft Installation (See Fig. 5)

IMPORTANT: Before installing a coupling shaft that has a fixed end-yoke (not a splined reverse-slip shaft), make sure the yokes are aligned to keep the U-joints in phase. See **Fig. 6**.

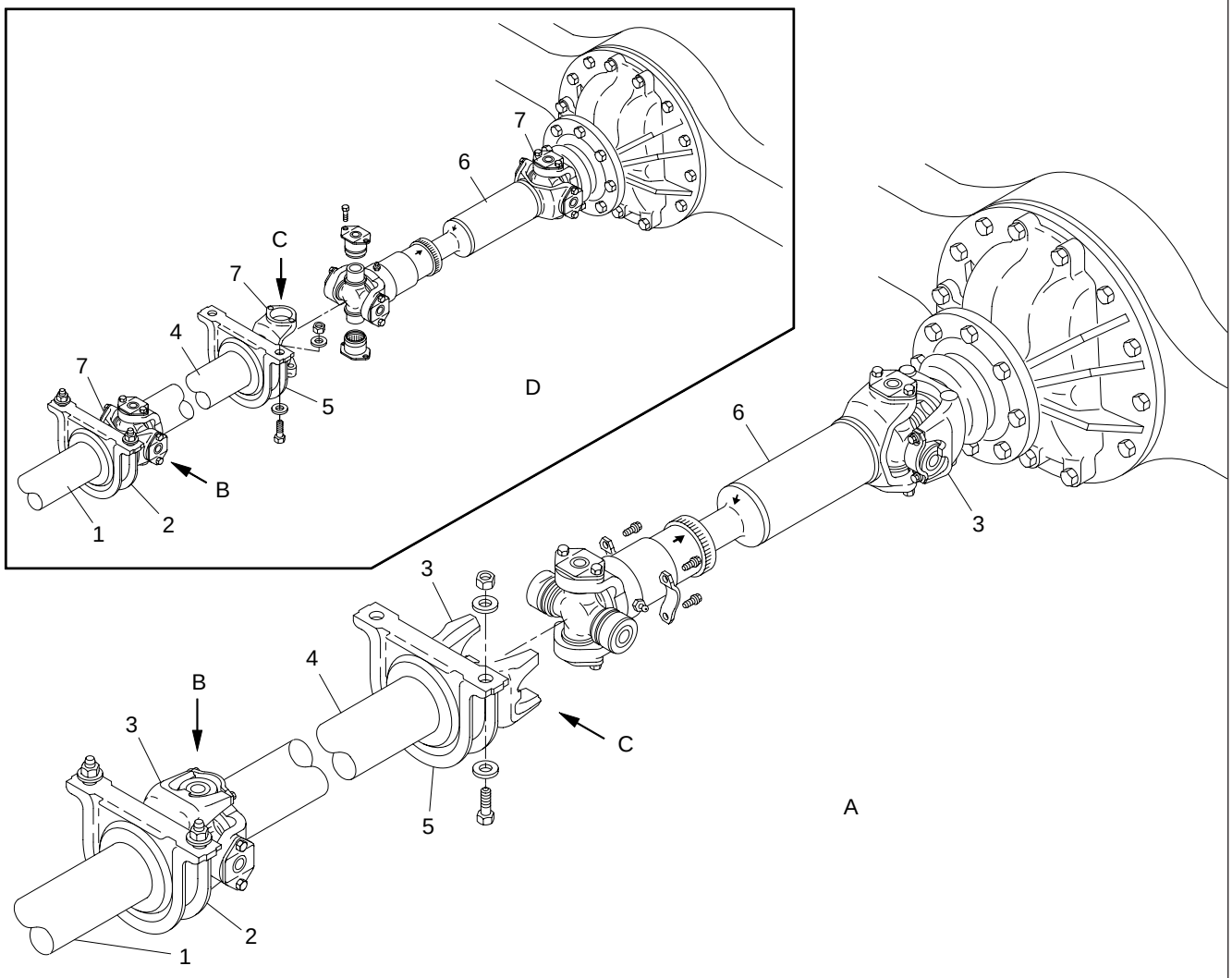
1. Place the primary coupling shaft under the vehicle and support it with nylon support straps so it can be coupled to the transmission end-yoke.

   If the No. 2 driveshaft was not removed from a vehicle with a Spicer SPL90 (1590) single-coupling-shaft driveline, align the alignment marks of the coupling shaft and the driveshaft sleeve-yoke, slide the sleeve-yoke over the splined reverse-slip shaft. See **Fig. 3**.
2. Couple the shaft to the transmission end-yoke (or flange-yoke). If the primary coupling shaft was coupled to a *half-round* end-yoke, follow the coupling procedure in **Subject 100**. If the primary coupling shaft was coupled to a *full-round* end-yoke, follow the coupling procedure in **Subject 110**.
3. *For a vehicle with one coupling shaft:*

   If the No. 2 driveshaft was also removed, install it as instructed in this subject.

   If the No. 2 driveshaft was not removed from a vehicle equipped with other than a Spicer SPL90 (1590) driveline, couple it to the primary coupling shaft end-yoke. If the primary coupling shaft has a half-round end-yoke, follow the coupling proce-

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NOTE: Not all fasteners are shown.

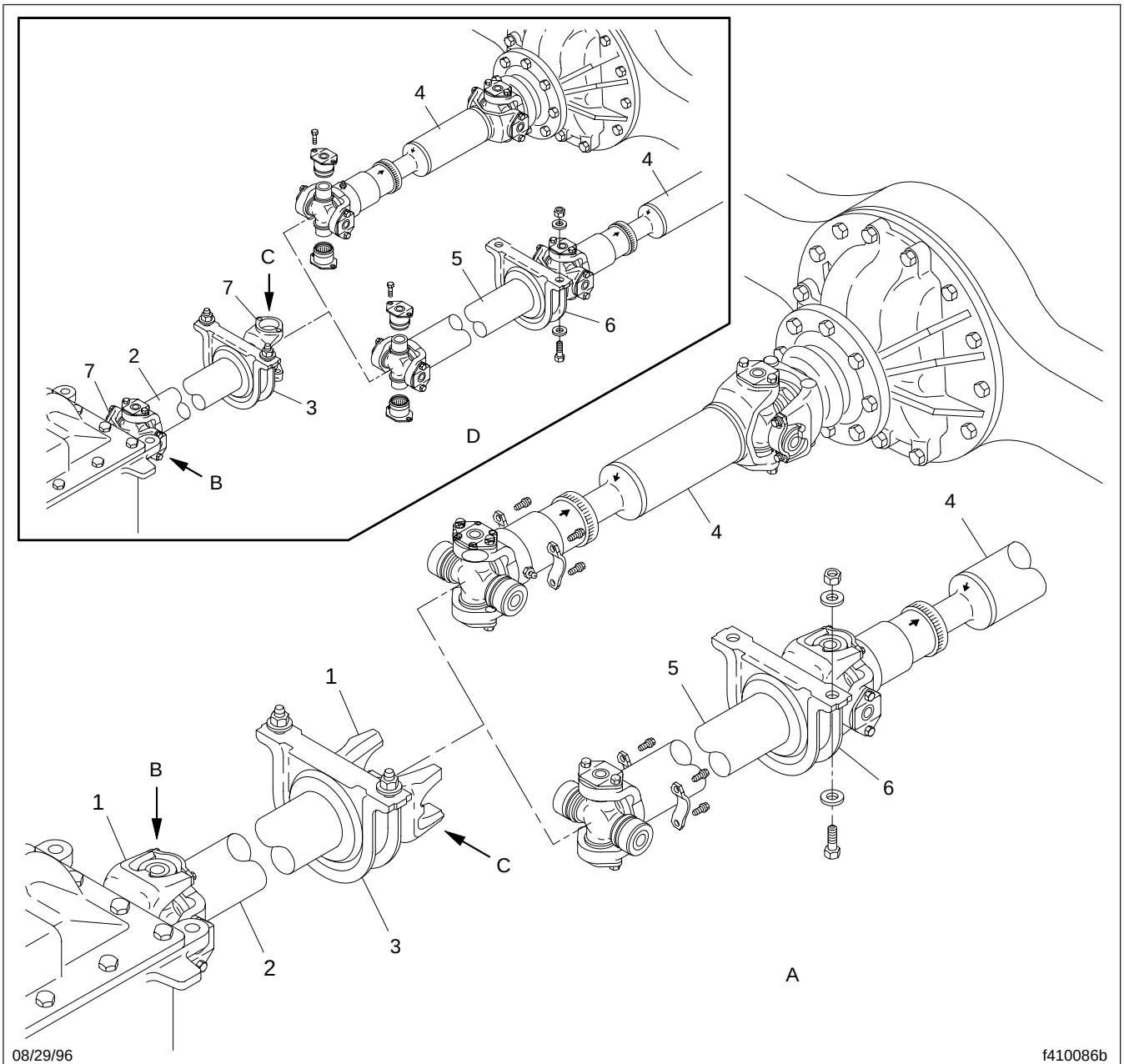
A. No. 2 Driveline With Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
C. Uncouple this end first; couple this end last.
D. No. 2 Driveline With Full-Round End-Yokes
1. Primary Coupling Shaft
2. Primary Coupling Shaft Midship Bearing
3. Half-Round End-Yoke
4. Intermediate Coupling Shaft
5. Intermediate Coupling Shaft Midship Bearing
6. No. 2 Driveshaft
7. Full-Round End-Yoke

Fig. 4, Removal/Installation of an Intermediate Coupling Shaft

dure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.

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Driveshaft Removal and Installation

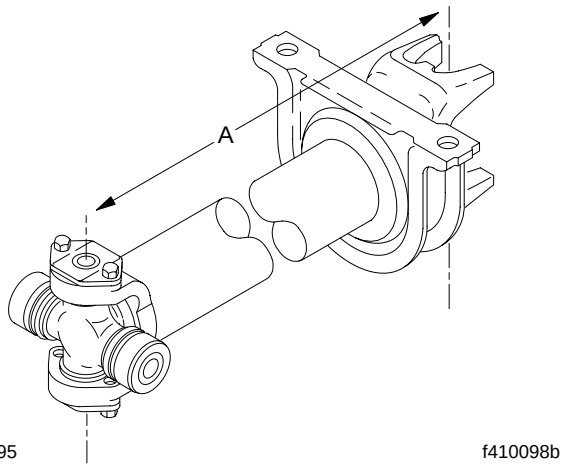


NOTE: Not all fasteners are shown.

A. No. 2 Driveline With Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
1. Half-Round End-Yoke
2. Primary Coupling Shaft
3. Primary Coupling Shaft Midship Bearing
4. No. 2 Driveshaft
C. Uncouple this end first; couple this end last.
D. No. 2 Driveline With Full-Round End-Yokes
5. Intermediate Coupling Shaft
6. Intermediate Coupling Shaft Midship Bearing
7. Full-Round End-Yoke

Fig. 5, Removal/Installation of a Primary Coupling Shaft

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A. Cross-hole centerlines of both yokes must be in alignment.

Fig. 6, U-Joint Phasing of a Coupling Shaft Equipped With an End-Yoke

For a vehicle with two coupling shafts:

If the intermediate coupling shaft was also removed, install it as instructed in this subject.

If only the primary coupling shaft was removed, couple the intermediate coupling shaft to the primary coupling shaft end-yoke. If the primary coupling shaft has a half-round end-yoke, follow the coupling procedure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.

Intermediate Coupling Shaft Installation (See Fig. 4)

IMPORTANT: Before installing a coupling shaft that has a fixed end-yoke (not a splined reverse-slip shaft), make sure the yokes are aligned to keep the U-joints in phase. See **Fig. 6**.

1. If the primary coupling shaft was also removed, install it first, as instructed in this subject.
2. Place the intermediate coupling shaft under the vehicle and support it with nylon support straps so it can be coupled to the primary coupling shaft end-yoke.

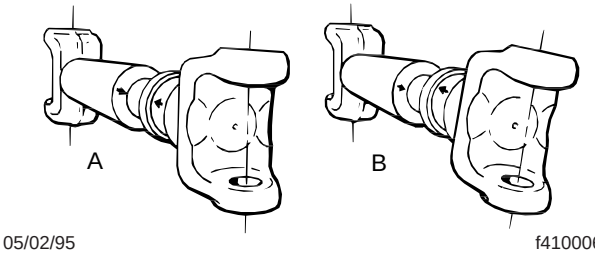
   If the No. 2 driveshaft was not removed from a vehicle with a Spicer SPL90 (1590) driveline, align the alignment marks of the coupling shaft and the driveshaft sleeve-yoke, slide the sleeve-yoke over the splined reverse-slip shaft. See **Fig. 3**.
3. Couple the intermediate coupling shaft to the primary coupling shaft end-yoke. If the intermediate coupling shaft was coupled to a *half-round* end-yoke, follow the coupling procedure in **Subject 100**. If the intermediate coupling shaft was coupled to a *full-round* end-yoke, follow the coupling procedure in **Subject 110**.
4. If the No. 2 driveshaft was also removed, install it as instructed in this subject.

   If the No. 2 driveshaft was not removed from a vehicle equipped with other than a Spicer SPL90 (1590) driveline, couple it to the intermediate coupling shaft end-yoke. If the intermediate coupling shaft has a half-round end-yoke, follow the coupling procedure in **Subject 100**. If the intermediate coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.

No. 2 Driveshaft Installation

(See Fig. 2)

IMPORTANT: Before installing a No. 2 driveshaft that has a sleeve-yoke (not a splined reverse-slip shaft) at its forward end, make sure the alignment marks on the slip-joint assembly are aligned, to keep the U-joints in phase. See **Fig. 7**.



A. In Phase B. Out of Phase

Fig. 7, U-Joint Phasing

1. If a primary coupling shaft was also removed, install it first, as instructed in this subject.

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Driveshaft Removal and Installation

2. If an intermediate coupling shaft was also removed, install it before installing the No. 2 driveshaft.
3. Place the No. 2 driveshaft under the vehicle with its sleeve-yoke at the forward end, and support its rear end with a nylon support strap.
4. For a vehicle with a Spicer SPL90 (1590) coupling shaft, align the alignment marks of the coupling shaft and the No. 2 driveshaft sleeve-yoke. Slide the sleeve-yoke over the splined reverse-slip shaft. See **Fig. 3**.

   For all other vehicles, couple the sleeve-yoke to the coupling shaft end-yoke or transmission output-shaft end-yoke, as applicable. If the No. 2 driveshaft was coupled to *half-round* end-yokes, follow the coupling procedure in **Subject 100**. If the No. 2 driveshaft was coupled to *full-round* end-yokes, follow the coupling procedure in **Subject 110**.
5. Couple the No. 2 driveshaft to the axle input-shaft end-yoke. If the No. 2 driveshaft was coupled to half-round end-yokes, follow the coupling procedure in **Subject 100**. If the No. 2 driveshaft was coupled to full-round end-yokes, follow the coupling procedure in **Subject 110**.

No. 3 Driveshaft Installation

(See Fig. 1)

IMPORTANT: Before installing a No. 3 driveshaft, make sure the alignment marks on the slip-joint assembly are aligned to keep the U-joints in phase. See **Fig. 7**.

1. Place the No. 3 driveshaft under the vehicle with its sleeve-yoke at the forward end, and support its rear end with a nylon support strap.
2. Couple the sleeve-yoke to the forward-rear axle output-shaft end-yoke. If the No. 3 driveshaft was coupled to *half-round* end-yokes, follow the coupling procedure in **Subject 100**. If the No. 3 driveshaft was coupled to *full-round* end-yokes, follow the coupling procedure in **Subject 110**.
3. Couple the No. 3 driveshaft to the axle input-shaft end-yoke. If the No. 3 driveshaft was coupled to half-round end-yokes, follow the coupling procedure in **Subject 100**. If the No. 3 driveshaft was coupled to full-round end-yokes, follow the coupling procedure in **Subject 110**.

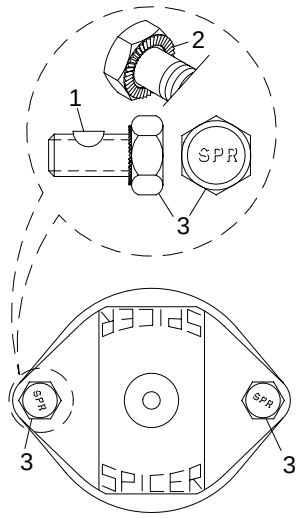
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Driveline Parking Brake Flange-Yoke or Companion Flange Removal

For removal of a driveline parking brake flange-yoke or companion flange, see **Group 42**.

Spicer 1610/1710/1760 U-Joint Removal

1. Remove the driveshaft from the vehicle; see **Subject 120**.
2. Place the driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
3. Remove and discard all four bearing-plate self-locking capscrews. See **Fig. 1**.



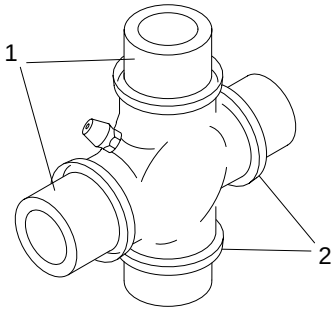
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1. Lock Patch
2. Serrations
3. Self-Locking Capscrew

Fig. 1, Spicer U-Joint Fasteners for Full-Round Yokes With Self-Locking Capscrews

IMPORTANT: If the U-joint will be reinstalled, use care not to nick the cross trunnions or damage the slingers. See **Fig. 2**.

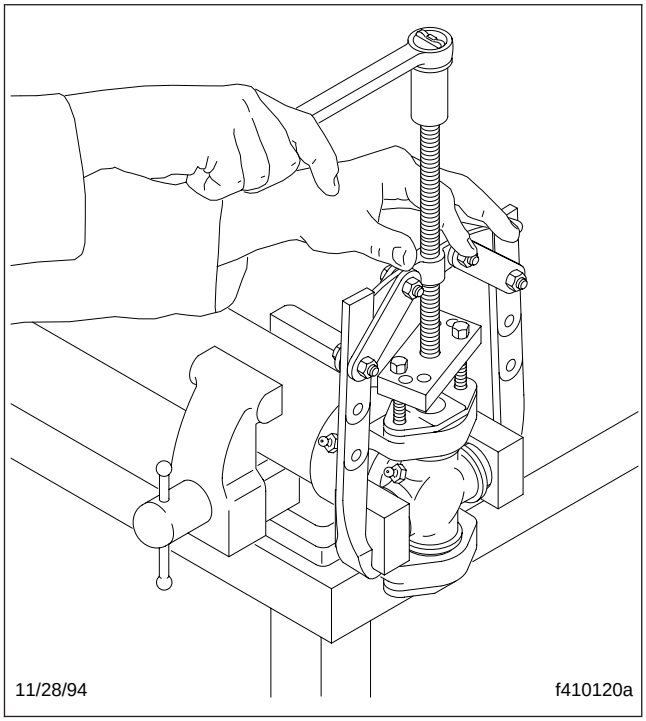
4. Using one of the U-joint pullers listed in **Specifications, 400**, remove both bearing cups from the yoke cross-holes. See **Fig. 3**. Remove the cross from the yoke.



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1. Trunnions
2. Slingers

Fig. 2, U-Joint Cross



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Fig. 3, Removing a Bearing Cup From a Full-Round Yoke

Spicer SPL90 (1590) U-Joint Removal

1. Remove the driveshaft from the vehicle. See **Subject 110**.

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Driveline Components Removal/Disassembly

2. Clamp the driveshaft in a soft-jawed vise; do not distort the tube with excessive grip.

NOTE: When removing a U-joint that connects the sleeve-yoke to the forward tube-yoke of the no. 2 driveshaft, mark the sleeve-yoke and driveshaft tube with alignment marks, clamp the driveshaft tube in the vise, and disconnect the U-joint from the tube-yoke. Clamp the sleeve-yoke in the vise and remove the U-joint from the sleeve-yoke. See **Fig. 4**.

3. Remove the U-joint snap rings from the yoke.

   3.1 Using a hammer and a soft drift, tap the outside of the bearing cup to loosen the snap ring. See **Fig. 5**. Tap the bearing only hard enough to break the assembly away from the snap ring.

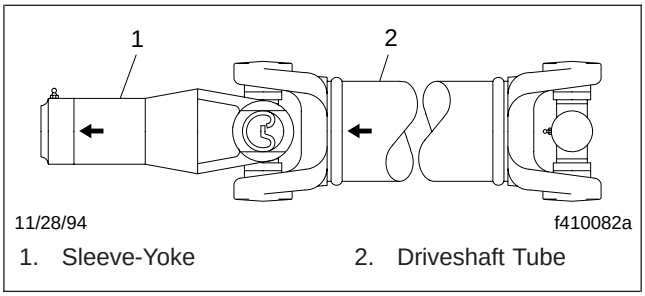


Fig. 4, Spicer SPL90 (1590) No. 2 Driveshaft (as used with a coupling shaft)

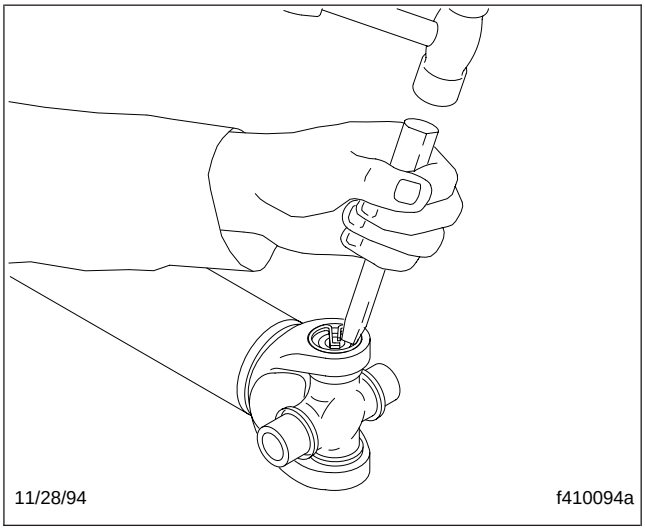


Fig. 5, Loosening a Spicer SPL90 (1590) U-Joint Snap Ring

   3.2 Using pliers, remove the snap ring. See **Fig. 6**.

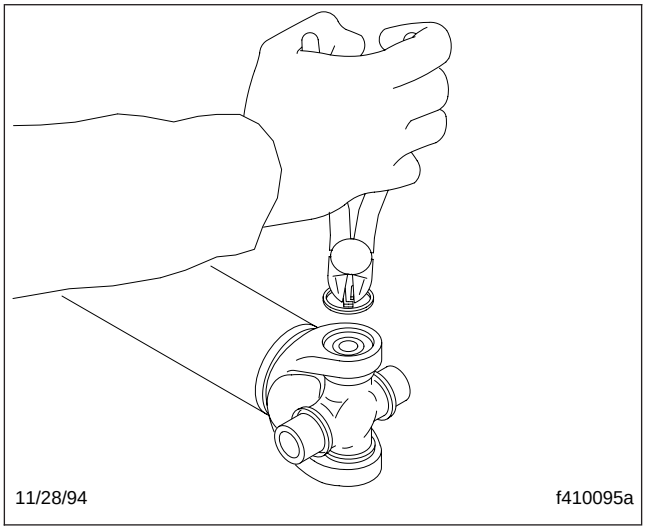


Fig. 6, Removing/Installing a Spicer SPL90 (1590) U-Joint Snap Ring

   3.3 Turn the shaft (or sleeve-yoke) over. Repeat this step for the opposite snap ring.

4. Press the U-joint bearing assemblies and cross out of the yoke. See **Fig. 7**.

   4.1 Set the yoke in an arbor press, on a piece of tube stock with an inside diameter larger than the outside diameter of the bearing cup. See **Fig. 7**.

   4.2 Place a solid plug with an outside diameter slightly smaller than the inside diameter of the yoke cross-holes, on the upper bearing assembly. Press it through the upper cross-hole to release the lower bearing assembly.

   If the bearing assembly will not pull out by hand after pressing, tap the base of the yoke lug near the bearing assembly to dislodge it.

   4.3 Remove the opposite bearing assembly by turning the yoke over, and straightening the cross in the open cross-hole. Carefully press on the end of the cross so the remaining bearing assembly moves straight out of the cross-hole.

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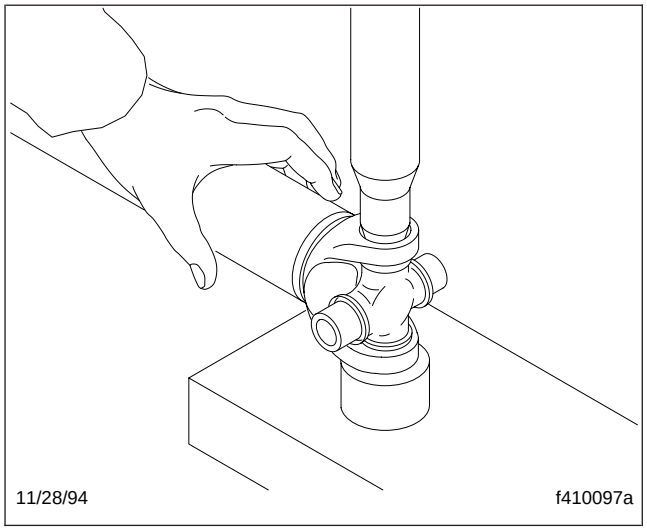
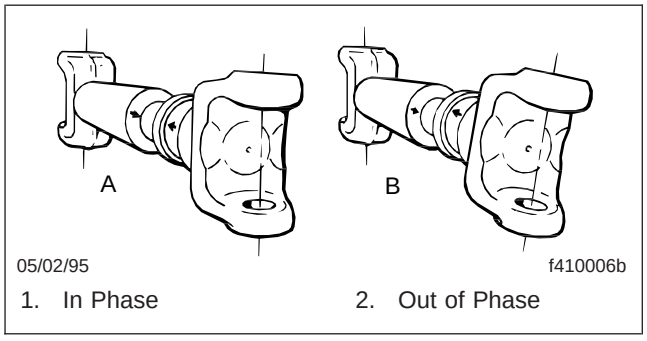


Fig. 7, Pressing a Spicer SPL90 (1590) U-Joint Out-of/ Into a Yoke

IMPORTANT: If the cross or bearing assembly is cocked, the bearing assembly will score the walls of the cross-hole and ruin the yoke.

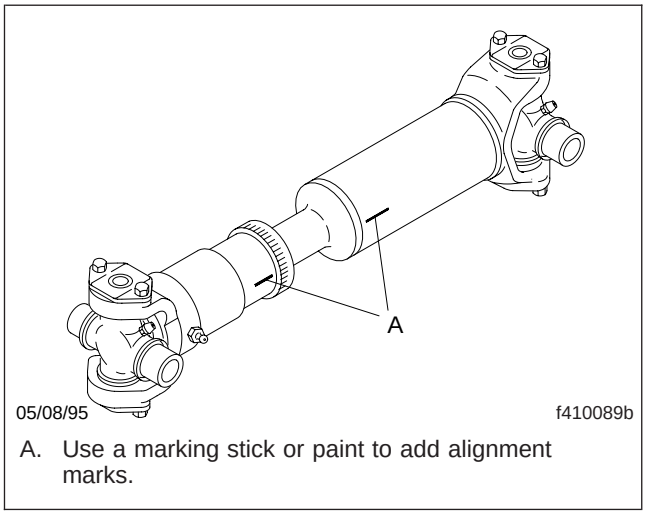
Slip-Joint Disassembly

1. Check that the driveshaft yokes are aligned to hold the U-joints at either end in phase, as shown in **Fig. 8**. Using a marking stick or paint, mark the sleeve-yoke and splined shaft with alignment marks, as shown in **Fig. 9**. This will ensure proper alignment of the slip-joint components when the driveshaft is assembled.



1. In Phase
2. Out of Phase

Fig. 8, U-Joint Phasing

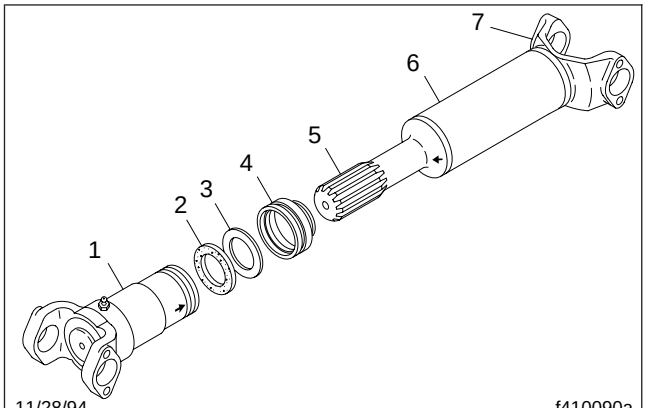


A. Use a marking stick or paint to add alignment marks.

Fig. 9, Slip-Joint Alignment Marks

IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

2. With the driveshaft uncoupled at one end, *or* removed from the vehicle, use a strap wrench to unscrew the slip-joint dust cap from the sleeve-yoke. Pull the sleeve-yoke off of the splined shaft. Remove the dust cap, and (if so equipped) the steel washer and cork seal. See **Fig. 10**.



1. Sleeve-Yoke
2. Cork Washer
3. Steel Washer
4. Dust Cap
5. Splined Stub Shaft
6. Tube
7. Tube-Yoke

Fig. 10, Slip-Joint Components

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Driveline Components Removal/Disassembly

Transmission/Axle End-Yoke Removal

IMPORTANT: Before removing a transmission output-shaft end-yoke or an axle shaft end-yoke, see **Subject 140**.

1. Uncouple the driveshaft from the end-yoke (**Subject 100** for a half-round yoke or **Subject 110** for a full-round yoke), or remove the driveshaft from the vehicle (**Subject 120**).
2. Remove the end-yoke locknut. See **Fig. 11**.

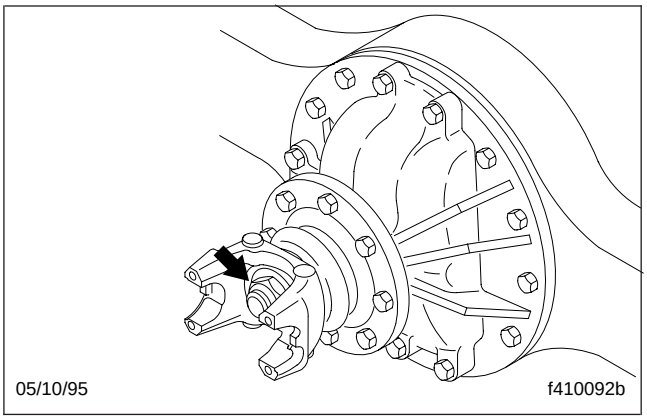


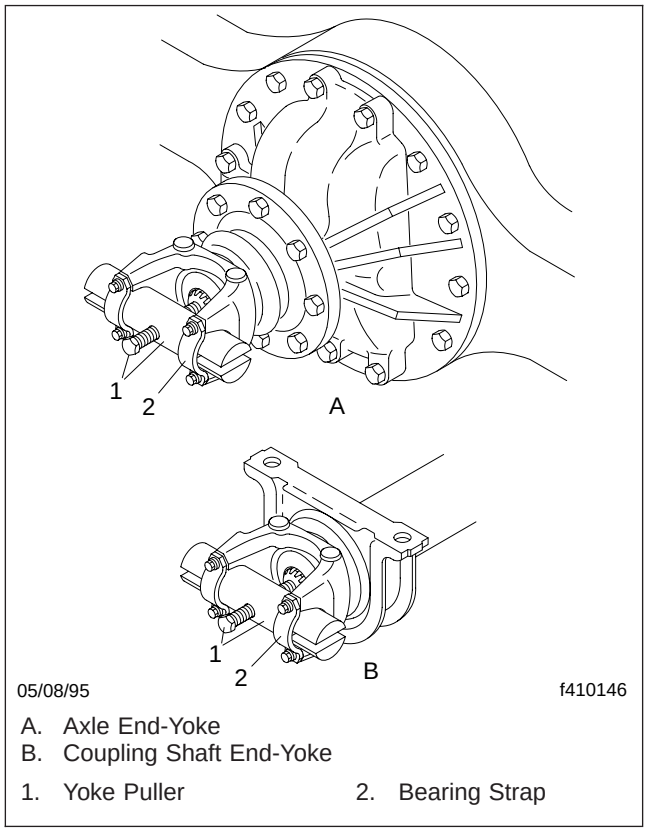
Fig. 11, Axle End-Yoke Locknut

3. Using a yoke puller, remove the end-yoke. See **Fig. 12** for a half-round end-yoke, or **Fig. 13** for a full-round end-yoke.

Coupling Shaft End-Yoke and Midship Bearing Removal

1. Remove the coupling shaft from the vehicle. See **Subject 120**.
2. Clamp the coupling shaft in a soft-jawed vise; do not distort the tube with excessive grip.
3. If the coupling shaft has an end-yoke (**Fig. 14**), not a splined reverse-slip shaft, go to the next step.

   If the coupling shaft has a splined reverse-slip shaft, not an end-yoke (**Fig. 15**), use a hammer and a brass drift to remove the midship bearing and slingers. See **Fig. 16**.



A. Axle End-Yoke
B. Coupling Shaft End-Yoke
1. Yoke Puller
2. Bearing Strap

Fig. 12, Removing a Half-Round End-Yoke

4. If the coupling shaft has an end-yoke, remove the end-yoke. See **Fig. 12** for a half-round end-yoke, or **Fig. 13** for a full-round end-yoke. Remove the midship bearing and slingers. See **Fig. 16**.

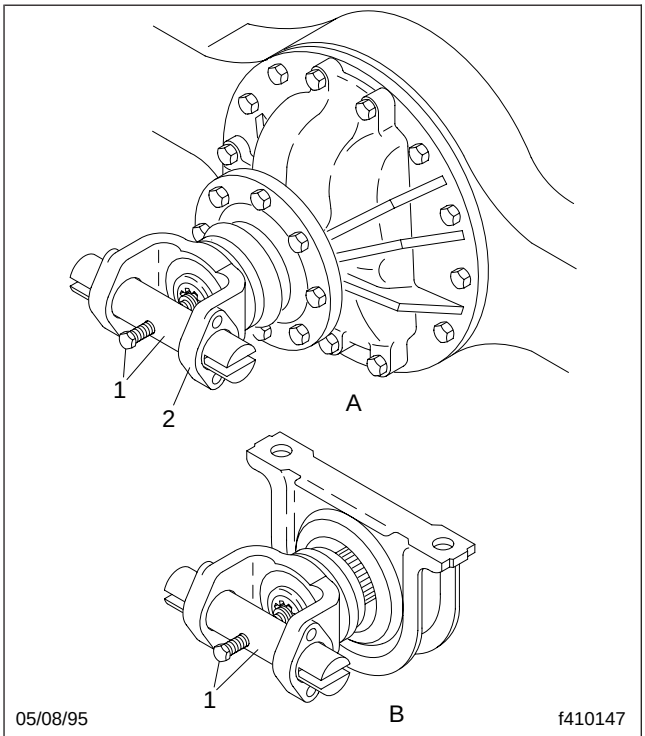
   4.1 Use a marking stick or paint to mark the end-yoke and coupling shaft with alignment marks. See **Fig. 14**.

   4.2 Remove the coupling shaft end-yoke locknut.

   4.3 Using a yoke puller, remove the end-yoke. See **Fig. 12** for a half-round end-yoke, or **Fig. 13** for a full-round end-yoke.

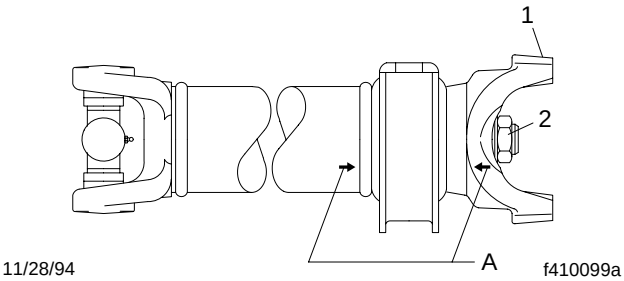
   4.4 Use a hammer and a brass drift to remove the midship bearing and slingers. See **Fig. 16**.

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A. Axle End-Yoke
B. Coupling Shaft End-Yoke
1. Yoke Puller
2. Full-Round End-Yoke

Fig. 13, Removing a Full-Round End-Yoke



A. Use a marking stick or paint to mark the end-yoke and coupling shaft with alignment marks.
1. Half-Round End-Yoke
2. End-Yoke Locknut

Fig. 14, Alignment Marks on a Coupling Shaft With an End-Yoke

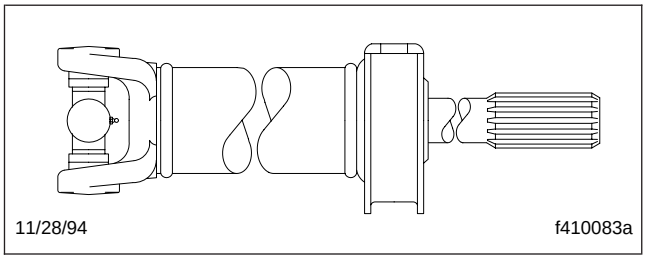
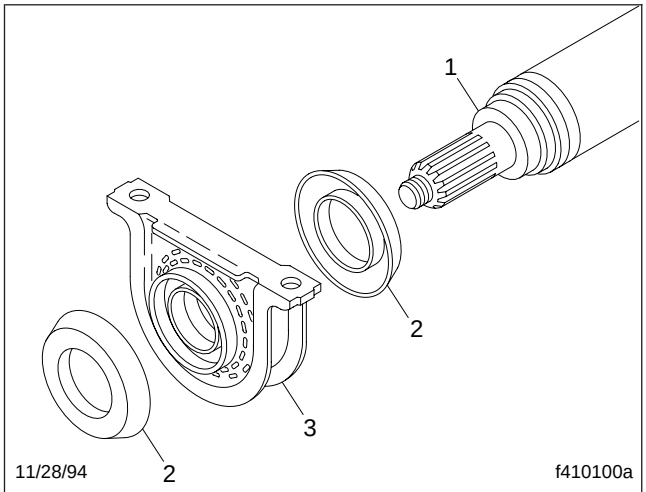


Fig. 15, Spicer SPL90 (1590) Coupling Shaft With a Splined Reverse-Slip Shaft



1. Midship Bearing Shaft
2. Slinger
3. Midship Bearing

Fig. 16, Midship Bearing and Slingers

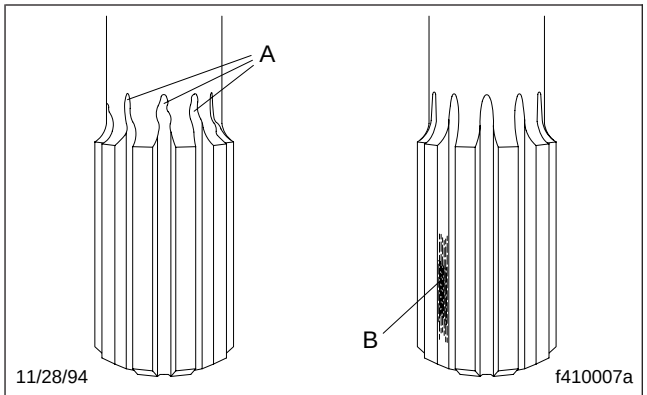
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Cleaning and Inspection

DRIVESHAFT TUBE, SLIP-JOINT, SLEEVE-YOKE AND TUBE-YOKE

1. With the driveshaft removed, scrape or soak away any foreign material.
2. Examine the driveshaft tube for dents, bends, twists, splitting weld-seams and signs of missing balance weights.

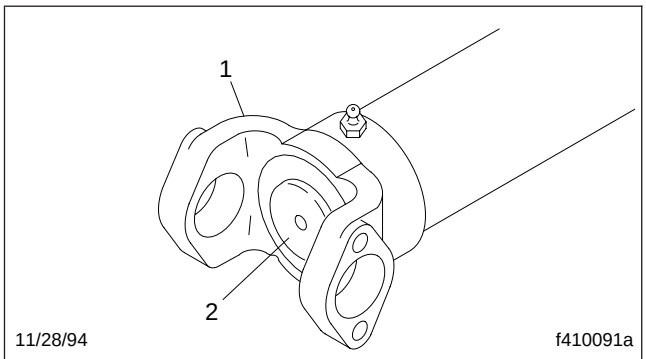
   Replace the driveshaft tube if damaged. See **Subject 130**. If balance weights appear to be missing, have the driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.
3. Clean the slip-joint (male and female) splines, then check them for twisting and galling. See **Fig. 1**. Replace both the sleeve-yoke and the splined shaft if the slip-joint is damaged. See **Subject 130**. Remove any burrs or rough spots using fine emery cloth.



A. Twisted Splines
B. Galling

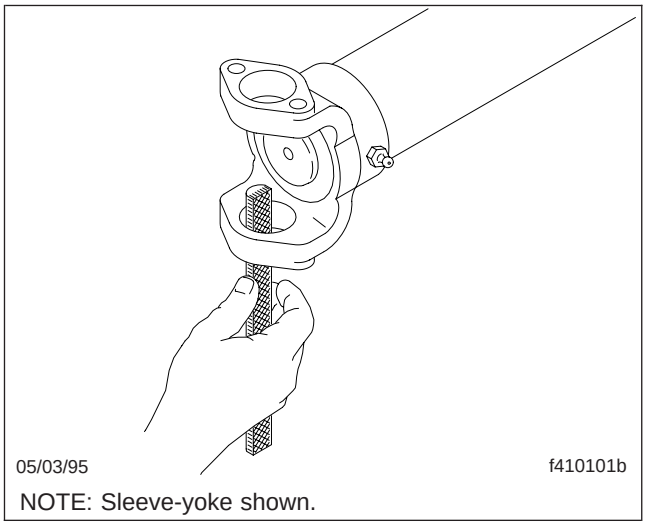
Fig. 1, Damaged Slip-Joint Splines

4. Check for a loose or missing sleeve-yoke plug. See **Fig. 2**. Repair or replace the plug as needed.
5. With the U-joint assemblies removed, check all driveshaft yoke cross-holes for raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3**.
6. Using a mill file, and holding it flat against the machined surface of the driveshaft yoke lug, file each yoke lug, to remove any burrs or raised metal. See **Fig. 4**.
7. Using fine emery cloth, smooth and clean the entire surface of all driveshaft yoke cross-holes. See **Fig. 5**.



1. Sleeve-Yoke
2. Yoke Plug

Fig. 2, Sleeve-Yoke Plug



NOTE: Sleeve-yoke shown.

Fig. 3, Removing Burrs From a Full-Round Yoke Cross-Hole

MIDSHIP BEARING

1. With the midship bearing removed from the coupling shaft, use clean rags or paper towels to wipe off the outside of the midship bearing, rubber cushion and slingers.

IMPORTANT: Do not immerse the midship bearing in cleaning solvent. The solvent will wash

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Driveline Components Cleaning and Inspection

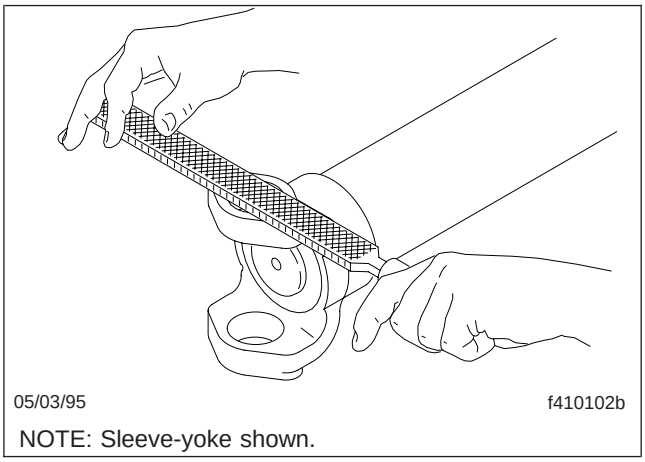


Fig. 4, Removing Burrs From the Machined Surface of a Full-Round Yoke Lug

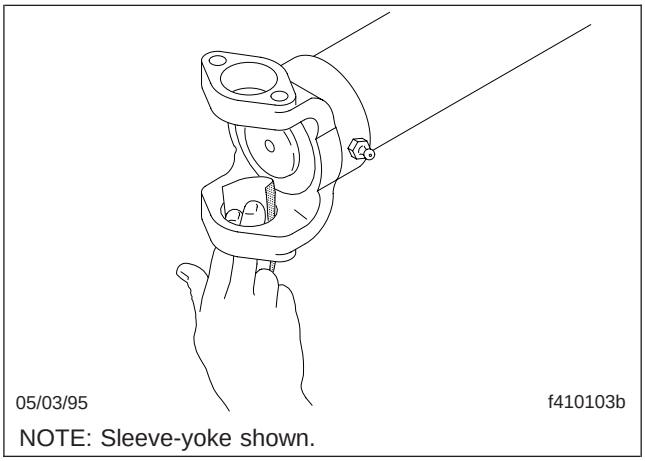


Fig. 5, Smoothing a Full-Round Yoke Cross-Hole

out the lubricant, requiring bearing-assembly replacement.

2. Check the midship bearing for roughness or rattles by holding the outside of the bearing while manually turning the inner bearing race. Replace the bearing assembly if there are any rough spots or rattles.
3. Check the rubber cushion for deterioration or oil-soaking and replace the midship bearing assembly if needed.

END-YOKE

1. With the transmission output-shaft and axle shaft end-yokes installed, check them for cracks and looseness.

   Replace cracked yokes. If the end-yoke can be moved in or out on its shaft, or can be rocked on its shaft, uncouple the driveshaft from the end-yoke. Check the drive component's shaft seal for leakage or other visible damage that may have been caused by the loose yoke. Replace the shaft seal if needed. Tighten the end-yoke nut to the torque value given in **Specifications, 400**. If the end-yoke is still loose after tightening the yoke nut, install a new yoke and yoke nut.

NOTE: If the end-yoke locknut is removed for any reason, install a new one.

2. With the U-joints uncoupled from the end-yokes, check all driveshaft and input/output shaft end-yoke cross-holes for raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3** for full-round yokes, or **Fig. 6** for half-round yokes.

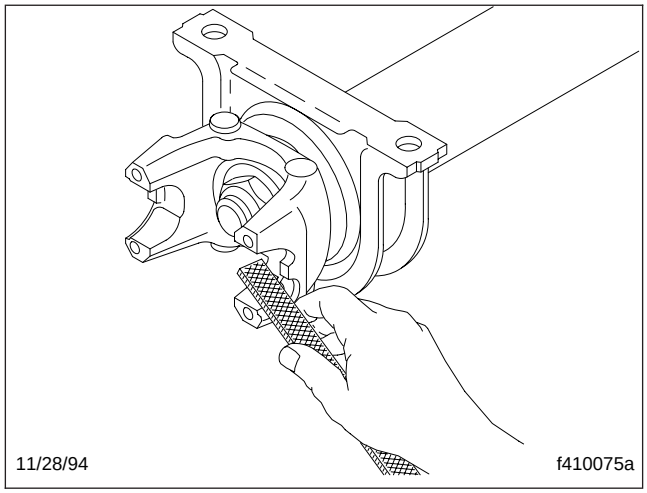
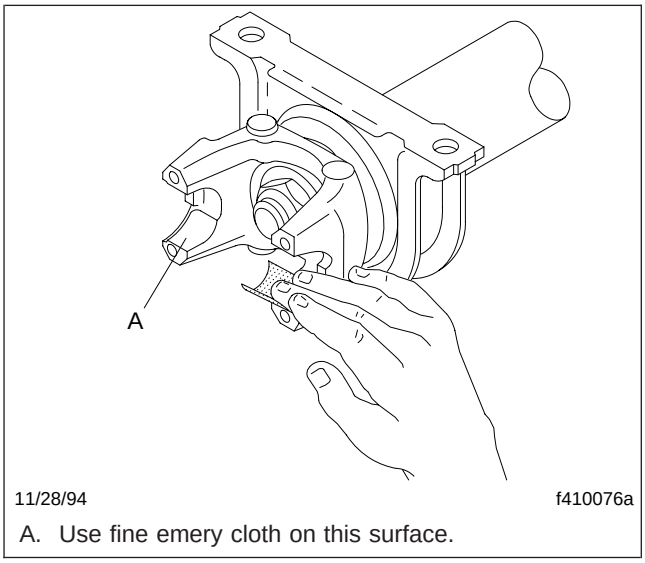


Fig. 6, Removing Burrs From a Half-Round End-Yoke Cross-Hole

3. Using a mill file, and holding it flat against the machined surface of the *full-round* end-yoke lug, file each yoke lug to remove any burrs or raised metal. See **Fig. 4**.
4. Smooth and clean the entire surface of all end-yoke cross-holes, using fine emery cloth. See

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Fig. 5 for full-round yokes, or **Fig. 7** for half-round yokes.



A. Use fine emery cloth on this surface.

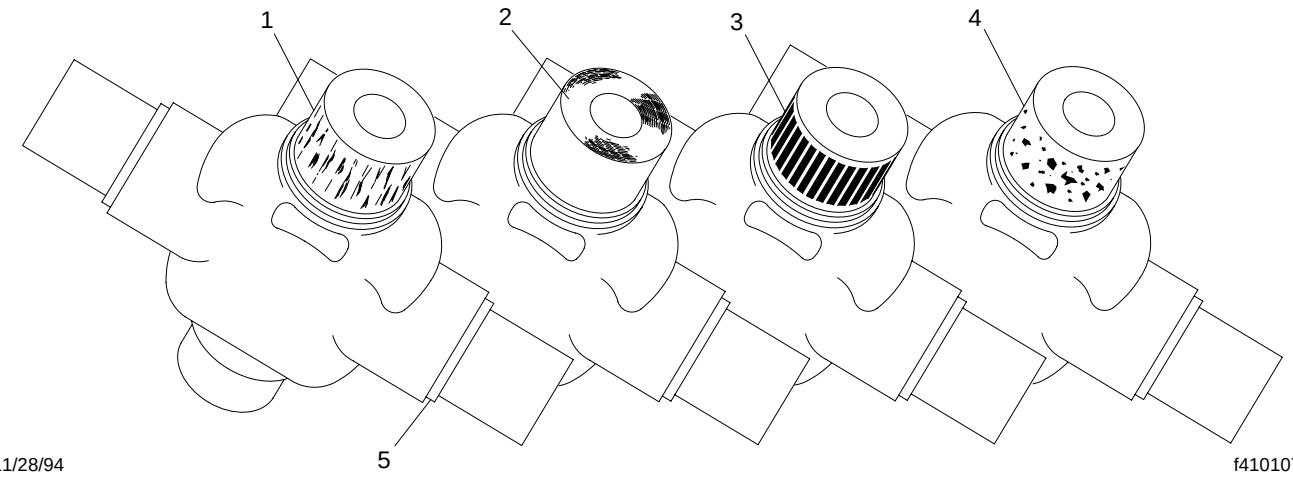
Fig. 7, Smoothing a Half-Round End-Yoke Cross-Hole

U-JOINT

1. With the U-joints removed from the yokes, and the bearing cups removed from the crosses, inspect the U-joint cross slingers for damage, then inspect the U-joint trunnions for spalling (flaking metal), end galling (displacement of metal), brinelling (grooves caused by bearing needles), and pitting (small craters caused by corrosion). See **Fig. 8**. If damaged, replace the U-joint assembly.
2. Using a hand-type grease gun, apply multipurpose chassis grease to the fitting on each U-joint cross until all old lubricant is forced out. See **Fig. 9**. Examine the old lubricant. If it appears rusty, gritty, or burnt, replace the U-joint assembly.
3. Soak the bearing cups in a non-flammable cleaner until particles of grease and foreign matter are loosened or dissolved. Do not disassemble the bearing cups; clean the bearing needles with a short, stiff brush, then blow them dry with compressed air. Check for minute particles of dirt or grit, and clean again if necessary.
4. Check each bearing cup for missing bearing needles. Check the bearing-cup seals for nicks. See **Fig. 10** for a half-round-yoke U-joint bearing cup, or **Fig. 11** for a full-round-yoke U-joint bearing cup. Replace the U-joint assembly if any bearing needles are missing or any seals are damaged.
5. Apply a small quantity of multipurpose chassis grease to the bearing needles in each cup, then apply a small amount of light-weight oil to the lips of the bearing-cup seals. Rotate each bearing cup on the cross to check for wear. Replace the U-joint assembly if any bearing surfaces are worn.
6. Check the underside of each bearing-cup plate for burrs or raised metal. Use a mill file to remove any burrs or raised metal. See **Fig. 12**.
7. Using fine emery cloth, smooth and clean the outside surfaces of all bearing cups. See **Fig. 12** and **Fig. 13**.

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Driveline Components Cleaning and Inspection



1. Spalling
2. End Galling
3. Brinelling
4. Pitting
5. Slinger

Fig. 8, Damaged U-Joint Crosses

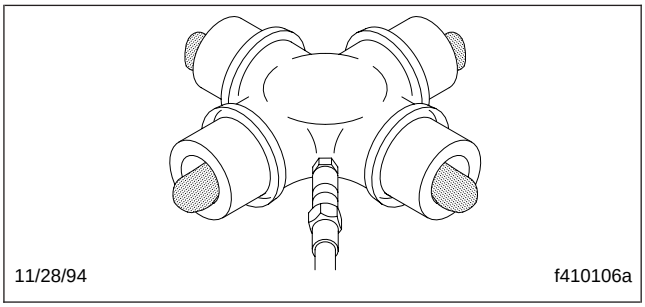
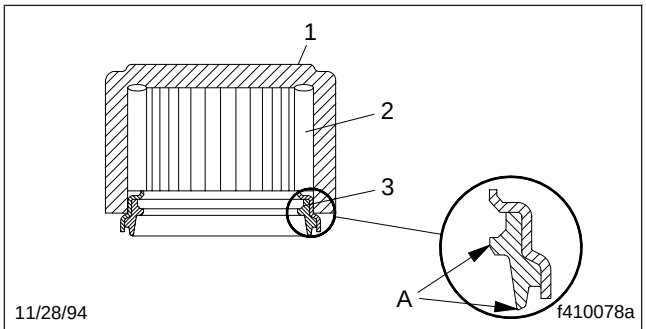


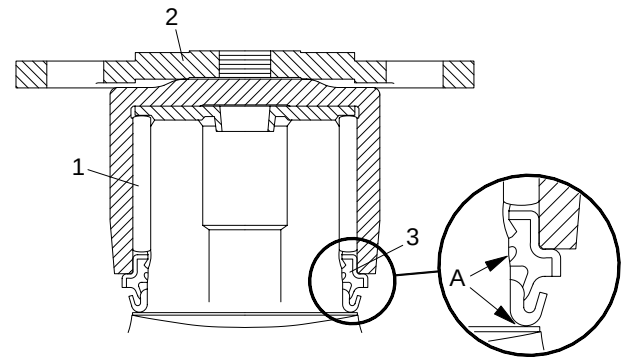
Fig. 9, Forcing Out Old Lubricant From a U-Joint Cross



A. Lubricate seal lips here.
1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

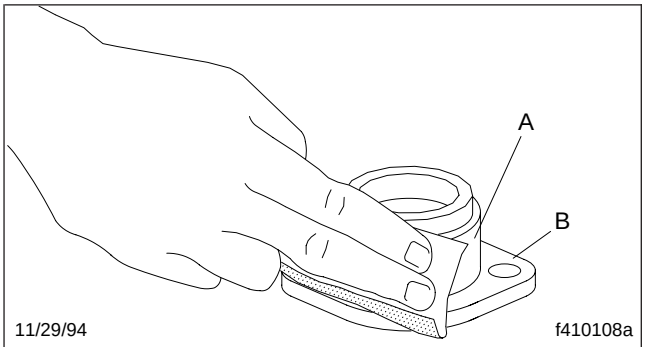
Fig. 10, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup

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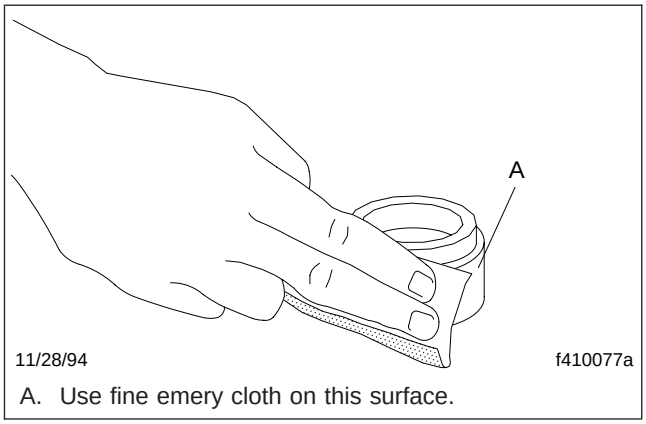
A. Lubricate seal lips here.
1. Bearing Needle
2. Bearing-Cup Plate
3. Bearing-Cup Seal

Fig. 11, Sectional View of a Full-Round Yoke U-Joint Bearing Cup



A. Use fine emery cloth on this surface.
B. Use a mill file on this surface.

Fig. 12, Smoothing a Full-Round Yoke U-Joint Bearing Cup



A. Use fine emery cloth on this surface.

Fig. 13, Smoothing a Half-Round Yoke U-Joint Bearing Cup

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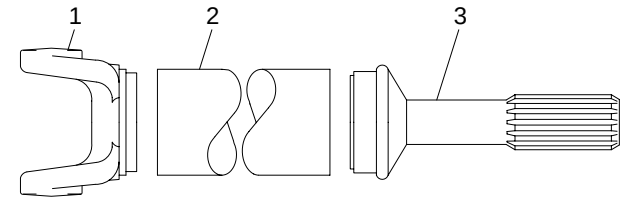
Driveline Components Replacement or Installation/ Assembly

Replacement

DRIVESHAFT TUBE, STUB SHAFT (SLIP-JOINT) AND TUBE-YOKE

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

To replace a driveshaft tube, a tube-yoke or a stub shaft, the driveshaft must be chucked in a lathe so the welds can be removed. See **Fig. 1**. Driveshaft rebuilding should be done by a machine shop that specializes in driveline repair.



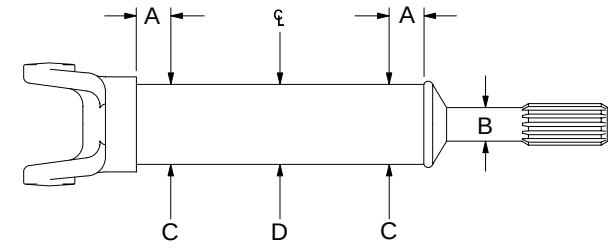
1. Tube-Yoke
2. Driveshaft Tube
3. Stub Shaft

Fig. 1, Driveshaft Tube, Stub Shaft, and Tube-Yoke

Runout limits for a new (rebuilt) driveshaft are (see **Fig. 2**):

- 0.015 inch (0.38 mm) T.I.R. (Total Indicator Reading) on the smooth portion of the stub shaft neck;
- 0.020 inch (0.51 mm) T.I.R. on the tube 3 inch (76 mm) from the front and rear welds;
- 0.025 inch (0.635 mm) T.I.R. at the center of the tube.

Balance the rebuilt driveshaft to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.



A. Measurement: 3 in (76 mm)
B. Measurement: 0.015 in (0.38 mm)
C. Measurement: 0.020 in (0.51 mm)
D. Measurement: 0.025 in (0.635 mm)

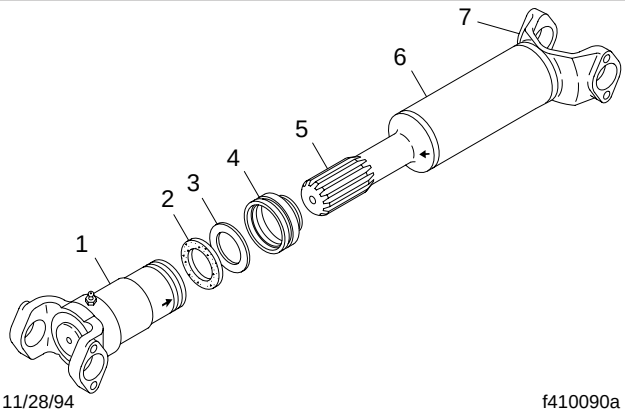
Fig. 2, Driveshaft Runout Specifications

Replacement or Assembly

SLIP-JOINT

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

1. Place the slip-joint dust cap, and (if so equipped) steel washer and cork seal, over the splined shaft. See **Fig. 3**.



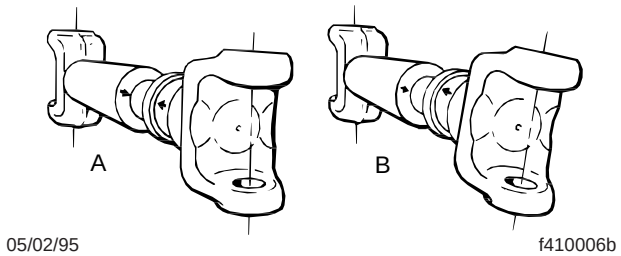
1. Sleeve-Yoke
2. Cork Washer
3. Steel Washer
4. Dust Cap
5. Splined Stub Shaft
6. Tube
7. Tube-Yoke

Fig. 3, Slip-Joint Components

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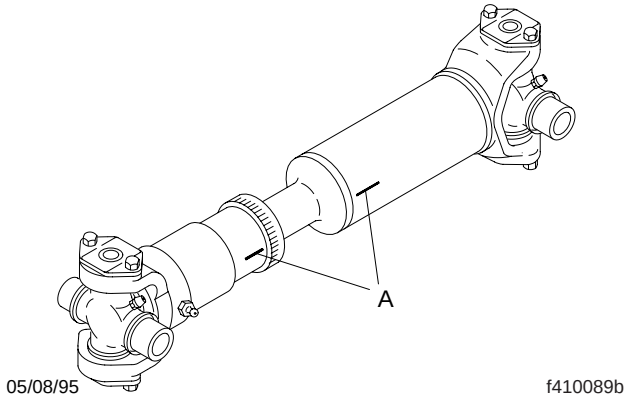
Driveline Components Replacement or Installation/ Assembly

2. Coat the splines of the shaft with multipurpose chassis grease.
3. Insert the splined shaft in the sleeve-yoke, so that the alignment marks are aligned, and the U-joints at each end of the driveshaft will be in phase. See **Fig. 4** and **Fig. 5**.



1. In Phase
2. Out of Phase

Fig. 4, U-Joint Phasing



A. Use a marking stick or paint to add alignment marks.

Fig. 5, Slip-Joint Alignment Marks

IMPORTANT: If no alignment marks are visible, or new slip-joint components have been installed, align the yokes, assemble the slip-joint, then have the driveline balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.

4. Using a strap wrench, tighten the slip-joint dust cap. Use only enough torque to seat the steel washer and cork seal (if so equipped) snug against the end of the sleeve-yoke; do not overtighten.

NOTE: The splines should slide freely, with only a slight drag from the slip-joint dust cap.

MIDSHIP BEARING AND COUPLING SHAFT END-YOKE

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

1. Place the coupling shaft in a soft-jawed vise; do not distort the tube with excessive grip.
2. Fill the entire cavity around the midship bearing with a waterproof grease, to shield the bearing from water and contaminants. Use enough grease to fill the cavities to the extreme edge of the slingers that surround the front and rear of the bearing. See **Fig. 6**.

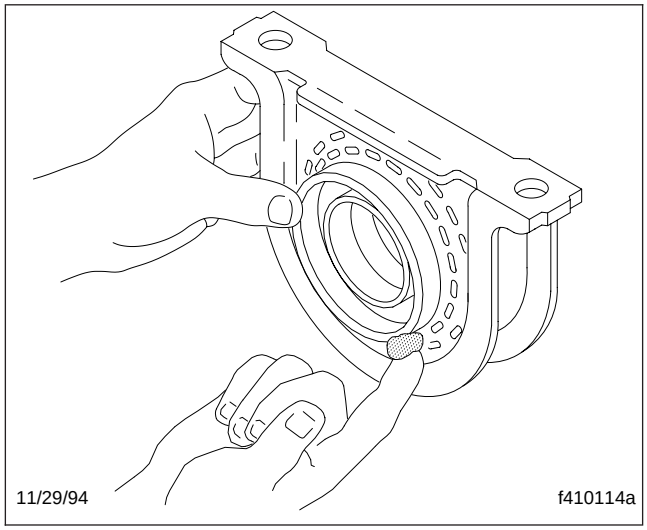


Fig. 6, Greasing a Midship Bearing

NOTE: Spicer midship bearings are permanently lubricated when manufactured; it is not necessary to pack the bearing with grease.

3. Install one of the slingers, the midship bearing, then the other slinger on the coupling shaft. Press the bearing and slingers on by hand, as far as they will go.

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4. If the coupling shaft has a splined reverse-slip shaft (not an end-yoke), coat the shaft splines with multipurpose chassis grease. See **Fig. 7**.

   If the coupling shaft has an end-yoke, install the end-yoke. See **Fig. 8**.

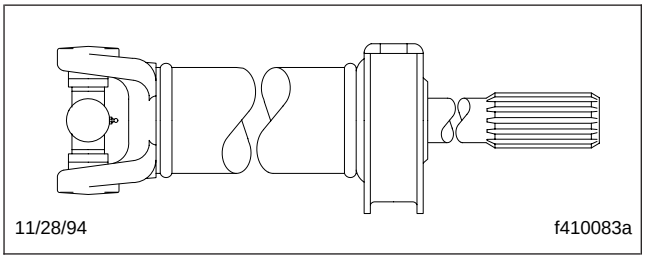
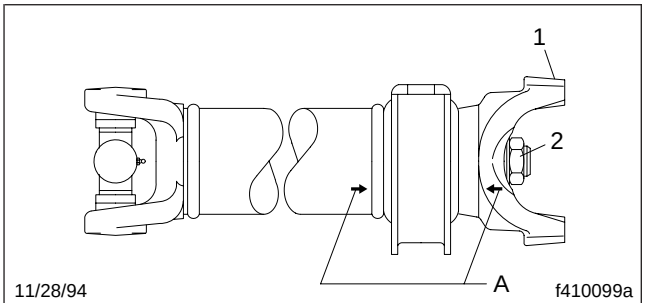


Fig. 7, Spicer SPL90 (1590) Coupling Shaft With a Splined Reverse-Slip Shaft



A. Use a marking stick or paint to mark the end-yoke and coupling shaft with alignment marks.

1. Half-Round End-Yoke
2. End-Yoke Locknut

Fig. 8, Alignment Marks on a Coupling Shaft With an End-Yoke

4.1 Apply Loctite® 242 to the shaft threads where the end-yoke locknut will be installed.

4.2 Align the marks added to the coupling shaft and end-yoke during removal, then place the end-yoke on the shaft so the yoke bores are aligned at both ends of the shaft. See **Fig. 8**.

4.3 Install the end-yoke nut, and tighten it 475 to 525 lbf·ft (645 to 710 N·m). Back the nut off slightly and tighten it to the same torque.

Replacement or Installation

SPICER 1610/1710/1760 U-JOINT

IMPORTANT: Parts for different series drivelines must not be intermixed. Also, components of the various makes of U-joints may not be interchangeable, and must be assembled only with compatible products. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

Worn bearing assemblies used with a new cross, or new bearing assemblies used with a worn cross will wear rapidly, making another replacement necessary in a short time. Always replace the cross and all four bearing assemblies at the same time.

If the slip-joint of a No. 2 or No. 3 driveshaft has been disassembled, assemble the slip-joint before installing the U-joints.

1. Place the assembled driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
2. For a No. 2 or No. 3 driveshaft, check that the slip-joint alignment marks are aligned, so that the U-joints at each end of the driveshaft will be in phase. See **Fig. 4** and **Fig. 5**.

   For a coupling shaft, check that the end-yoke and tube-yoke are aligned, so that the U-joints at each end of the coupling shaft will be in phase. See **Fig. 8**.

IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

3. Inspect and lubricate the U-joint.

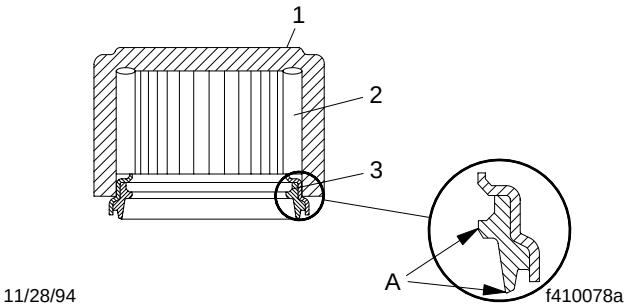
   3.1 Remove the bearing cups from the cross. Inspect the bearing-cup seals for nicks or other damage. See **Fig. 9** for a half-round-yoke U-joint bearing cup, or **Fig. 10** for a full-round-yoke U-joint bearing cup.

⚠ CAUTION

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of

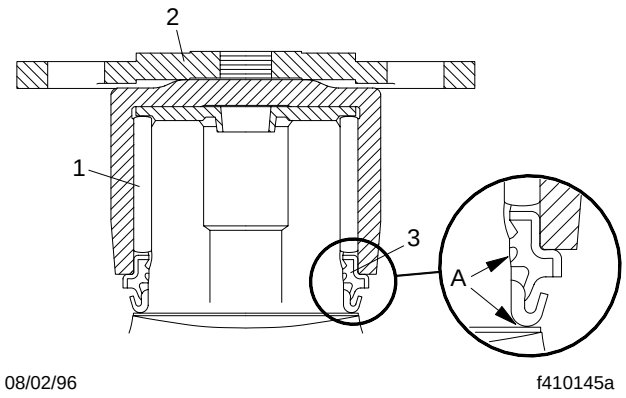
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Driveline Components Replacement or Installation/ Assembly



A. Lubricate seal lips here.
1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

Fig. 9, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup



A. Lubricate seal lips here.
1. Bearing Needle
2. Bearing-Cup Plate
3. Bearing-Cup Seal

Fig. 10, Sectional View of a Full-Round Yoke U-Joint Bearing Cup

dirt or grit can cause rapid wear and serious damage to the U-joint.

3.2 Using a hand-type grease gun, or a high-pressure gun equipped with a low-pressure adapter, fill the lube passages in the cross with multipurpose chassis grease (lithium 12-hydroxy stearate, NLGI grade 2 with EP additives). See **Fig. 11**.

3.3 Wipe a heavy coating of the same grease on the needles and the inside end of each bearing cup; then, using a light-weight oil, lubricate the lips of the bearing-cup seals. See **Fig. 9** for a half-round-yoke U-joint bearing cup, or **Fig. 10** for a full-round-yoke U-joint bearing cup.

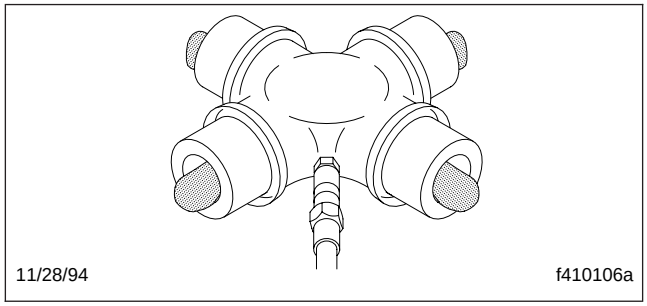
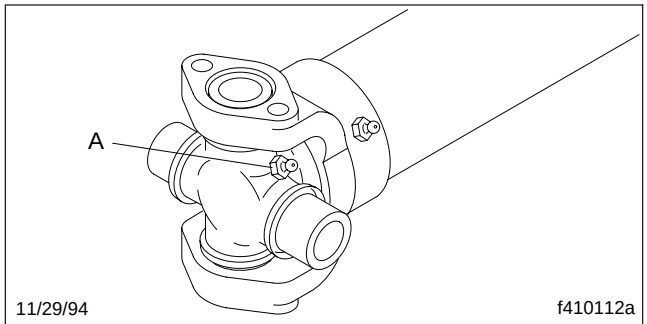


Fig. 11, Forcing Out Old Lubricant From a U-Joint Cross

4. Install the U-joint cross and bearing assemblies in the yoke.

4.1 Position the U-joint cross in the driveshaft yoke so one grease fitting points toward the driveshaft, and aligns with the grease fitting on the sleeve-yoke (if so equipped). See **Fig. 12**.



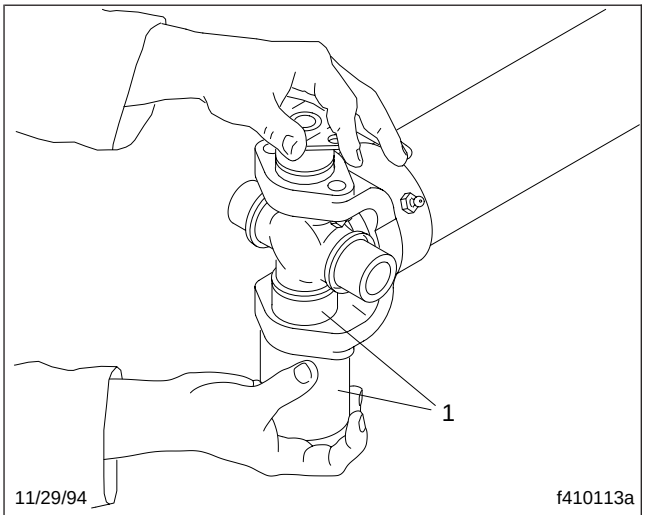
A. Install cross with grease fitting pointing toward driveshaft, and aligned with sleeve-yoke grease fitting.

Fig. 12, U-Joint Grease Fitting Positioning

4.2 Move one end of the cross until a trunnion projects through the cross-hole, beyond the outer machined face of the yoke lug. Using a Spicer trunnion (journal) locator (see **Specifications, 400**), hold the trunnions in alignment with the cross-holes, while placing a bearing cup (plate-type) over the projected trunnion, and aligning it with the cross-hole. See **Fig. 13**.

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Driveline Components Replacement or Installation/ Assembly



NOTE: Sleeve-yoke shown.
1. Trunnion Locator

Fig. 13, Using a U-Joint Trunnion Locator

IMPORTANT: A Spicer trunnion (journal) locator should be used, to prevent damage to the U-joint trunnions and slingers.

4.3 By hand, press the bearing-cup-plate flush with the face of the yoke. If the bearing cup binds in the cross-hole, tap the *center* of the bearing-cup plate with a leather or rubber mallet; do not tap the outer edges of the plate. See **Fig. 14**.

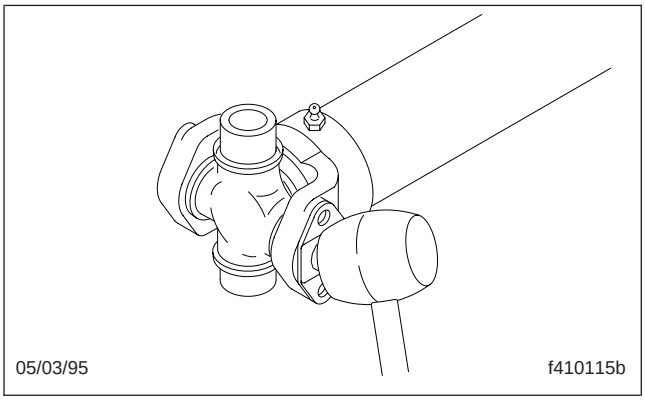
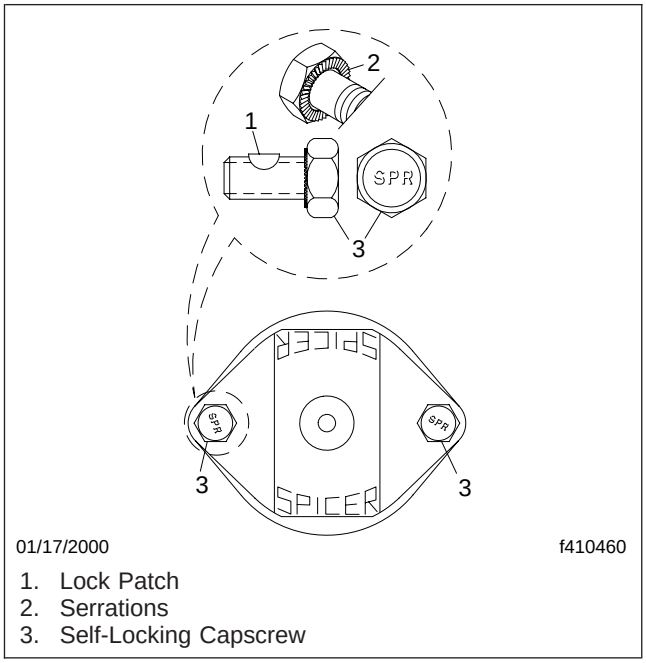


Fig. 14, Seating a U-Joint Bearing Cup In a Full-Round Yoke

4.4 As equipped, install *new* bearing-cup-plate self-locking capscrews. See **Fig. 15**. Tighten the capscrews until all the parts are drawn down tight, with no gaps; do not tighten the capscrews to their final torque value.



1. Lock Patch
2. Serrations
3. Self-Locking Capscrew

Fig. 15, Spicer U-Joint Fasteners for Full-Round Yokes With Self-Locking Capscrews

⚠ WARNING

Self-locking bearing-cup-plate capscrews must not be reused; replace the capscrews with new ones. Also, do not undertighten or overtighten any bearing-cup-plate capscrews. A loose or broken fastener at any point in the driveline weakens the driveline connection, which could cause serious vehicle damage, or could result in a driveshaft separating from the vehicle, possibly causing loss of vehicle control that could result in serious personal injury or death.

4.5 Move the cross until it projects beyond the machined surface of the opposite yoke lug. Using the above procedure, install the opposite bearing assembly and its fasteners.

4.6 Slightly back off all four capscrews. Alternately tighten them in increments of 5 lbf·ft (7 N·m) to the applicable torque value in **Specifications, 400**.

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Driveline Components Replacement or Installation/ Assembly

SPICER SPL90 (1590) U-JOINT

IMPORTANT: Worn bearing assemblies used with a new cross, or new bearing assemblies used with a worn cross will wear rapidly, making another replacement necessary in a short time. Always replace the cross and all four bearing assemblies at the same time.

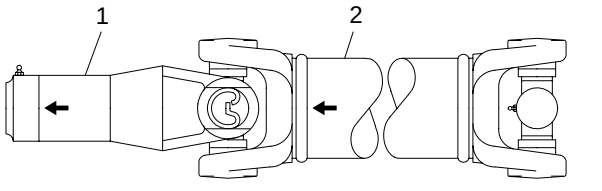
1. Place the driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
2. For a No. 2 driveshaft that has a sleeve-yoke (not a splined reverse-slip shaft) at its forward end, make sure the alignment marks on the slip-joint assembly are aligned, to keep the U-joints in phase. See **Fig. 4** and **Fig. 5**.

IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

NOTE: For a No. 2 driveshaft that has a splined reverse-slip shaft, install the U-joint in the sleeve-yoke. Align the alignment marks that were added to the sleeve-yoke and driveshaft tube. Connect the U-joint to the forward tube-yoke of the driveshaft. See **Fig. 16**.

NOTE: For a coupling shaft that has an end-yoke and a tube-yoke, check that the yokes are aligned so that the U-joints at each end of the coupling shaft will be in phase. See **Fig. 8**.

3. Lubricate the U-joint.



1. Sleeve-Yoke
2. Driveshaft Tube

Fig. 16, Spicer SPL90 (1590) No. 2 Driveshaft (as used with a coupling shaft)

3.1 Using a hand-type grease gun, or a high-pressure gun equipped with a low-pressure adapter, fill the lube passages in the cross with multipurpose chassis grease (lithium 12-hydroxy stearate, NLGI grade 1 or 2 with EP additives). See **Fig. 11**.

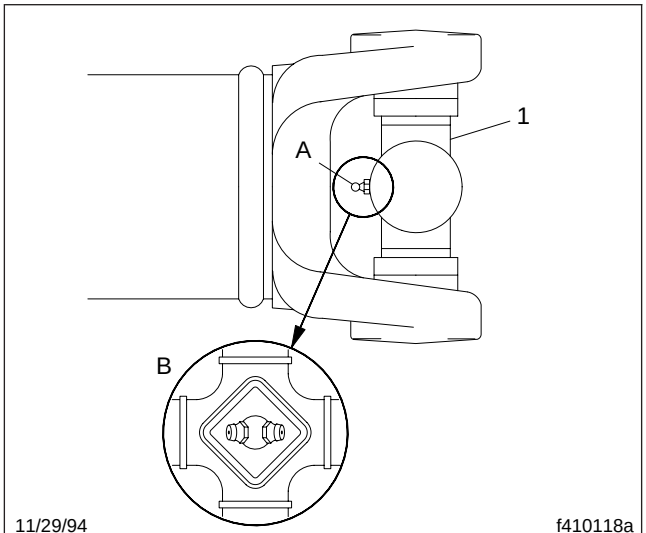
3.2 Wipe a heavy coating of the same grease on the needles of each bearing cup, and pack each bearing cup about one-quarter full of grease. See **Fig. 9**.

⚠ CAUTION

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

4. Install the U-joint cross and bearing assemblies in the yoke.

4.1 Position the U-joint cross in the yoke with its lube fitting on the inboard side (toward the driveshaft) and pointing 90 degrees away from the driveshaft yoke lugs. See **Fig. 17**.



A. Install U-joint cross with grease fitting toward the driveshaft, and pointing 90 degrees away from the yoke lugs.
B. Detail of Grease Fitting
1. Spicer SPL90 (1590) U-Joint Cross

Fig. 17, Spicer SPL90 (1590) U-Joint Grease Fitting Positioning

4.2 Move one end of the cross until a trunnion projects through the cross-hole, be-

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yond the outer machined face of the yoke lug. Hold the trunnions in alignment with the cross-holes, while placing a bearing cup over the projected trunnion and aligning it with the cross-hole. See **Fig. 18**.

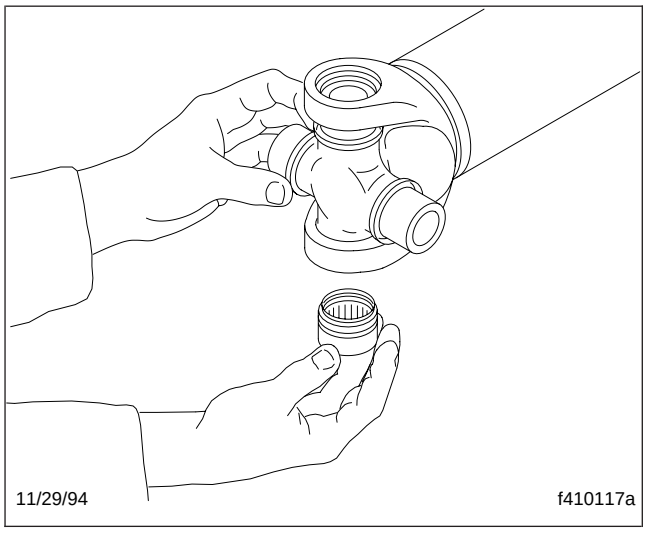


Fig. 18, Installing a Spicer SPL90 (1590) U-Joint Bearing Cup In a Full-Round Yoke

4.3 Using an arbor press, and holding the trunnion in alignment with the cross-hole, place a solid plug (with an outside diameter slightly smaller than the inside diameter of the cross-holes) on the upper bearing cup. See **Fig. 19**. Press the bearing cup into the cross-hole enough to install a snap ring.

4.4 Install the snap ring. See **Fig. 20**.

IMPORTANT: Be sure the snap ring is properly seated in its groove.

4.5 Turn the yoke over, and install the opposite bearing cup and snap ring.

If movement of the U-joint is stiff, strike the yoke ears with a soft hammer to seat the bearing needles.

TRANSMISSION/AXLE END-YOKE

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled

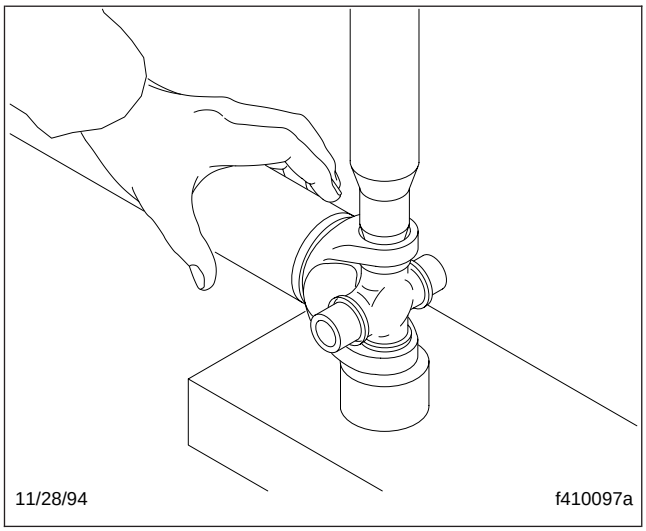


Fig. 19, Pressing a Spicer SPL90 (1590) U-Joint Out-of/ Into a Yoke

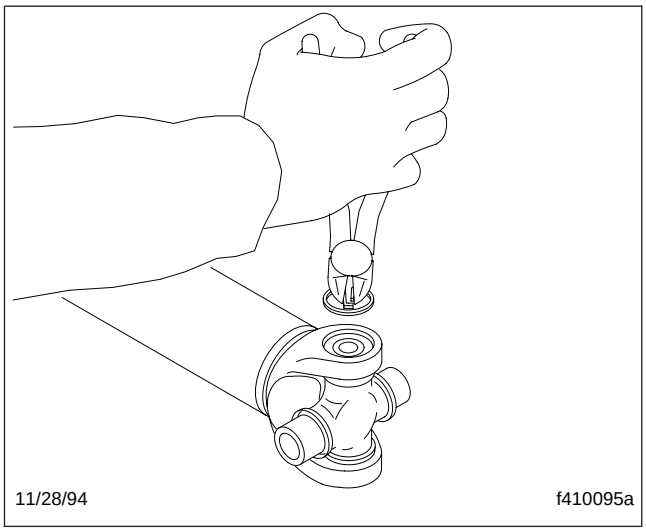


Fig. 20, Removing/Installing a Spicer SPL90 (1590) U-Joint Snap Ring

or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

1. Apply Loctite® 242 to the input- or output-shaft threads where the end-yoke locknut will be installed. See **Fig. 21**.
2. By hand, install the end-yoke on the input or output shaft as far as it will go.

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Driveline Components Replacement or Installation/ Assembly

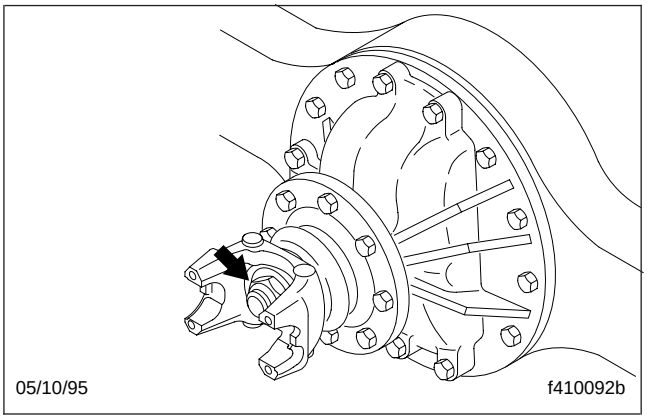


Fig. 21, Axle End-Yoke Locknut

3. Install a new end-yoke locknut and tighten it to the applicable torque value in **Specifications, 400**.

DRIVELINE PARKING BRAKE FLANGE-YOKE OR COMPANION FLANGE

For replacement or installation of a driveline parking brake flange-yoke or companion flange, see **Group 42**.

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Troubleshooting

Noise or vibration associated with the driveline can be caused by non-driveline parts. To find the cause of noise or vibration, road test the loaded vehicle. Drive in all gears and at all speed ranges for which the vehicle was designed, including those at which problems are reported.

NOTE: Operating a vehicle at speeds that exceed its drivetrain design specifications may cause an out-of-balance vibration.

The following is a troubleshooting elimination process; checks should be made in the order listed. At each step where a problem is found, correct the problem before proceeding to the next step. Test drive the vehicle to see if other problems still exist. If no other problems exist, the elimination process may be ended at that step.

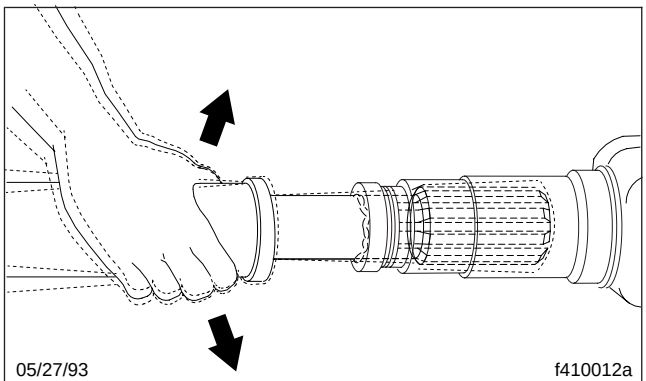
1. Check all tires for uneven wear and for out-of-roundness. Check for mismatched tires. Look for wheels and rims that are out of alignment. For instructions, see **Group 40**.
2. Check the rear suspension for loose or broken U-bolts; broken, shifted or mismatched rear springs; or broken spring seats. If so equipped, check the air suspension for incorrect air spring height. Look for anything that could cause angular misalignment of the rear axle pinion(s). For instructions, see **Group 32**.
3. Check the frame rails and crossmembers for bends, twists or breaks; for frame-alignment-checking and crossmember-replacement instructions, see **Group 31**.
4. Check the engine and transmission mounts; see **Group 01** and **Group 26**. Check the coupling shaft's midship bearing mounts. Replace mountings that are deteriorated or oil-soaked; tighten loose mounting bolts. Oil-soaked or deteriorated mountings or loose mounting bolts can cause driveline angular misalignment.
5. Check for loose U-joint bearing-cup-plate and bearing-strap capscrews and for loose flange-yoke locknuts. Tighten any loose fastener to the applicable torque value in **Specifications, 400**.

⚠ CAUTION

Do not overtighten the bearing-cup-plate or bearing-strap capscrews, or the flange-yoke locknuts. A loose or broken fastener at any point in the driveline weakens the driveline connection, which could result in serious vehicle damage.

6. Check all U-joint assemblies, slip-joint splines and midship bearings for wear.
   - 6.1 Try to move each driveshaft up and down, and from side to side. If movement is greater than 0.006 inch (0.15 mm) of a U-joint cross in its bearings, replace the U-joint assembly.
   - 6.2 If the midship bearing rattles or is loose on its shaft, replace it.
   - 6.3 Try to bend the sleeve-yoke and splined shaft up and down, and from side to side. See **Fig. 1**. If looseness is greater than 0.007 inch (0.18 mm), replace the sleeve-yoke and splined shaft.

     If driveline components must be replaced, see **Subject 150**.



Try to bend the sleeve-yoke and splined shaft up and down, and from side to side.

Fig. 1, Checking for Slip-Joint Spline Wear

7. Check each driveshaft for an indication of missing balance weights. If any weights appear to be missing, have the driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.
8. Check each driveshaft for dents, bends, twists or other damage.

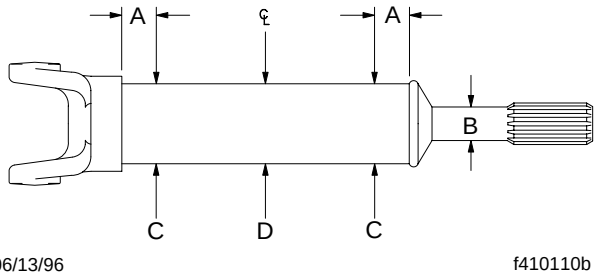
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Troubleshooting

If damaged, jack up the rear axle, support it on jackstands, place the transmission in neutral, and turn the driveshaft by hand to check runout.

The driveshaft must be straight within 0.015 inch (0.38 mm) on the slip-joint seal surface of the splined shaft, 0.020 inch (0.51 mm) on the tube 3 inch (76 mm) from the front and the rear welds, and 0.025 inch (0.635 mm) at the center of the tube. See **Fig. 2**.

If the driveshaft is not straight within specifications, replace the tube. See **Subject 150** for runout specifications for a *new* (or rebuilt) driveshaft.

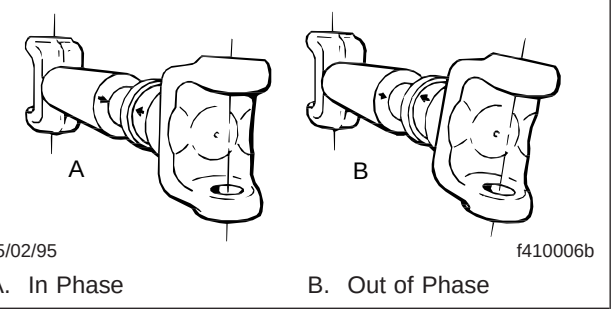


A. Measurement: 3 in (76 mm)
B. Measurement: 0.015 in (0.38 mm)
C. Measurement: 0.020 in (0.51 mm)
D. Measurement: 0.025 in (0.635 mm)

Fig. 2, Used Driveshaft Runout Specifications

9. Check each driveline for proper U-joint phasing. See **Fig. 3**.

   9.1 On No. 2 and No. 3 driveshafts, if the U-joints are out of phase, check the slip-joint for alignment marks. If necessary, disassemble the slip-joint and align the marks.



A. In Phase
B. Out of Phase

Fig. 3, U-Joint Phasing

NOTE: To disassemble the slip-joint, uncouple the U-joint at one end of the driveshaft, unscrew the slip-joint seal from the sleeve-yoke, then pull the sleeve-yoke and splined shaft apart. Reverse the procedure to assemble the slip-joint.

9.2 If no alignment marks are present, disassemble the slip-joint, and reassemble it with the U-joints in one of the two in-phase positions (180 degrees apart).

Test drive the vehicle. Assemble the slip-joint in the other in-phase position. Test drive the vehicle again.

Determine which in-phase position provides vibration-free operation. Assemble the slip-joint in the correct in-phase position and mark the slip-joint with alignment marks.

9.3 If the U-joints are out of phase on a coupling shaft, uncouple the U-joint from the coupling shaft end-yoke. Remove the end-yoke nut. Remove the end-yoke, using a yoke puller. See **Fig. 4** for a half-round end-yoke, or see **Fig. 5** for a full-round end-yoke. Align the end-yoke. Install it by hand. Install the end-yoke nut and tighten it 475 to 525 lbf·ft (645 to 710 N·m). Slightly back off the nut and again tighten it to the same torque. Couple the coupling shaft to the driveshaft U-joint.

10. Check the torque on all of the end-yoke nuts in the drivetrain; see the applicable torque values in **Specifications, 400**.

    If any yoke nut was not at its specified torque, check the yoke for wear by trying to move it up and down and back and forth. If the yoke can be rocked on its shaft or moved in or out on its shaft, replace the yoke and yoke nut. See **Subject 150**.

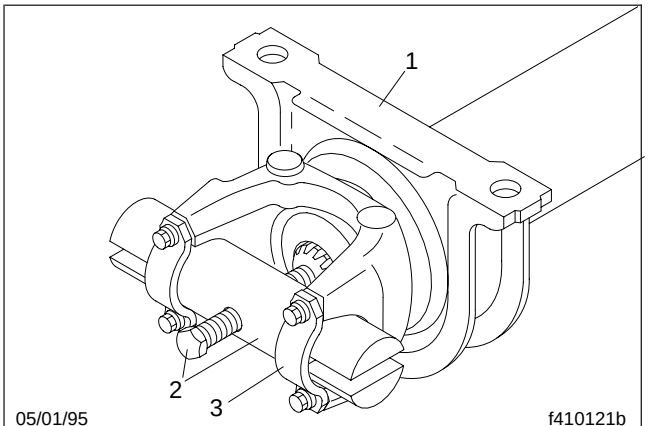
    If the yoke is not worn, tighten the yoke nut to its torque value.

11. *On single-drive vehicles:*

    Have the No. 2 driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.

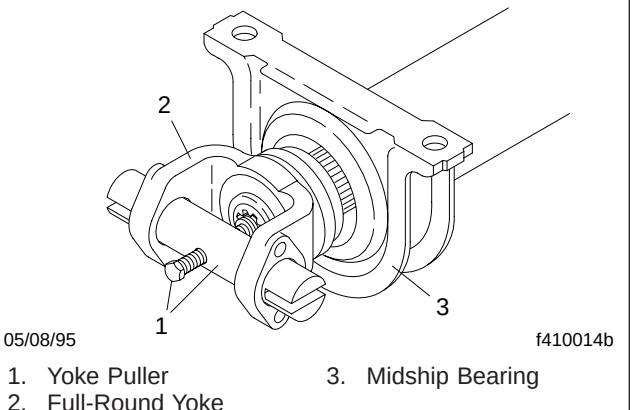
    On dual-drive vehicles:

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1. Midship Bearing
2. Yoke Puller
3. Bearing Strap

Fig. 4, Removing a Half-Round End-Yoke From a Coupling Shaft



1. Yoke Puller
2. Full-Round Yoke
3. Midship Bearing

Fig. 5, Removing a Full-Round End-Yoke From a Coupling Shaft

11.1 Remove the No. 3 driveline. With the interaxle differential locked, test drive the vehicle.

11.2 If vibration still exists, install the No. 3 driveline. Have the No. 2 driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.

If *no* vibration exists, check that both rear axle gear ratios are matched. If the gear ratios do not match, replace one of the gear sets with a gear set having the correct ratio. Install the No. 3 driveline.

11.3 Have the No. 3 driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.

11.4 Have the No. 2 driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.

12. If so equipped, balance the coupling shaft(s) to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.

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Specifications

Fastener Torques		
Description	**Size**	**Torque: lbf·ft (N·m)**
End-Yoke Nut		
Transmission Output Shaft	1-1/4–18	300–350 (405–475)
	1-1/2–18	400–450 (540–610)
	2–16	600–800 (815–1085)
Single Axle Input Shaft	M32 x 1.5	740–920 (1000–1250)
	M45 x 1.5	1000–1230 (1355–1670)
	M39 x 1.5	920–1130 (1250–1530)
Forward-Rear Axle Input Shaft	M39 x 1.5	600–800 (815–1085)
Forward-Rear Axle Output Shaft	M39 x 1.5	450–600 (610–815)
Rearmost Axle Input Shaft	M39 x 1.5	920–1130 (1250–1530)
Midship Bearing (coupling shaft)	1-1/4–18	475–525 (645–710)
Companion-Flange Nut		
Transmission Output Shaft	1-1/4–18	300–350 (405–475)
U-Joint Capscrew		
Bearing Plate (for full-round end-yoke)	5/16–24	20 (27)
	3/8–24	36 (49)
Bearing Strap (for half-round end-yoke)	3/8–24	53 (72)
	1/2–20	125 (169)
Flange-Yoke Locknut		
Flange-Yoke to Companion Flange	3/8–24	40–48 (54–65)
Midship Bearing Flanged Locknut		
Bracket to Crossmember	1/2–13	91 (123)
Bearing Mount to Bracket	1/2–13	91 (123)

Table 1, Fastener Torques

Special Tools

JOURNAL LOCATOR

(For installing Spicer 1610, 1710 and 1760 U-joints in full-round yokes)

To order, Contact your Dana Corporation Spicer Service Representative.

U-JOINT REMOVAL TOOL KIT

(For removing Spicer 1610, 1710 and 1760 U-joints from full-round yokes)

To order Owatonna Tool Kit No. 7057, Contact:

Owatonna Tool Company
Owatonna, Minnesota 55060

END-YOKE/FLANGE-YOKE PULLER

(For removing end-yokes from transmission output shafts, coupling shafts, and rear-axle input and output shafts)

To order End-Yoke Puller J 7804–01, contact:

Kent-Moore Tool Division
29784 Little Mack
Roseville, MI 48066-2298
Telephone: 1–800–328–6657 Telex: 244040 KMTR
UR FAX: (313) 774–9870

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Specifications

To order Yoke and Flange Remover SP–450, contact:

G & W Tool Company
907 South Dewey
Wagoner, OK 74467

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General Information

The Bosch hydraulic disk brake system consists of a power booster, a master cylinder and reservoir, hydraulic lines (both rigid and flexible), a brake rotor on each wheel hub, and a brake caliper and pad assembly at each rotor. See **Fig. 1**.

There are two completely separate hydraulic systems, which use different and incompatible hydraulic fluids, lines, and seals. See **Fig. 2**.

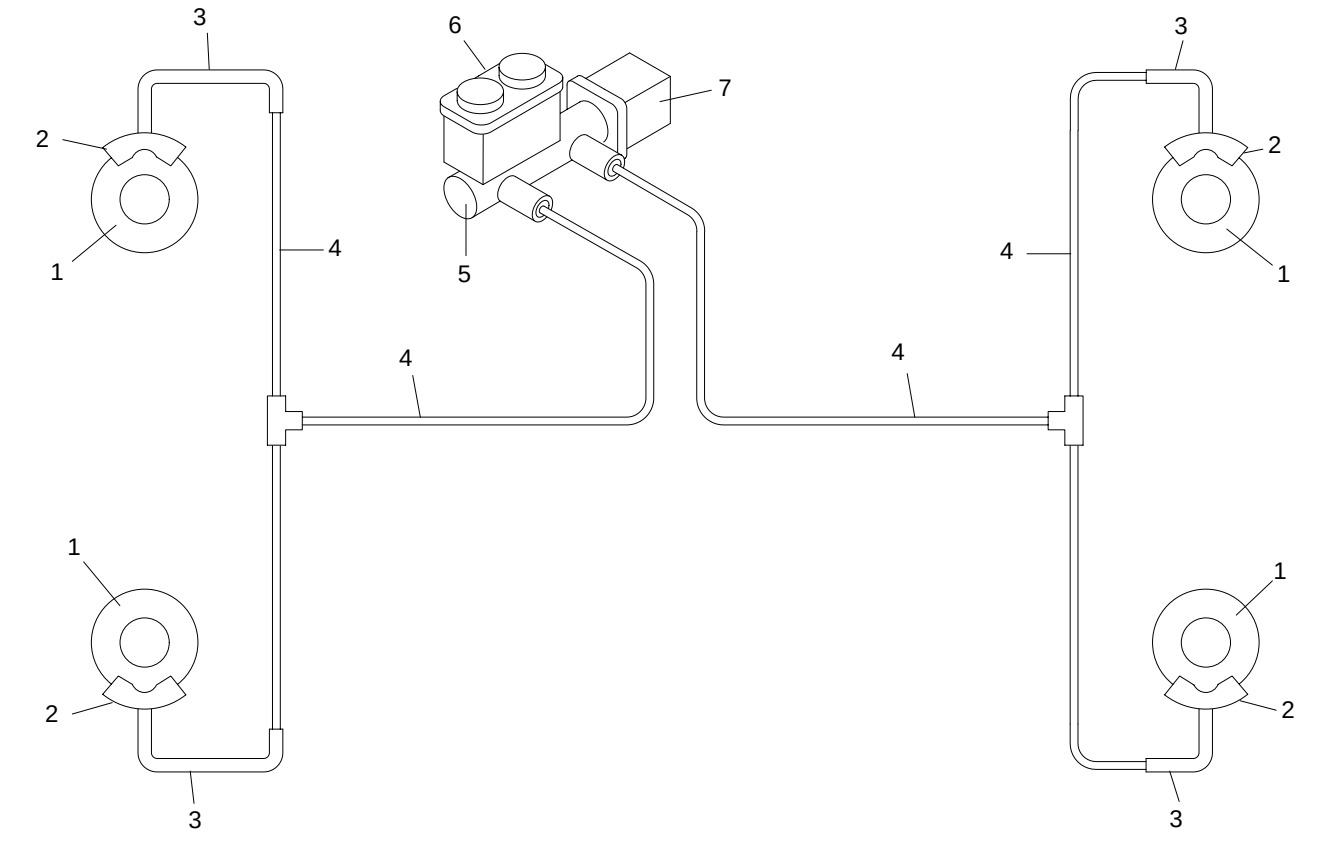
The power booster system, which provides power to the brake master cylinder and uses power steering fluid, is plumbed into the power steering system.

The service brake system, consisting of the master cylinder, the brake hydraulic lines and the brake calipers, uses DOT 3 approved brake fluid.

Power Booster **(See Fig. 3)**

The Hydro-Max II® power booster, mounted on the firewall, is attached to the rear of the master cylinder. It consists basically of a reaction piston, a power piston assembly, an end-cap assembly and a back-up electric pump.

At the rear of the power piston, and inside it, is the reaction piston. The power piston assembly is connected to the brake pedal by way of the brake pedal rod. Surrounding the reaction piston is the power pis-

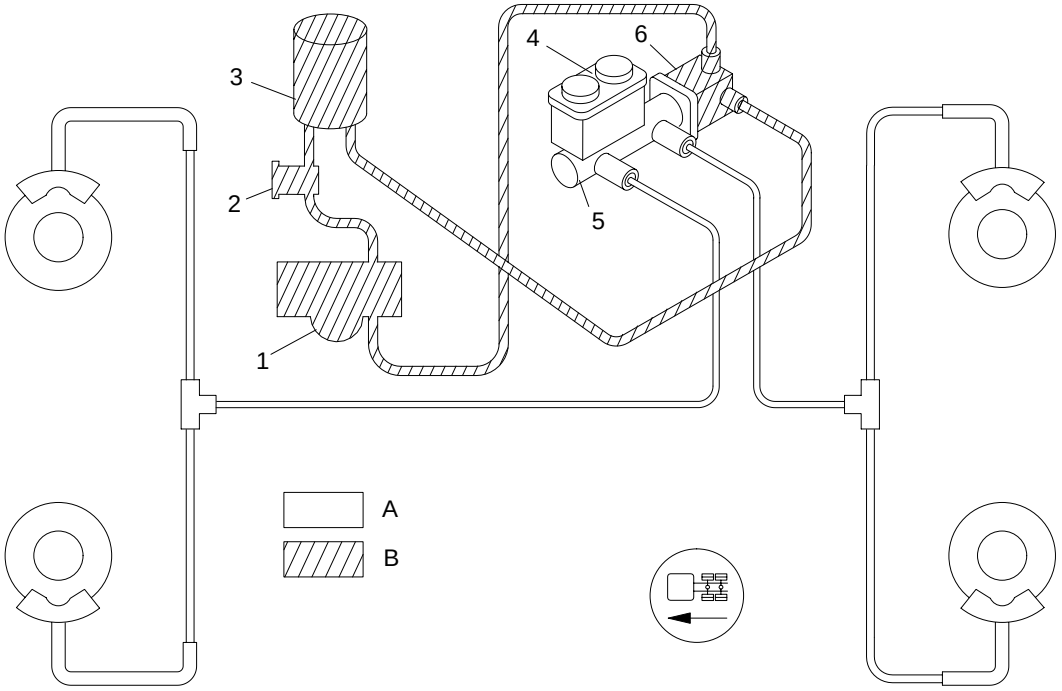


1. Rotor
2. Caliper and Pad Assembly
3. Flexible Brake Line
4. Rigid Brake Line
5. Master Cylinder
6. Reservoir
7. Power Booster

Fig. 1, Brake System Major Parts

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General Information



A. Brake System (Brake Fluid)
B. Brake Booster and Power Steering System (Power Steering Fluid)

1. Power Steering Gear
2. Power Steering Pump
3. Power Steering Reservoir
4. Brake Master Cylinder Reservoir
5. Brake Master Cylinder
6. Power Booster

Fig. 2, Brake System Major Parts

ton assembly, the forward end of which fits through the end-cap assembly, and rests against the rear of the brake master cylinder. The end-cap assembly prevents the power steering fluid in the power booster from mixing with the brake fluid in the master cylinder.

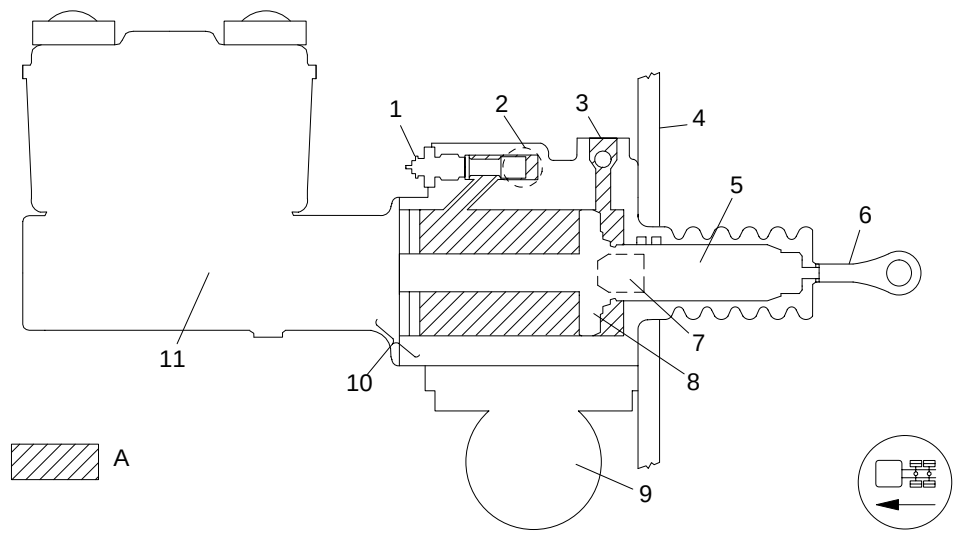
The power booster is connected to the vehicle's power steering system, which supplies it with pressurized power steering fluid. The power booster supply port is connected to the power steering pump via the steering gear, and the return port is connected to the power steering reservoir. A flow switch activates the back-up pump if, for any reason, the power steering pump does not supply the power booster with fluid.

Master Cylinder

The brake master cylinder functions as a dual supply system: the primary system supplies pressurized brake fluid to the rear brakes; the secondary system supplies it to the front brakes. See **Fig. 4**. For safety, each system is independent of the other, so a problem with one set of brakes won't affect the function of the other.

The master cylinder, attached to the front of the power booster, consists mainly of the primary pressure chamber, the primary piston/actuator assembly and return spring, the primary reservoir section, and the secondary pressure chamber, piston/actuator assembly, return spring, and reservoir section. See **Fig. 5**. Both pressure chambers have outlet ports that connect them to either the front or rear brake caliper assemblies by way of hydraulic lines. At the bottom of each reservoir section is a compensating

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NOTE: Not all parts are shown.

A. Power Steering Fluid

1. Flow Switch
2. Return Port
3. Supply Port
4. Firewall
5. Rubber Boot
6. Brake Pedal Rod
7. Reaction Piston
8. Power Piston Assembly
9. Backup Electric Pump
10. End-Cap Assembly
11. Master Cylinder and Reservoir

Fig. 3, Power Booster

valve, which when open, connects that reservoir section with the applicable pressure chamber in the master cylinder. A pressure differential valve operates a pressure differential switch (not shown), which activates a dash warning system, should one brake system not work.

Brake Caliper Assemblies

Each brake caliper assembly, attached to a wheel, consists of a housing with dual cylinders and pistons, a supply port, and a bleeder fitting. See **Fig. 6** and **Fig. 7**. The assembly fits over the rotor like a "U", with the pistons on the inboard face of the rotor. The caliper fits onto an anchor plate at the top and bottom, and the anchor plate is attached to the axle. The caliper is held in place on the anchor plate by a key, a spring (not shown), and bolt. The brake pads fit into slots in the caliper housing.

Brake Control Module

The brake control module, located behind dash panel B, monitors electronic signals from various sensors in the brake system. If a problem is detected, the module activates the applicable warning light and buzzer on the dashboard.

The control module has nine input terminals and three output terminals (one terminal is a ground). See **Fig. 8**. The output terminals are used for the brake system pressure and parking brake warning lights, and a buzzer; the input terminals are connected to sensors in the brake system that detect problems.

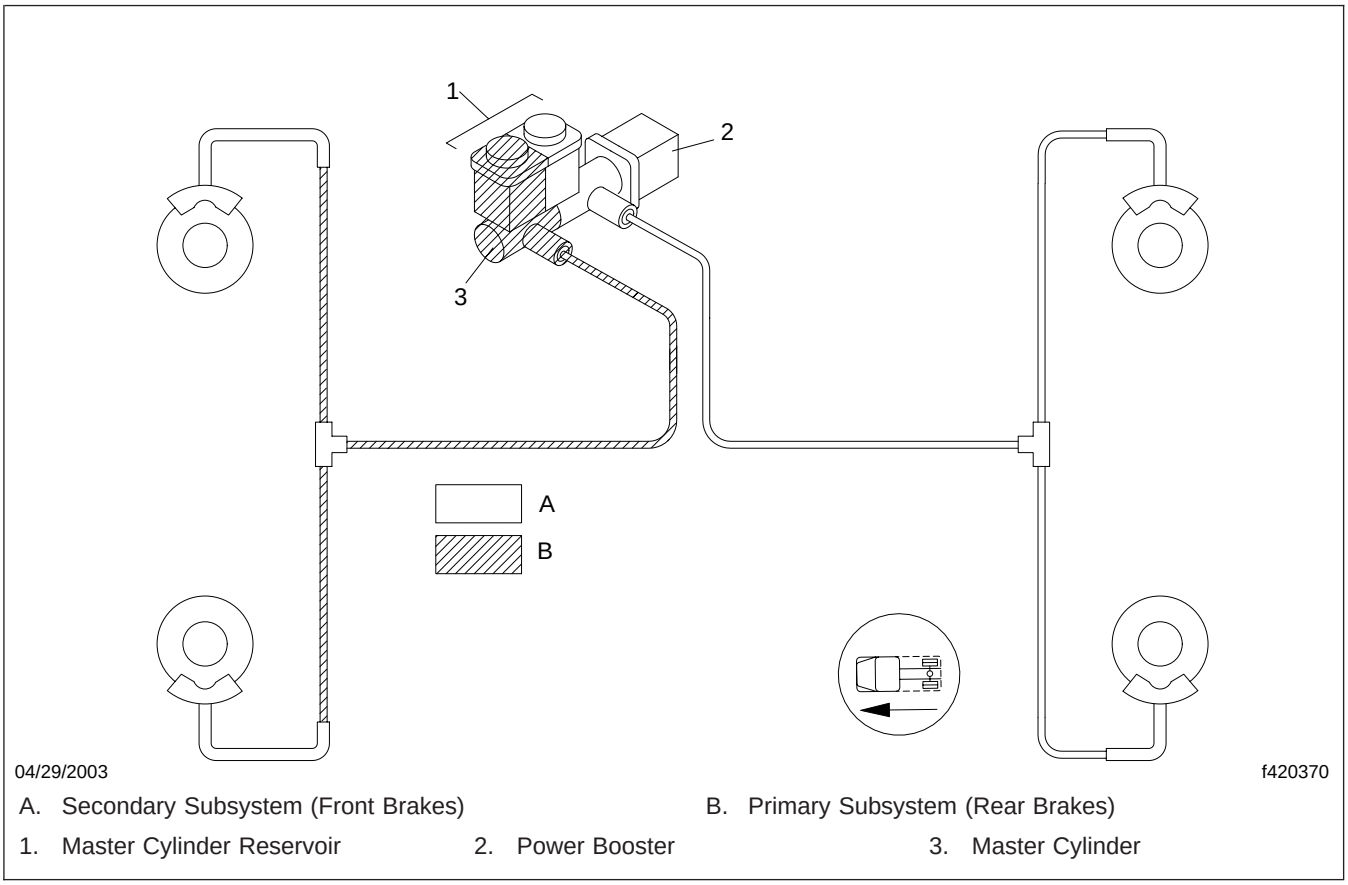
See **Table 1** for identification of the output and input terminals on the back of the module, and the circuits to which they are connected.

The control module, which operates on 9 to 16 volts DC, is active (monitoring the hydraulic brake system) under any of the following conditions:

- When the ignition is on;

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General Information



A. Secondary Subsystem (Front Brakes) B. Primary Subsystem (Rear Brakes)

1. Master Cylinder Reservoir 2. Power Booster 3. Master Cylinder

Fig. 4, Dual Supply System

- When the brake pedal switch is powered;
- If the ignition is off, but the driver's door is open and the parking brake is not applied.

When the ignition is turned on, the control module starts a self-test mode, which lasts from about one to three seconds. The warning lights and buzzer come on, then go off if the system is working all right. The module then goes into the active mode, monitoring the hydraulic brake system. If a problem is detected, the applicable input or output terminal is activated, and a warning light and buzzer come on. The output terminals are activated as follows:

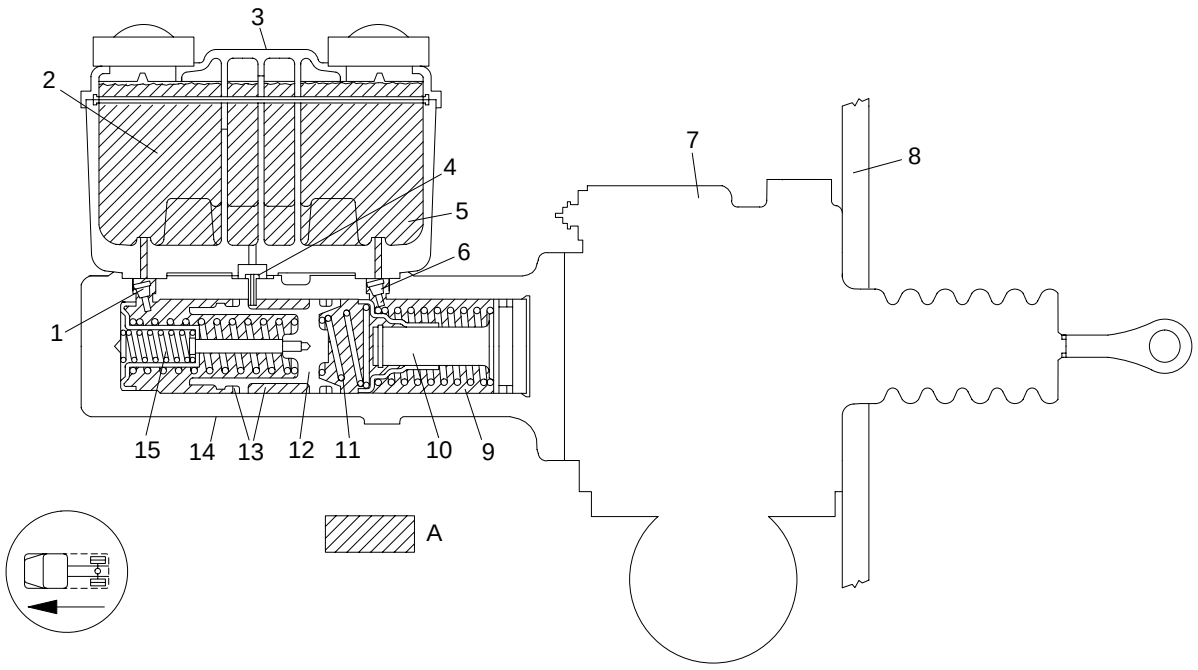
The "R" light (brake pressure) output—terminal 3—is activated when any of the following conditions exist:

- The flow switch on the power booster closes, due to a reduced flow of power steering fluid;
- The pressure differential switch on the master cylinder closes, due to a drop in pressure in either the front or rear brake system;
- The fluid level switch on the master cylinder reservoir closes, due to a drop in the fluid level;
- Too much electrical resistance is in the backup pump motor.

The "P" light (parking brake) output—terminal 2—is activated when any of the following conditions exist:

- The parking brake is applied, and the ignition is on;
- The driver's door is open, the parking brake is not applied, and the ignition is off. This condition will also cause the control module buzzer to come on.

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NOTE: Not all parts are shown.

A. Brake Fluid

1. Secondary Compensating Valve (open)
2. Secondary Reservoir Section
3. Brake Fluid Reservoir
4. Piston Stop
5. Primary Reservoir Section
6. Primary Compensating Valve (open)
7. Power Booster Assembly
8. Firewall
9. Primary Pressure Chamber
10. Primary Piston/Actuator Assembly
11. Primary Piston Return Spring
12. Secondary Piston/Actuator Assembly
13. Secondary Pressure Chamber
14. Housing
15. Secondary Piston Return Spring

Fig. 5, Master Cylinder

NOTE: The vehicle is equipped with two dash buzzers: one on the control module itself, which comes on when the light "P" output (parking brake) is activated due to the driver's door being open and the parking brake not applied; and one mounted separately from the control module, which comes on when the light "R" output (brake system pressure) is activated.

See **Table 2** for information on when the input terminals are activated.

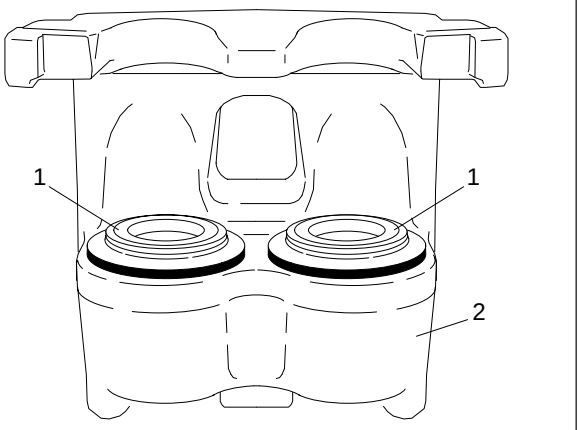
Applying the Brakes

When the brake pedal is applied, the brake pedal rod pushes the actuator pin which pushes the reaction piston forward inside the power piston. See **Fig. 9**. This closes the pressure valve, which restricts the flow of power steering fluid through the power piston. The increased fluid pressure pushes the power piston forward, through the end-cap assembly, and into the master cylinder primary piston/actuator assembly.

As the primary piston/actuator assembly moves forward in the master cylinder, the primary compensating valve closes. This closes the outlet to the primary

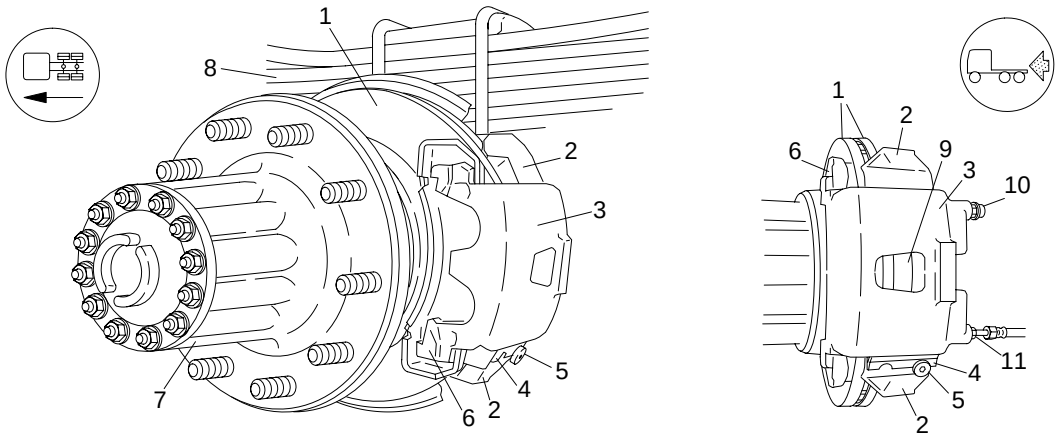
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General Information



1. Piston
2. Housing

Fig. 6, Brake Caliper Assembly



1. Rotor
2. Anchor Plate
3. Caliper Assembly
4. Key
5. Bolt
6. Brake Pad (outboard)
7. Wheel Hub
8. Leaf Spring
9. Brake Pad (inboard)
10. Bleeder Fitting
11. Supply Port

Fig. 7, Rear Brake Caliper

reservoir section, and causes hydraulic pressure to build up in the primary pressure chamber.

The primary piston/actuator assembly continues moving forward, and moves the secondary piston/actuator assembly. This closes the secondary compensating valve, pressurizing the secondary pressure chamber.

The primary and secondary pressure chambers are connected by outlet ports (not shown) to the primary and secondary brake lines and caliper assemblies. When pressurized brake fluid enters the caliper housings from the brake lines, the dual pistons in each caliper move outward toward the rotors, pushing the inboard brake pads against the rotors. At the same time, the caliper assemblies slide slightly inboard, causing both inboard and outboard pads to squeeze the rotors tightly, which slows down or stops the wheels.

If for any reason the power steering pump does not supply the power booster with fluid, the flow switch assembly turns on the electric pump and closes the return port. The check valve in the power booster supply port closes, and the check valve in the electric pump opens. The electric pump then recirculates the fluid in the power booster, maintaining emergency pressure. This provides enough reserve power for the master cylinder to pressurize the brake lines.

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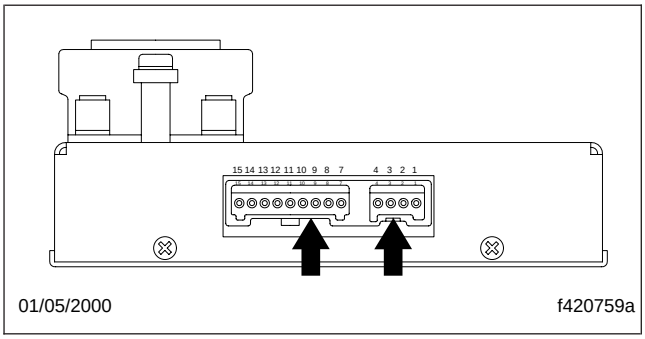


Fig. 8, Control Module Terminals

Releasing the Brakes

When the brake pedal is released, a return spring in the power booster pushes the power piston and the reaction piston (inside the power piston) toward the rear of the booster housing, and away from the master cylinder primary piston/actuator assembly. This reduces the fluid pressure in the power booster. See **Fig. 9**.

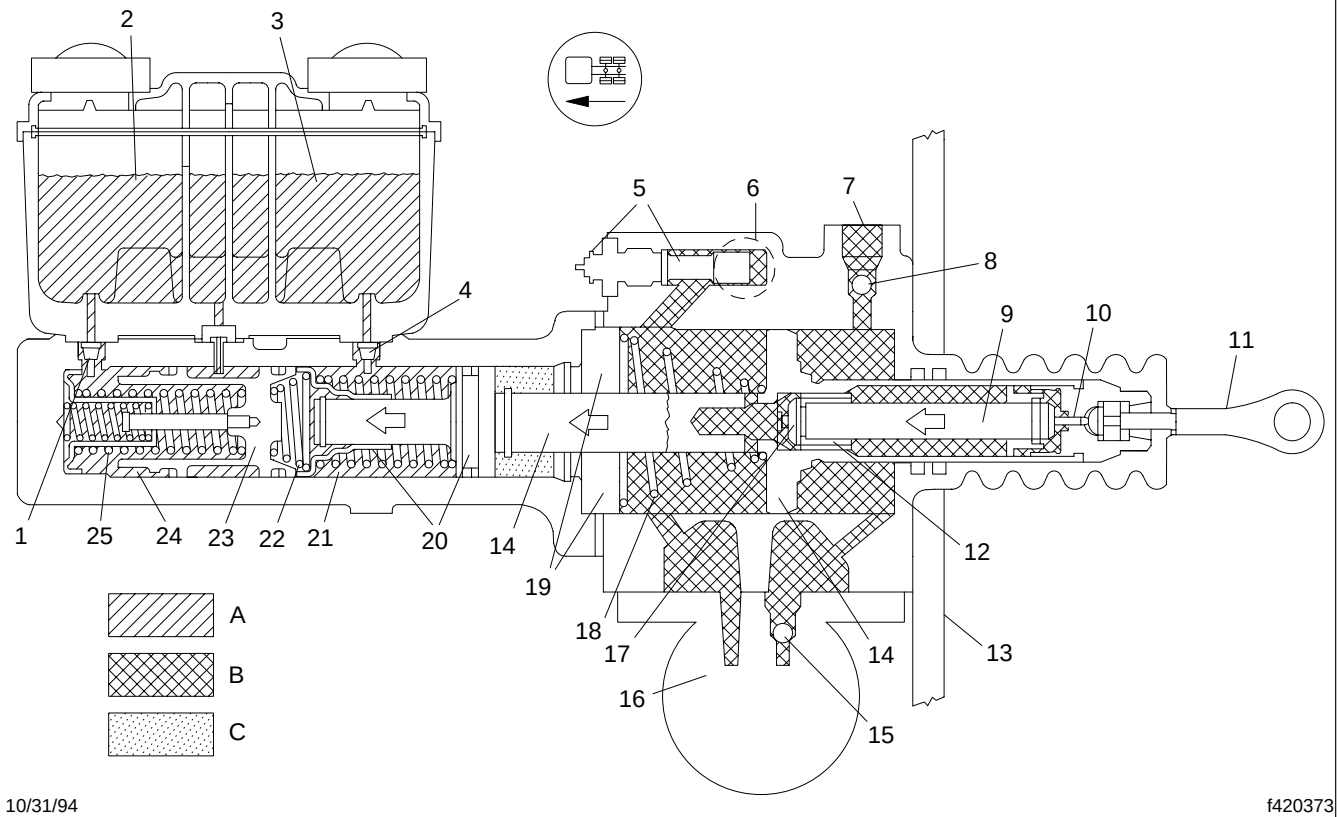
In the master cylinder, the return springs center the primary and secondary pistons. This opens up the primary and secondary compensating valves, decreasing hydraulic pressure throughout the master cylinder. The pressure in the hydraulic lines drops, which allows the dual pistons in each caliper housing to retract. The calipers slide back outboard, and the brake pads no longer squeeze the rotors, allowing the rotors and wheel hubs to turn freely.

Control Module Terminal Identification		
Terminal Number	**Function**	**Circuit Number**
1	Light "P" (Parking Brake) Output	394
2	Buzzer Output	396
3	Light "R" (Brake System Pressure) Output	390
4	Ground	GND
7	Ignition Input	388
8	Parking Brake Input	309
9	Relay Input	389
10	Door Open Input	397
11	Pressure Differential Switch Input	36F
12	Brake Pedal Input	500
13	Pump Motor Input	398
14	Fluid Level Input	395
15	Flow Switch Input	393

Table 1, Control Module Terminal Identification

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General Information



NOTE: Not all parts shown.

A. Brake Fluid
B. Power Steering Fluid
C. Air Space

1. Secondary Compensating Valve
2. Secondary Reservoir Section
3. Primary Reservoir Section
4. Primary Compensating Valve
5. Flow Switch Assembly
6. Return Port
7. Supply Port
8. Check Valve (shown open)
9. Pressure Regulator Assembly
10. Actuator Pin
11. Brake Pedal Rod
12. Reaction Piston
13. Firewall
14. Power Piston
15. Check Valve (shown closed)
16. Electric Motor Pump Assembly
17. Pressure Valve
18. Return Spring
19. End-Cap Assembly
20. Primary Piston/Actuator Assembly
21. Primary Pressure Chamber
22. Primary Piston Return Spring
23. Secondary Piston/Actuator Assembly
24. Secondary Pressure Chamber
25. Secondary Piston Return Spring

Fig. 9, Brake Components

Input Terminal Activation			
Terminal Number	**Function**	**Circuit Number**	**Activated if**
7	Ignition Input	388	The ignition is on.
8	Parking Brake Input	309	Parking brake is applied.
9	Relay Input	389	The ignition is on or brake pedal is depressed.

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Input Terminal Activation			
Terminal Number	**Function**	**Circuit Number**	**Activated if**
10	Door Open Input	397	Driver's door open, and parking brake not applied.
11	Pressure Differential Switch Input	36F	Pressure difference between front and rear systems becomes more than 483 kPa (70 psi).
12	Brake Pedal Input	500	Brake pedal depressed.
13	Pump Motor Input	398	Electrical resistance of backup pump motor too high.
14	Fluid Level Input	395	Fluid level of master cylinder below 25 percent capacity.
15	Flow Switch Input	393	No hydraulic flow through power booster.

Table 2, Input Terminal Activation

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General Safety Precautions

⚠ WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- Disconnect the batteries.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

⚠ WARNING

Hydraulic brake fluid is hazardous, and can cause blindness if it gets in your eyes. Always wear safety glasses when handling brake fluid or bleeding brake components. Brake fluid may also be a skin irritant. If you get it on your skin, wash it off as soon as possible.

Special care must be taken when disposing of used brake fluid. Put the fluid in a sealed plastic container and label it "Used Brake Fluid." Then dispose of it in an approved manner. Check with local and state regulations as to the correct disposal procedure.

IMPORTANT: During service procedures, keep grease and other foreign material away from caliper assemblies, disc brake pads, brake rotors and external surfaces of the hub. Handle parts carefully to avoid damage to the caliper, rotor, disc brake pads or brake lines.

Asbestos and Non-Asbestos Safety

⚠ WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH.

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the

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Safety Precautions

brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

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Bleeding

⚠ WARNING

Before doing any of the work below, read the information in Subject 100. Failure to read the safety precautions and to be aware of the dangers of brake fluid could result in injury.

Whenever any hydraulic system fitting is loosened or disconnected, the entire system must be bled to remove any air that may have entered it.

⚠ CAUTION

Power steering fluid and brake fluid are incompatible. Never mix these two fluids or serious damage to both hydraulic systems will result. Use only brake fluid for the master cylinder and brake lines. Use only power steering fluid for the power booster.

Always use new, clean brake fluid that meets DOT 3 specifications when bleeding the master cylinder and service brake system. Never reuse brake fluid and do not use brake fluid containers for any other purpose. Keep brake fluid containers tightly closed to keep new brake fluid clean and dry.

IMPORTANT: Do not let brake fluid touch any painted surfaces, as it will remove the paint. Brake fluid may also damage certain non-metal surfaces. Do not let it get on brake pads or rotors.

PRESSURE BLEEDING

NOTE: Pressure bleeding is the preferred method for bleeding the service brake system. It requires the use of a special pressure bleeder kit, consisting of a tank, pressure pump and valve, gauge, tubing and adapter. These are available from a number of manufacturers and include instructions for use. See **Fig. 1**.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.

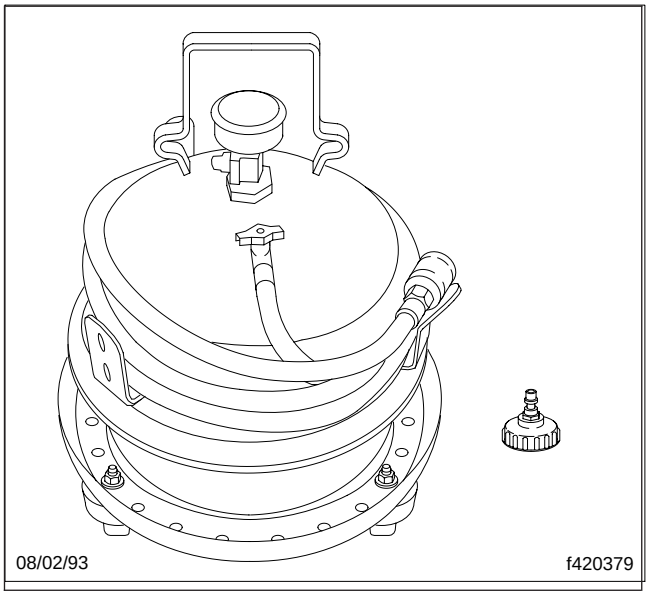


Fig. 1, Pressure Bleeder Kit

3. Connect the pressure bleeder to the brake master cylinder reservoir following the manufacturer's instructions.
   - 3.1 Fill the pressure bleeder with new DOT 3 approved brake fluid. Pressurize it according to the manufacturer's instructions.
   - 3.2 Using the supplied adapter, connect the pressure bleeder to the rear compartment of the master cylinder reservoir.
4. Bleed the hydraulic connections at the rear wheel calipers starting on the right side.
   - 4.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.
   - 4.2 Loosen the bleeder fitting about 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.
   - 4.3 Move to the left rear caliper and repeat steps for bleeding the caliper.
5. Disconnect the pressure bleeder from the rear compartment of the master cylinder reservoir. Connect it to the front compartment of the reservoir.

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Hydraulic System Bleeding

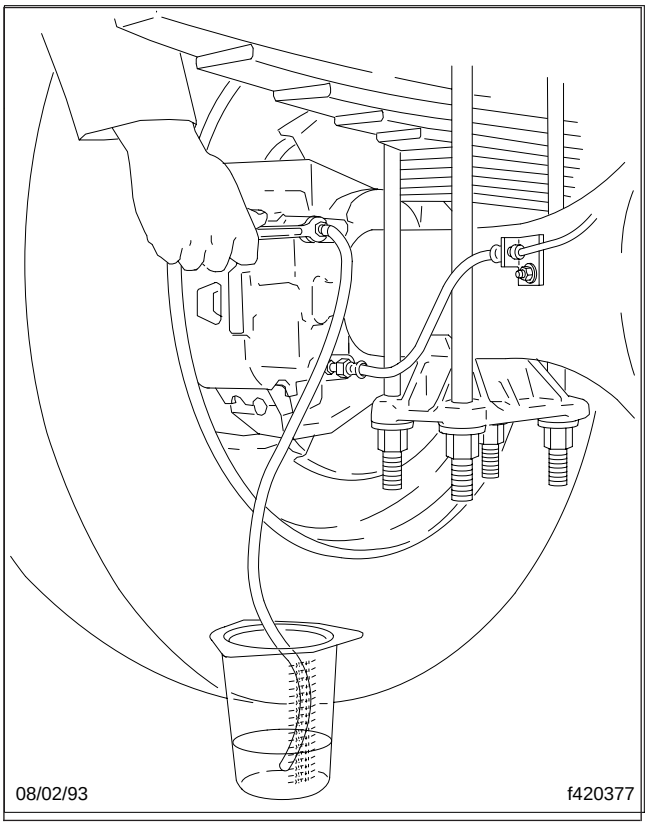


Fig. 2, Bleed the Hydraulic Connection

6. Bleed the front wheel brake calipers starting at the right side.
   - 6.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.
   - 6.2 Loosen the bleeder fitting about 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.
   - 6.3 Move to the left front wheel caliper and repeat steps for bleeding the caliper.
7. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.
8. Check the operation of the brakes by depressing the brake pedal several times, until if feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting, 300** and find the problem.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

MANUAL BLEEDING

NOTE: If you do not have pressure bleeding equipment, you can use the manual bleeding procedure.

⚠ WARNING

Read over the information in Subject 100 before starting the procedure below. Failure to do so may result in either serious injury to yourself, or damage to the brake system, resulting in an accident causing serious personal injury or property damage.

IMPORTANT: Do not let the brake master cylinder run dry during manual bleeding operations. Keep the master cylinder reservoir filled with new, DOT 3 approved brake fluid. Failure to keep the brake reservoir filled could result in more air entering the system, making it impossible to effectively bleed the system.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Bleed the master cylinder.
   - 3.1 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the rear outlet port on the master cylinder. See **Fig. 3**. Loosen the fitting about one turn.
   - 3.2 Have someone push the brake pedal down slowly by hand to the floor. Brake fluid, and any air in the master cylinder, will squirt from the fitting.
   - 3.3 *With the brake pedal held down*, tighten the rear hydraulic line fitting firmly.

   IMPORTANT: Do not release the brake pedal until the fitting is tightened, or more air will get into the system.

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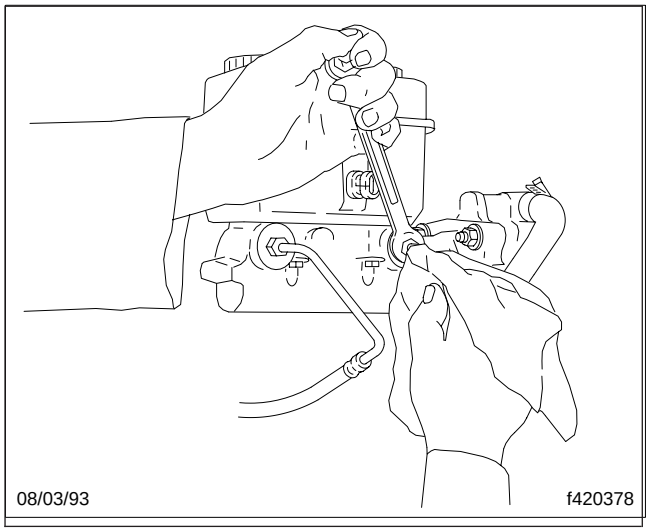


Fig. 3, Rear Outlet Port

3.4 Release the brake pedal.

3.5 Loosen the fitting again, and repeat steps for bleeding as required until no air escapes from the fitting, and the brake pedal feels firm.

3.6 Check the level of the rear compartment of the reservoir, then add new DOT 3 approved brake fluid if needed.

3.7 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the front outlet port on the master cylinder. See **Fig. 4**. Loosen the fitting about one turn.

3.8 Repeat steps as required for the front outlet port.

3.9 Check the brake fluid level in the front compartment of the reservoir. Add new DOT 3 approved brake fluid if needed.

4. Bleed the hydraulic connections at the wheel calipers, starting at the right rear wheel caliper.

4.1 Put a wrench on the bleeder fitting at the caliper, then attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

4.2 Loosen the bleeder fitting about 3/4 turn.

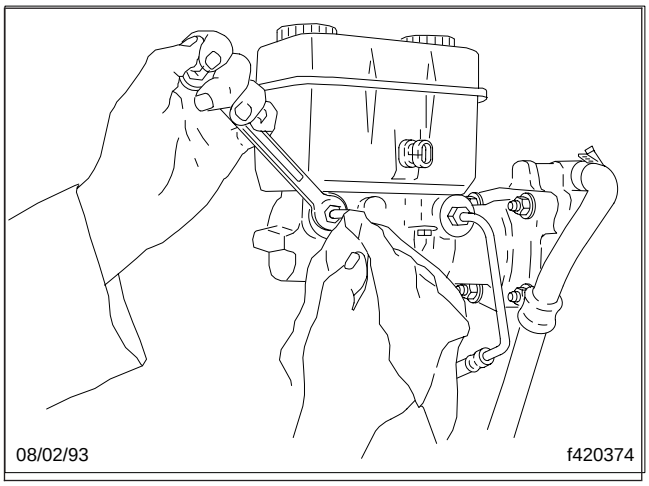


Fig. 4, Front Outlet Port

4.3 Have someone slowly push the brake pedal to the floor. *With the brake pedal depressed*, tighten the bleeder fitting.

IMPORTANT: Make sure the brake pedal stays depressed while you tighten the fitting. If it is released before you tighten the fitting, more air will get into the system.

4.4 Release the brake pedal. Check the fluid in the tube. If there are air bubbles present, repeat the steps as required until the fluid in the tube is completely free of air bubbles.

4.5 Check the brake fluid level in the reservoir. Add new DOT 3 approved brake fluid if needed.

4.6 Repeat the steps for bleeding the connections for the left rear caliper, the right front caliper and the left front caliper.

5. Close and latch the hood.

6. Remove the chocks from the rear tires.

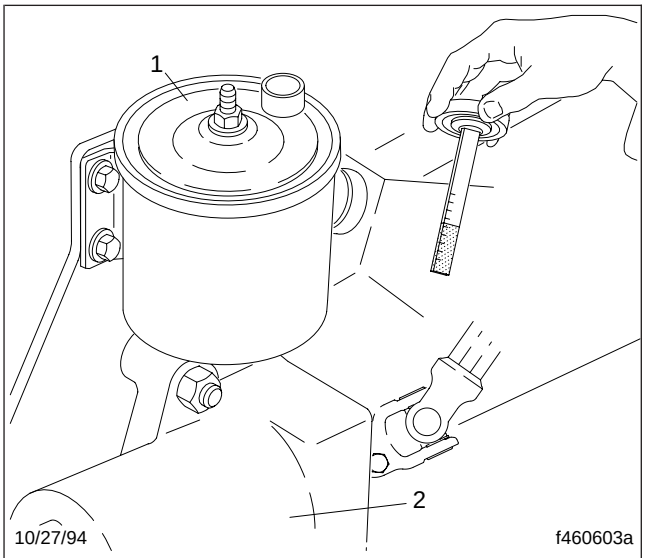
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Booster Bleeding

⚠ WARNING

Use only clean, approved power steering fluid for the procedure below. Do not use brake fluid. Mixing brake fluid with power steering fluid will damage the seals and O-rings in the power booster, the power steering pump and the power steering gear. This could result in a loss of steering, which could possibly cause an accident resulting in serious personal injury or property damage.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Check the level of fluid in the power steering reservoir. See **Fig. 1**. If needed, fill it with approved power steering fluid. See **Specifications, 400** for approved power steering fluid.



1. Power Steering Fluid Reservoir
2. Steering Gear

Fig. 1, Fluid Level Check

4. Crank the starter several times, but do not start the engine.
5. Check the fluid level in the power steering reservoir. Fill it if needed.
6. Crank the starter and check the fluid level again.
7. Check the operation of the brakes.
   - 7.1 With the engine off, depress the brake pedal. The dash warning light and buzzer should come on, and the electric motor assist should come on.
   - 7.2 Start the engine. Depress the brake pedal. The dash warning light and buzzer should not come on; neither should the electric motor. If they do, see **Troubleshooting, 300** and find the problem.
   - 7.3 Stop the engine. Check the fluid level in the power steering reservoir. Fill it if needed.
8. Close and latch the hood.
9. Remove the chocks from the rear tires.

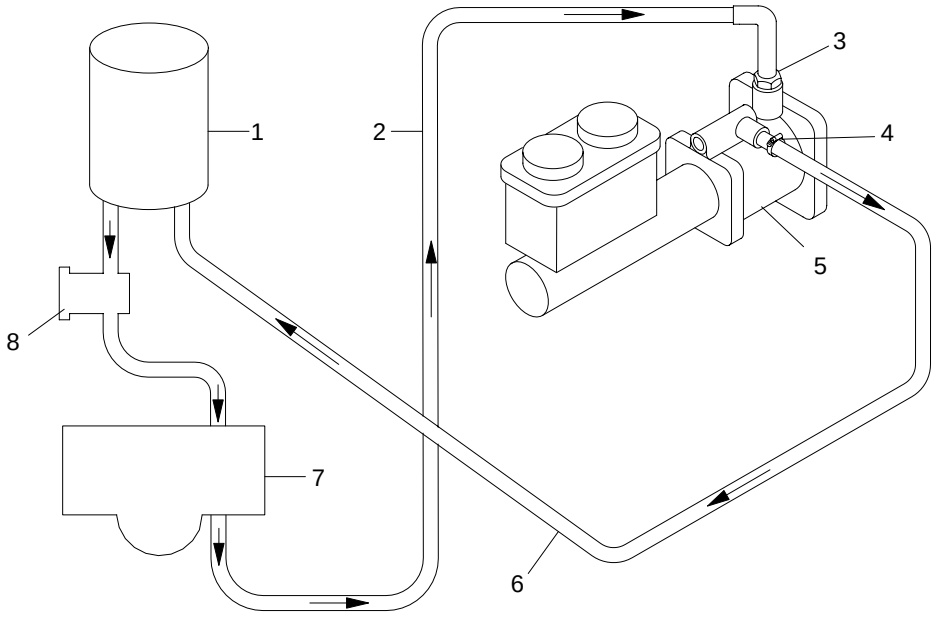
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Replacing Hydraulic Lines

POWER BOOSTER SYSTEM

The power booster is plumbed into the power steering system and uses the same type of high pressure rubber hoses as that system.

The power booster has two hoses connected to it: one from the steering gear to the booster supply port, and one from the booster return port to the power steering reservoir. See **Fig. 1**.



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1. Power Steering Reservoir
2. Hydraulic Supply Line
3. Steel Fitting
4. Hose Clamp
5. Power Booster
6. Hydraulic Return Line
7. Power Steering Gear

Fig. 1, Power Booster System

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Replace the power booster hoses if they are leaking or show signs of cracking, softening or bulging. Replace the entire hose if there are problems; do not repair it.

3.1 Remove all hose clamps and tie straps used for routing the hose.

3.2 Using a shop towel over the fittings to catch any power steering fluid, disconnect both ends of the hose being replaced.

3.3 Install the new hose.

If replacing the booster supply hose, tighten the supply port connection 22 lbf·ft (30 N·m), and the outlet connection on the power steering gear 41 lbf·ft (56 N·m).

If replacing the booster return hose, tighten the hose clamps at the booster return fitting and the power steering reservoir firmly.

3.4 Install the hose clamps and replace any tie straps removed above.

Check the routing of the hose. Make sure it is away from heat sources and moving parts, such as the steering driveline.

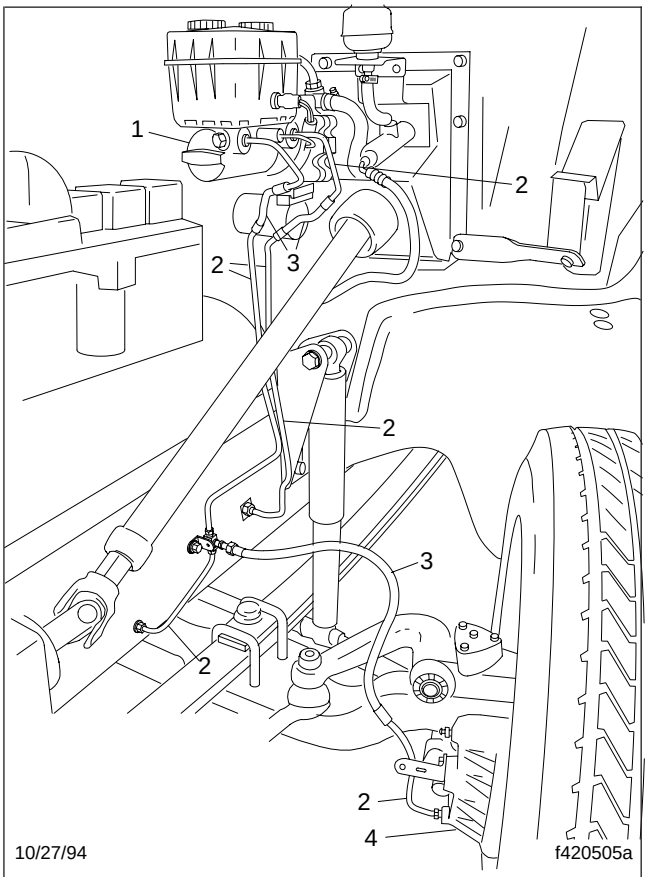
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Replacing Hydraulic Lines

4. Bleed the power booster system following the instructions in **Subject 120**.
5. Close and latch the hood.
6. Remove the chocks from the rear tires.

SERVICE BRAKE SYSTEM

The service brake system has two types of hydraulic brake lines: rigid steel tubing and flexible rubber hose. See **Fig. 2**.



1. Master Cylinder
2. Steel Tubing
3. Rubber Hose
4. Caliper

Fig. 2, Service Brake System

The steel brake lines are 1/4-inch o.d. double-walled tubing, and run from the master cylinder to points on the chassis near each wheel. The rubber brake hoses are 1/8-inch i.d. low-expansion rubber; they connect the end of each rigid line to the caliper assembly at each wheel.

If a brake line is leaking, replace the whole section of line. Replace flexible brake hoses if they show signs of cracking, softening, or bulging.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Locate the leak in the brake line. Determine the length and configuration (if a steel line) of the section involved.
4. If necessary, loosen and remove any brackets holding the brake line to the frame or axle, so that you can remove the damaged section.
5. Put a container under the connection on one side of the leak. Disconnect the line. Plug both ends of the connection.

   Repeat at the connection on the other side of the leak.
6. Remove the plugs installed earlier. Install the new section of brake line and tighten the connections 15 lbf·ft (20 N·m).
7. Install any brackets that were removed above.
8. Bleed the brake system following the procedure in **Subject 110**.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

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Replacement

WARNING

Before starting the procedure below, read the information in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

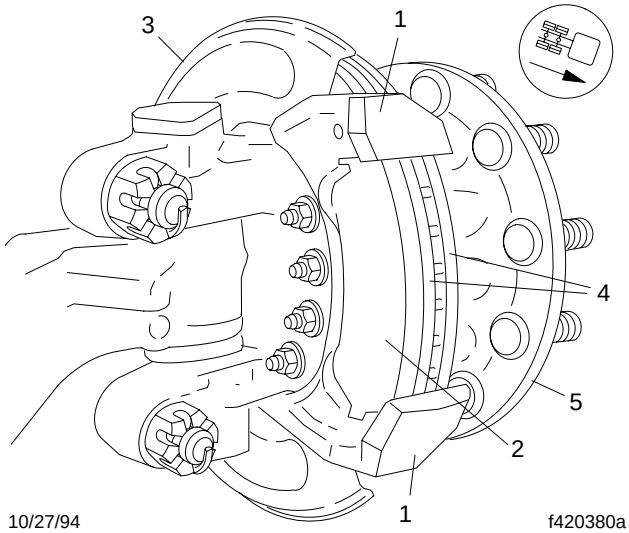
IMPORTANT: When replacing brake pads, always replace them on both wheels of the axle (right and left side). If the brake pad linings are worn down to the minimum thickness of 1/16 inch (1.6 mm), you must also rebuild the calipers, as dirt has probably gotten into the caliper cylinders. For instructions, see **Subject 150** and **Subject 160**.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires of the axle you will not be working on.
2. Remove the brake caliper from the wheel. For instructions, see **Subject 150**.
3. Remove the brake pads.
   - 3.1 Remove the outboard brake pad from the caliper assembly.
   - 3.2 Pull the inboard pad away from the rotor and the anchor plate. See **Fig. 1**.
4. Using a wet rag that is wrung out until nearly dry, clean the caliper housing (especially around the piston boots) and the dust shield.
5. Check the rotor. See **Fig. 2**.
   - 5.1 Check the rotor surface for discoloration, cracks, scoring, and heat checking.

     If the rotor is cracked, has a bluish color, or has severe heat checking, replace it. If it has minor heat checking or is scored have it resurfaced.

   IMPORTANT: If the rotor will be 1.32 inches (33.5 mm) or less after it is resurfaced, replace it.

   - 5.2 Using a vernier caliper, check the thickness of the rotor. If it is less than 1.32 inches (33.5 mm) thick, replace it.



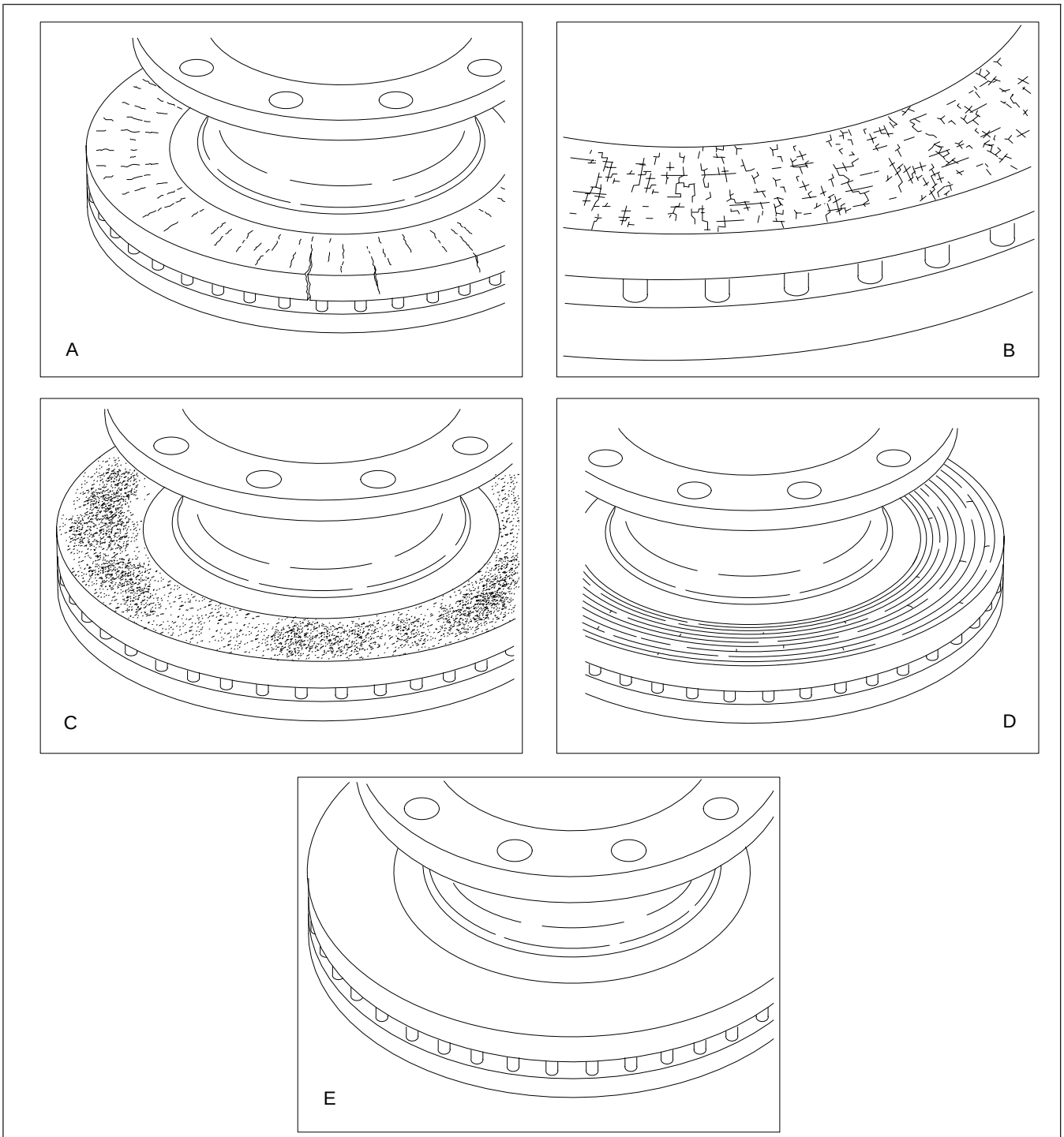
1. Anchor Plate
2. Inboard Brake Pad
3. Dust Shield
4. Rotor
5. Wheel Hub

Fig. 1, Left Front Wheel Shown; Caliper Removed

   - 5.3 Check for runout and parallelism. For instructions, see **Subject 180**.
6. Check the caliper.
   - 6.1 Check the piston dust boots for cracks or leaks. See **Fig. 3**. Also check the piston heat shields for damage. If a problem is found, disconnect the brake hose from the caliper, plug the hose and rebuild the caliper, following the instructions in **Subject 160**.
   - 6.2 Check the supply port and bleeder fitting on the caliper housing for damage or leaks. See **Fig. 4**. If a problem is found, replace the fitting, following the instructions in **Subject 160**.
7. Clean and lubricate the sliding surfaces (V-ways) of the caliper housing and the anchor plate rails with anti-corrosion grease. See **Fig. 5**.
   - 7.1 Using a fine file or emery cloth, clean the sliding surfaces (V-ways) of the caliper housing, and the corresponding surfaces of the anchor plate.
   - 7.2 Grease the surfaces lightly with anti-corrosion grease.

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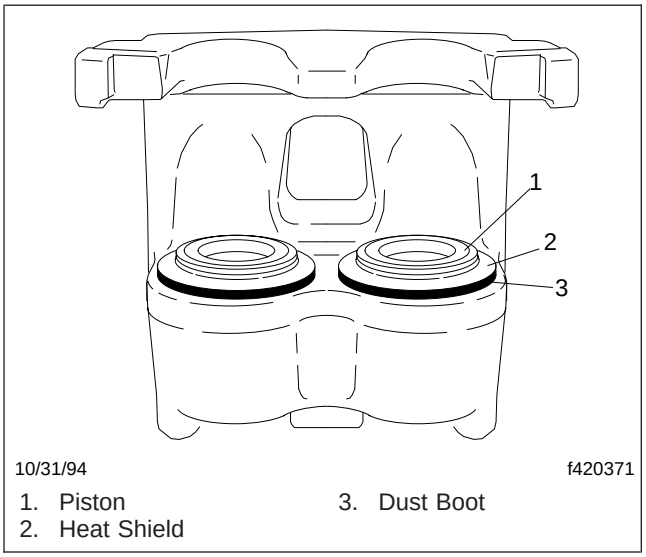
Brake Pad Replacement



A. Cracking
B. Heat Checking
C. Discoloration
D. Scoring
E. Normal Finish

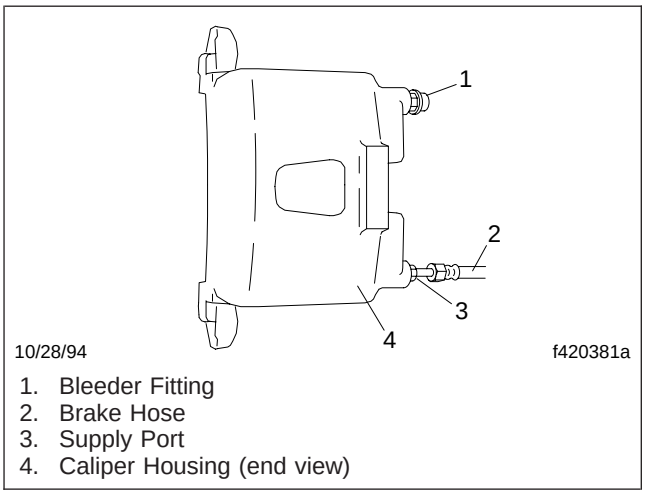
Fig. 2, Rotor Surface Check

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1. Piston
2. Heat Shield
3. Dust Boot

Fig. 3, Caliper Assembly



1. Bleeder Fitting
2. Brake Hose
3. Supply Port
4. Caliper Housing (end view)

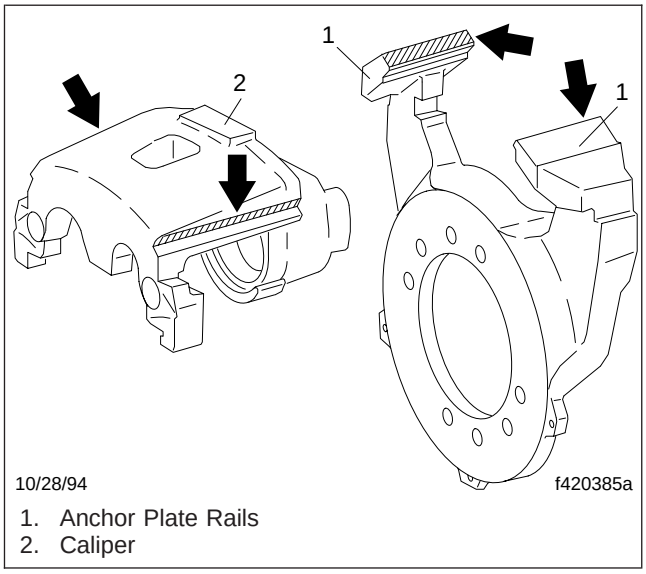
Fig. 4, Caliper Connections Check

8. Install the new brake pads.

⚠ WARNING

Do not get any dirt, oil, grease, or brake fluid on the brake lining material or the rotor surfaces. To do so could cause loss of brake control, which could result in an accident causing personal injury or property damage.

8.1 Install the inboard (smaller) brake pad into the mating notches of the anchor plate, as shown in **Fig. 1**. Make sure the pad lining is facing the rotor.



1. Anchor Plate Rails
2. Caliper

Fig. 5, Sliding Surfaces

8.2 Using a piece of wood and a C-clamp, push the pistons all the way into the caliper housing. See **Fig. 6**. Be careful not to damage the piston heat shields. Remove the C-clamp and block of wood.

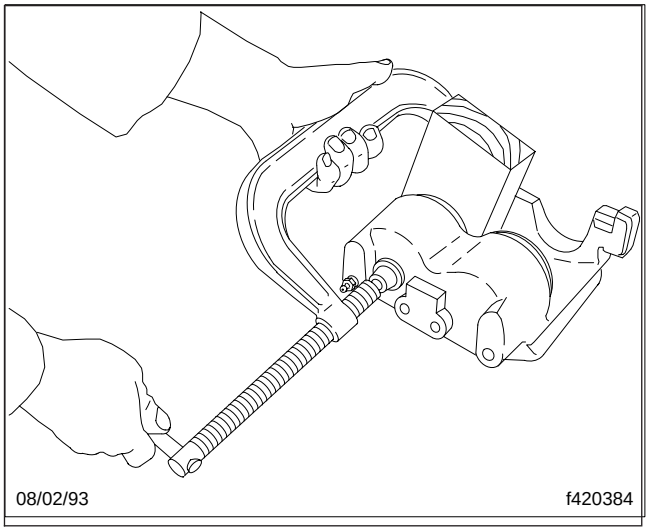
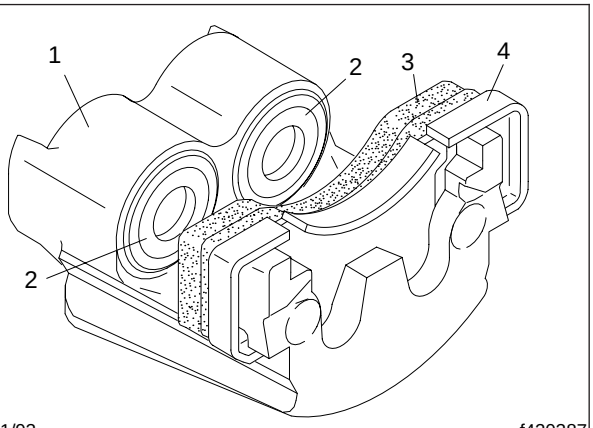


Fig. 6, Caliper Housing

8.3 Install the outboard (larger) brake pad in the housing, with the pad lining facing the piston, as shown in **Fig. 7**.

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Brake Pad Replacement



1. Caliper Housing
2. Piston
3. Brake Pad Lining
4. Outboard Brake Pad

Fig. 7, Pad Installation

9. Install the caliper following the instructions in **Subject 150**.
10. Install the tires. Remove the jackstands and lower the vehicle. Remove the chocks.
11. Pump the brake pedal until it feels firm. If it does not get firm, check for leaks or air in the brake system. Repair any leaks, if needed. Bleed the system, following the instructions in **Subject 110**.

⚠ WARNING

Do not move the vehicle until the brake pedal feels firm. To do otherwise could result in loss of vehicle control, and cause an accident resulting in personal injury or property damage.

12. Road test the vehicle and seat the brake pads.

    Accelerate the vehicle to 30 mph (48 km/h). Brake to a stop using medium brake pedal pressure. *Do not slam on the brakes*.

    Repeat this step between 20 and 30 times, allowing a one-minute interval between brake applications.

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Brake Caliper Removal and Installation

Removal

⚠ WARNING

Before starting the procedure below, read the information in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine.
2. Open the hood.
3. If you are removing the rear wheel caliper(s), remove half the fluid from the rear section of the master cylinder reservoir. If you are removing the front wheel caliper(s), remove half the fluid from the front section.
4. Chock the front or rear tires, depending on which axle you are working on. Jack up the axle and support it with jackstands.
5. Remove the tires.
6. Remove the brake caliper.
   - 6.1 If you are going to do work on the caliper, disconnect and plug the brake supply hose; otherwise, leave it attached.
   - 6.2 Remove the allen-head bolt that holds the key and spring assembly in place (on the upper anchor plate rail for the front wheel; on the lower rail for the rear wheel). See **Fig. 1**.
   - 6.3 Using a punch, drive out the key and spring from between the caliper and the anchor plate rail, as shown in **Fig. 2**. Save the parts.
   - 6.4 Tilt the caliper up so the outboard brake pad clears the rotor. Slide the caliper off the anchor plate rails. See **Fig. 3**. Be careful not to stretch the brake hose.

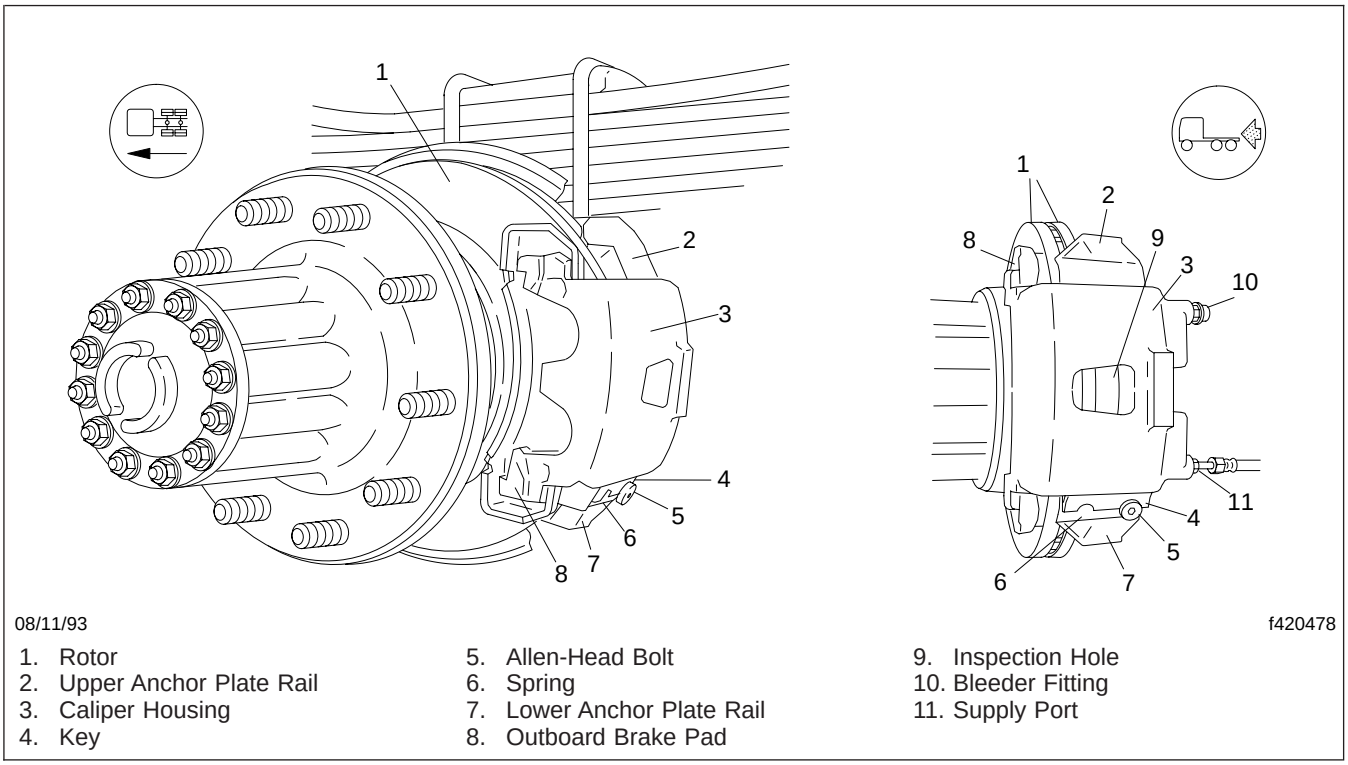
     The inboard brake pad will stay in place between the upper and lower rails of the anchor plate.
   - 6.5 If the brake supply hose is attached, support the caliper with a wire, or rest it on the axle suspension. *Do not let the caliper hang by its brake hose*.
7. Remove the outboard brake pad from the caliper housing.
8. Remove the inboard brake pad from the anchor plate. See **Fig. 4**.

Installation

1. Check the brake pad linings for wear and damage.
   - 1.1 Check the linings for wear. If they are 1/16 inch (1.6 mm) or less thick, replace the brake pads following the instructions in **Subject 140**.
   - 1.2 Check the linings for pits, cracks, separation of the material (delaminating), or other damage. See **Fig. 5**. Replace the brake pads if they are damaged.
   - 1.3 Check the linings for glazing. If they are glazed but not otherwise damaged, deglaze the linings using deglazing compound. Follow the manufacturer's directions.
2. Check the caliper.
   - 2.1 Check the piston dust boots for damage or leaks. See **Fig. 6**. If a problem is found, rebuild the caliper following the instructions in **Subject 160**.
   - 2.2 Check the bleeder fitting for leaks or damage. If there are signs of leakage, check the tightness of the fitting. If the fitting is damaged, replace it. For instructions, see **Subject 160**.
3. Check the rotor following the instructions in **Subject 140**.
4. Clean and lightly lubricate the sliding surfaces (V-ways) of the caliper housing and the anchor plate rails with Aeroshell Grade 5 (ES-1246) grease (do not use any type of anti-seize compound, such as Never-Seeze). See **Fig. 7**.
   - 4.1 Using a fine file or emery cloth, clean the sliding surfaces (V-ways) of the caliper housing, and the corresponding surfaces of the anchor plate rails.
   - 4.2 Grease the surfaces lightly with Aeroshell Grade 5 (ES-1246) grease (do not use

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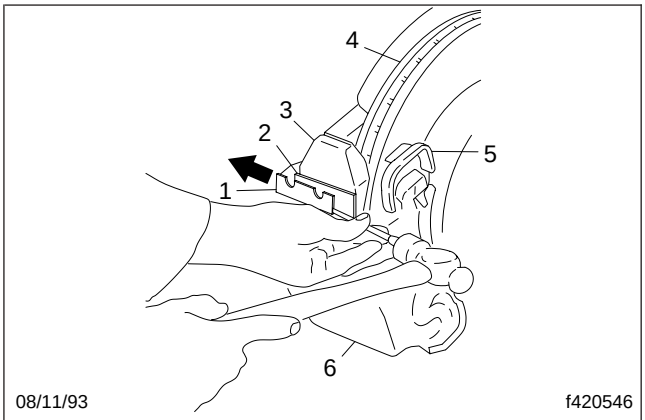
Brake Caliper Removal and Installation



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1. Rotor
2. Upper Anchor Plate Rail
3. Caliper Housing
4. Key
5. Allen-Head Bolt
6. Spring
7. Lower Anchor Plate Rail
8. Outboard Brake Pad
9. Inspection Hole
10. Bleeder Fitting
11. Supply Port

Fig. 1, Rear Caliper Shown

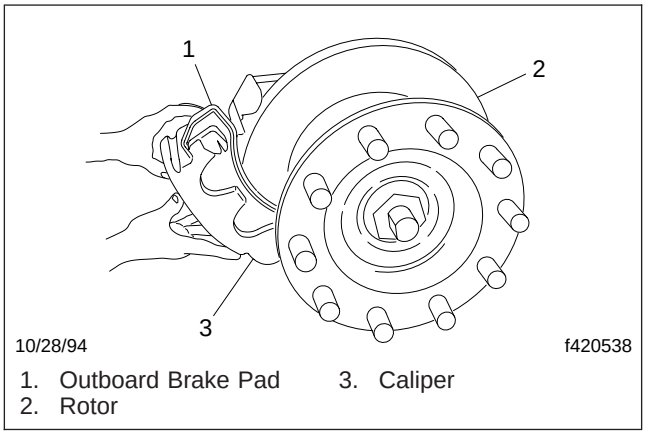


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1. Key
2. Spring
3. Upper Rail of Anchor Plate
4. Rotor
5. Outboard Brake Pad
6. Caliper Housing

Fig. 2, Front Caliper Shown

any type of anti-seize compound, such as Never-Seeze).



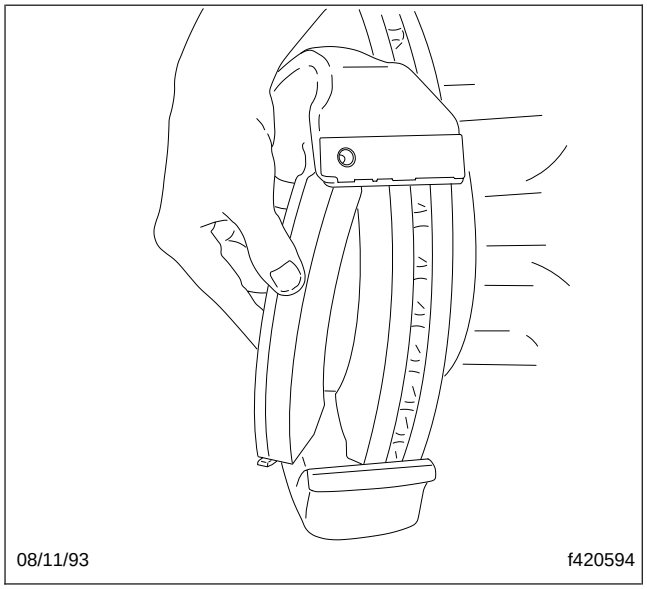
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1. Outboard Brake Pad
2. Rotor
3. Caliper

Fig. 3, Tilt the Caliper

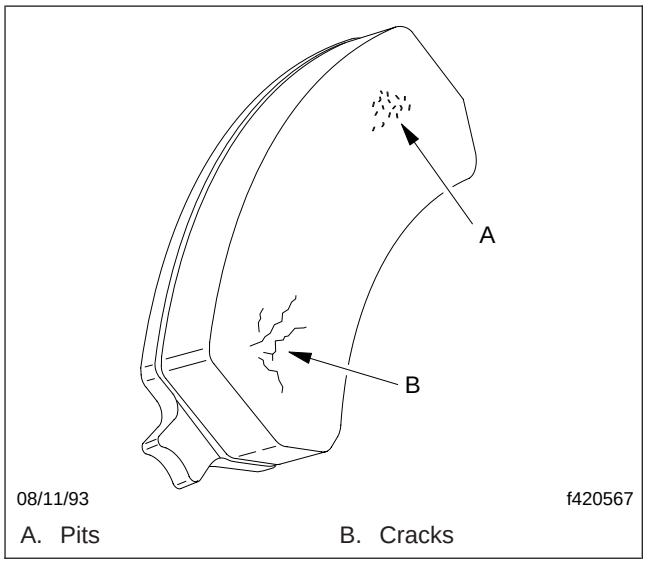
5. Install the inboard (smaller) brake pad between the upper and lower rails of the anchor plate. Make sure the lining material is facing the rotor.
6. Install the caliper.
   - 6.1 Using a piece of wood and a C-clamp, push the pistons all the way into the cali-

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Fig. 4, Inboard Brake Pad



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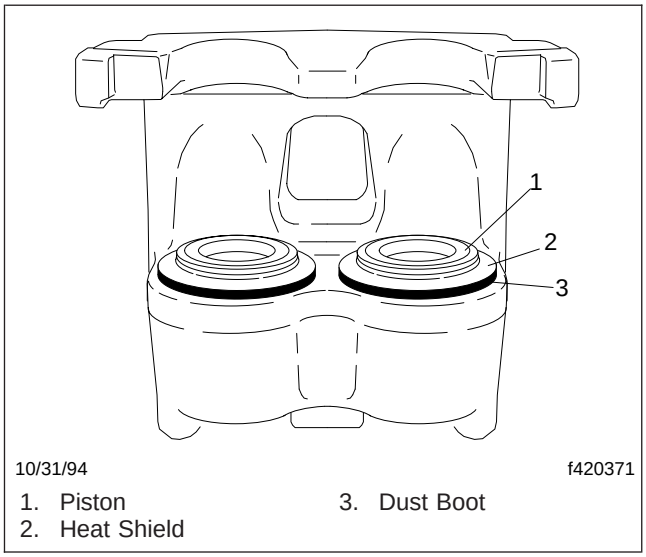
A. Pits B. Cracks

Fig. 5, Lining Check

per housing. See **Fig. 8**. Be careful not to damage the piston heat shields. See **Fig. 6**.

6.2 Install the outboard (larger) brake pad in the housing, with the pad lining facing the piston, as shown in **Fig. 9**.

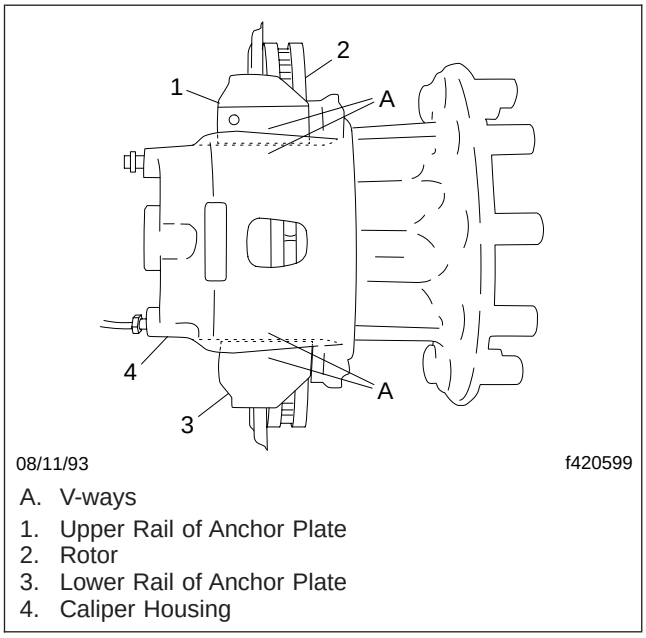
6.3 Tilt the caliper housing so that the outboard brake pad will fit over the rotor.



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1. Piston
2. Heat Shield
3. Dust Boot

Fig. 6, Caliper Assembly



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A. V-ways
1. Upper Rail of Anchor Plate
2. Rotor
3. Lower Rail of Anchor Plate
4. Caliper Housing

Fig. 7, Sliding Surfaces

Push the caliper down onto the anchor plate rails. See **Fig. 3**.

IMPORTANT: 2.88-inch calipers have pads that are chamfered on one end. Depending on mounting location (steer axle or rear axle), make sure that the 2.88-inch calipers are installed as shown in **Fig. 10**.

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Brake Caliper Removal and Installation

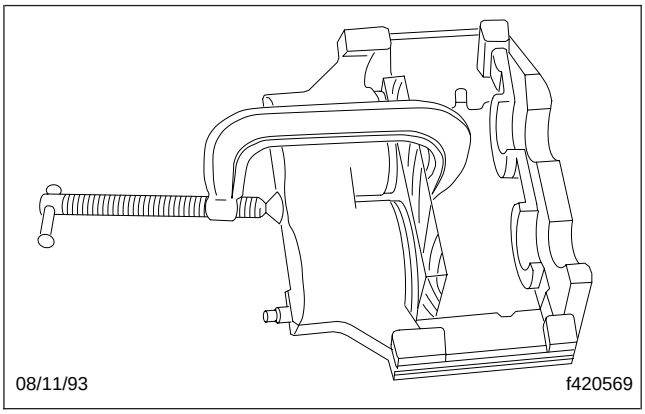
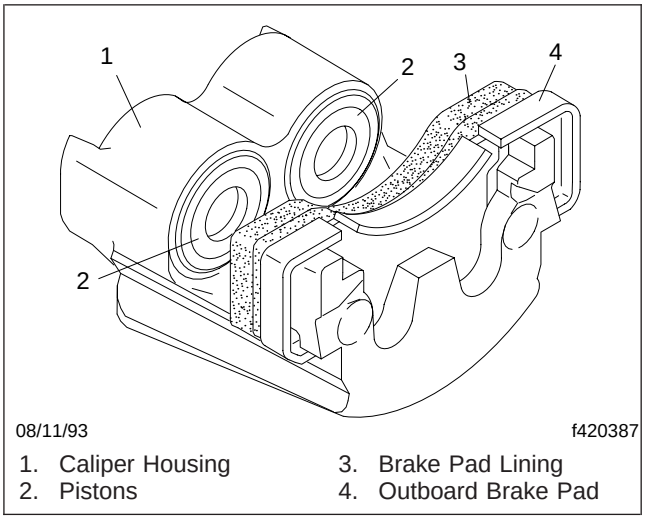


Fig. 8, Caliper Housing



1. Caliper Housing
2. Pistons
3. Brake Pad Lining
4. Outboard Brake Pad

Fig. 9, Pad Installation

6.4 Assemble the spring and key as shown in **Fig. 11**. Install them between the caliper housing and the anchor plate rail (the upper rail for front wheel calipers, or the lower rail for rear wheel calipers).

6.5 Drive the key and spring into place, using a punch and mallet. See **Fig. 12**. Make sure the notch in the key lines up with the hole in the anchor plate rail.

6.6 Install the allen-head bolt and tighten it 15 lbf·ft (20 N·m).

7. If the brake supply hose was disconnected, connect it; otherwise go to the next step and check the fluid level.

7.1 Tighten the brake supply hose fitting 15 lbf·ft (20 N·m).

7.2 Bleed the brake supply line to the caliper, following the instructions in **Subject 110**. If you have removed more than one brake caliper, bleed the entire brake system.

8. Check the fluid level in the master cylinder reservoir and add the necessary amount of new DOT 3 approved brake fluid.

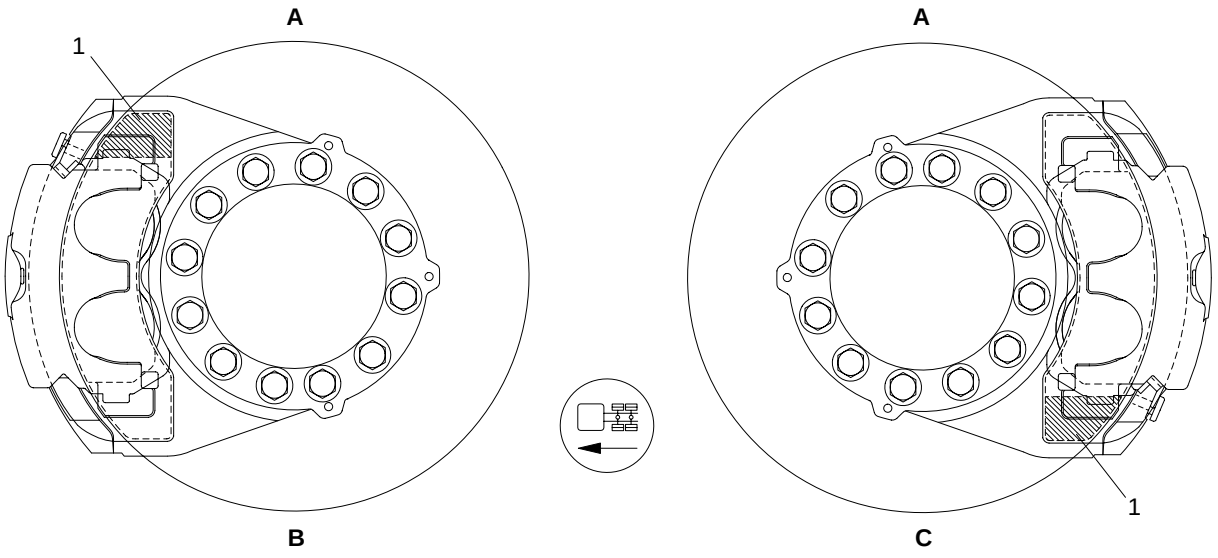
9. Seat the brake pads by pressing firmly on the brake pedal several times.

   If new brake pads were installed, seat them following the instructions in **Subject 140**.

10. Close and latch the hood.

11. Remove the chocks from the tires.

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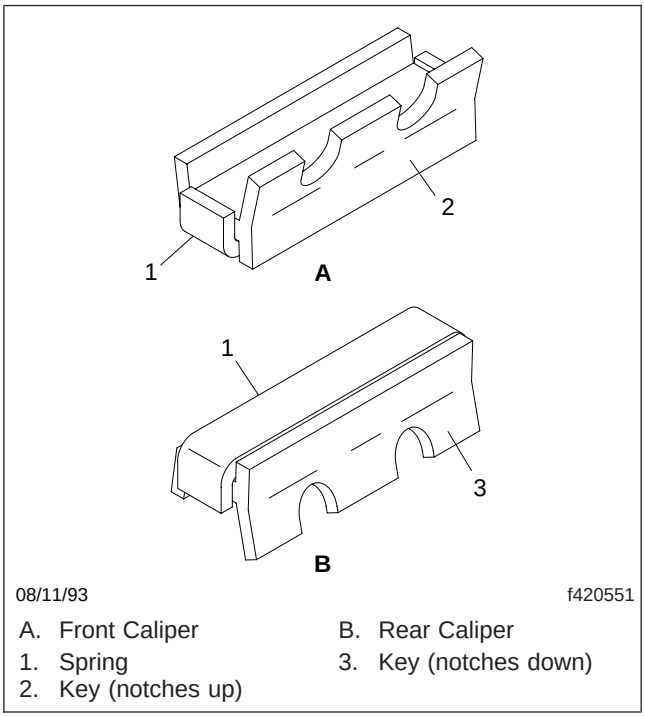
NOTE: Left-side mountings shown.

A. Top
B. Front Steer Axle Installation
C. Rear Axle Installation
1. Chamfer

Fig. 10, Caliper Installation

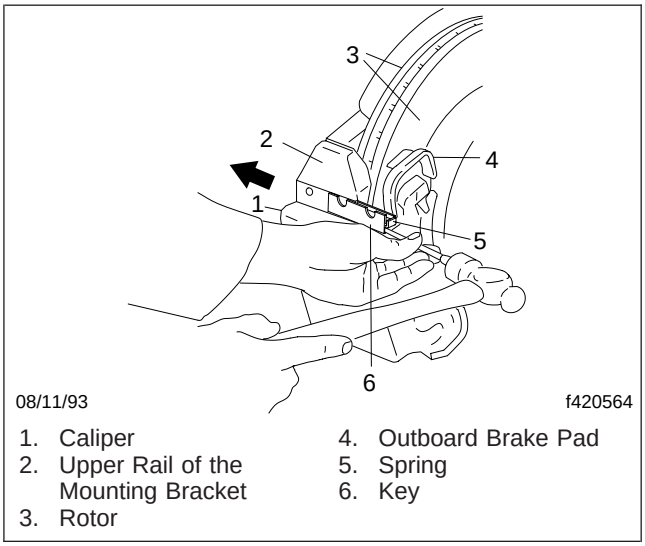
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Brake Caliper Removal and Installation



A. Front Caliper
B. Rear Caliper
1. Spring
2. Key (notches up)
3. Key (notches down)

Fig. 11, Spring and Key Assembly



1. Caliper
2. Upper Rail of the Mounting Bracket
3. Rotor
4. Outboard Brake Pad
5. Spring
6. Key

Fig. 12, Spring and Key Installation

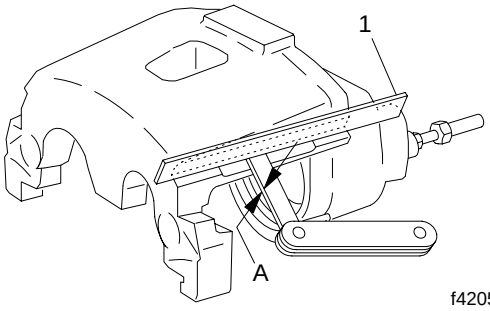
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Rebuild

WARNING

Before starting the procedure below, read the information in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires of the axle(s) you are not working on.
2. Remove the tire.
3. Clean the outside of the caliper housing, using a damp rag.
4. Remove the caliper from the wheel, following the instructions in Subject 150.
5. Drain any remaining brake fluid from the caliper housing. Discard the fluid.
6. Measure the wear depth of both caliper V-ways.
   - 6.1 Using a wire brush, clean the V-way surfaces of the caliper housing. File smooth any deep nicks or gouges.
   - 6.2 Lay the caliper housing on a bench. Put a straight edge on a V-way surface, as shown in Fig. 1.



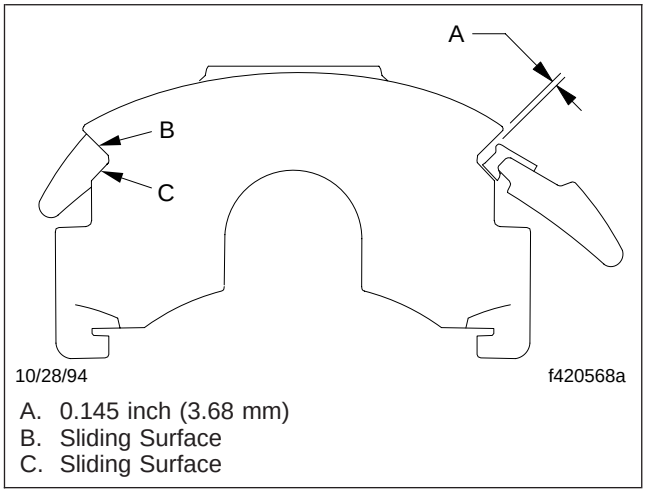
A. 0.05 in (1.27 mm)
1. Straightedge

Fig. 1, Measure the Wear Depth

   - 6.3 Using a feeler gauge, measure the gap between the V-way surface and the straight edge. See Fig. 1. Record the measurement.

Repeat this measurement for all the V-way surfaces. If any measurement is 0.05 inch (1.27 mm) or more, replace the caliper housing; otherwise, go to the step for checking caliper-to-anchor plate looseness.

7. Check for caliper-to-anchor plate looseness.
   - 7.1 Install the caliper on the rotor.
   - 7.2 Install a new key and the existing allen head bolt, but do not install the spring.
   - 7.3 Put a screwdriver in the gap (bumper gap) between the key and the V-way of the caliper. Pry up to seat the caliper against the sliding surfaces B and C, as shown in Fig. 2.



A. 0.145 inch (3.68 mm)
B. Sliding Surface
C. Sliding Surface

Fig. 2, Measure the Bumper Gap

   - 7.4 Using a feeler gauge, measure the bumper gap (the distance between the key and the caliper V-way). See Fig. 2.
   - 7.5 If the bumper gap is more than 0.145 inch (3.68 mm), replace the caliper, and repeat steps checking caliper-to-anchor plate looseness. If the bumper gap is more than 0.145 inch (3.68 mm) with the new caliper installed, replace the anchor plate.

     If the bumper gap is 0.145 inch (3.68 mm) or less, check Table 1 for the correct size wear shim to install on the anchor plate. Remove the caliper from the rotor and go to the step for removing the pistons from the caliper housing.

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Brake Caliper Rebuild

Bumper Gap Sizes		
Bumper Gap inch (mm)		Shim Thickness
More than	But Not Over	
0	0.058 (1.47)	None needed
0.058 (1.47)	0.101 (2.57)	0.025
0.101 (2.57)	0.145 (3.68)	0.045
0.145 (3.68)	—	Replace the caliper

Table 1, Bumper Gap Sizes

8. Remove the pistons from the caliper housing.

8.1 Connect a compressed air line with a control nozzle to the supply port of the caliper housing. See **Fig. 3**.

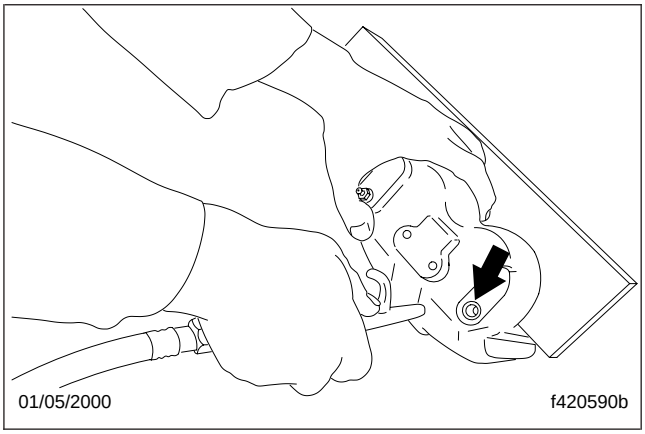


Fig. 3, Supply Port

8.2 Put a padded block of wood up against the outboard legs of the caliper, opposite the pistons, as shown in **Fig. 4**.

⚠ WARNING

Be careful when using compressed air to remove the caliper pistons from their cylinders. Keep your hands away from the front of the pistons. Use only enough air pressure to ease out the pistons or they may fly out forcibly, which could cause personal injury, or damage the pistons.

8.3 Slowly release compressed air, and ease the pistons out of the cylinders until they are up against the wooden block. Do not pop the pistons out.

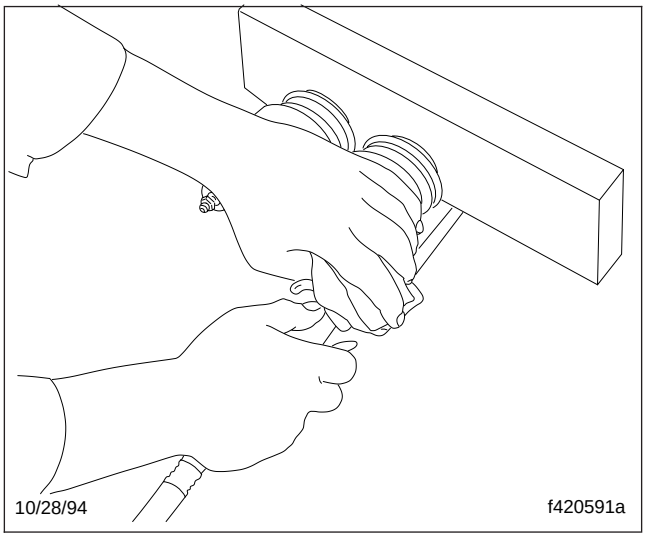
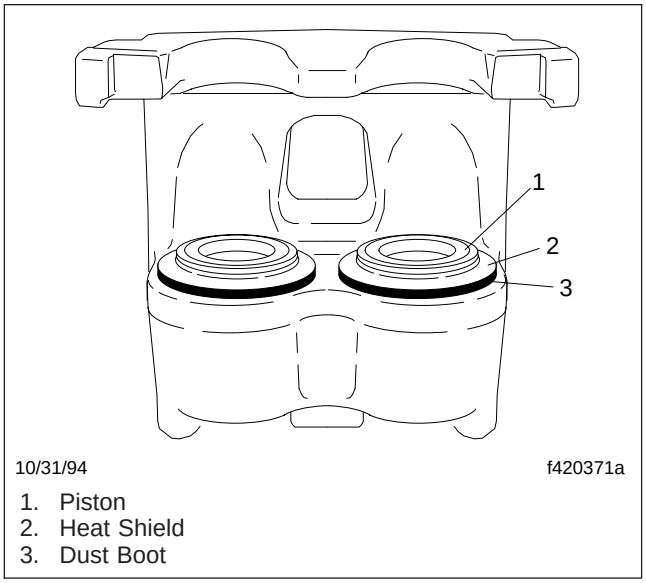


Fig. 4, Block of Wood

8.4 Using tin snips, cut both piston heat shields. See **Fig. 5**. Remove them from the pistons.



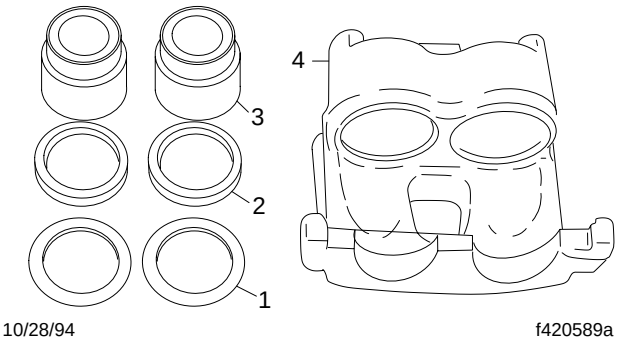
1. Piston
2. Heat Shield
3. Dust Boot

Fig. 5, Caliper Assembly

8.5 Pry the dust boot of one of the pistons from its seat in the cylinder. Do the same for the other dust boot. Remove and discard both dust boots.

8.6 Remove both pistons from their cylinders. See **Fig. 6**.

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1. Heat Shield
2. Dust Boot
3. Piston
4. Caliper Housing

Fig. 6, Piston Assembly

8.7 Remove the piston seal from inside each cylinder. See **Fig. 7**.

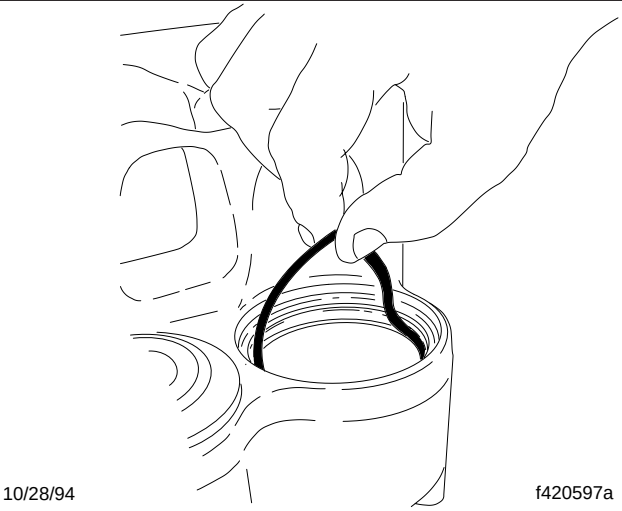


Fig. 7, Piston Seal

9. Using denatured alcohol, clean the pistons and the caliper housing. Clean both the outside of the caliper and the piston cylinders. Blow dry all the parts with compressed air.
10. Check the outside of the pistons for pitting, scoring, corrosion, or damage. If any problem is found, replace the piston.
11. Check the caliper seal grooves and dust boot seats for pitting. See **Fig. 8**. If pitting is found, replace the caliper housing. Clean any corrosion from the area between the seal groove and dust boot seat.

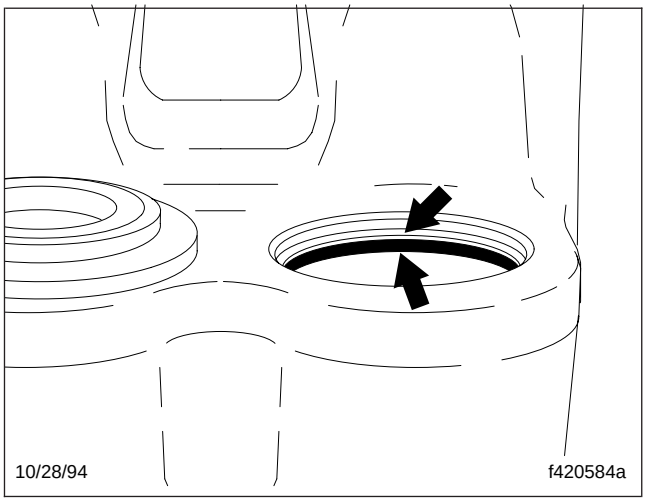
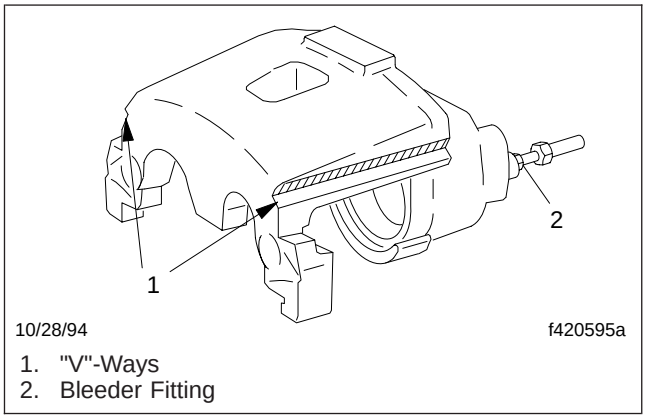


Fig. 8, Caliper Seal Grooves

12. Check the bleeder fitting for damage or wear. See **Fig. 9**. If a problem is found, replace the fitting.



1. "V"-Ways
2. Bleeder Fitting

Fig. 9, Fitting Check

13. Install new piston seals.

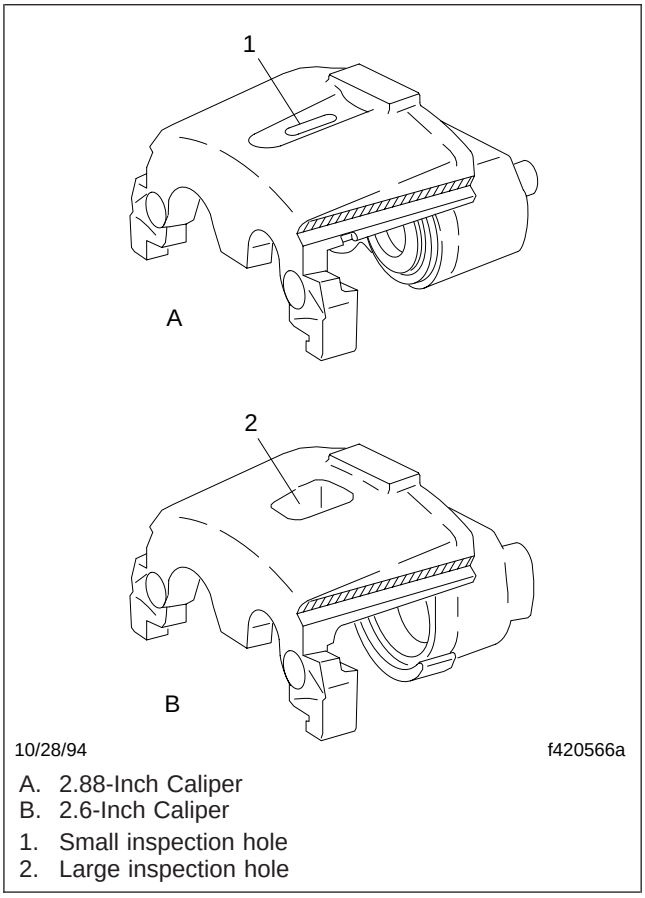
    IMPORTANT: Two different types of brake calipers are used: calipers with 2.6 inch-diameter pistons, and those with 2.88 inch-diameter pistons. Make sure you use the right seals, dust boots, and heat shields, for the type of caliper you are rebuilding.

    To determine the type of caliper, check the inspection hole on the rear of the caliper housing. If it is large, the pistons are 2.6 inches in diameter; if the hole is small, they are 2.88 inches. See **Fig. 10**.

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Brake Caliper Rebuild

13.1 Coat a new piston seal with new, clean brake fluid. See **Fig. 11**.



A. 2.88-Inch Caliper
B. 2.6-Inch Caliper
1. Small inspection hole
2. Large inspection hole

Fig. 10, Inspection Hole Check

13.2 Install a new piston seal in each of the cylinders. Make sure the seal is not twisted.

14. Install new dust boots on the pistons, as shown in **Fig. 12**.

15. Install the pistons.

15.1 Coat the bottom half (closed end) of one of the pistons with new brake fluid. *Do not get any brake fluid on the dust boot.*

15.2 Place the bottom (closed end) of the piston into its cylinder, making sure it is perfectly straight. See **Fig. 13**.

IMPORTANT: Make sure the piston is lined up in the cylinder perfectly straight before you install it; otherwise it will bind. If the piston binds in the cylinder, it will be impossible to install, and very difficult to remove.

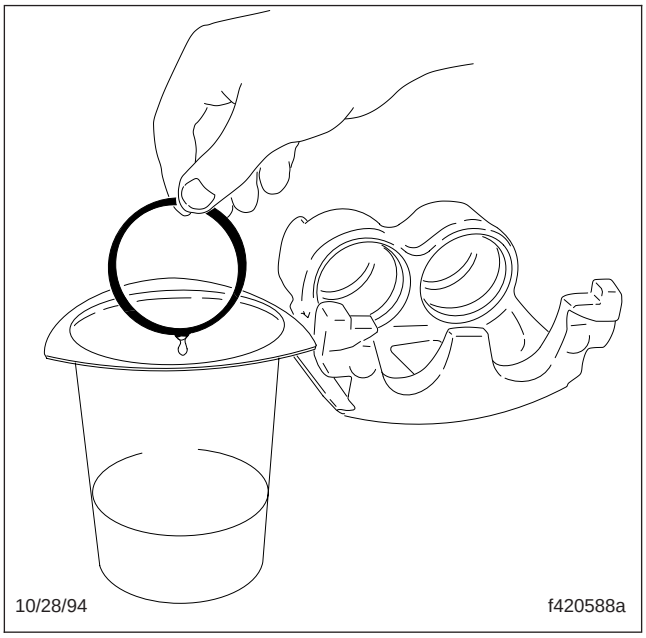


Fig. 11, Piston Seal Coating

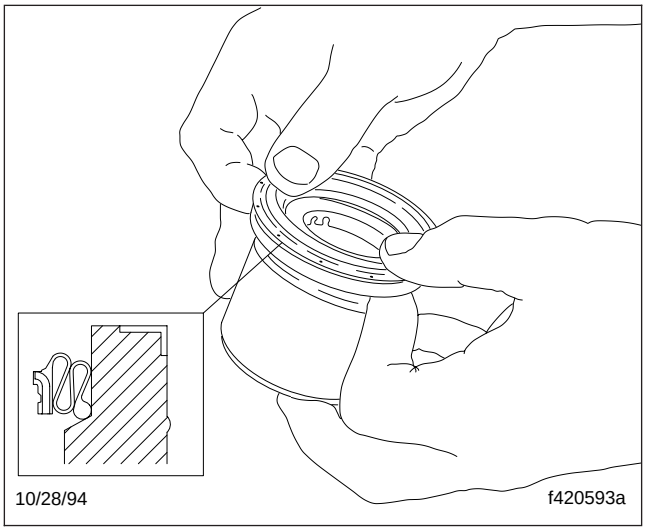


Fig. 12, Dust Boot Installation

15.3 Put a piece of thick metal or a block of wood over the top (open end) of the piston. Using a C-clamp, push the piston all the way into the cylinder until it bottoms out. See **Fig. 14**. Be careful not to dam-

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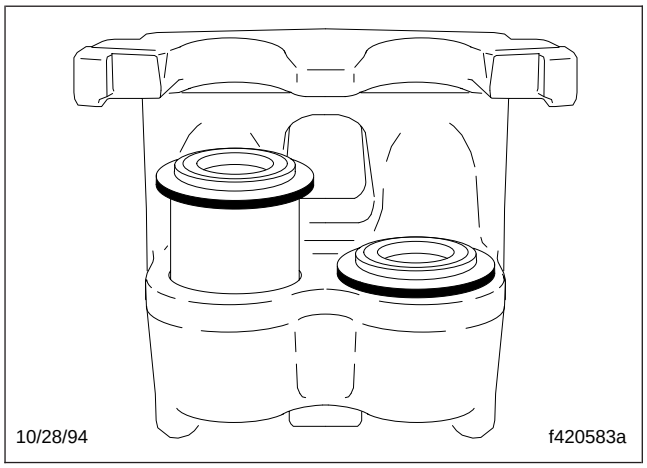


Fig. 13, Piston Installation

age the dust boot. If you feel resistance, the piston is in crooked. Remove it and start over.

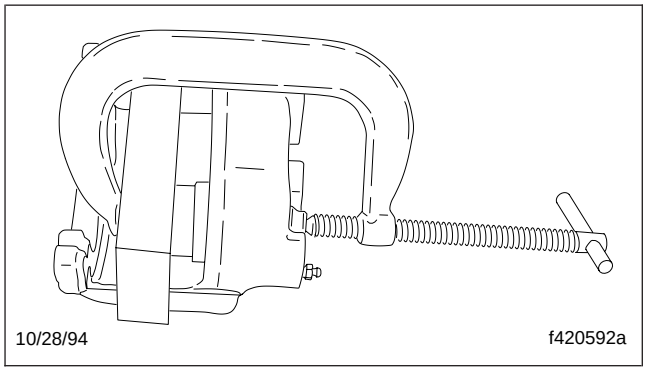


Fig. 14, Push the Piston

15.4 Take the Kent-Moore special tool (KMS/ZTSE4275 for 2.88-inch pistons, or KMS/ZTSE4343 for 2.60-inch pistons), and put the side of the tool marked "Boot" against the dust boot. Using the C-clamp, seat the dust boot into its groove in the cylinder.

15.5 Repeat the previous steps as needed for installing the other piston.

16. Install the heat shields on the pistons.

16.1 Put a new heat shield over the top of one piston as shown in **Fig. 15**. Make sure the heat shield is positioned correctly.

16.2 Put the side of the Kent-Moore special tool (KMS/ZTSE4275 for 2.88-inch pistons, or KMS/ZTSE4343 for 2.6-inch pistons) marked "Heat Shield" against the heat shield. See **Fig. 16**. Using the C-clamp, seat the new heat shield onto the piston.

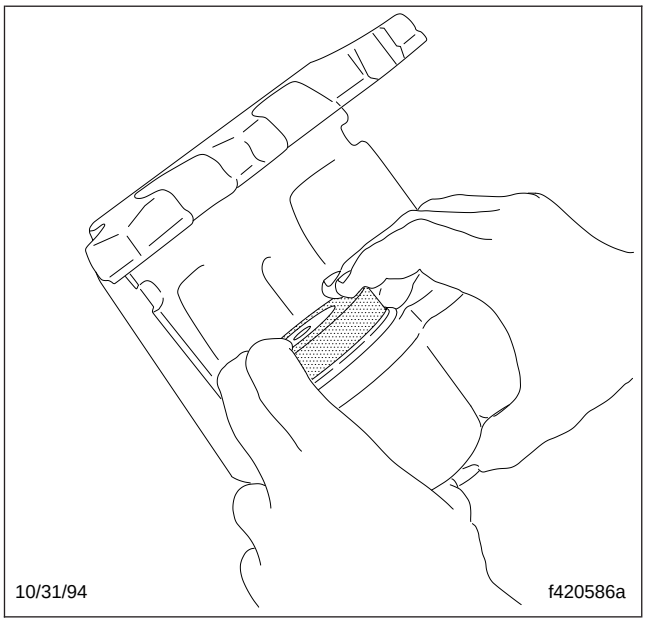


Fig. 15, Position the Heat Shield

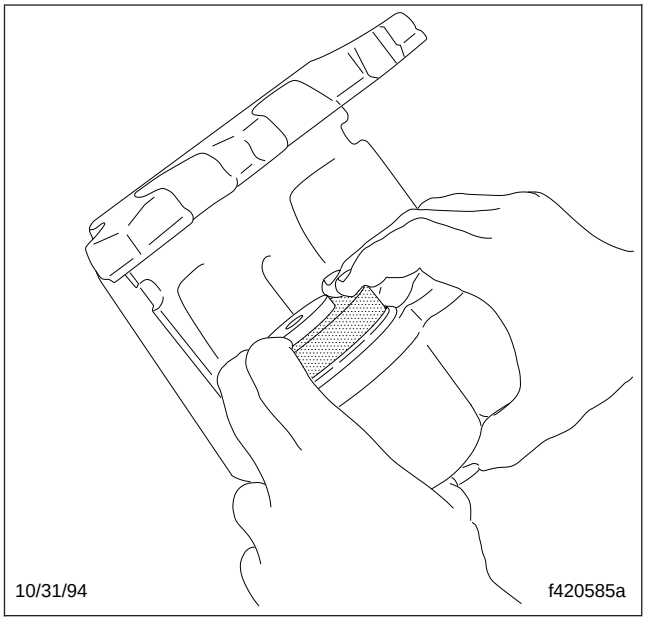
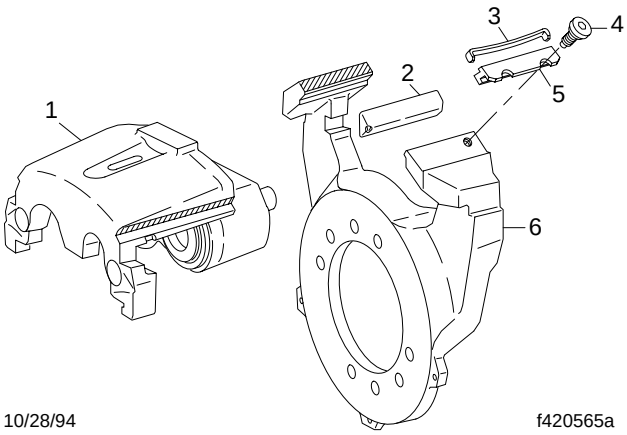


Fig. 16, Seat the Heat Shield

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Brake Caliper Rebuild

17. If a wear shim is required, install the applicable wear shim (chosen according to **Table 1**) on the opposite anchor plate V-way from which the key and spring are installed. See **Fig. 17**.



1. Caliper
2. Wear Shim
3. Spring
4. Allen Head Bolt
5. Key
6. Anchor Plate

Fig. 17, Wear Shim Installation

18. Install the caliper on the rotor following the instructions in **Subject 150**.
19. Install the tire.
20. Remove the chocks.

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Brake Rotor Removal and Installation

WARNING

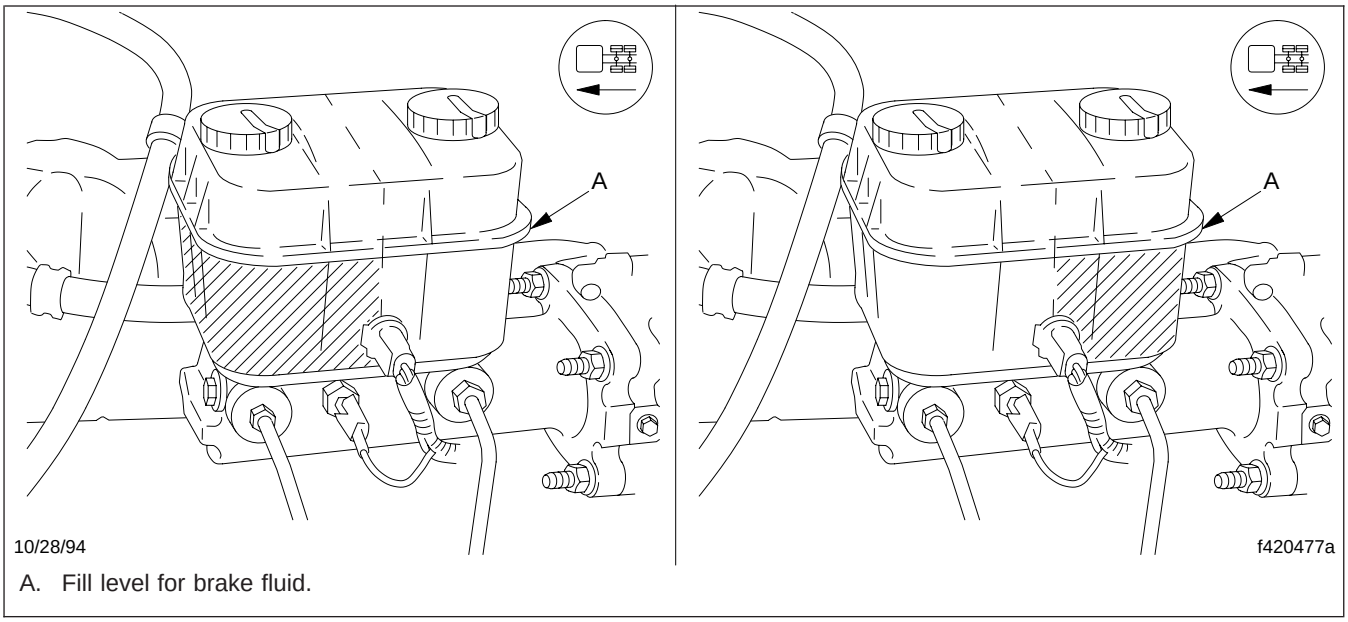
Before starting the procedure below, read the information in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires.
2. Open the hood.
3. Remove about half the brake fluid from the front section (if removing a front-axle rotor) or the rear section (rear-axle rotor) of the master cylinder reservoir. See **Fig. 1**.
4. Chock the front or rear tires, as required.
5. Jack up the vehicle. Support the axle with jackstands.
6. Remove the tire.
7. Remove the brake caliper from the rotor, following the instructions in **Subject 150**.
8. Remove the hub and rotor assembly from the axle, following the instructions in **Group 33** or **Group 35**. Put the hub on the floor so the rotor is facing up.
9. Remove the brake rotor from the wheel hub.
   - 9.1 Remove the hexbolts and washers that attach the rotor to the hub. See **Fig. 2**.
   - 9.2 Lift the brake rotor off the hub.

Installation

1. Install the rotor on the wheel hub.
   - 1.1 Position the rotor on the hub as shown in **Fig. 3**. Make sure the holes in the rotor are lined up with those of the hub.
   - 1.2 Install the mounting hexbolts and washers. Using a star pattern, tighten the hexbolts 130 lbf·ft (175 N·m). See **Fig. 4**.
2. Install the hub and rotor assembly on the axle, following the instructions in **Group 33** or **Group 35**.
3. Install the brake caliper on the rotor, following the instructions in **Subject 150**.



A. Fill level for brake fluid.

Fig. 1, Master Cylinder Reservoir

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Brake Rotor Removal and Installation

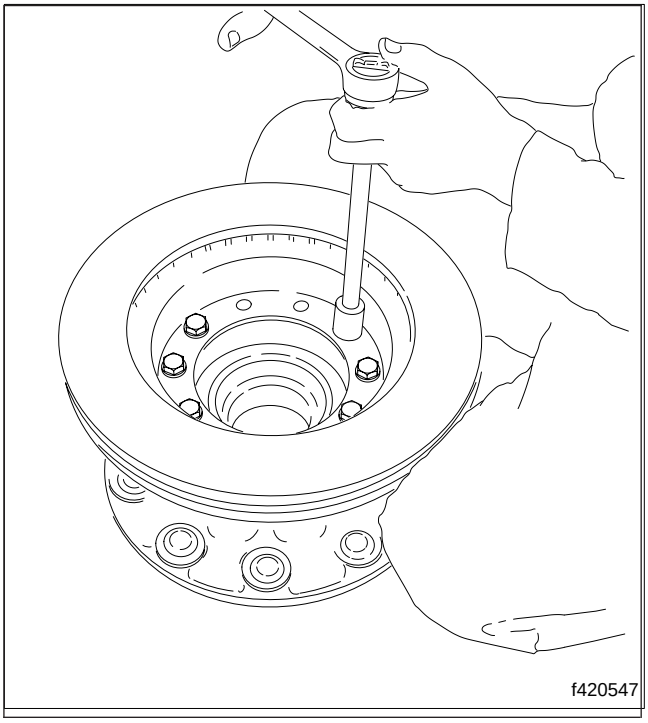
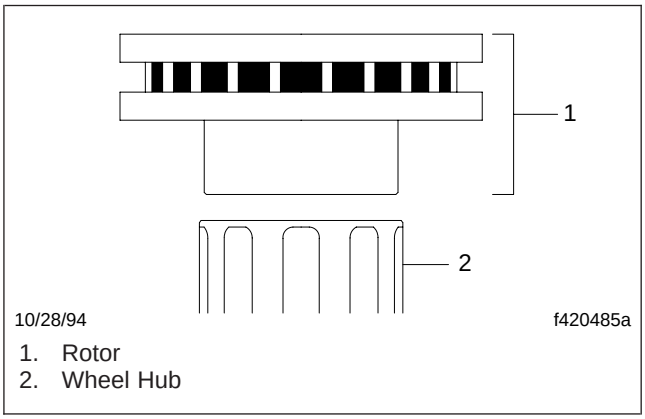


Fig. 2, Rotor-to-Hub Fasteners



1. Rotor
2. Wheel Hub

Fig. 3, Rotor-to-Hub Position

4. Install the tire.
5. Remove the jackstands. Lower the vehicle.
6. Fill the applicable section of the master cylinder reservoir with new DOT 3 approved brake fluid. The brake fluid level should be even with the raised seam on the outside circumference of the reservoir. See **Fig. 1**.
7. Close and latch the hood.

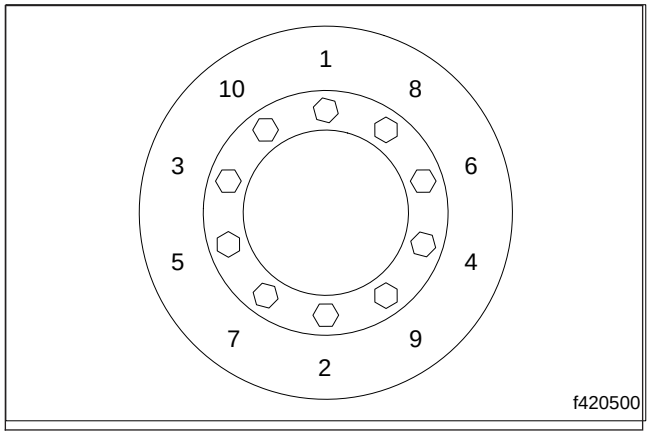


Fig. 4, Tightening Pattern

8. Remove the chocks from the tires.

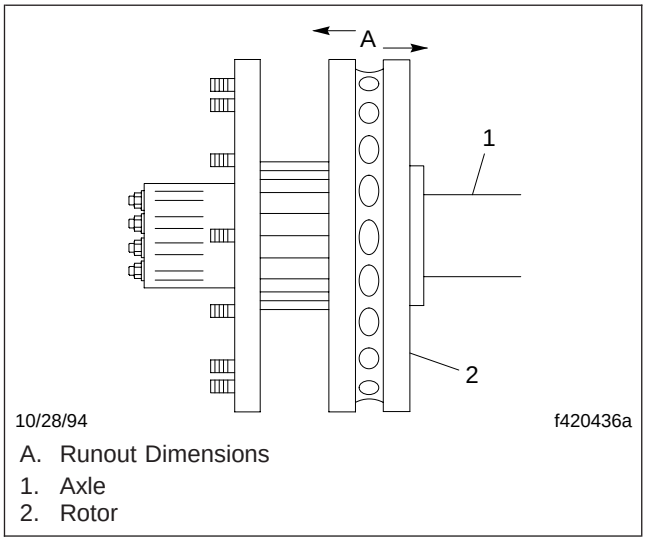
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Brake Rotor Runout and Parallelism Checking

Runout Checking

Brake rotor runout refers to the amount of lateral wobble the rotor has when it is turning, with the wheel bearings correctly adjusted. See **Fig. 1**. Check the rotor runout whenever you replace the brake pads.

1. If not already done, chock the tires, jack up the axle you are working on and support it with jackstands. Remove the wheels and tires.
2. If working on the rear axle, put the transmission in neutral.
3. Using a dial indicator, measure the amount of runout while spinning the rotor, as shown in **Fig. 2**. Make sure the indicator is centered on the rotor face (between the outer and inner edges).
4. If the runout is more than 0.015 inch (0.38 mm), check that the rotor is securely mounted to the hub. Also check the wheel bearing end-play, following the instructions **Group 33** or **Group 35**.
5. Repeat the runout measurement. If the runout is still more than 0.015 inch (0.38 mm), replace the rotor.



A. Runout Dimensions
1. Axle
2. Rotor

Fig. 1, Brake Rotor Runout

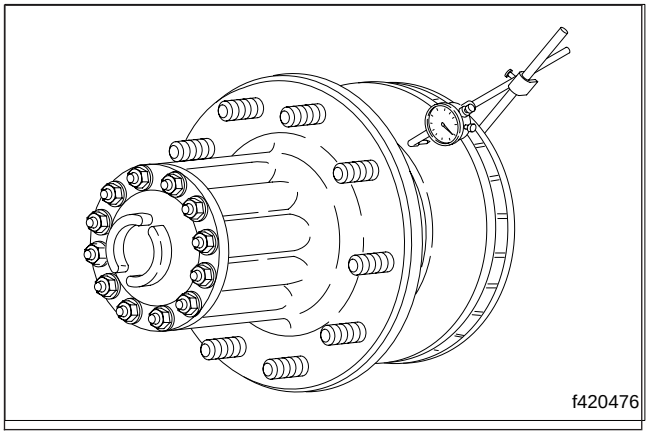


Fig. 2, Measure Runout

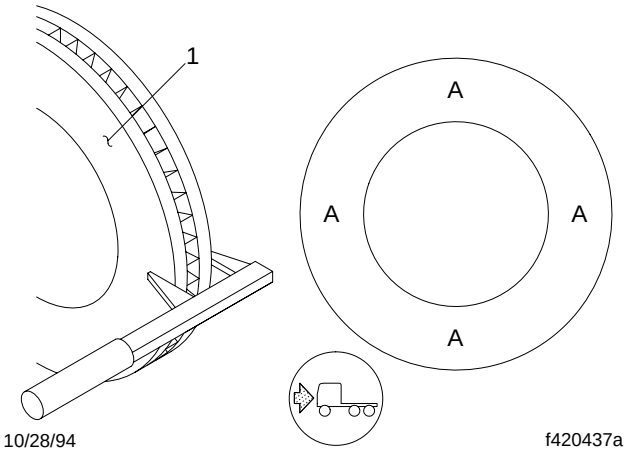
Parallelism Checking

Parallelism is the difference in rotor thickness at different points around the rotor. It should be checked whenever the brake pads are replaced.

1. Using a vernier caliper or a micrometer, measure the thickness of the rotor (between the inboard and outboard faces) at four or more equally spaced points around the rotor. See **Fig. 3**.
2. If there is a difference of more than 0.005 inch (0.13 mm) between any two measurements, have the rotor resurfaced. If resurfacing will decrease the overall thickness of the rotor to 1.32 inches (33.5 mm) or less, replace the rotor.

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Brake Rotor Runout and Parallelism Checking



A. Measure thickness here.
1. Rotor Face

Fig. 3, Measure Rotor Thickness

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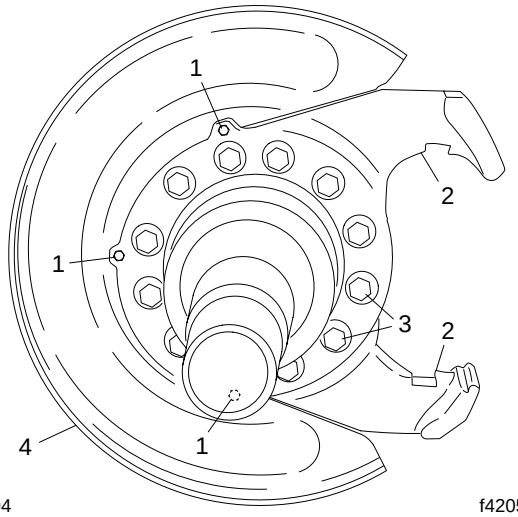
Anchor Plate Removal and Installation

Removal

1. Chock the rear or front tires, as required.
2. Jack up the vehicle. Support the axle with jackstands.
3. Remove the tire.
4. Remove the brake caliper from the anchor plate following the instructions in **Subject 150**.
5. Remove the wheel hub and rotor assembly from the axle, following the instructions in **Group 33** or **Group 35**.
6. Remove the anchor plate from the axle.
   - 6.1 Remove the three screws holding the dust shield to the anchor plate, then remove the dust shield.
   - 6.2 Remove the hexbolts, washers and nuts that hold the anchor plate to the axle. See **Fig. 1**.
   - 6.3 Remove the anchor plate from the axle.

Installation

1. Install the anchor plate on the axle.
   - 1.1 Position the anchor plate in place against the outboard side of the axle flange, making sure the holes in both are lined up.
   - 1.2 From the outboard side of the anchor plate, install the hexbolts and washers. Install the nuts and remaining washers. See **Fig. 1**. Using a star pattern, tighten the hexnuts as follows:
     - Rear Axle; 105 lbf·ft (142 N·m)
     - Front Axle Type FC; 75 lbf·ft (102 N·m)
     - Front Axle Type FD/FF; 145 lbf·ft (197 N·m)
2. Install the dust shield on the anchor plate. See **Fig. 1**.
3. Install the wheel hub and rotor assembly onto the axle, following the instructions in **Group 33** or **Group 35**.
4. Install the brake caliper on the anchor plate following the instructions in **Subject 150**.



1. Dust Shield Screws (3 qty.)
2. Anchor Plate
3. Mounting Hexbolts (12 qty.)
4. Dust Shield

Fig. 1, Axle End

5. Install the tire.
6. Remove the jackstands. Lower the vehicle.
7. Remove the chocks.

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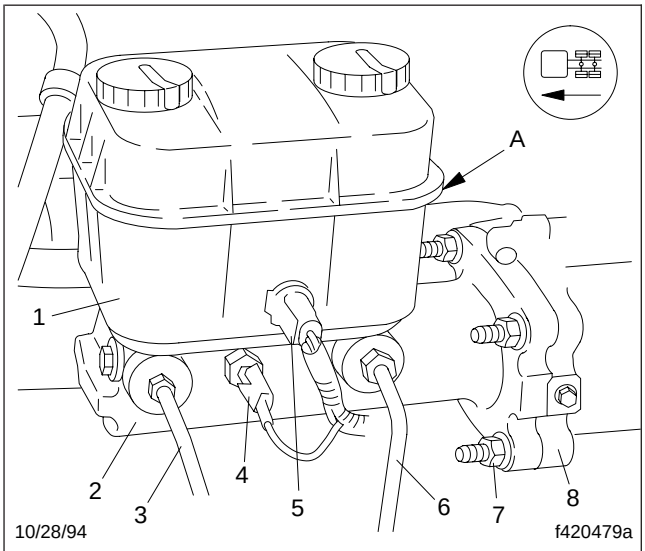
Master Cylinder Removal and Installation

Removal

⚠ WARNING

Before starting the procedure below, read the information in Subject 100. Failure to be aware of the dangers of brake fluid exposure could result in serious and permanent health damage.

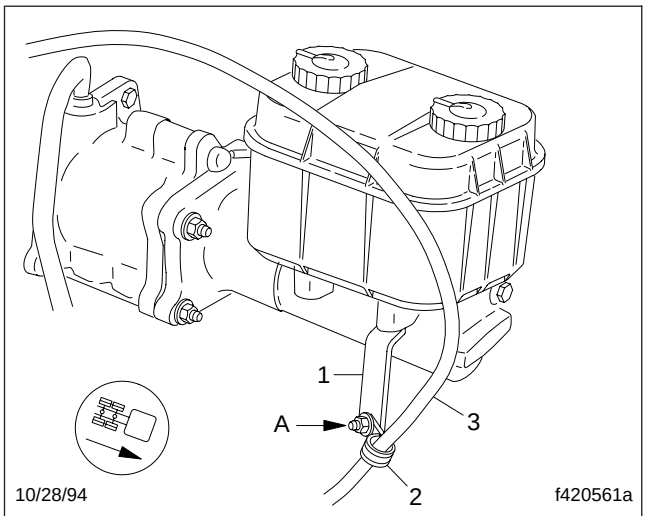
1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires
2. Open the hood.
3. Disconnect the wires from the pressure differential switch on the master cylinder and the fluid level sensor on the reservoir. See **Fig. 1**.
4. Remove the accelerator cable clamp from the L-bracket attached to the front inboard side of the master cylinder. See **Fig. 2**.



A. Fill reservoir sections to this level.

1. Reservoir
2. Master Cylinder
3. Front (secondary) Circuit Brake Line
4. Pressure Differential Switch
5. Fluid Level Sensor
6. Rear (primary) Circuit Brake Line
7. Flanged Hexnut
8. Power Booster

Fig. 1, Electrical Connections



A. Disconnect here.

1. L-Bracket
2. Hose Clamp
3. Accelerator Cable

Fig. 2, Accelerator Cable Clamp

⚠ CAUTION

Do not let the brake fluid get on any painted surface, as it will dissolve the paint. Use a rag around fittings, or put a container underneath it to catch any fluid.

5. Disconnect the brake lines from the front and rear outlet ports of the master cylinder. See **Fig. 3**. Plug the brake lines.
6. Remove the four flanged hexnuts that attach the master cylinder to the power booster unit. See **Fig. 4**.

   Remove the master cylinder and reservoir assembly from the vehicle. See **Fig. 5**. Keep it upright so you do not spill any brake fluid from the reservoir.
7. Remove the caps from the master cylinder reservoir, then carefully invert the master cylinder and reservoir assembly, and dump the brake fluid into a container. Dispose of the brake fluid in an approved manner.

Installation

1. Bench bleed the master cylinder.

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Master Cylinder Removal and Installation

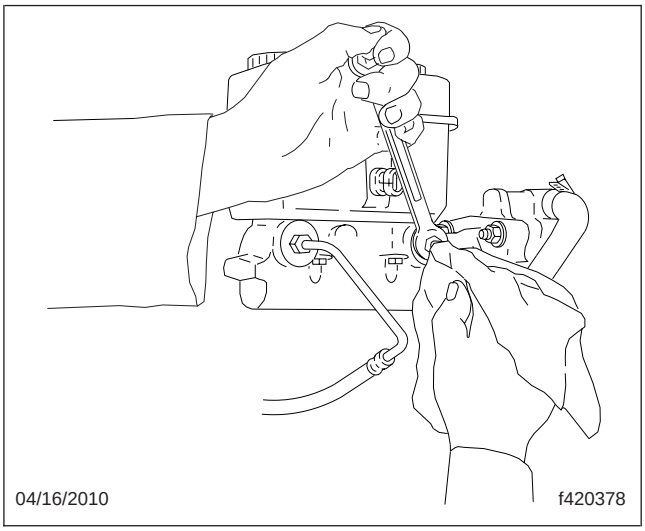
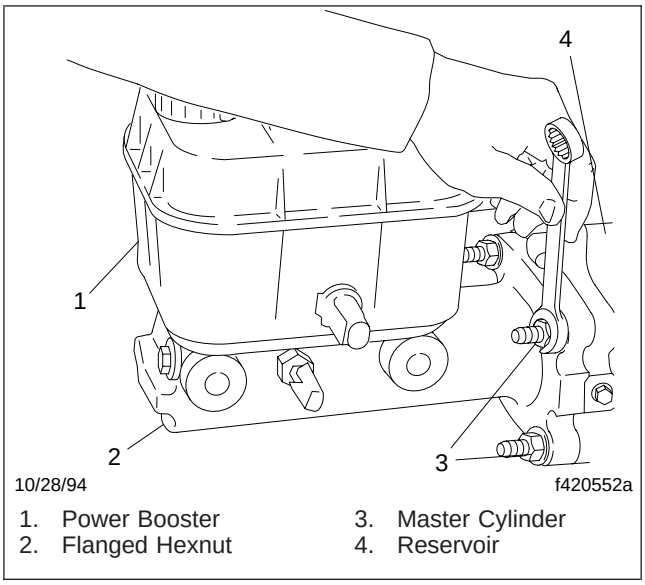


Fig. 3, Brake Lines



1. Power Booster
2. Flanged Hexnut
3. Master Cylinder
4. Reservoir

Fig. 4, Remove Hexnuts

1.1 Put the master cylinder and reservoir assembly in a vise.

1.2 Install a plastic adapter and clear rubber hose on the primary and secondary outlet ports, as shown in **Fig. 6**.

1.3 Put the other end of each tube into its section of the reservoir, as shown in **Fig. 6**.

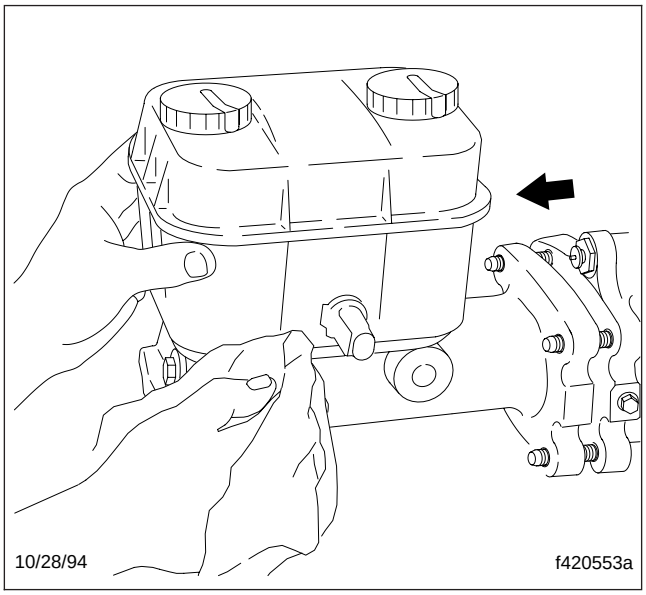


Fig. 5, Remove the Master Cylinder

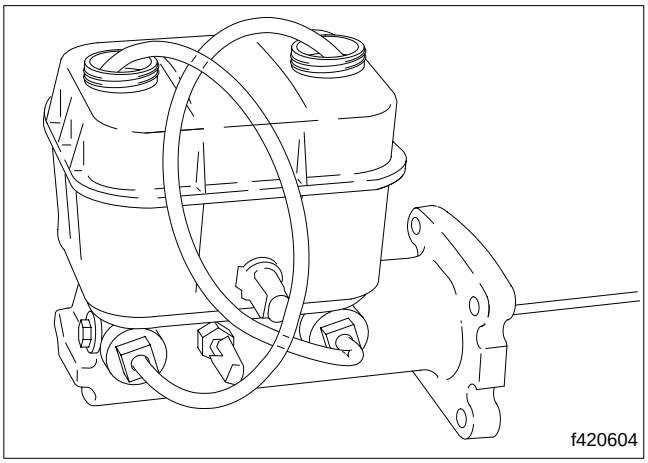


Fig. 6, Outlet Ports

1.4 Fill the reservoir sections about half-full with new DOT 3 approved brake fluid.

1.5 Using a metal rod with a rounded end, depress and release the primary piston several times.

1.6 Reposition the master cylinder in the vise, with the front (closed) end tilted slightly up. Depress and release the primary piston again until you feel increased resistance.

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2. Position the master cylinder on the front of the power booster.
3. Install the four flanged nuts on the studs of the power booster, then tighten them 25 lbf·ft (34 N·m).
4. Connect the rear brake (primary circuit) line to the rear outlet port on the master cylinder. Connect the front brake (secondary circuit) line to the front outlet port. Tighten the fittings 15 lbf·ft (20 N·m).
5. Connect the accelerator cable clamp to the L-bracket on the front inboard side of the master cylinder. See **Fig. 2**.
6. Connect the wires to the pressure differential switch and the fluid level sensor. See **Fig. 1**.
7. Fill both sections of the reservoir with new DOT 3 approved brake fluid. Fill to the raised seam on the outside of the reservoir. See **Fig. 1**.
8. Bleed the entire brake system following the instructions in **Subject 110**.
9. Close and latch the hood.
10. Remove the chocks from the tires.

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Master Cylinder Disassembly, Inspection and Assembly

WARNING

Before starting the procedure below, read the information in Subject 100. Failure to be aware of the dangers of brake fluid exposure could result in serious and permanent health damage.

Disassembly (See Fig. 1)

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Remove the master cylinder and reservoir assembly from the vehicle following the instructions in Subject 200.
4. Remove the reservoir from the master cylinder.
   - 4.1 Remove the four flanged hexbolts that attach the reservoir to the top of the master cylinder. See Fig. 2. Note that one of the bolts has an L-bracket on it.
   - 4.2 Lift the reservoir off the master cylinder. Turn the reservoir over. Remove the two compensating valve seals from the bottom of it. See Fig. 3.
5. Remove the small O-ring. Remove the two compensating valves and their springs from the top of the master cylinder housing. See Fig. 4 and Fig. 5.

CAUTION

Do not remove the piston stop at this time, or you may damage it and the piston bore in the master cylinder housing.

6. Remove the differential pressure indicator assembly from the front of the housing.
   - 6.1 Unscrew the aluminum plug at the front end of the housing. See Fig. 6.
   - 6.2 Using an allen wrench, remove the nylon insert underneath the aluminum plug. See Fig. 7.
   - 6.3 Remove the differential pressure switch from the side of the housing. See Fig. 8.
   - 6.4 Put a compressed air hose into the port on top of the housing where the primary compensating valve was. Put a shop towel over the hole at the front end of the housing. Place the housing so that the front end is facing down toward a padded surface. Keep your hands away from the front of the master cylinder housing.

WARNING

Be careful when using compressed air to remove the differential pressure indicator assembly from the master cylinder housing. It may come out of the housing with considerable force, which could cause personal injury or damage to the part.

   - 6.5 Plug the primary circuit outlet. See Fig. 1. Release just enough air pressure to force out the brass spool, O-ring and collar. Discard the O-ring.

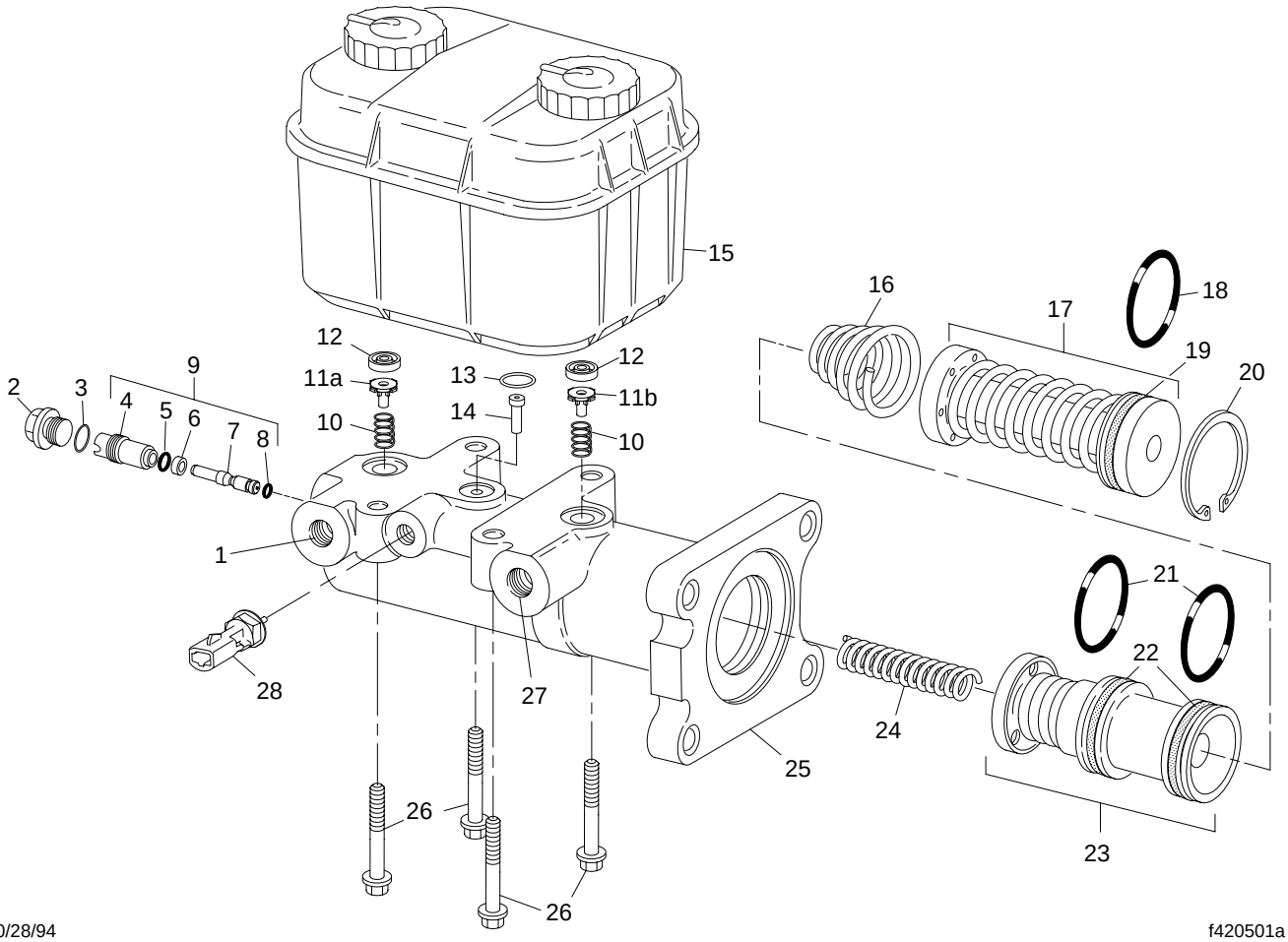
     Remove and discard the small O-ring from the brass spool.
7. Remove the primary piston assembly from the master cylinder bore.
   - 7.1 Put the master cylinder in a vise.
   - 7.2 Using a crossbar puller, a C-clamp, or other suitable tool, push the primary piston about 1/2 inch (13 mm) into the bore. See Fig. 9.
   - 7.3 With the primary piston pushed in, remove the lock ring from the open end of the bore. See Fig. 9. Remove the small piston stop from the top of the master cylinder housing. See Fig. 10.
   - 7.4 Carefully release the tension on the primary piston, and ease it and its return spring out of the bore. See Fig. 11.
   - 7.5 Remove and discard the pressure seal and back-up ring from the primary piston. See Fig. 1.

WARNING

Be careful when using compressed air to remove the secondary piston and actuator assembly from the master cylinder bore. Make sure the open end of the bore is pointed down toward a padded sur-

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Master Cylinder Disassembly, Inspection and Assembly



1. Secondary Outlet Port
2. Aluminum Plug
3. O-Ring
4. Nylon Insert
5. Large O-Ring
6. Brass Collar
7. Brass Spool
8. Small O-Ring
9. Pressure Differential Indicator Assembly
10. Compensating Valve Spring (2 qty.)
11a. Secondary Compensating Valve
11b. Primary Compensating Valve
12. Compensating Valve Seal (2 qty.)
13. O-Ring
14. Piston Stop
15. Reservoir
16. Primary Piston Return Spring
17. Primary Piston Assembly
18. Primary Pressure Seal
19. Primary Back-Up Ring
20. Lock Ring
21. Secondary Pressure Seal (2 qty.)
22. Secondary Back-Up Ring (2 qty.)
23. Secondary Piston Assembly
24. Secondary Return Spring
25. Master Cylinder Housing
26. Flanged Hexbolts (4 qty.)
27. Primary Outlet Port
28. Pressure Differential Switch

Fig. 1, Master Cylinder Exploded View

face. Keep your hands away from the open end of the bore to prevent injury.

8. Using compressed air, remove the secondary piston assembly from the master cylinder bore.

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Master Cylinder Disassembly, Inspection and Assembly

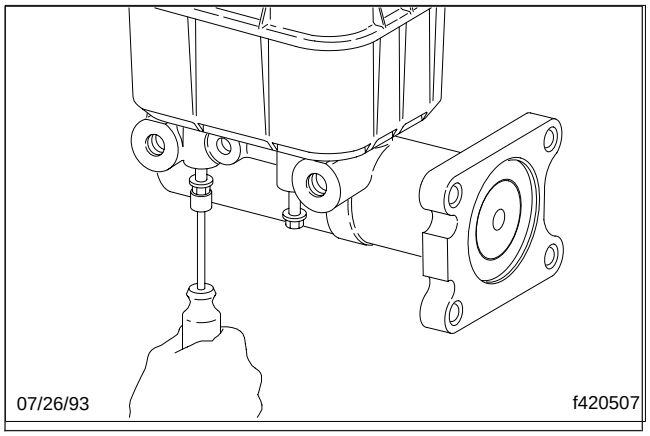


Fig. 2, Hexbolts

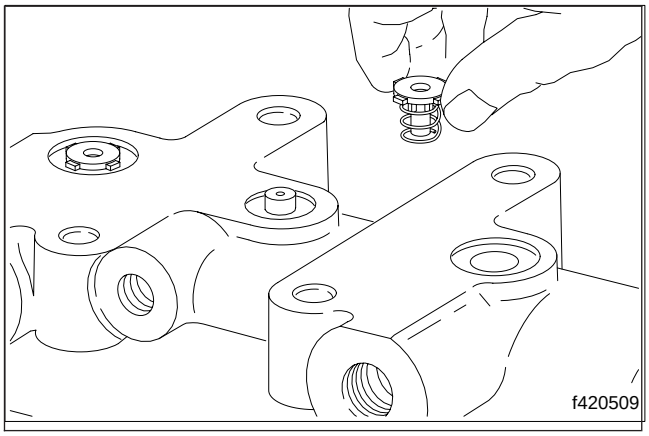


Fig. 5, Remove the Compensating Valves

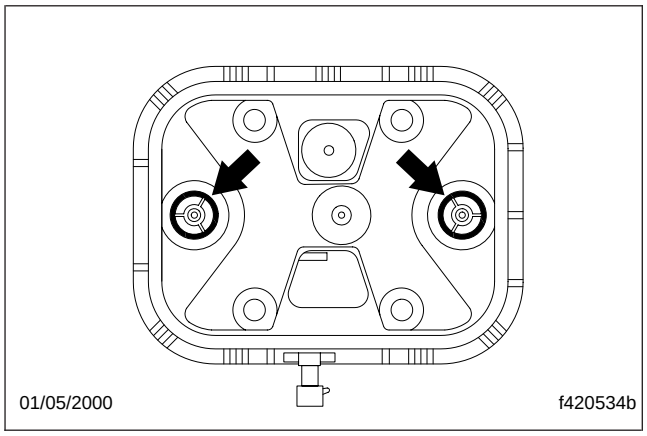
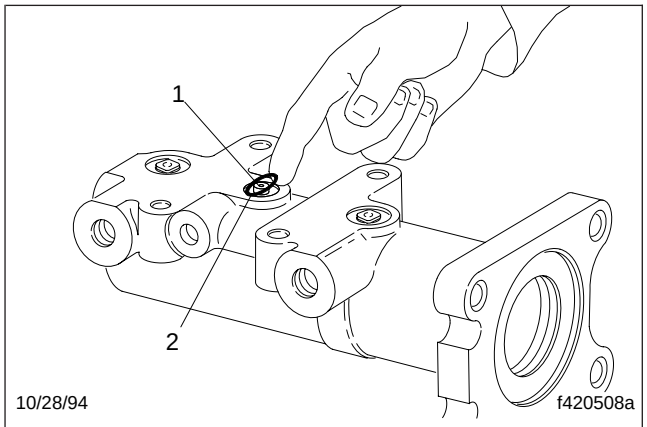


Fig. 3, Compensating Valve Seals



1. Piston Stop
2. Small O-Ring

Fig. 4, Remove the Small O-Ring

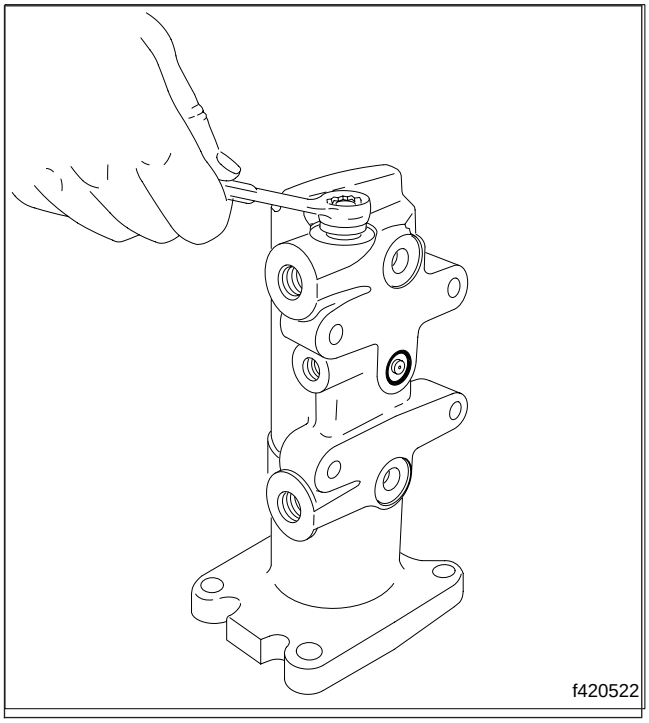


Fig. 6, Unscrew the Aluminum Plug

8.1 Connect a compressed air hose to the front compensating valve port on top of the housing. See **Fig. 12**.

8.2 Plug the secondary outlet port and the hole where the pressure differential indicator was on the housing. See **Fig. 1**.

8.3 With the open end of the housing bore facing down, and about an inch away

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Master Cylinder Disassembly, Inspection and Assembly

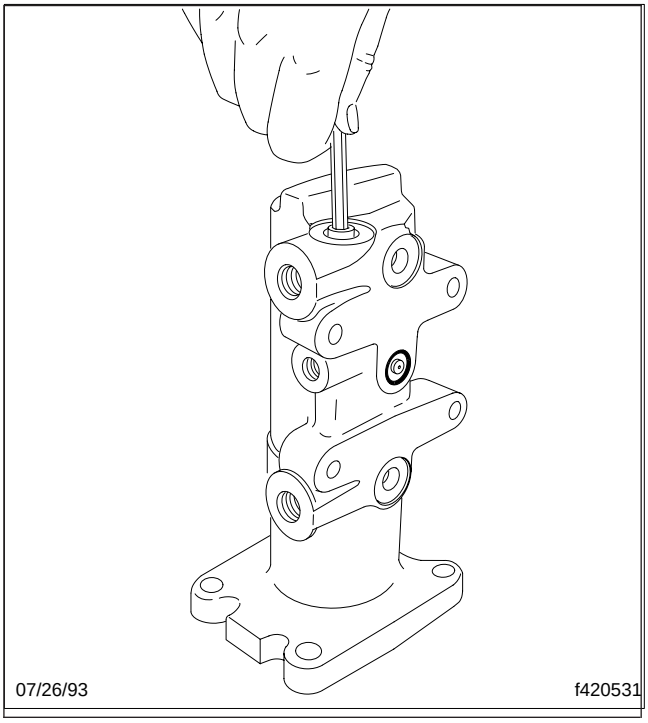


Fig. 7, Nylon Insert

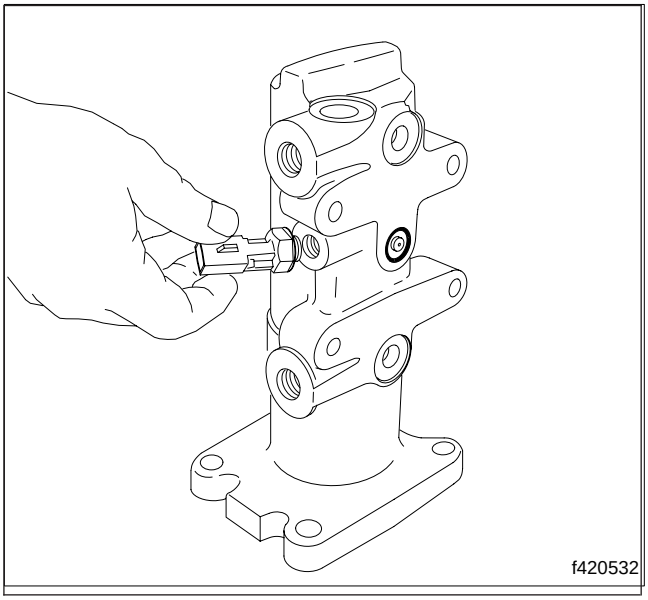


Fig. 8, Differential Pressure Switch

from a padded surface, carefully apply just enough air pressure to remove the secondary piston assembly and its return

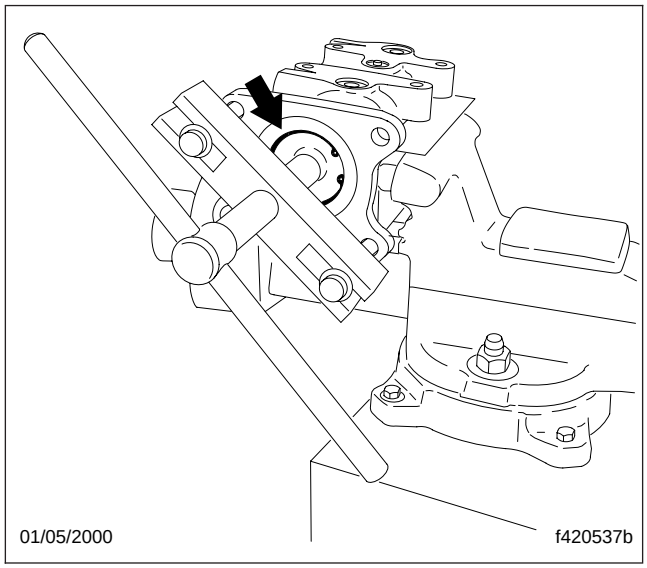


Fig. 9, Lock Ring

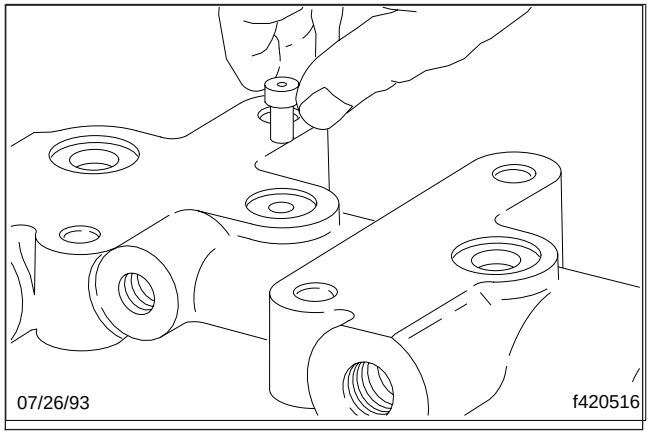


Fig. 10, Piston Stop

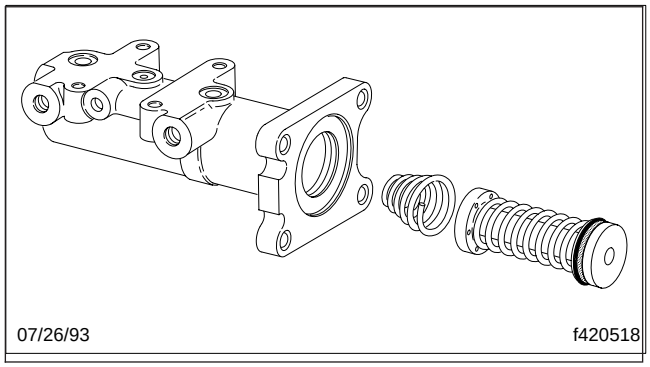


Fig. 11, Primary Piston Assembly

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Master Cylinder Disassembly, Inspection and Assembly

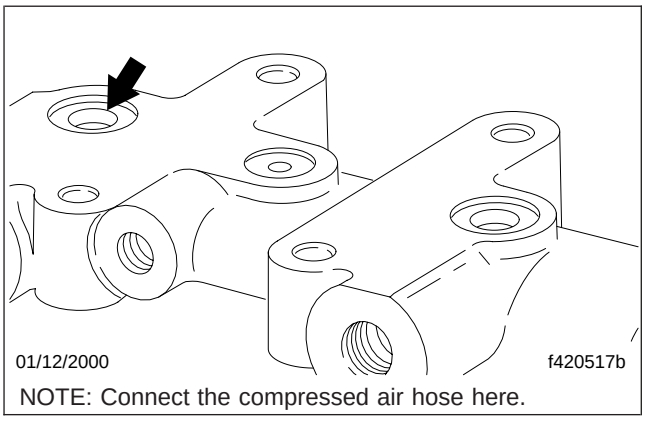


Fig. 12, Front Compensating Valve Port

spring from the bore. Do not pop it out. See **Fig. 13**.

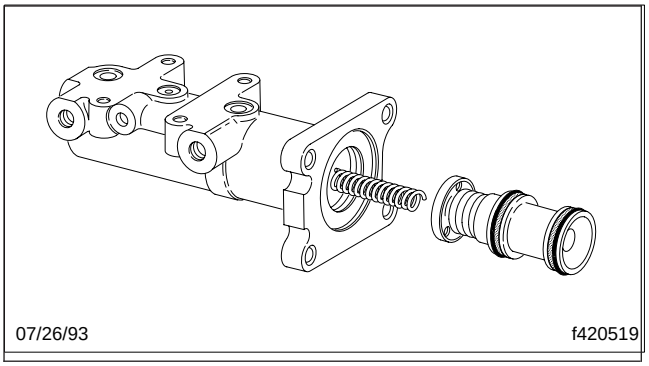


Fig. 13, Secondary Piston Assembly

8.4 Remove and discard the pressure seal and back-up ring from the secondary piston.

Inspection

1. Check the master cylinder bore for scoring or corrosion. If the master cylinder housing is pitted, rough or corroded, replace the entire master cylinder assembly.
2. If needed, polish any discolored or stained areas in the bore with a crocus cloth. *Do not use emery cloth or sandpaper; they could scratch the bore, which could cause leakage*.

Assembly (See Fig. 1)

IMPORTANT: When assembling the master cylinder, use new seals and rings. Do not reuse old ones.

1. Wash all the parts and the cylinder bore in clean, new DOT 3 approved brake fluid. Discard the brake fluid afterward.
2. Install the secondary piston assembly in the master cylinder bore.

   2.1 Install two new pressure seals and back-up rings on the secondary piston. See **Fig. 1**

   2.2 Lubricate the piston assembly, the seals and the cylinder bore with clean DOT 3 approved brake fluid. See **Fig. 14**.

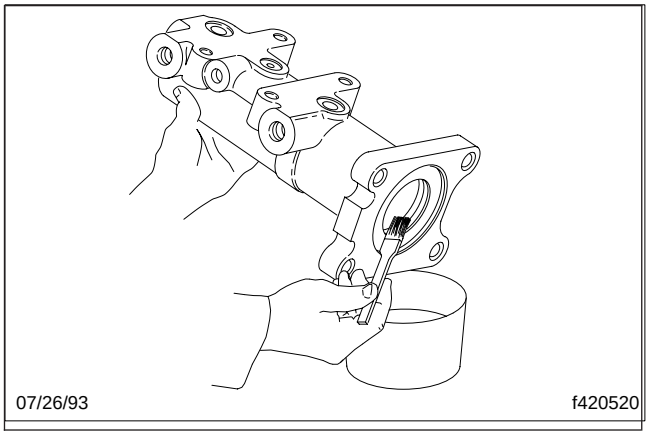


Fig. 14, Lubricate the Cylinder Bore

   2.3 Put the secondary return spring on the actuator (flanged) end of the secondary piston assembly. See **Fig. 1**. Insert the piston assembly, spring end first, into the cylinder bore. See **Fig. 13**. Push it all the way to the bottom of the bore.

3. Install the primary piston assembly in the master cylinder bore.

   3.1 Install a new pressure seal and back-up ring on the primary cylinder. See **Fig. 1**.

   3.2 Lubricate the piston assembly and the seal with new DOT 3 approved brake fluid.

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Master Cylinder Disassembly, Inspection and Assembly

3.3 Insert the small end of the primary return spring into the master cylinder bore. See **Fig. 1**.

3.4 Insert the primary piston assembly into the master cylinder bore, actuator (flanged) end first. See **Fig. 11**.

4. Put the master cylinder housing into a vise. Using a crossbar puller or a C-clamp, push the pistons far enough into the master cylinder bore to install the lock ring in its groove. See **Fig. 9**.

5. Install the compensating valve seals on the bottom of the reservoir. See **Fig. 3**. Make sure the seals are completely seated.

6. Using a crossbar puller or a C-clamp, push the primary piston 1 inch (25 mm) into the bore. See **Fig. 15**.

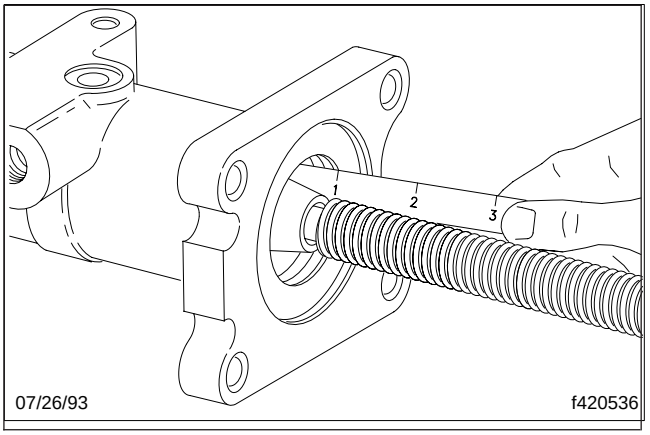


Fig. 15, Primary Piston in the Bore

7. Install the compensating valve poppets and their springs in the top of the master cylinder housing. Install the piston stop and the O-ring. See **Fig. 10**.

8. With the primary piston still pushed in, install the reservoir onto the top of the master cylinder, using the four mounting hexbolts. See **Fig. 2**. Make sure the L-bracket goes on the front inboard (when the master cylinder is installed on the vehicle) mounting hexbolt. Tighten the bolts 15 lbf·ft (20 N·m).

9. Assemble the pressure differential indicator See **Fig. 16**.

9.1 Install a new small O-ring in the groove on the end of the brass spool.

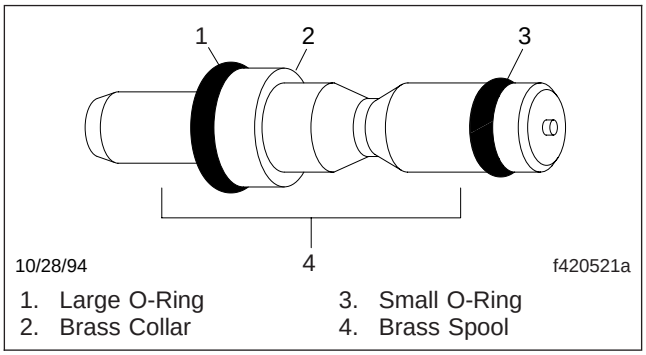


Fig. 16, Pressure Differential Indicator

9.2 Install the collar on the brass spool.

9.3 Install a new large O-ring onto the other end of the brass spool and push it down onto the collar as shown in **Fig. 16**.

10. Install the spool and collar assembly, with the collar end up, into the hole at the front of the master cylinder housing as shown in **Fig. 17**. Using a small piece of wood, seat the assembly at the bottom of its hole.

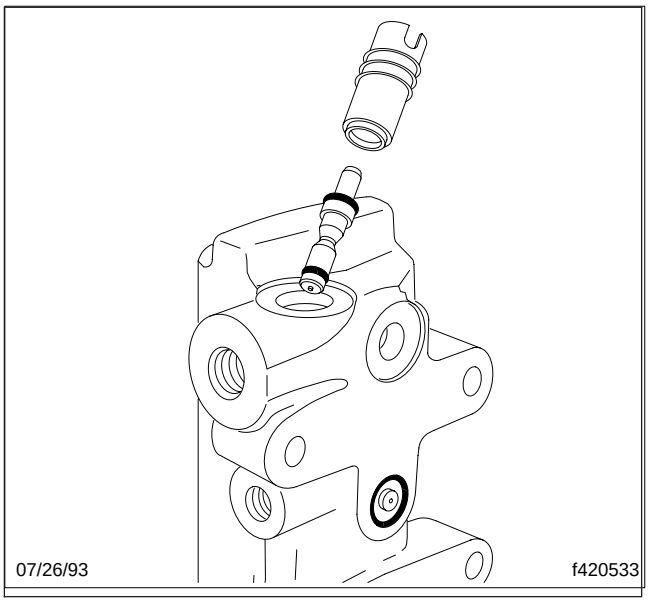


Fig. 17, Spool and Collar Assembly

11. Using an allen wrench, install the nylon insert on top of the brass spool. See **Fig. 7**.

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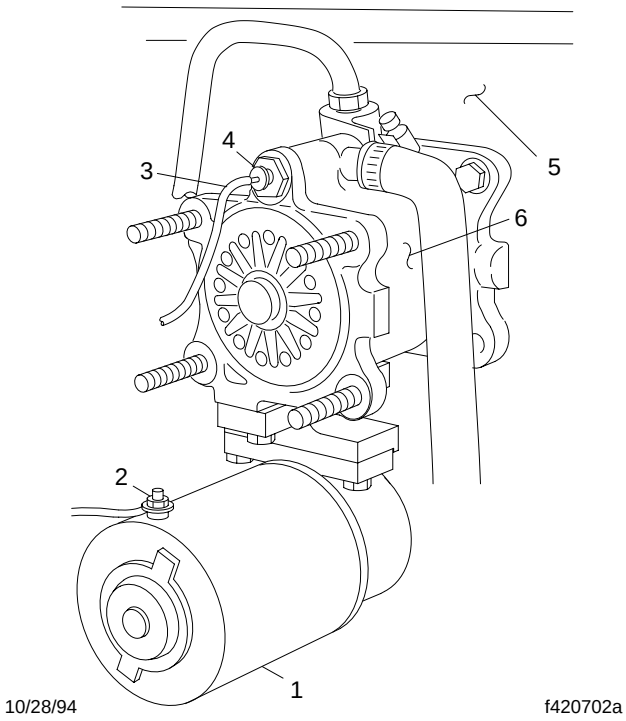
12. Install a new O-ring on the aluminum plug. See **Fig. 1**. Install the plug into the hole at the front of the master cylinder housing. Tighten the plug firmly.
13. Install the pressure differential switch in the side of the master cylinder housing as shown in **Fig. 8**. Finger-tighten it.
14. Check the operation of the compensating valves by poking a wire through the hole in the bottom of each reservoir section. The compensating valves should depress easily, about 1/16 inch (1.5 mm), then spring back. If not, remove the reservoir and install it again. Check the valves again.
15. Remove the cross-bar puller or C-clamp installed to push the primary piston into the bore.
16. Bench bleed the master cylinder. Install the master cylinder on the booster following the instructions in **Subject 200**.
17. Close and latch the hood.
18. Remove the chocks from the rear tires.

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Hydro-Max II® Power Booster Removal and Installation

Removal

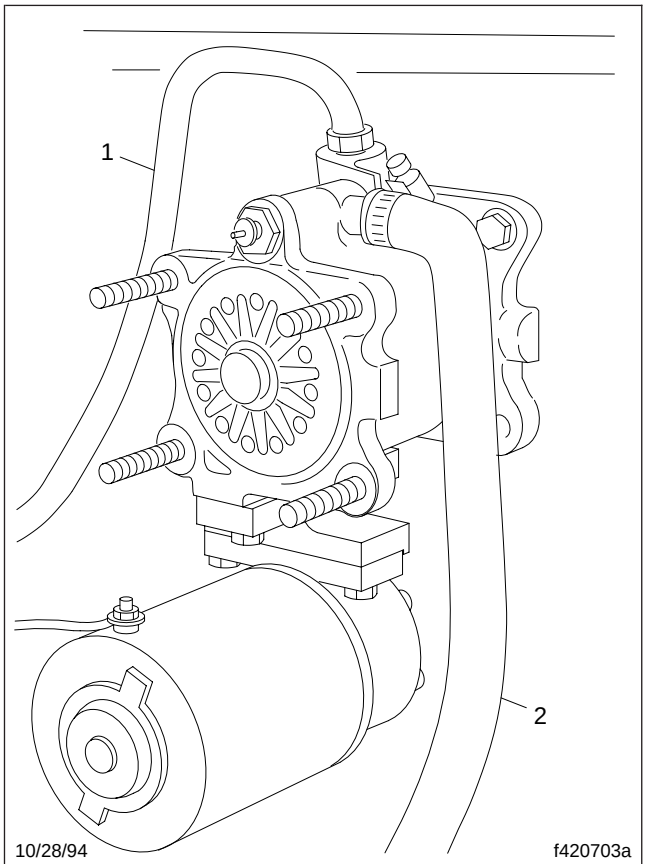
1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Disconnect the batteries at the negative cable.
4. If not already done, disconnect the master cylinder from the power booster, following the instructions in **Subject 200**.
5. From inside the cab, disconnect the push rod from the brake pedal.
6. Disconnect the wiring from the auxiliary electric pump assembly. See **Fig.1**.



1. Auxiliary Electric Pump
2. Auxiliary Electric Pump Power Lead
3. Flow Switch Wiring
4. Flow Switch
5. Frontwall
6. Power Booster Housing

Fig. 1, Auxiliary Electric Pump Assembly

7. Disconnect the wiring from the flow switch at the front of the power booster. See **Fig.1**.
8. Using a shop towel or a container to catch any power steering fluid, disconnect the hydraulic supply and return lines from the power booster. See **Fig.2**. Plug the lines.



1. Supply Line (steel)
2. Return Line (rubber)

Fig. 2, Power Booster Lines

9. Remove the four hexbolts and washers that hold the power booster to the frontwall. See **Fig.3**. Pull the power booster straight out from the frontwall. See **Fig.4**.

Installation

1. Position the power booster on the frontwall so the push rod fits through the large hole and into

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Hydro-Max II® Power Booster Removal and Installation

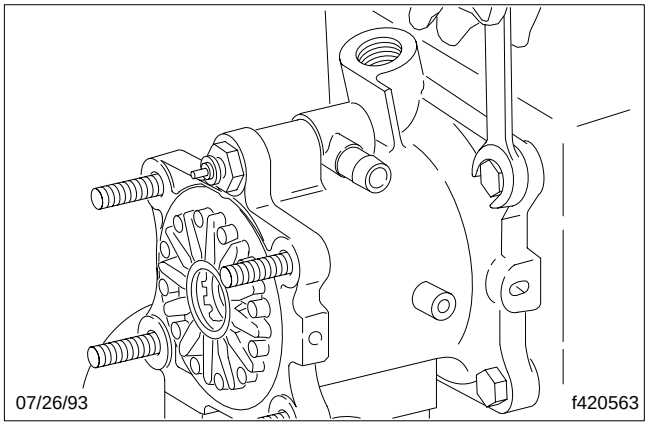


Fig. 3, Power Booster Mounting

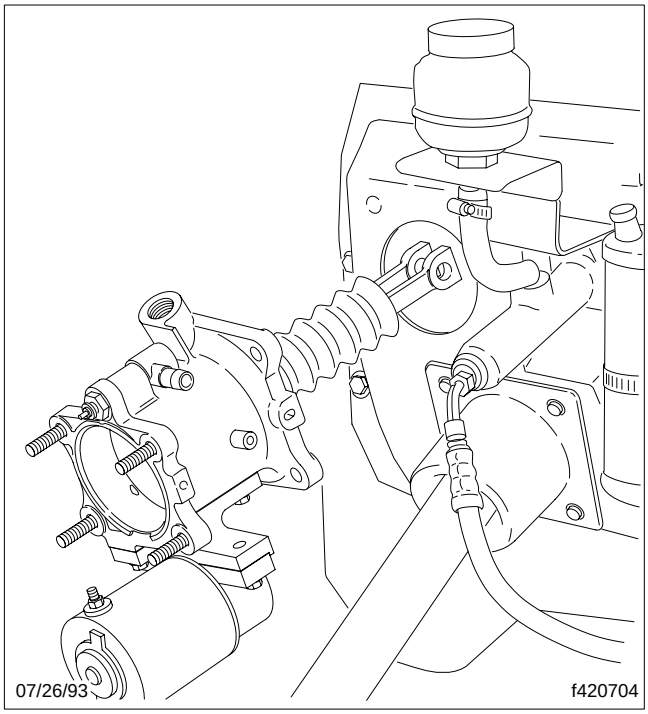
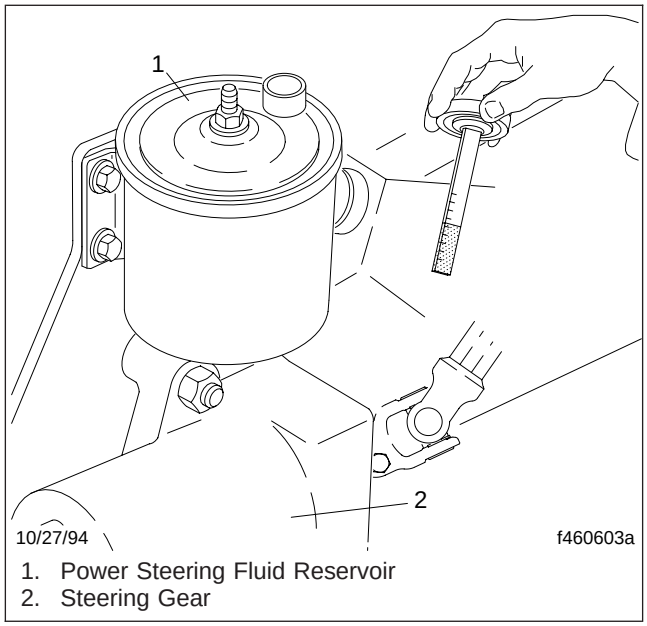


Fig. 4, Power Booster Removal

the cab, and the four holes in the power booster line up with those on the frontwall. See **Fig.4**.

2. Install the four mounting hexbolts and washers. See **Fig.3**. Tighten them 20 lbf·ft (27 N·m).
3. Install the master cylinder on the power booster, following the instructions in **Subject 200**.
4. Connect the hydraulic supply and return lines. See **Fig.2**. Tighten the supply line 15 lbf·ft (20 N·m). Firmly tighten the hose clamp on the return line.
5. Connect the wiring to the auxiliary electric pump assembly and to the flow switch assembly. See **Fig.1**.
6. Connect the push rod to the brake pedal.
7. Check the fluid level in the power steering reservoir. See **Fig.5**. Add approved power steering fluid if needed. See **Specifications, 400** for the approved power steering fluid.



1. Power Steering Fluid Reservoir
2. Steering Gear

Fig. 5, Fluid Level Check

8. Connect the batteries.
9. Bleed the power booster following the instructions in **Subject 120**.
10. Close and latch the hood.
11. Remove the chocks from the rear tires.

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Hydro-Max II® Power Booster Disassembly, Inspection and Assembly

Disassembly (See Fig. 1)

⚠ WARNING

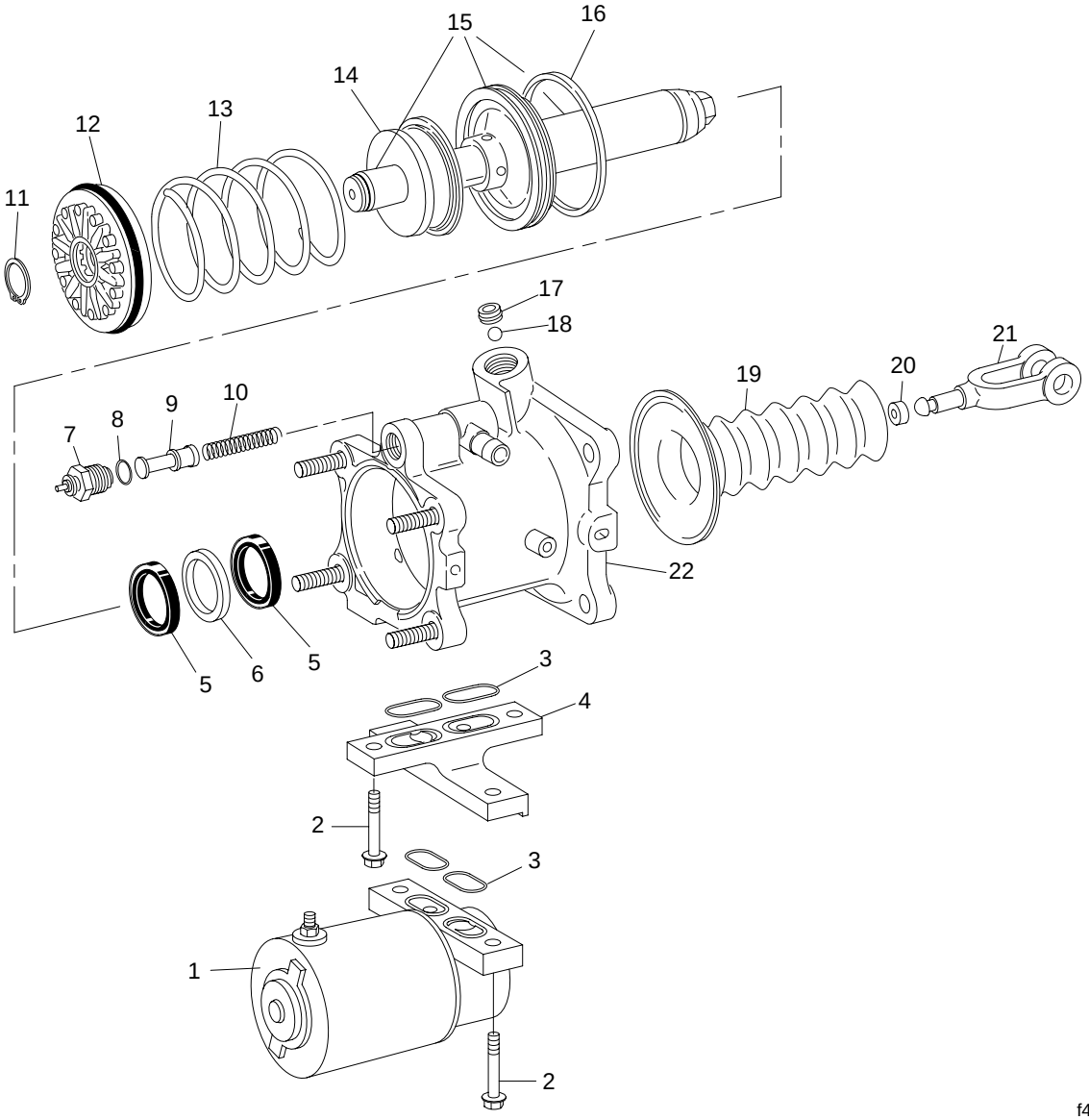
Always wear safety goggles or glasses when working on the power booster. Some power booster parts are under compression (such as springs, snap-rings, and the like), and they could release with some force, possibly causing injury.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Remove the power booster from the vehicle, following instructions in **Subject 220**.
4. Remove the auxiliary electric pump from the power booster housing. See **Fig. 1**.
   - 4.1 Hold the booster and pump assembly over a container. There are about 3 cups of fluid in the assembly.
   - 4.2 Remove the two screws that hold the pump and the adapter block to the bottom of the booster. See **Fig. 2**.

     Remove the two screws that attach the pump to the adapter (if applicable).
   - 4.3 After the power steering fluid has been drained, remove and discard the oval seal rings from the electric pump and the adapter block. See **Fig. 1**.
5. Remove and discard the rubber boot from the pushrod. See **Fig. 1**.
6. Remove pushrod from the end of the power piston. See **Fig. 1**.
   - 6.1 Put the booster unit in a padded vise so the wrench flats at the end of the power piston are in the vise jaws as shown in **Fig. 3**.
   - 6.2 Put a round pry bar through the eyes of the pushrod clevis, then pry the pushrod out of the end of the power piston. See **Fig. 3**.
   - 6.3 Remove all the plastic grommet pieces from inside the power piston end and the pushrod.
7. Remove the power piston assembly and the end cap from the booster housing.
   - 7.1 Place the booster housing on a padded surface, with the end cap facing down.
   - 7.2 Push down on the end of the power piston until the end cap and power piston come out of the front of the housing.
   - 7.3 Pull the power piston and end cap straight out of the booster housing. Be careful not to scratch the piston or the housing bore. See **Fig. 4**.
8. Remove and discard the three input seals from the small bore at rear of the booster housing. See **Fig. 1**.
9. Remove and discard the piston seal from the power piston.
10. Remove the end cap and the filter basket from the power piston.
    - 10.1 Put the end cap and power piston on a padded surface.
    - 10.2 Push down on the end cap to release the pressure on the snap ring, as shown in **Fig. 5**.
    - 10.3 Remove and discard the snap ring from the output shaft of the power piston. See **Fig. 6**.
    - 10.4 Remove and discard the end cap and the return spring. See **Fig. 6**.
    - 10.5 Remove the filter basket.
11. Remove the flow switch assembly from the front of the booster housing.
    - 11.1 Unscrew the nylon flow switch contact assembly from the housing. See **Fig. 7**.
    - 11.2 Using a small magnet, remove the flow switch piston and spring from the booster housing. See **Fig. 8**.
    - 11.3 Remove and discard the O-ring from the nylon contact assembly.
12. Using a hooked piece of wire, remove the inlet check valve from the inlet port on the booster housing. Remove the check ball. Discard both parts. See **Fig. 9**, **Fig. 10** and **Fig. 11**.

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Hydro-Max II® Power Booster Disassembly, Inspection and Assembly



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1. Auxiliary Electric Pump
2. Mounting Hexbolt
3. Oval Seal Rings (4 qty.)
4. Adapter Block
5. Black Input Seal (2 qty.)
6. White Input Seal
7. Flow Switch Contact Assembly
8. O-Ring
9. Flow Switch Piston
10. Flow Switch Spring
11. Snap Ring
12. End Cap Assembly
13. Return Spring
14. Filter Basket
15. Power Piston Assembly
16. Piston Seal
17. Inlet Check Valve Assembly
18. Check Ball
19. Rubber Boot
20. Grommet
21. Pushrod
22. Booster Housing

Fig. 1, Power Booster Exploded View

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Hydro-Max II® Power Booster Disassembly, Inspection and Assembly

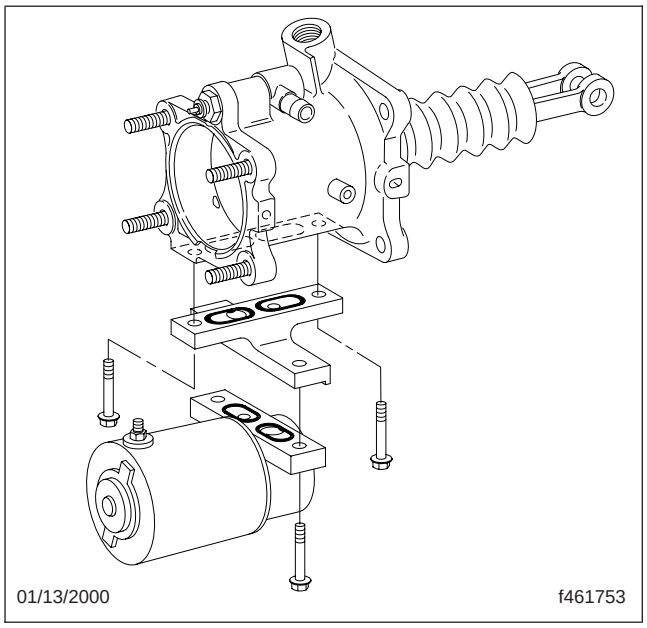
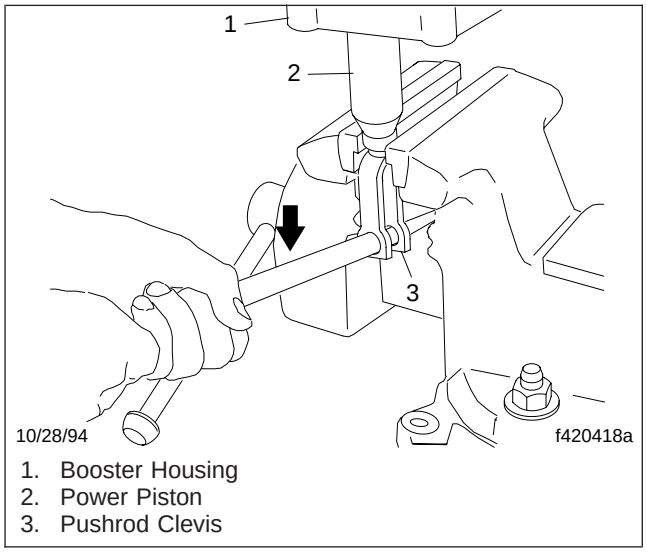


Fig. 2, Pump Mounting



1. Booster Housing
2. Power Piston
3. Pushrod Clevis

Fig. 3, Padded Vise

Inspection

1. Check the power piston surface for nicks or scratches. Pay special attention to the sealing surface and the input and output shafts. See **Fig. 12**. If there is any damage, replace the power piston assembly.

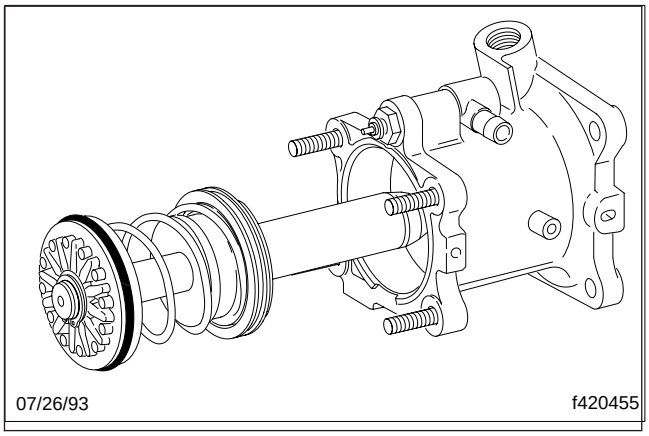


Fig. 4, Remove the Power Piston

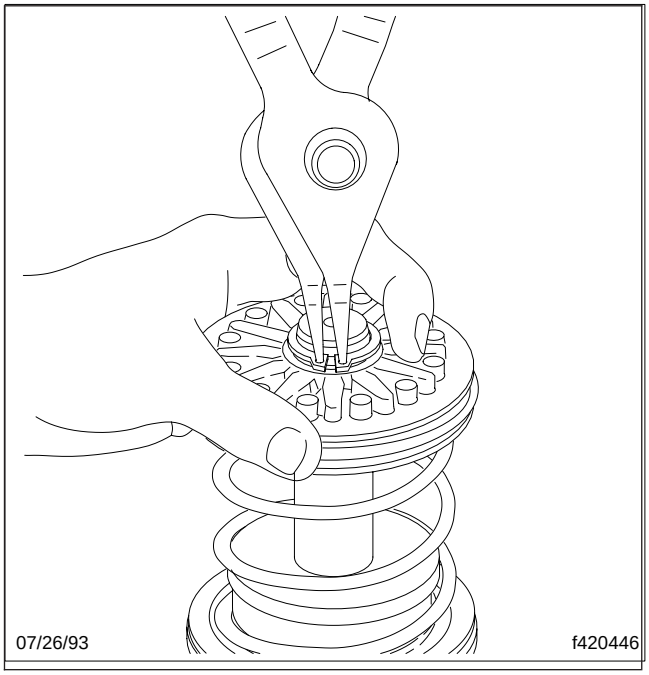
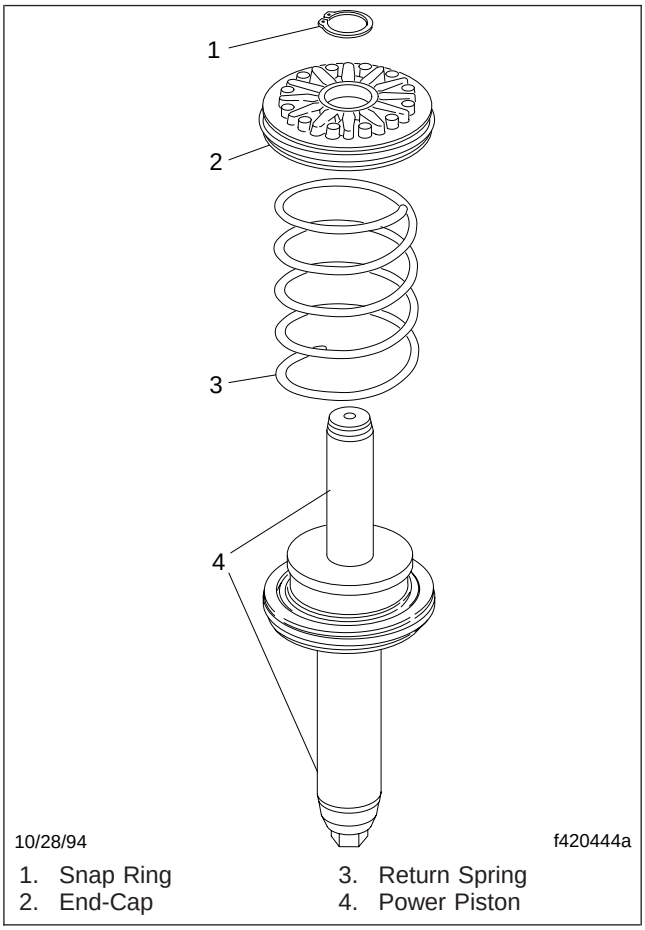


Fig. 5, End Cap

2. Check the bore in the booster housing. If it is grooved, nicked, or otherwise damaged, replace the entire power booster assembly.

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Hydro-Max II® Power Booster Disassembly, Inspection and Assembly



1. Snap Ring
2. End-Cap
3. Return Spring
4. Power Piston

Fig. 6, Output Shaft

Assembly (See Fig. 1)

⚠ WARNING

Use only clean Dexron II® ATF for cleaning or lubricating power booster parts. Do not use brake fluid. Using other types of fluids may destroy seals and O-rings, which could cause the eventual loss of brake control.

1. Using clean power steering fluid, clean and lightly lubricate all the power booster parts.
2. Install new input seals in the small bore of the booster housing. Install the white seal between the two black ones, as shown in **Fig. 13**.

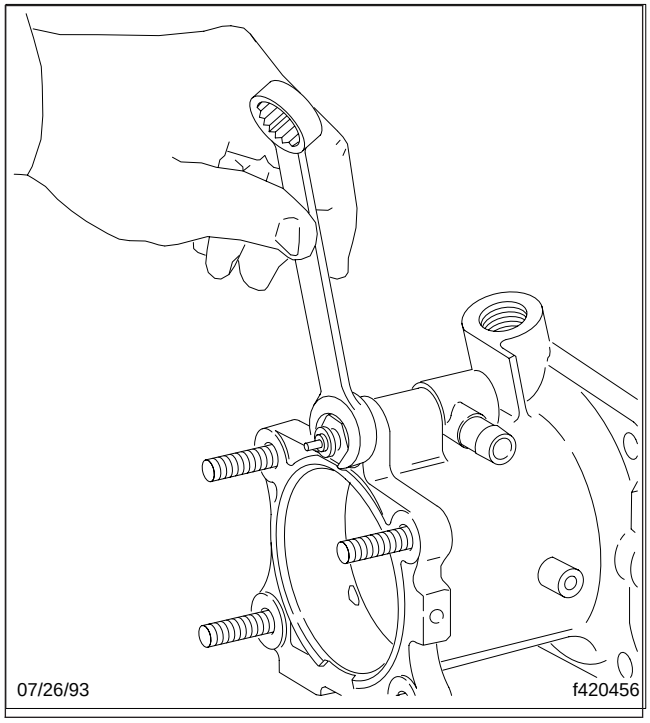
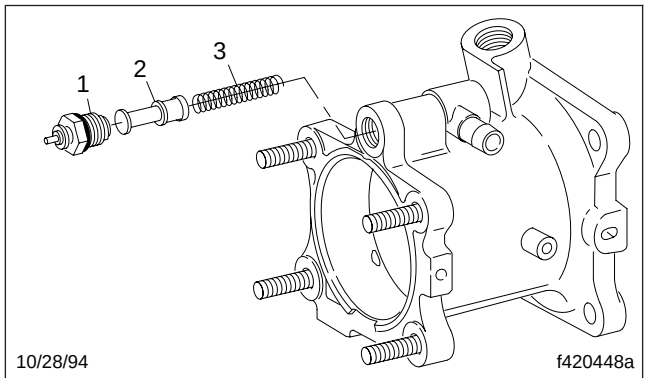


Fig. 7, Nylon Flow Switch



1. Flow-Switch Contact Assembly (with O-ring)
2. Flow-Switch Piston
3. Flow-Switch Spring

Fig. 8, Flow Switch Assembly

3. Install a new check ball in the inlet port on top of the booster housing. Install a new inlet check valve assembly. Make sure it is seated firmly.
4. Install the flow switch assembly in the front of the booster housing. See **Fig. 8**.

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Hydro-Max II® Power Booster Disassembly, Inspection and Assembly

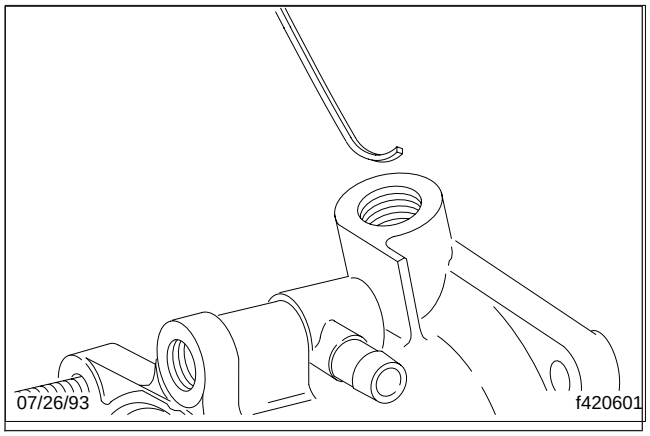


Fig. 9, Hooked Wire

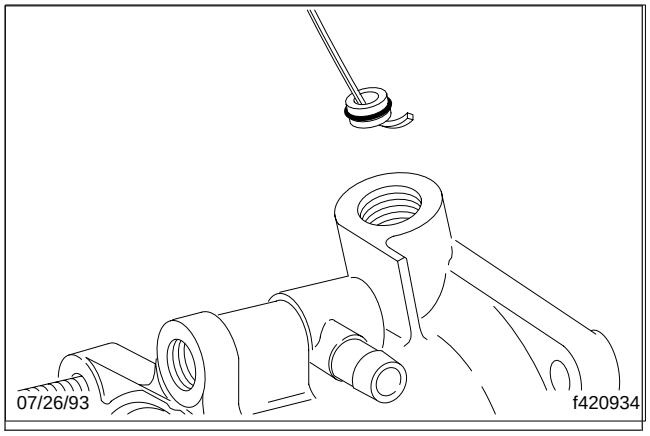


Fig. 10, Inlet Check Valve

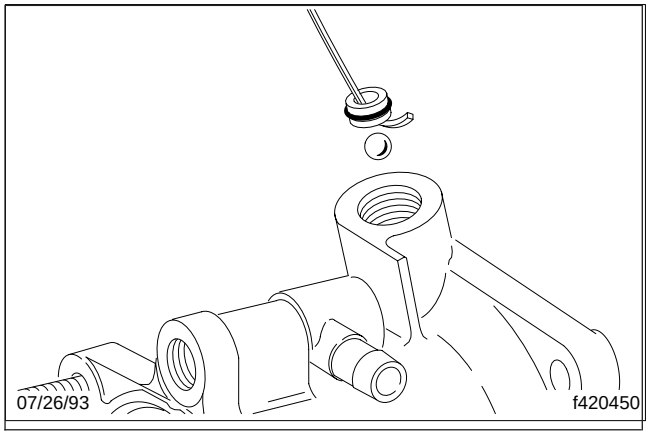
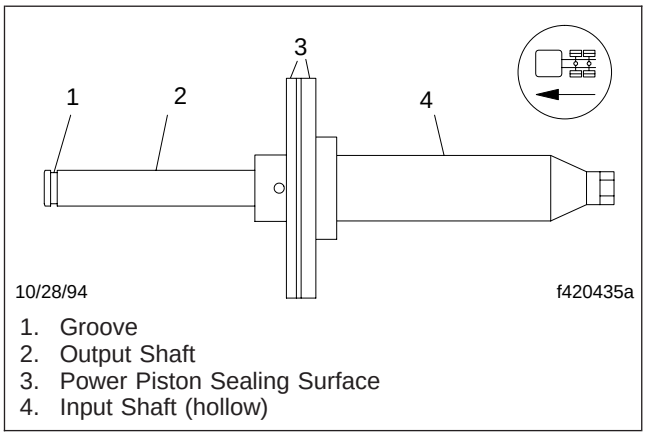


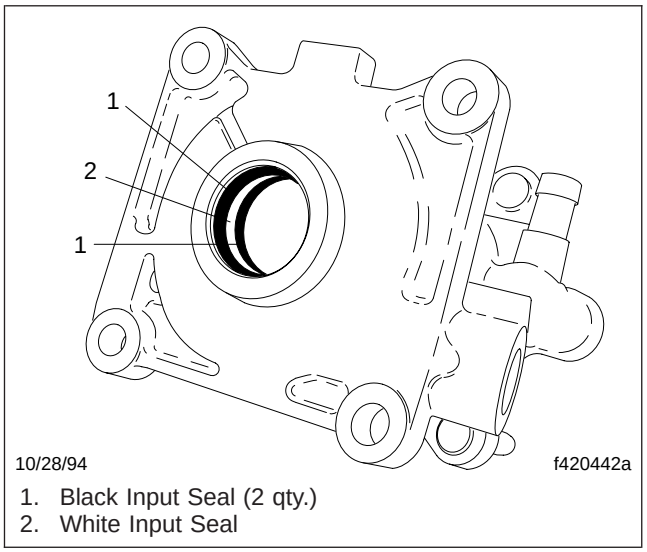
Fig. 11, Check Ball

4.1 Install the flow switch spring in its hole at the front of the booster housing.



1. Groove
2. Output Shaft
3. Power Piston Sealing Surface
4. Input Shaft (hollow)

Fig. 12, Power Piston Assembly



1. Black Input Seal (2 qty.)
2. White Input Seal

Fig. 13, Seals

4.2 Install the flow switch piston.

4.3 Install a new O-ring on the flow-switch contact assembly. Install the assembly in the hole at the front of the booster housing. Finger-tighten it.

5. Install a new filter basket, open end first, over the power piston output shaft and push it up against the power piston.
6. Install the return spring on the power piston output shaft.
7. Install a new end-cap assembly on the power piston output shaft.

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Hydro-Max II® Power Booster Disassembly, Inspection and Assembly

7.1 Install a new square cut seal on the outside diameter of the new end cap. Install a new O-ring inside the small bore of the end cap.

7.2 Lubricate the O-ring and lip seal in the end-cap hole with power steering fluid.

7.3 Carefully install the end-cap assembly (ribbed side up) on the power piston output shaft.

7.4 Keeping the end cap pushed down, install the snap ring in the groove of the power piston output shaft. See **Fig. 5**.

8. Install the power piston assembly in the booster housing.

8.1 Install the power piston, larger shaft first, into the large bore at the front of the booster housing.

⚠ WARNING

Be careful not to damage the input seals in the small bore of the booster housing when you install the power piston shaft through the small bore. If these seals are damaged, the booster assembly will leak, causing loss of braking power.

8.2 Carefully work the end of the power piston shaft through the small bore of the booster housing. Use a gentle twisting motion to work the shaft past the two seals in the bore. See **Fig. 13**.

IMPORTANT: If the seals are damaged by the power piston shaft, replace them. Then repeat steps for installation of the power piston.

8.3 Seat the end cap in the large bore of the housing.

9. Install a new boot on the pushrod.

10. Install the pushrod on the end of the power piston.

10.1 Install a new grommet on the pushrod.

10.2 Put the flats of the power piston end into a padded vise, then install the pushrod and the grommet firmly into the end of the power piston.

⚠ WARNING

Be sure the pushrod is seated all the way into the power piston end. If it's not, it could become disconnected later, which could result in the loss of braking control.

11. Install new oval face seals on the mating surface of the auxiliary electric pump. See **Fig. 14**.

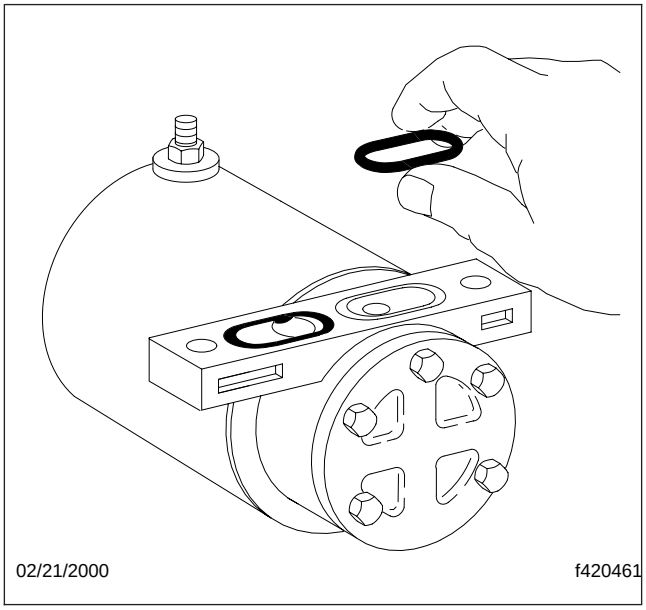


Fig. 14, Face Seals

12. Install the adapter block on the electric pump, with the machined lip on the block down, and hanging over the front edge of the electric pump. See **Fig. 15**. Tighten the mounting bolts 22 lbf·ft (30 N·m).

13. Install new oval face seals on the top of the adapter block, then install the adapter block and electric pump assembly on the bottom of the booster housing, as shown in **Fig. 16**. Tighten the two mounting bolts 22 lbf·ft (30 N·m).

14. Install the power booster assembly on the vehicle following the instructions in **Subject 220**.

15. Close and latch the hood.

16. Remove the chocks from the rear tires.

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Hydro-Max II® Power Booster Disassembly, Inspection and Assembly

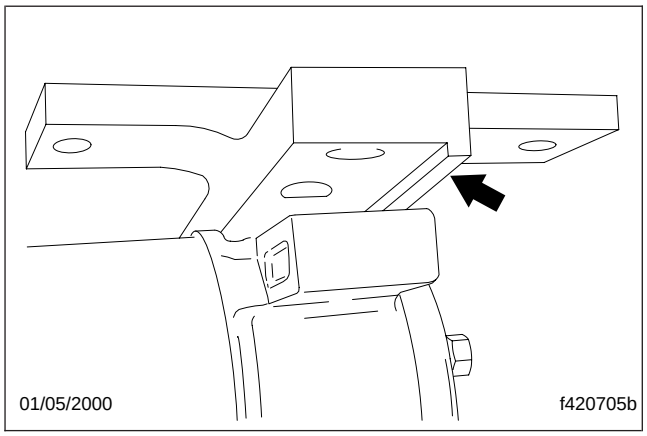


Fig. 15, Adapter Block Machined Lip

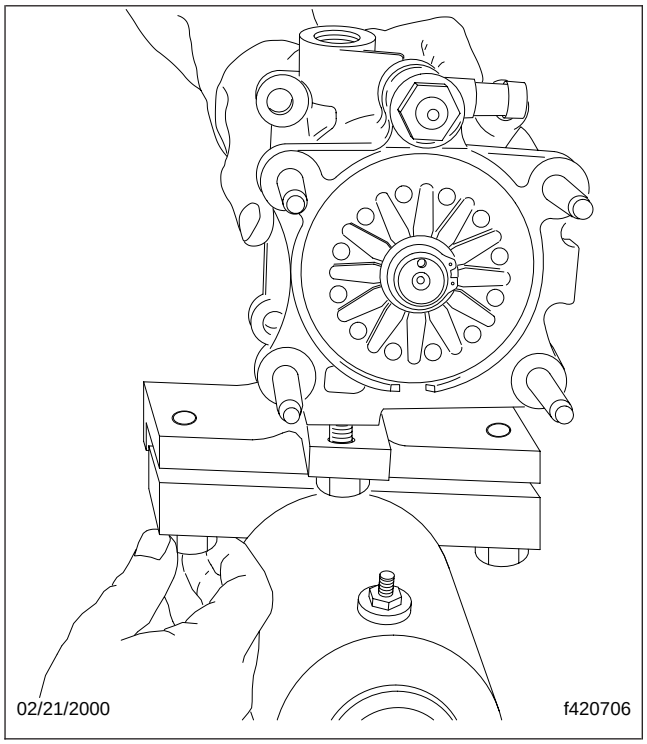


Fig. 16, Install Pump Assembly

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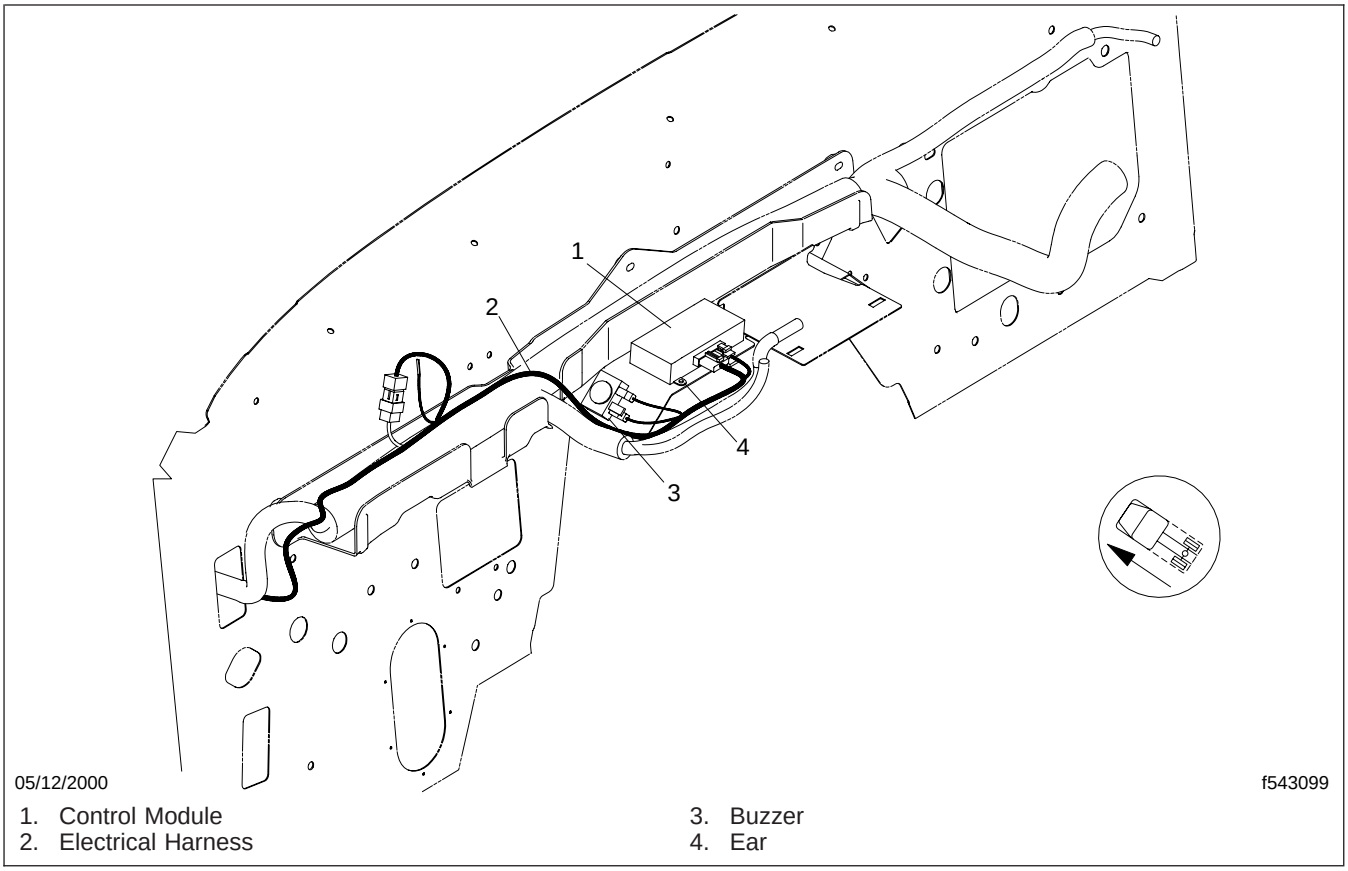
Hydraulic Brake Electronic Control Module Removal and Installation

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries at the negative terminals.
3. From inside the cab, loosen the engine cover.
4. Remove the two screws that attach the module to the mounting bracket. Remove the control module. See **Fig. 1**.

Installation

1. Connect the 9-pin and the 4-pin connectors to the control module.
2. Install the control module on the mounting bracket.
3. Install the engine cover.
4. Connect the batteries.
5. Remove the chocks from the rear tires.



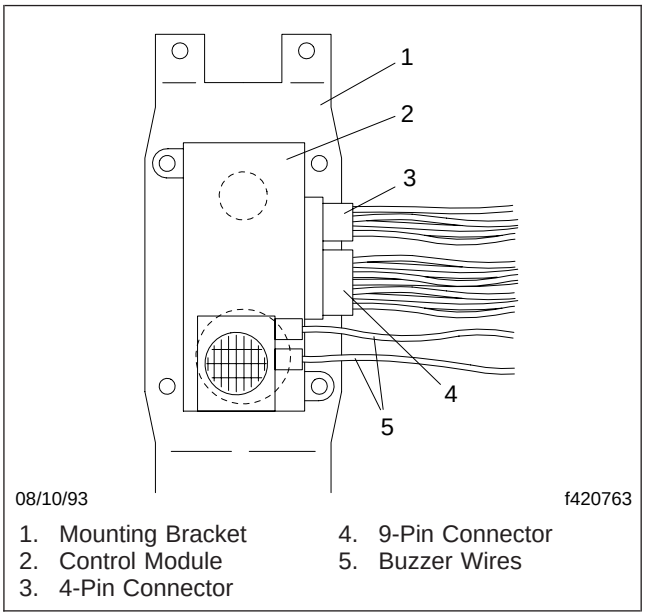
1. Control Module
2. Electrical Harness
3. Buzzer
4. Ear

Fig. 1, Control Module Mounting

5. Disconnect the 9-pin connector and the 4-pin connector from the module. See **Fig. 2**.

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Hydraulic Brake Electronic Control Module Removal and Installation



1. Mounting Bracket
2. Control Module
3. 4-Pin Connector
4. 9-Pin Connector
5. Buzzer Wires

Fig. 2, Electrical Connections

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Troubleshooting Tables

Pedal

Problem—The Power Booster Works Sluggishly or Not at All

Problem—The Power Booster Works Sluggishly or Not at All	
Possible Cause	**Remedy**
Binding power booster push rod	Check the linkage between the brake pedal and the power booster push rod. Check the hole in the cab front wall through which the push rod fits. Repair or replace parts as needed.

Problem—Pedal Does Not Return, The Brakes are Dragging, Grabbing, or the Brake Action is Uneven

Problem—Pedal Does Not Return, The Brakes are Dragging, Grabbing, or the Brake Action is Uneven	
Possible Cause	**Remedy**
Brake pedal binding or restricted from returning	Check the brake pedal for a restriction. Repair as needed.

Problem—The Brake Pedal Is Hard to Depress With the Engine Running

Problem—The Brake Pedal Is Hard to Depress With the Engine Running	
Possible Cause	**Remedy**
Binding brake pedal	Check the brake pedal linkage. Repair or replace as needed.
Pedal misalignment (side-to-side)	

Wheel-End Components

Problem—Fluid Level Indicator Light Illuminated

Problem—Fluid Level Indicator Light Illuminated	
Possible Cause	**Remedy**
Brake pads worn out	Inspect the brake pads and replace as necessary in axle sets. Add fluid as required.

Problem—The Brakes Pull To the Left or Right

Problem—The Brakes Pull To the Left or Right	
Possible Cause	**Remedy**
Low tire pressure	Inflate the tires to the correct pressure.
Front wheels out of alignment	Align the front wheels. See **Section 33.00**.
Mismatched tires	Check the tire sizes and correct as needed.
Kinked brake lines	Check the routing of the brake lines and hoses. Repair or replace as needed.
Loose or not working caliper	Repair the caliper.
Oily brake pads	Replace the brake pads in axle sets.
Rear brakes not working	Check the rear brakes and repair or replace parts as needed.

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Troubleshooting

Problem—The Brakes Pull To the Left or Right	
Possible Cause	**Remedy**
Loose suspension parts	Check the front and rear suspension, and repair as needed.
Mismatched or worn brake pads	Replace the brake pads in axle sets. Repair or replace the rotor(s) as needed.
Grease on pads or rotor	Clean the parts as needed.
Caliper piston sticking	Replace caliper as required.
Caliper or anchor plate V-ways sticking	Clean V-ways and anchor plate rails thoroughly and lubricate with approved grease.

Problem—Brake Noises With the Brakes Not Applied

Problem—Brake Noises With the Brakes Not Applied	
Possible Cause	**Remedy**
Worn out front pads	Replace the pads in axle sets.
Dust or oil on rotors	Clean the rotors. Check for and repair an oil leak.

Problem—Roughness, Chattering, or Pulsating Is Felt When the Brakes are Applied

Problem—Roughness, Chattering, or Pulsating Is Felt When the Brakes are Applied	
Possible Cause	**Remedy**
Too much rotor lateral runout	Check the lateral runout on the rotors. Repair or replace as needed.
Rotor parallelism not to specifications	Check the parallelism of the rotors. Repair or replace as needed.
Incorrectly adjusted wheel bearings	Check the end play of the front and rear wheel bearings. Adjust as needed. See **Group 33** for front axles and **Group 35** for rear axles.
Brake pad installed backwards (steel side toward the rotor face)	Install the brake pad correctly.
Foreign material imbedded in pads	Replace pads in axle sets.

Problem—Too Much Effort Is Needed to Apply the Brakes (Hard Pedal)

Problem—Too Much Effort Is Needed to Apply the Brakes (Hard Pedal)	
Possible Cause	**Remedy**
Worn brake pads	Replace the brake pads in axle sets.
Stuck or binding caliper piston	Check the caliper pistons. Rebuild the caliper(s) as needed.
Fading brakes due to incorrect pads	Install the correct brake pads in axle sets.
Glazed rotors or brake pads	Replace the glazed rotors or brake pads in axle sets.
Grease or oil on brake pads or rotors	Clean the brake pads or rotors.
Overloaded vehicle	Do not exceed rated vehicle loads.

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Problem—Excessive Pedal Travel (Low Pedal)

Problem—Excessive Pedal Travel (Low Pedal)	
Possible Cause	**Remedy**
Worn brake pads	Replace the brake pads in axle sets.
Pad and piston knockback caused by loose wheel bearings	Adjust, tighten or replace parts as necessary.

Problem—One Brake Drags

Problem—One Brake Drags	
Possible Cause	**Remedy**
Loose or worn front wheel bearings	Adjust to specifications or replace.
Worn or damaged brake hose or hydraulic tube preventing return of brake fluid	Replace worn or damaged hose or tube as necessary.
Sticking caliper piston	Repair or replace the caliper.
Swollen caliper piston seal	Replace the caliper. Flush hydraulic brake system and fill with clean, approved brake fluid.
Sticking caliper V-ways	Clean the V-ways and anchor plate rails and thoroughly lubricate with approved grease.

Hydro-Max II® Power Booster and Master Cylinder

Problem—Fluid Level Indicator Light Illuminated

Problem—Fluid Level Indicator Light Illuminated	
Possible Cause	**Remedy**
Low fluid level	Inspect brake pads, replace as necessary in axle sets. Add fluid as required.
Fluid level indicator switch not working	Replace the master cylinder.

Problem—Silicon Floating in Master Cylinder

Problem—Silicon Floating in Master Cylinder	
Possible Cause	**Remedy**
None	This material is an assembly lubricant and is harmless.

Problem—Brakes Self-Apply

Problem—Brakes Self-Apply	
Possible Cause	**Remedy**
Constricted master cylinder reservoir vent	Clean the vent passage in the reservoir cap.

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Troubleshooting

Problem—Pedal Does Not Return

Problem—Pedal Does Not Return	
Possible Cause	**Remedy**
Fluid contamination	Drain the system and fill with the correct type of fluid. Bleed the air from the system. Replace the power booster or master cylinder as needed. Replace the power steering reservoir filter as needed.
Master cylinder not working	Replace the master cylinder.
Binding power booster	Replace the power booster.

Problem—Too Much Effort Is Needed to Apply the Brakes (Hard Pedal)

Problem—Too Much Effort Is Needed to Apply the Brakes (Hard Pedal)	
Possible Cause	**Remedy**
Overloaded vehicle	Do not exceed rated vehicle loads.
Power booster not working	Go to "System Pressure Test," under "Pressure Tests" in this subject.
Master cylinder not working	Replace the master cylinder.
Tube and hose passages blocked shut	Replace the parts containing blocked passages.

Problem—Too Much Brake Pedal Travel (Low Pedal)

Problem—Too Much Brake Pedal Travel (Low Pedal)	
Possible Cause	**Remedy**
Leak in hydraulic system	Check for and repair any leaks found in either the power booster (power steering) hydraulic system or the brake hydraulic system.
Low fluid level or leak in master cylinder	Find the cause of the low fluid level and remedy the problem. Fill the master cylinder compartments to the correct level.
Air in the hydraulic system	Bleed the brake hydraulic system and the power steering system as needed.
Plugged master cylinder cap	Clean or replace the master cylinder cap.
Wrong type of brake fluid in system	Drain the system and fill with the correct type of brake fluid. Bleed the air from the system.
Master cylinder not working	Replace the master cylinder.
Weak brake hoses that expand under pressure	Replace the hoses.

Problem—The Brakes are Dragging

Problem—The Brakes are Dragging	
Possible Cause	**Remedy**
Master cylinder pistons not returning	Repair or replace the master cylinder.
Kinked or pinched brake lines or hoses	Check the brake lines and hoses. Repair or replace as needed.
Power piston in power booster not returning	Repair or replace the power booster.
Restriction or blockage inside a brake line or hose	Go to "Residual Pressure Test," under "Pressure Tests" in this subject.

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Problem—The Brakes are Dragging	
Possible Cause	**Remedy**
Soft or swollen master cylinder seals due to brake fluid contamination	Flush out the old brake fluid and replace the master cylinder. Fill the system with new brake fluid.
Soft or swollen rubber parts caused by incorrect or contaminated brake fluid	Replace all rubber parts including calipers (which have internal rubber seals). Flush the hydraulic system and fill with approved fluid.
Trapped pressure in brake lines caused by master cylinder or power booster not fully releasing	Repair or replace the master cylinder or power booster as necessary.

Problem—The Brakes are Grabbing or the Brake Action is Uneven

Problem—The Brakes are Grabbing or the Brake Action is Uneven	
Possible Cause	**Remedy**
Power booster not working	Repair or replace the power booster.

Problem—Fluid Is Leaking at the Power Booster or the Power Steering Pump

Problem—Fluid Is Leaking at the Power Booster or the Power Steering Pump	
Possible Cause	**Remedy**
Worn or damaged seals between the auxiliary electric pump and the power booster	Replace the seals.
Loose hexbolts attaching the auxiliary electric pump to the power booster	Tighten the hexbolts 22 lbf·ft (30 N·m).
Worn or damaged power booster housing	Replace the power booster.
Worn or damaged power booster flow switch seals	Repair the power booster.
Leaking master cylinder reservoir vent caps	Replace the diaphragms and the caps.
Fluid contamination	Drain the system and fill with the correct type of fluid. Bleed the air from the system. Replace the power booster or master cylinder as needed. Replace the power steering reservoir filter as necessary.
Leaking flow switch seal	Replace the O-ring.
Leaking hydraulic fittings and connections	Check the fittings and connections. Tighten and replace as necessary.

Problem—The Power Booster Works Sluggishly or Not at All

Problem—The Power Booster Works Sluggishly or Not at All	
Possible Cause	**Remedy**
Binding power booster push rod	Check the linkage between the brake pedal and the power booster push rod. Check the hole in the cab front wall through which the push rod fits. Repair or replace parts as needed.
Worn or damaged power booster	Replace or rebuild the power booster.

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Troubleshooting

Auxiliary Electric Pump

Problem—Fluid is Leaking at the Power Booster or the Power Steering Pump

Problem—Fluid is Leaking at the Power Booster or the Power Steering Pump	
Possible Cause	**Remedy**
Worn or damaged seals between the auxiliary electric pump and the power booster	Replace the seals.
Worn or damaged auxiliary electric pump	Replace the auxiliary electric pump.
Loose hexbolts attaching the auxiliary electric pump to the power booster	Tighten the hexbolts 22 lbf·ft (30 N·m).
Leaking auxiliary electric pump mounting seals	Replace the seals.

Problem—The Auxiliary Electric Pump Does Not Work With the Engine Off and the Brake Pedal Depressed

Problem—The Auxiliary Electric Pump Does Not Work With the Engine Off and the Brake Pedal Depressed	
Possible Cause	**Remedy**
Disconnected or damaged wiring to auxiliary electric pump	Check the wiring. Repair or replace as needed.
Dead batteries	Check the batteries. Recharge them as needed.
Out of adjustment brake switch	Check the brake switch and adjust it as needed.
Worn or damaged brake switch	Replace the brake switch.
Relay to the auxiliary electric pump not working	Check the relay. Replace it if needed.
Auxiliary electric pump not working	Check the operation of the auxiliary electric pump and replace as needed.
Open circuit	Repair the circuit.

Problem—The Auxiliary Electric Pump Runs Continuously When the Ignition Is Off and the Brake Pedal Is Not Depressed

Problem—The Auxiliary Electric Pump Runs Continuously When the Ignition Is Off and the Brake Pedal Is Not Depressed	
Possible Cause	**Remedy**
Brake light switch not working or incorrectly adjusted	Check the brake light switch and repair or replace as needed.
Relay to the auxiliary electric pump not working	Check the relay. Replace if needed.
Flow switch not working	Remove the switch components, clean and inspect them for damage or contamination. Repair or replace as necessary.

Power Steering Pump

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Problem—The Brakes Are Dragging, Brakes Self-Apply or Pedal Does Not Return

Problem—The Brakes Are Dragging, Brakes Self-Apply or Pedal Does Not Return	
Possible Cause	**Remedy**
Self-applied booster (fluid flow too high)	Repair or replace the power steering pump.

Problem—Fluid Is Leaking at the Power Booster or the Power Steering Pump

Problem—Fluid Is Leaking at the Power Booster or the Power Steering Pump	
Possible Cause	**Remedy**
Worn or damaged power steering pump	Replace the power steering pump.
Fluid contamination	Drain the system and fill with the correct type of fluid. Bleed the air from the system. Replace the power booster or master cylinder as needed. Replace the power steering reservoir filter as necessary.
Leaking hydraulic fittings and connections	Check the fittings and connections. Tighten and replace as necessary.

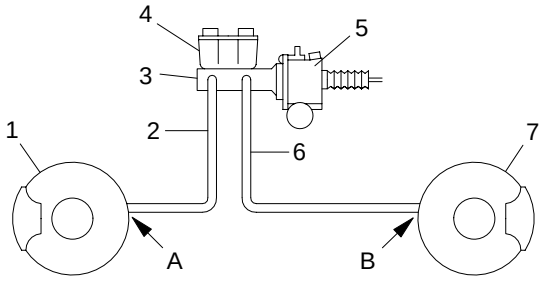
Problem—The Power Steering Pump Is Noisy

Problem—The Power Steering Pump Is Noisy	
Possible Cause	**Remedy**
Hydraulic supply and return lines touching chassis	Reroute the power booster supply and return lines.
Low fluid level in power steering reservoir	Fill the power steering reservoir to the correct level.
Air in power steering fluid	Bleed the power steering system.
Contaminated power steering fluid	Change the power steering fluid or replace the power steering pump.

Pressure Tests

Residual Pressure Test

1. Install two pressure gauges with a range of 0 to 50 psi (345 kPa)—one in the primary circuit (at the rear wheel), and one in the secondary circuit (at the front wheel). See **Fig. 1**.
2. Bleed the two circuits following the procedure in **Subject 110**.
3. With the ignition off, lightly apply the brakes several times. Do not apply full pressure to the brake pedal or you may damage the pressure gauges.
4. Release the brakes. Read the residual pressure on the two gauges. Record the information.
5. If the residual pressure on one or both gauges is less than 2 psi (14 kPa), go to "System Pressure Test" in this subject.



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A. Install gauge #2 here.
B. Install gauge #1 here.

1. Front Brake
2. Secondary Circuit
3. Master Cylinder
4. Reservoir
5. Power Booster
6. Primary Circuit
7. Rear Brake

Fig. 1, Gauge Installation

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If the residual pressure on one or both gauges is more than 2 psi (14 kPa), check the linkage between the brake pedal and the booster. Adjust or repair the linkage as needed. Repeat steps 3 and 4. If the problem is solved, go to "System Pressure Test" in this subject. If the problem is not solved, continue with the procedure.

6. If the check ports of the master cylinder have check valves, replace the master cylinder. Repeat steps 2 and 3. If the problem is solved, go to "System Pressure Test" in this subject. If the problem is not solved, continue with the procedure.

   If the check ports of the master cylinder do not have check valves, check the hydraulic lines for internal blockage. Repair or replace lines as needed. Repeat steps 3 and 4. If the problem is solved, go to "System Pressure Test" in this subject. If the problem is not solved, continue with the procedure.

7. Check the master cylinder function. Repair or replace as needed. Go to "System Pressure Test" in this subject.

System Pressure Test

1. Install two pressure gauges with a range of 0 to 2500 psi (17 237 kPa)—one in the primary circuit (at the rear wheel), and one in the secondary circuit (at the front wheel). See **Fig. 1**.

   If you have previously done the residual pressure test, remove the two low-pressure gauges installed for that test, and replace them with the two high-pressure gauges.

2. Bleed the primary and secondary brake circuits following the procedure under **Subject 110**.

3. Make a copy of **Table 1**. Use this copy to record the results from the next step.

4. Start the engine. Quickly apply the brakes using full pedal force. Hold the pedal down for 15 to 20 seconds. Record the speed of the pressure rise, the highest pressure registered on each gauge and whether the pressure stayed constant while the pedal was depressed. See **Table 1**.

Test Results				
Pressure Test	**Gauge 1 (installed at rear wheel)**		**Gauge 1 (installed at front wheel)**	
Rapid Pressure Rise	Yes	No	Yes	No
Slow Pressure Rise	Yes	No	Yes	No
Highest Reading (psi)		psi		psi
Pressure Constant	Yes	No	Yes	No

Table 1, Test Results

5. If the pressure reading on both gauges is not within 10 percent, repair or replace the master cylinder as needed. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

6. If the pressure reading on both gauges is within 10 percent, but the gauges show less than 1170 psi (8067 kPa), turn off the engine; ignition on. Apply the brakes hard, hold the pedal down 15 to 20 seconds.

   If both gauges show at least 860 psi (5930 kPa), repair or replace the power booster. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

   If both gauges do not show at least 860 psi (5930 kPa), repair or replace the power steering pump. Bleed the system following the instructions in **Subject 110**.

7. If the pressure reading on both gauges is within 10 percent and the gauges show at least 1170 psi (8067 kPa), but the pressure came up slowly on both gauges, turn off the engine; ignition on. Apply the brakes hard, hold down the pedal 15 to 20 seconds. If there was an instant pressure rise on both gauges, repair or replace the power steering pump. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

   If there was not an instant pressure rise on both gauges, repair or replace the power booster. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

8. If the pressure reading on both gauges is within 10 percent and the gauges show at least 1170 psi (8067 kPa), but the pressure came up fast on one gauge and slowly on the other gauge, locate

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the restriction in the circuit having the slow gauge. Remove and install the gauge closer to the master cylinder until the pressure rises quickly. The restriction is between that point and the point of previous installation. Repair or replace the brake line as needed. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

9. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1170 psi (8067 kPa) and the pressure came up instantly on both gauges, but there was not constant gauge pressure while the pedal was depressed, turn off the engine; ignition on. Apply the brakes hard, hold down the pedal for 15 to 20 seconds. If there is constant pressure on both gauges while the pedal is down, repair or replace the power steering pump. Bleed the system following the instructions in **Subject 110**.

   If there is not constant pressure on both gauges while the pedal is down, repair or replace the power booster. Bleed the system following the instructions in **Subject 110**.

10. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1170 psi (8067 kPa), the pressure came up instantly on both gauges and there was constant gauge pressure while the pedal was depressed, but the brake pedal did not stay firm, repair or replace the master cylinder as needed. Bleed the system following the instructions in **Subject 110**.

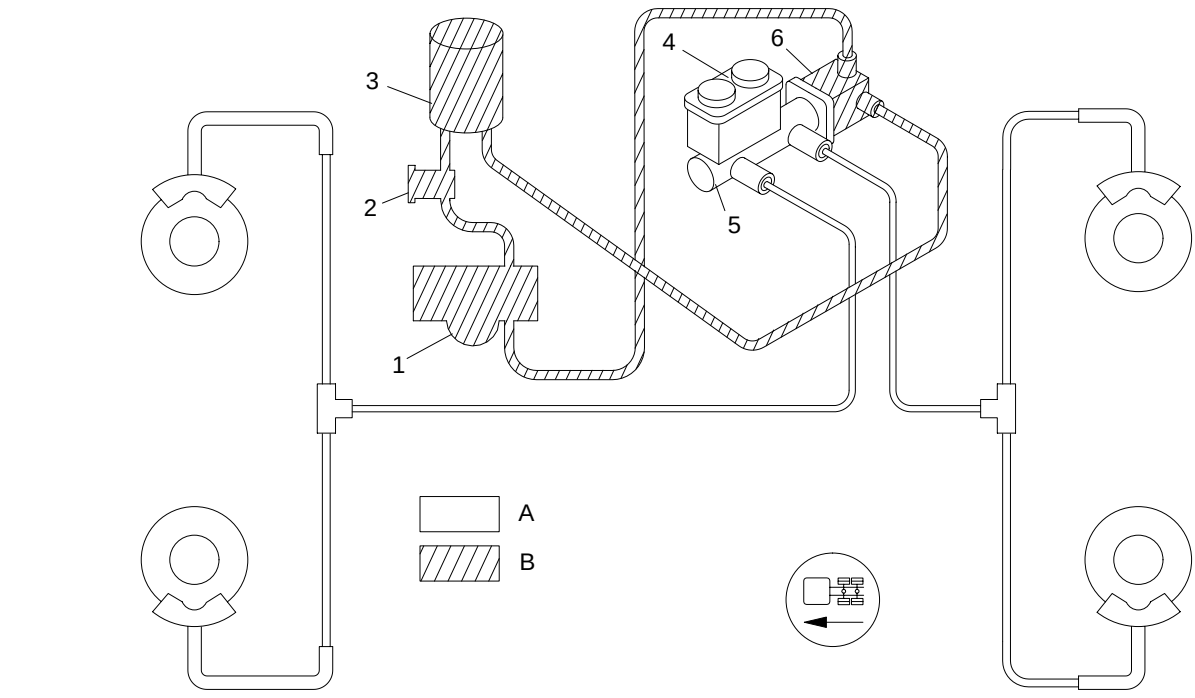
11. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1170 psi (8067 kPa), the pressure came up instantly on both gauges, there was constant gauge pressure while the pedal was depressed and the brake pedal stayed firm, remove the pressure gauges. Bleed the system following the instructions in **Subject 110**. If the problem still exists, check the foundation brakes.

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See **Fig. 1** for the hydraulic brake system plumbing diagram.

See **Fig. 2** for a full view of the hydraulic brake system wiring.

See **Fig. 3** and **Fig. 4** for partial views of the hydraulic brake system wiring.



A. Brake System (Brake Fluid)
B. Brake Booster and Power Steering System (Power Steering Fluid)
1. Power Steering Gear
2. Power Steering Pump
3. Power Steering Reservoir
4. Brake Master Cylinder Reservoir
5. Brake Master Cylinder
6. Power Booster

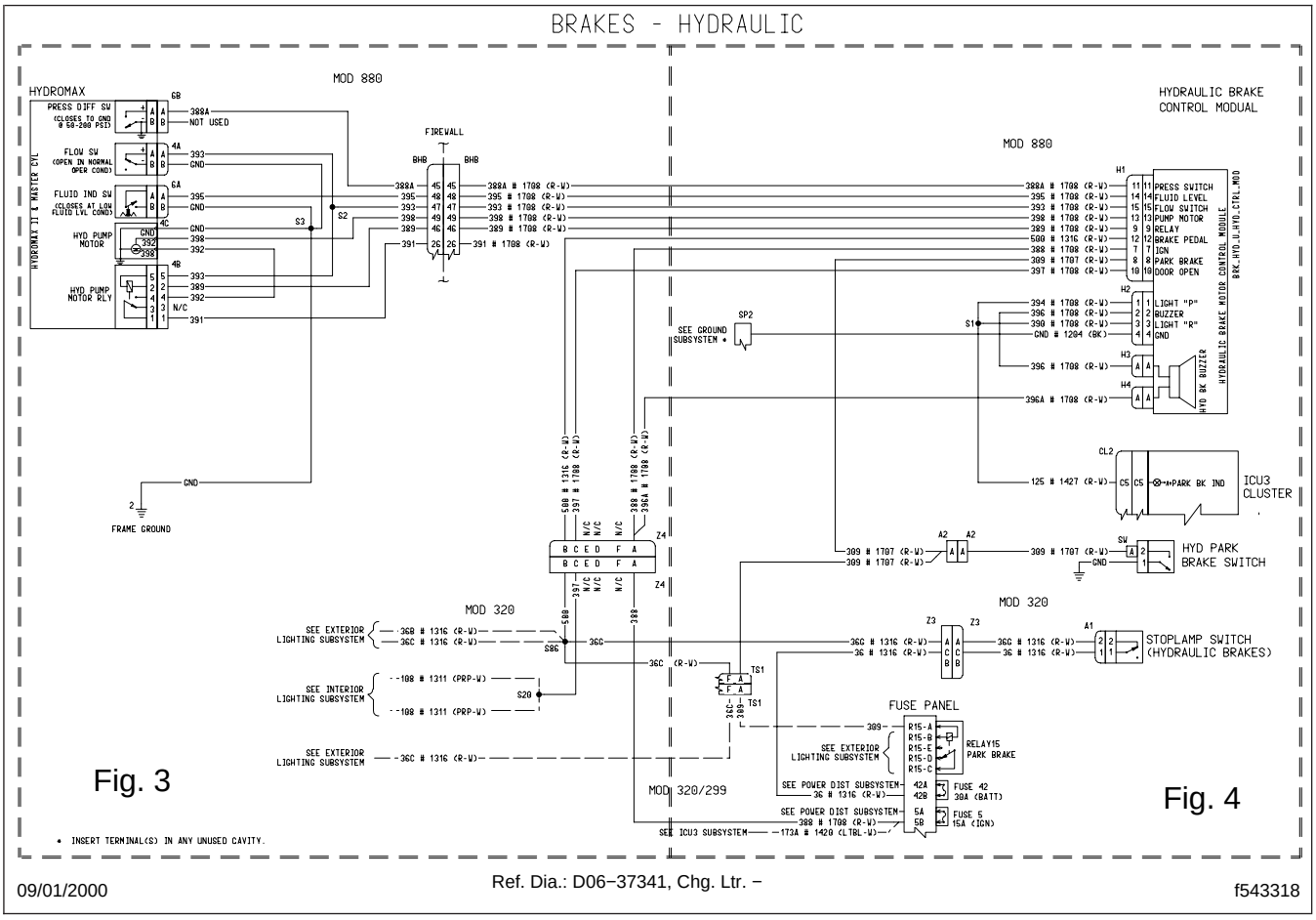
Fig. 1, Hydraulic Brake System Plumbing Diagram

Kent-Moore Tools	
Kent-Moore Part Number	**Tool**
KMS/ZTSE4276	Seating Tool for 2.88-Inch Caliper Pistons
KMS/ZTSE4343	Seating Tool for 2.6-Inch Caliper Pistons

Table 1, Kent-Moore Tools, Kent-Moore Tool Division, 29784 Little Mack, Roseville, MI 48066

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Specifications



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Fig. 2, Hydraulic Brake System Wiring (full view)

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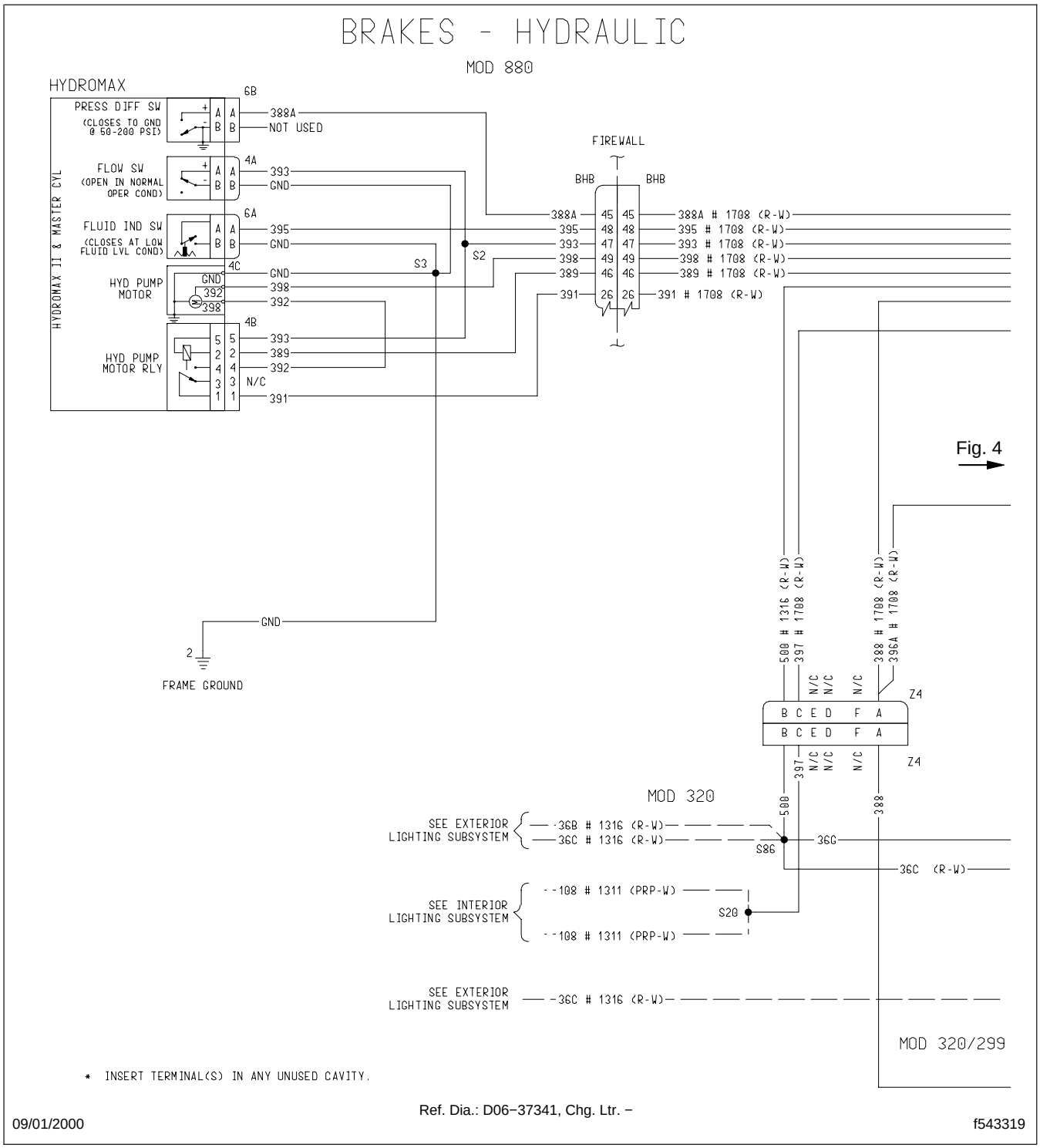


Fig. 3, Hydraulic Brake System Wiring (partial view)

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Specifications

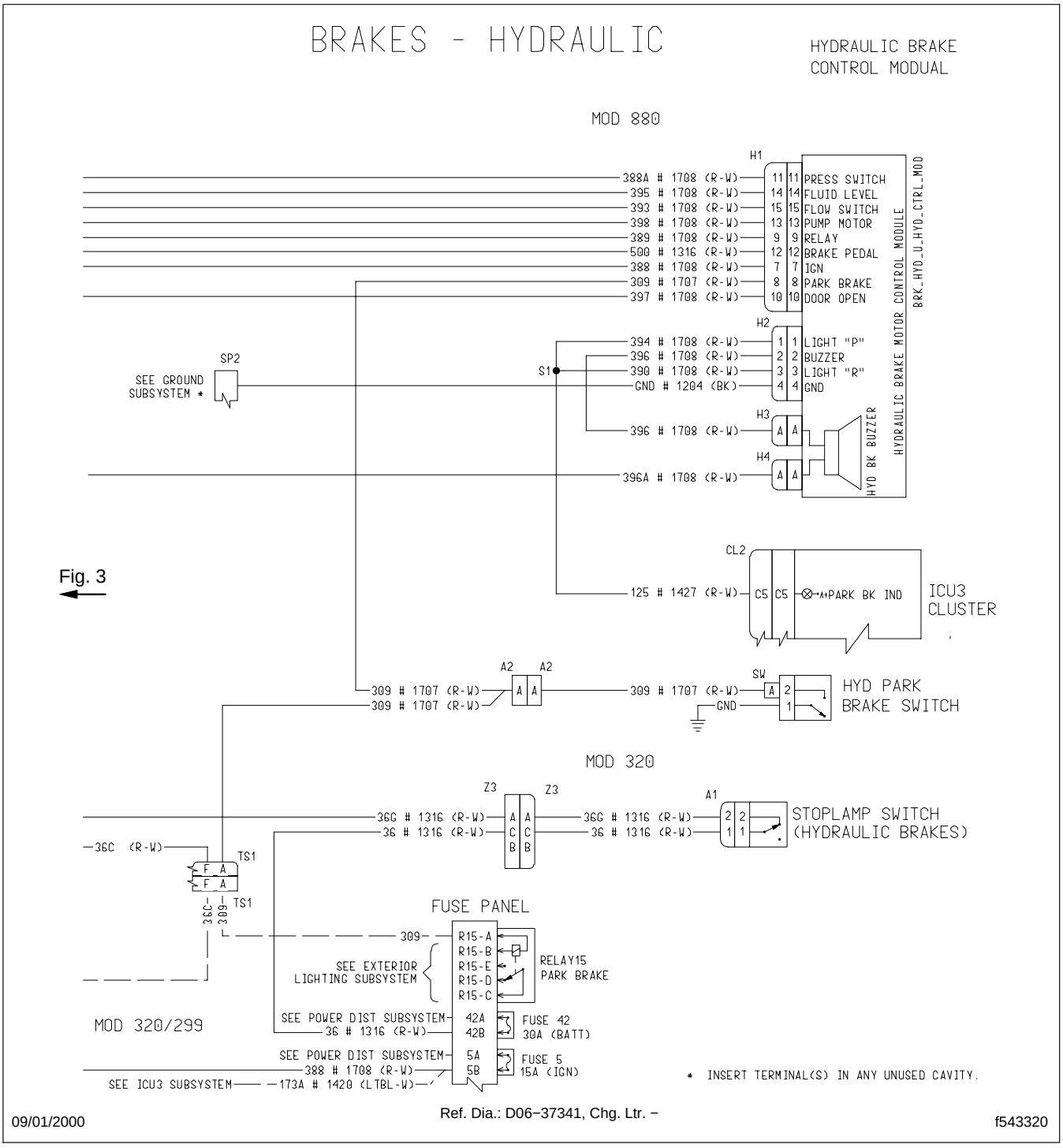


Fig. 4, Hydraulic Brake System Wiring (partial view)

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Fastener Torques			
Description	**Bolt or Nut Size**	**Grade**	**Torque lbf·ft (N·m)**
Power Booster Mounting Bolts	—	—	20 (27)
Master Cylinder Mounting Nuts	—	—	28 (38)
Brake Line Tube Nuts	7/16–24	—	15 (20)
Caliper Supply Fitting	7/16–24	—	15 (20)
Allen-Head Key Retainer Bolts	—	—	18 (24)
Reservoir Mounting Hexbolts	—	—	15 (20)
Anchor Plate Mounting Hexbolts	1/2–13	8	70 (95)
Rotor Mounting Hexbolts	9/16–12	8	130 (175)
Dust Shield Mounting Bolts	—	—	15 (20)
Master Cylinder Outlet Fittings	7/16–24	—	15 (20)
Power Booster Supply Line Fitting	—	—	20 (27)

Table 2, Fastener Torques

Approved Power Steering Fluid for Power Booster	
Fluid Type	**Recommended Fluid**
Automatic Transmission Fluid	Dexron II®

Table 3, Approved Power Steering Fluid for Power Booster

Approved Brake Fluid for Brake System	
Fluid Type	**Recommended Fluid**
DOT 3	Wagner-Premium Plus Super HD Delco Supreme II Dow HD 50-4

Table 4, Approved Brake Fluid for Brake System

Rotor Specifications		
Maximum Allowable Lateral Runout inch (mm)	**Minimum Allowable Thickness inch (mm)**	**Maximum Difference in Parallelism inch (mm)**
0.015 (0.38)	1.32 (33.5)	0.005 (0.13)

Table 5, Rotor Specifications

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Specifications

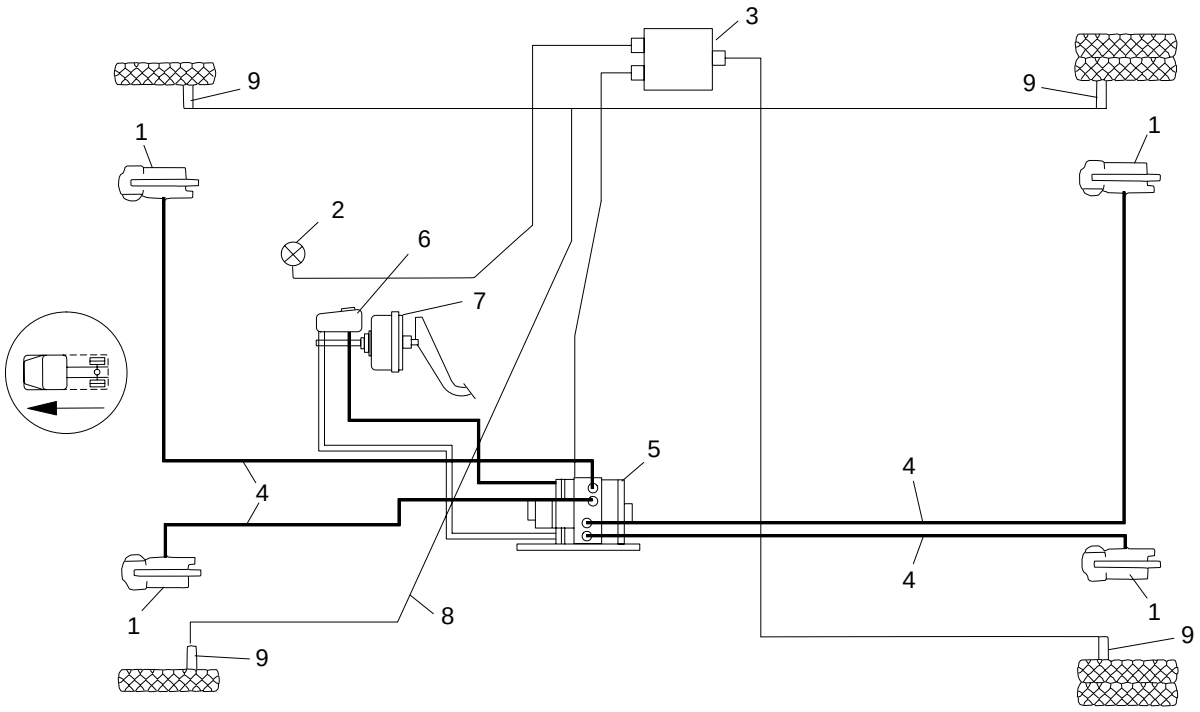
Approved Brake System Grease	
Component	**Recommended Grease**
Brake Caliper V-Ways and Anchor Plate Rails	Aeroshell Grade 5 (ES-1246)

Table 6, Approved Brake System Grease

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General Information

The Meritor WABCO antilock braking system (ABS) is an electronic wheel speed monitoring and control system that works with the hydraulic brake system. See **Fig. 1**. ABS passively monitors vehicle wheel speed at all times and controls wheel speed during emergency stops. In normal braking applications, the hydraulic brake system is in effect.



1. Brake
2. ABS Warning Light
3. Electronic Control Unit (ECU)
4. Hydraulic Brake Line
5. ABS Modulator Assembly
6. Master Cylinder
7. Hydraulic Booster
8. ABS Sensor Cable
9. Sensor Assembly

Fig. 1, Hydraulic ABS Components, Frame-Mounted ECU

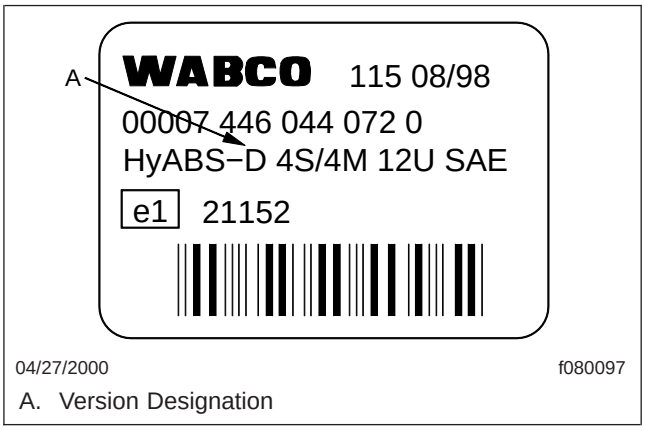
Acterra vehicles use the "D" version of this system. The "D" version ECU has a "D" designation printed on the part number identification tag. See **Fig. 2**.

ABS includes signal-generating tone wheels and sensors located in the rotor assembly of each sensed wheel. The sensors transmit vehicle wheel speed information to an electronic control unit. During emergency braking, the control unit signals the ABS modulator assembly to reduce, maintain or increase hydraulic fluid pressure to the brake caliper. This prevents front and rear wheel lockup and enhances steering control during emergency braking situations.

The ABS electronic control unit is a digital microcomputer that serves as the information processing and command center for the antilock braking system. See **Fig. 3**. The control unit receives and processes vehicle wheel speed information from the sensors. During emergency brake applications, the control unit regulates the braking force applied to each wheel by sending control signals to the ABS modulator assembly. See **Fig. 4**.

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General Information



A. Version Designation

Fig. 2, ECU Identification Tag

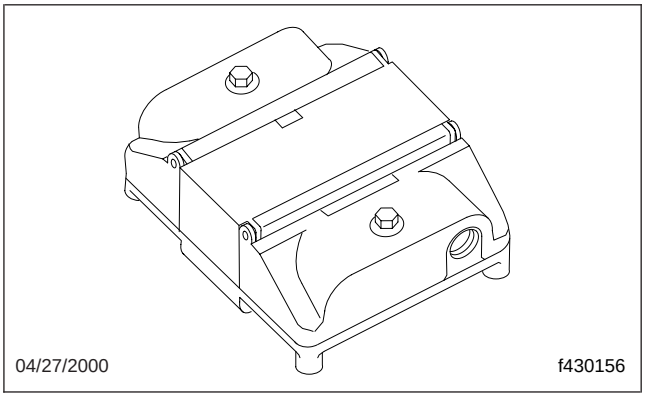


Fig. 3, Frame-Mounted Electronic Control Unit, "D" Version

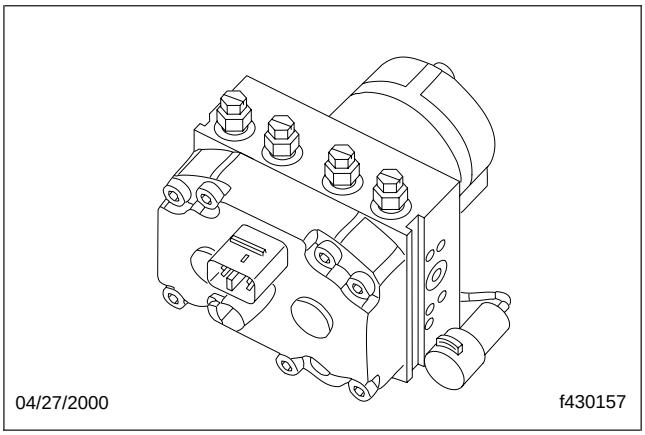


Fig. 4, ABS Modulator Assembly, "D" Version

ABS MAJOR COMPONENTS

Wheel Speed Sensor

When the vehicle is moving, the teeth of the tone wheel cause changes in the magnetic field created by the sensor. The changes create an AC voltage signal that is generated by the sensor to the electronic control unit.

Electronic Control Unit

The electronic control unit (ECU) contains microcomputers to monitor the front and rear control channels. The ECU receives wheel speed signals and interprets these signals to calculate wheel speed and a vehicle reference speed. If the calculations indicate that a wheel is about to lock up, the ECU signals the ABS modulator assembly to adjust braking pressure. When this occurs, drivers may notice a pulsation of the brake pedal.

The ECU constantly monitors the wheel sensors, the ABS modulator assembly and the electrical circuitry.

IMPORTANT: After the ignition switch is turned on, the ABS warning light comes on for about three seconds. After about three seconds, the light goes out only if all of the ABS components are working correctly.

If, during vehicle operation, the ECU senses a failure in any part of the ABS system (a sensor, ABS modulator assembly, short circuit, etc.), the ABS warning light comes on and the circuit where the failure occurred is switched to normal braking action. Even if the ABS system is completely inoperative, normal braking is maintained. See Chapter 6 in the *Acterra Driver's Manual* for complete operating instructions.

ABS Modulator Assembly

The ABS modulator assembly is attached to the left frame rail just ahead of the center or forward rear-suspension crossmember. Depending on the signal received from the electronic control unit, the modulator prevents wheel lockup by adjusting the hydraulic fluid pressure. During normal braking applications, hydraulic fluid flows freely to the brake caliper housing through the modulator.

Within the modulator are an inlet and outlet control valve for each sensed wheel. If the electronic control unit signals indicate wheel lockup is close to occurring, fluid pressure to the brake caliper of the sensed

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wheel is reduced. The inlet valve of the sensed wheel closes, preventing fluid delivery to the brake caliper. At the same time, the outlet valve opens, allowing fluid to flow to an accumulator within the module. From the accumulator, a recirculation pump within the module delivers brake fluid back to the master cylinder.

As wheel speed increases, the ABS modulator assembly allows increases (inlet valve opens and outlet valve closes) or maintains brake pressure until the proper wheel speed is obtained or until wheel lockup occurs and the control cycle starts again.

If maintaining brake pressure, both valves are closed, preventing fluid delivery and maintaining fluid pressure.

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Safety Precautions

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by NIOSH or MSHA. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

Because many brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Because medical experts believe that long-term exposure to some non-asbestos fibers could also be a health hazard, also observe the following precautions if servicing non-asbestos brake linings.

NOTE: The vehicle is originally equipped with non-asbestos brake linings.

Exposure to airborne brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

During brake servicing, wear an air purifying respirator with high-efficiency filters. The respirator and filter must be approved by NIOSH or MSHA, and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, or can’t be used, clean the brake assembly in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with an HEPA filter system, remove dust from the brake rotors, caliper assemblies, dust shields, and brake pads. After vacuuming, remove any remaining dust using a rag soaked in water and wrung until nearly dry.

⚠ WARNING

Hydraulic brake fluid is hazardous, and can cause blindness if it gets in your eyes. Always wear safety glasses when handling brake fluid or bleeding brake components. Brake fluid may also be a skin irritant. If you get it on your skin, wash it off as soon as possible.

Special care must be taken when disposing of used brake fluid. Put the fluid in a sealed plastic container and label it "Used Brake Fluid." Dispose of it in an approved manner. Check with local and state regulations as to the correct disposal procedure.

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Wheel Speed Sensor Replacement

⚠ WARNING

Before working on or around hydraulic brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Replacement

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals.

Front Axle

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Twist and pull the sensor to remove it from the sensor bracket. See Fig. 1.

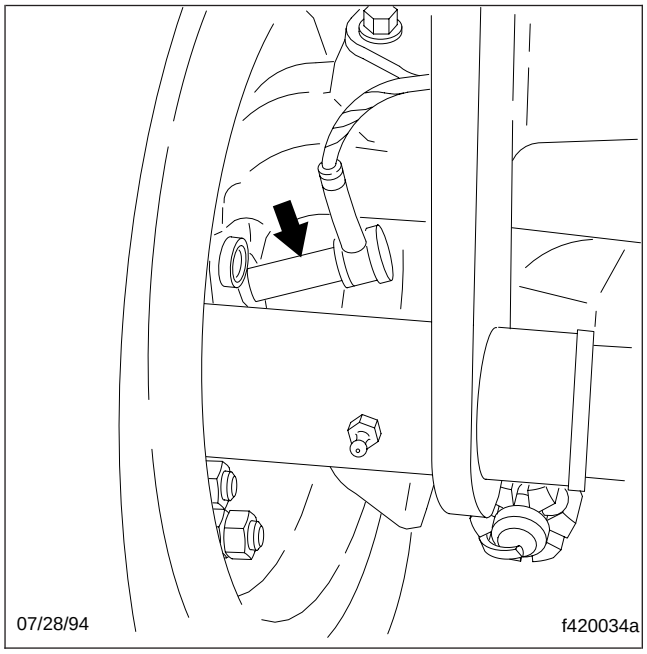


Fig. 1, Remove the Wheel Speed Sensor

3. Remove the sensor cable clip from the top cap.
4. Disconnect the sensor cable from the chassis harness.
5. Remove the sensor spring clip from the sensor bracket.
6. Connect the sensor cable to the chassis harness.
7. Attach the sensor cable to the steering knuckle top cap.
8. Coat the sensor spring clip and the sensor with Mobil HP, Valvoline EP 633, Penzoil 707L or an equivalent.
9. Press the sensor spring clip into the sensor bracket at the brake spider hole until it stops. Make sure the spring clip tabs are on the inboard side of the vehicle.
10. Press the sensor into the sensor spring clip until it is stopped by the tone wheel.
11. Remove the chocks from the rear tires.

Rear Axle

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front tires to prevent vehicle movement.
2. Twist and pull the sensor to remove it from the mounting block in the axle housing.
3. Remove the sensor spring clip.
4. Remove the capscrew that attaches the sensor cable and the hose clamp to the axle tube.
5. Disconnect the sensor cable from the chassis harness.
6. Connect the new sensor cable to the chassis harness.
7. Attach the hose clamp and sensor cable to the axle tube located between the backing plate and the spring plate.
8. Press the sensor spring clip into the mounting block until it stops.
9. Coat the sensor with Mobil HP, Valvoline EP633, Penzoil 707L or an equivalent. Using your hand, push the sensor into the sensor spring clip until it is stopped by the tone wheel.
10. Remove the chocks from the front tires.

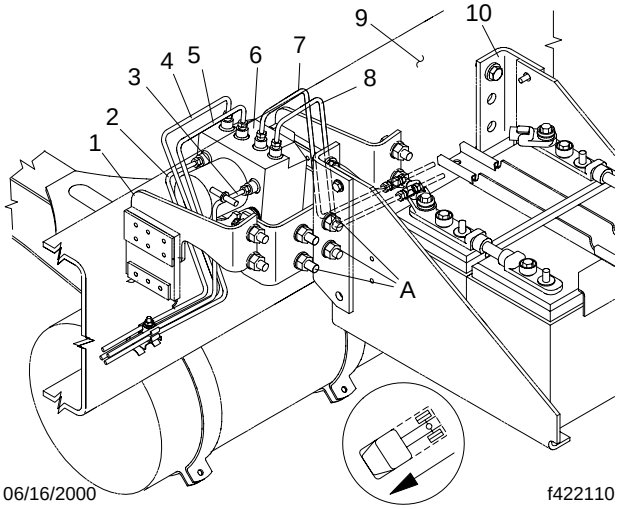
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ABS Modulator Assembly Removal and Installation

⚠ WARNING

Before working on or around hydraulic brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Removal (See Fig. 1)



A. These fasteners hold both the battery box and the hydraulic ABS modulator assembly bracket on the rail.
1. Muffler Mounting Bracket (left-side mounted)
2. To Master Cylinder, Front
3. To Master Cylinder, Rear
4. To Right Front Caliper
5. To Left Front Caliper
6. ABS Modulator Assembly
7. To Right Rear Caliper
8. To Left Rear Caliper
9. Left-Side Frame Rail
10. Battery Box Mounting Bracket

Fig. 1, ABS Modulator Assembly Mounting, "D" Version

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See Group 54 for information on special terminals and connectors and on ordering tools for them.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front and rear tires.
2. Put a container under the modulator to catch leaking brake fluid.
3. Disconnect the wiring from the modulator.

⚠ CAUTION

The modulator assembly contains hydraulic brake fluid, a caustic substance. Remove the brake lines and modulator carefully so that fluid does not leak and cause skin irritation or damage to components.

4. Mark the brake lines for ease of installation. Disconnect the lines.
5. Remove the mounting capscrews, washers and nuts that attach the modulator and bracket assembly to the bracket on the frame rail.
6. Remove the modulator and bracket assembly.

Installation

1. Install the modulator and bracket assembly. Install the mounting capscrews, washers and nuts that attach the modulator and bracket assembly to the bracket on the frame rail. Tighten the modulator and bracket assembly mounting nuts 132 lbf·in (1500 N·cm).
2. Connect the brake lines. Tighten the two small adapters (M10XI) 108 lbf·in (1200 N·cm). Tighten the four large adapters (M12XI) 132 lbf·in (1500 N·cm).
3. Connect the wiring to the modulator.
4. Bleed the brake system following the instructions in Subject 130.
5. Remove the chocks from the tires.

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⚠ WARNING

Before working on or around hydraulic brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Bleeding

⚠ WARNING

Failure to bleed the system whenever any hydraulic system fitting is loosened or disconnected will allow air to remain in the system. This will prevent the hydraulic pressure in the brake system from rising enough to apply the brakes properly. This will cause the stopping distance to increase and can result in serious personal injury.

Properly discard hydraulic brake fluid that is removed from the brake system. Hydraulic brake fluid that is removed can be contaminated and can cause damage, loss of braking and serious personal injury.

Power steering fluid and brake fluid are incompatible. Use only brake fluid for the master cylinder and brake lines. Use only power steering fluid for the power booster. Never mix these two fluids or serious damage to both hydraulic systems will result. The wrong hydraulic brake fluid will damage the rubber parts of the brake caliper and can cause damage, loss of braking and serious personal injury.

Always use new, clean brake fluid that meets DOT 3 specifications when bleeding the master cylinder and service brake system. Never reuse brake fluid, and don't use brake fluid containers for any other purpose. Keep brake fluid containers tightly closed to keep new brake fluid clean and dry.

IMPORTANT: Do not let brake fluid touch any painted surfaces, as it will remove the paint. Brake fluid may also damage certain non-metal surfaces. Do not let fluid get on brake pads or rotors.

Pressure Bleeding

Pressure bleeding is the preferred method for bleeding the service brake system. It requires the use of a special pressure bleeder kit, consisting of a tank, pressure pump and valve, gauge, tubing and adapter. These are available from a number of manufacturers and include instructions for use. See Fig. 1.

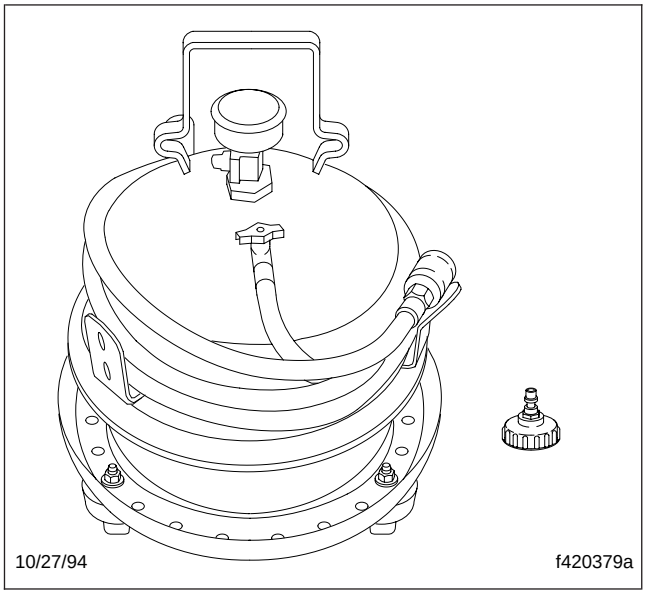


Fig. 1, Pressure Bleeder Kit

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries. The ignition must remain off for the entire bleed procedure.
3. Open the hood.
4. Connect the pressure bleeder to the brake master cylinder reservoir following the manufacturer's instructions.
   - 4.1 Fill the pressure bleeder with new DOT 3 approved brake fluid. Pressurize it according to the manufacturer's instructions.
   - 4.2 Using the supplied adapter, connect the pressure bleeder to the rear compartment of the master cylinder reservoir.
5. Bleed the hydraulic connections at the rear wheel calipers, starting on the right side.

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Hydraulic System Bleeding

5.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

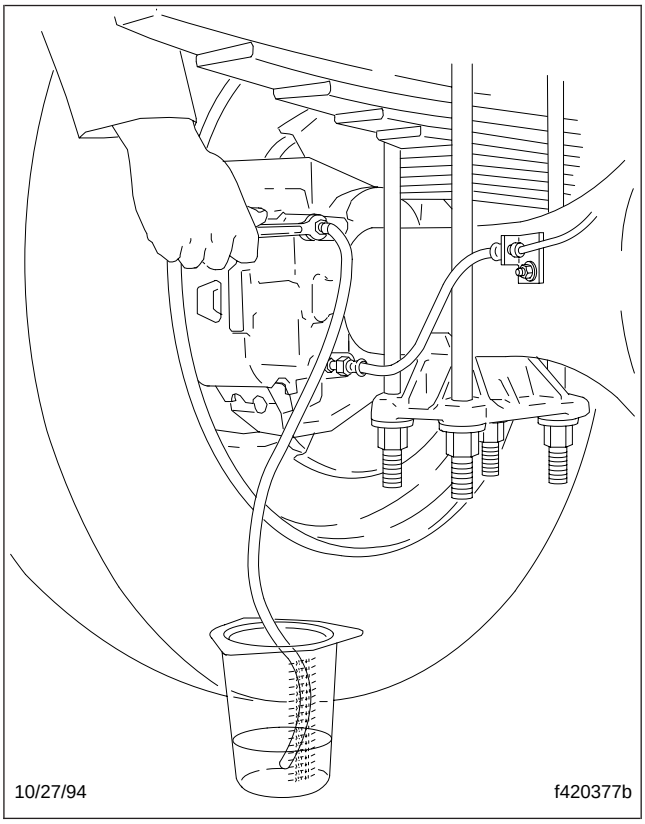


Fig. 2, Bleed the Connections at the Rear Wheel Calipers

5.2 Loosen the bleeder fitting by about a 3/4-turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.

5.3 Move to the left rear caliper and repeat steps for bleeding the caliper.

6. Disconnect the pressure bleeder from the rear compartment of the master cylinder reservoir. Connect it to the front compartment of the reservoir.

7. Bleed the front wheel brake calipers, starting at the right side.

7.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

7.2 Loosen the bleeder fitting by about a 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.

7.3 Move to the left front wheel caliper and repeat steps for bleeding the caliper.

8. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.

9. Check the operation of the brakes by depressing the brake pedal several times until if feels firm. The brake pedal should not go all the way down to the floor. If it does, see "Troubleshooting" in **Section 42.00, Subject 300** and find the problem.

10. Close and latch the hood.

11. Connect the batteries.

12. Remove the chocks from the rear tires.

Manual Bleeding

If you do not have pressure bleeding equipment, you can use the manual bleeding procedure.

IMPORTANT: Do not let the brake master cylinder fluid level get too low during manual bleeding operations. Keep the master cylinder reservoir filled with new, DOT 3 approved brake fluid. Failure to keep the brake reservoir filled could result in more air entering the system, making it impossible to effectively bleed the system.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.

2. Open the hood.

3. Disconnect the batteries. The ignition must remain off for the entire bleed procedure.

4. Bleed the master cylinder.

4.1 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at

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the rear outlet port on the master cylinder. See **Fig. 3**. Loosen the fitting about one turn.

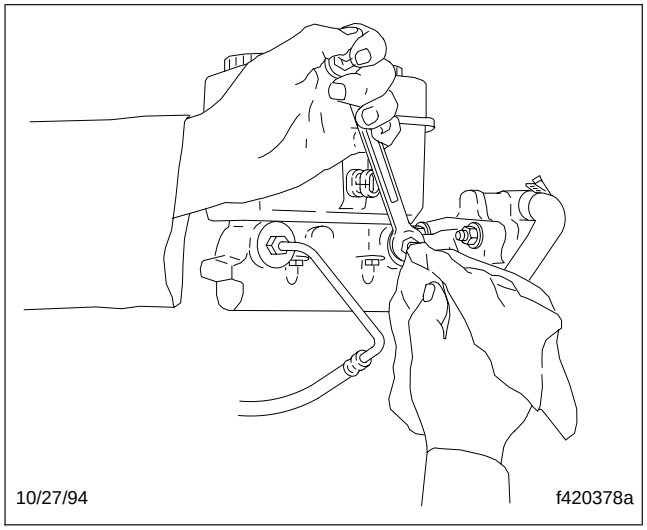


Fig. 3, Loosen the Fitting at the Rear Outlet Port

4.2 Have someone push the brake pedal down slowly by hand to the floor. Brake fluid and any air in the master cylinder will squirt from the fitting.

4.3 *With the brake pedal held down*, tighten the rear hydraulic line fitting firmly.

IMPORTANT: Do not release the brake pedal until the fitting is tightened or more air will get into the system.

4.4 Release the brake pedal.

4.5 Loosen the fitting again and repeat the steps for bleeding as required until no air escapes from the fitting and the brake pedal feels firm.

4.6 Check the fluid level of the rear compartment of the reservoir. Add new DOT 3 approved brake fluid if needed.

4.7 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the front outlet port on the master cylinder. See **Fig. 4**. Loosen the fitting about one turn.

4.8 Repeat steps as required for the front outlet port.

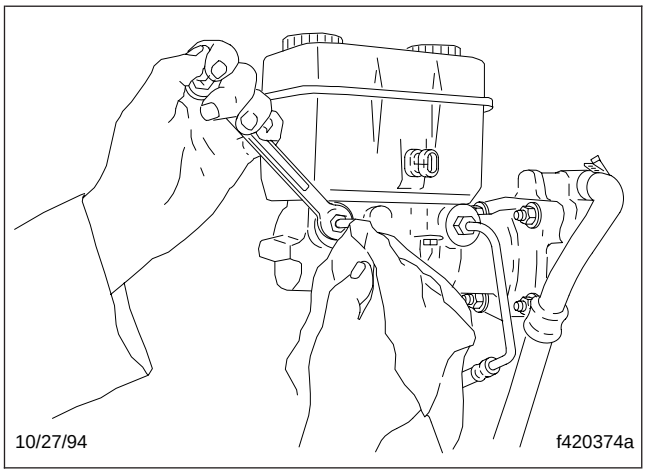


Fig. 4, Loosen the Fitting at the Front Outlet Port

4.9 Check the brake fluid level in the front compartment of the reservoir. Add new DOT 3 approved brake fluid if needed.

5. Bleed the hydraulic connections at the wheel calipers, starting at the right rear wheel caliper.

5.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

5.2 Loosen the bleeder fitting by about a three-quarter turn.

5.3 Have an assistant slowly push the brake pedal to the floor. *With the brake pedal depressed*, tighten the bleeder fitting.

IMPORTANT: Make sure the brake pedal stays depressed while you tighten the fitting. If it is released before you tighten the fitting, more air will get into the system.

5.4 Release the brake pedal. Check the fluid in the tube. If there are air bubbles present, repeat steps as required until the fluid in the tube is completely free of air bubbles.

5.5 Check the brake fluid level in the reservoir. Add new DOT 3 approved brake fluid if needed.

5.6 Repeat the steps for bleeding the connections for the left rear caliper, the right front caliper and the left front caliper.

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Hydraulic System Bleeding

6. Close and latch the hood.
7. Connect the batteries.
8. Remove the chocks from the rear tires.

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WARNING

Before working on or around hydraulic brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Voltage Check

NOTE: Along with the following, the voltage can also be checked using the Meritor WABCO TOOLBOX Software.

IMPORTANT: Voltage must be between 9.5 and 14 volts for the 12-volt hydraulic ABS to function properly.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Turn the ignition on.
3. Check the voltage between Pins 9 and 3, and Pins 9 and 2, on the black X2 ECU connector.
4. If voltage is not between 9.5 and 14 volts, verify proper wiring connections. Make corrections as required.
5. Remove the chocks from the rear tires.

ABS Indicator Light

IMPORTANT: If the ABS indicator light does not come on after the ignition is turned on, check all ABS fuses or circuit breakers and replace if necessary. Check the wiring to the ABS diagnostic switch and the indicator light and repair or replace the wiring as required.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Check the voltage potential at the light socket.
3. Check the continuity of the wires to the socket.
4. Replace the bulb.
5. Remove the chocks from the rear tires.

ABS Blink Code Switch

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Check the resistance between the terminals while cycling the switch. A lack of resistance is an indication of a faulty switch.
3. Disconnect the switch and place a jumper wire across the connector terminals. Check the continuity of the wires to the switch at Pins 8 and 9 on the black X2 ECU connector.
4. Remove the chocks from the rear tires.

Sensor Voltage Output Test

IMPORTANT: Sensor output voltage must be at least 0.2 volts AC at 30 rpm.

WARNING

Block the wheels to prevent the vehicle from moving. Support the vehicle with safety stands. Do not work under a vehicle supported only by jacks. Jacks can slip and fall over. Serious personal injury can result.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front and rear tires to prevent vehicle movement.
2. Turn the ignition off.
3. To measure voltage at the pins on the sensor connector, disconnect the sensor from the chassis harness.
4. Raise the vehicle off of the ground. Put safety stands under the axle.
5. Rotate the wheel by hand at 30 rpm (1/2 revolution per second).
6. Measure the voltage across the two pins at the sensor connector.
7. If the voltage is not greater than 0.2 volts AC, adjust the sensor and recheck. If the voltage is still not greater than 0.2 volts AC, replace the sensor.
8. Remove the safety stands and lower the vehicle.

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Component Tests

9. Remove the chocks from the rear tires.

Sensor Resistance

IMPORTANT: The sensor resistance must be between 500 and 2000 ohms. Measure resistance at the sensor connector or at the pins on the ECU connector.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Turn the ignition off.
3. Measure resistance at the sensor connector. Disconnect the sensor from the chassis harness.
4. Measure the resistance across the two pins at the sensor connector.
5. If the measurement is not between 500 and 2000 ohms, replace the sensor.
6. Remove the chocks from the rear tires.

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Troubleshooting

Meritor WABCO TOOLBOX Software

The Meritor WABCO TOOLBOX Software can be used to diagnose hydraulic antilock brake system (ABS) faults. This software is packaged and launched from ServiceLink and provides J1587 fault codes and on-screen information to make the necessary repairs or replacements. TOOLBOX must be used to reset the ECU memory. The "D" version ECU does not allow reconfiguration through the blink code switch. See *Meritor WABCO Maintenance Manual No. 39, Rev. 1/00*.

ServiceLink

ServiceLink can be used to troubleshoot the Meritor WABCO hydraulic ABS. J1587 fault codes can be read by connecting the vehicle to the ServiceLink computer.

J1587 Fault Codes

The J1587 fault codes are a combination of the message identifier (MID), which indicates the ECU or system with the fault (136 for the hydraulic ABS ECU), and the system identifier (SID), which indicates the specific component within the system with the fault. The failure mode indicator (FMI) identifies a specific problem with the system component. See **Table 1** for a listing of J1587 fault codes. This table also lists the appropriate troubleshooting table to consult for fault code diagnosis.

Fault Codes			
J1587 Fault Code (MID-SID)	**Blink Code**	**Description**	**Troubleshooting Table**
136-001	3-2, 4-2, 5-1, 5-2, 5-3, 5-4	Left Front Wheel Sensor *	**Table 4**
136-002	3-1, 4-1	Right Front Wheel Sensor	**Table 5**
136-003	3-4, 4-4	Left Rear Wheel Sensor	**Table 6**
136-004	3-3, 4-3	Right Rear Wheel Sensor	**Table 7**
136-013	7-3	Retarder	**Table 8**
136-014	8-1, 8-2	Power	**Table 9**
136-023	7-4	ABS Warning Light	**Table 10**
136-030	7-8	Recirculation Pump Relay	**Table 11**
136-042	2-2	Left Front Inlet Solenoid Valve	**Table 12**
136-043	2-1	Right Front Inlet Solenoid Valve	**Table 13**
136-044	2-4	Left Rear Inlet Solenoid Valve	**Table 14**
136-045	2-3	Right Rear Inlet Solenoid Valve	**Table 15**
136-048	2-2	Left Front Outlet Solenoid Valve	**Table 16**
136-049	2-1	Right Front Outlet Solenoid Valve	**Table 17**
136-050	2-4	Left Rear Outlet Solenoid Valve	**Table 18**
136-051	2-3	Right Rear Outlet Solenoid Valve	**Table 19**
136-054	7-7	Recirculation Pump	**Table 20**
136-055	2-7	ECU	**Table 21**
136-251	8-1, 8-2	Low Voltage	**Table 22**

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Troubleshooting

Fault Codes			
J1587 Fault Code (MID-SID)	**Blink Code**	**Description**	**Troubleshooting Table**
136-253	8-4	Internal Tire Parameter	**Table 23**
136-254	8-3	ECU Internal Fault	**Table 24**

* Blink codes 5-1, 5-3 and 5-4 indicate a fault with the right front, right rear and left rear wheel sensors respectively.

Table 1, Fault Codes

Instrument Panel Blink Codes

This system has built-in diagnostics to ensure that all components are operating properly. The ABS warning light in the instrument control unit comes on when the ignition is turned on. After about 3 seconds the light goes out if all of the ABS components are working correctly. If the light stays on, or comes back on later, a problem within the ABS has occurred. The vehicle can continue to be driven, but the ABS could be partially or completely inoperative. To check the fault code recorded, stop the vehicle and turn off the engine. Turn on the ignition switch, but do not start the engine. If the light stays on, there is an "active" system fault that must be repaired to ensure proper system operation. See **Table 1** for a listing of instrument panel blink codes. This table also lists the appropriate troubleshooting table to consult for fault code diagnosis.

Use the ABS CHECK switch, located under the left-side dash, and the ABS light to display system faults. With the ignition switch on, turn on the ABS CHECK switch. The ABS light should go out. After a 1-second pause, the ABS light will blink any active fault codes. The fault code will be indicated by two sets of flashes. The number of blinks displaying the first digit will be a number between one and eight. After a 1-1/2 second pause, the second digit will be displayed. The number of blinks displaying the second digit will be a number between one and eight. After a 4-second pause, the diagnostic code cycle continues to repeat the active fault code until the fault is repaired.

For example, after the ABS CHECK switch has been turned on, the fault code 2–3 will blink, shown by two flashes, a pause of 1-1/2 seconds, followed by three flashes. After a 4-second pause, the same fault code will continue to repeat, always ending with a 4-second pause.

- If it is an active fault, the same fault code will repeat until the ignition switch is turned off. See **Fig. 1**.
- If it is a stored fault, the next fault in the ECU memory will be displayed after the 4-second pause. See **Fig. 2**. The last fault stored in memory is displayed first; each stored fault is displayed only once.
- If there are no fault codes in the ECU memory, blink code 1–1 is displayed, meaning the system is clear. See **Fig. 3**.

Once a fault code has been identified, use a volt/ohmmeter to check the electrical harness at the electronic control unit (ECU) connectors or the modulator assembly connectors. Connect the ohmmeter leads to the applicable pins on each connector. See **Fig. 4** and **Table 2** for a description of the circuit wire numbers and their location within the pin connectors for the ECU. See **Fig. 5** and **Table 3** for the modulator assembly.

Make the necessary repairs and clear the fault code from the ECU memory. If more than one fault exists, it will be displayed after the first one has been cleared from memory.

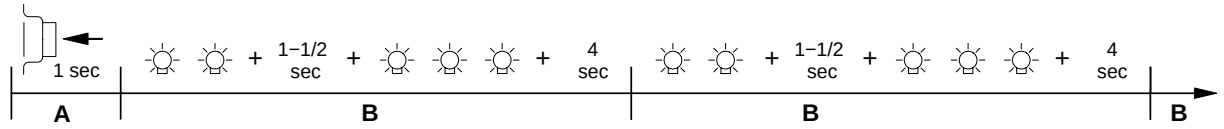
A volt ohmmeter (VOM) can determine the condition of the ABS valves, wheel end sensors and associated wiring.

IMPORTANT: The ignition switch must be off when connecting or disconnecting the ECU.

NOTE: The blink codes are erased from ECU memory as repairs are made. Once a repair has been made, cycle the ignition to ensure the blink code does not reappear. If there are any other outstanding faults, the next blink code will be displayed.

If the ABS light does not operate correctly after the ignition is turned on (the light does not come on at all or it does not go out after about 3 seconds), check

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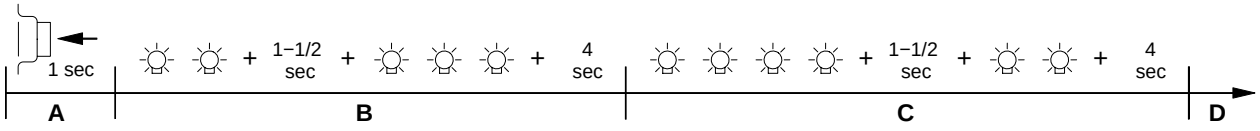


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NOTE: An active fault code repeats until the ignition switch is turned off.

A. Press the ABS CHECK switch. The ABS light goes out. After a 1-second pause, blink codes start.
B. Blink code 2–3: two blinks, a 1-1/2 second pause, three blinks, and a 4-second pause.

Fig. 1, Active Fault Codes Repeat (Blink Code 2-3 Shown)

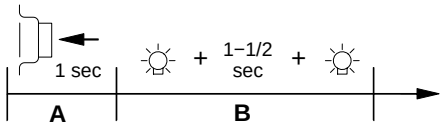


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NOTE: The last fault stored is displayed first; each stored fault is displayed only once.

A. Press the ABS CHECK switch. The ABS light goes out. After a 1-second pause, blink codes start.
B. The newest stored fault is displayed (blink code 2–3 is shown).
C. The second newest stored fault is displayed if one exists (blink code 3–2 is shown).
D. The third newest stored fault is displayed if one exists.

Fig. 2, Stored Fault Codes Display in Sequence



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A. Press the ABS CHECK switch. The ABS light goes out. After a 1-second pause, blink codes start.
B. Blink code 1–1: one blink, a 1-1/2 second pause, and 1 blink.

Fig. 3, No Faults, System OK

all circuit breakers in the control unit panel and replace if necessary. Check the wiring to the ABS CHECK switch and the warning light and repair or replace the wiring as needed. When checking the warning light:

- Replace the bulb;
- Check for a fault in the warning lamp circuit, use ServiceLink or Meritor PC-based diagnostics;

When checking the switch:

- Check the resistance between the terminals while cycling the switch;

The ABS system needs between 9.5 and 14 volts.

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Group 54** for information on special terminals and connectors and ordering tools for them.

See the wiring diagrams in **Specifications, 400** when troubleshooting the ABS system. If a fault cannot be repaired or erased from ECU memory, contact your District Service Manager or call Meritor WABCO at 1-800-535-5560.

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Troubleshooting

Circuit Wire Numbers and Descriptions, "D" Version			
Pin Connector	**Pin Number**	**Acterra Wire Number**	**WABCO Circuit Description**
12-Pin Gray X1	1	—	Not Used
	2	GRDE	Ground
	3	378LFI	Left Front Inlet Valve
	4	378RFI	Right Front Inlet Valve
	5	378LRI	Left Rear Inlet Valve
	6	378RRI	Right Rear Inlet Valve
	7	378RRO	Right Rear Outlet Valve
	8	376LRO	Left Rear Outlet Valve
	9	378RFO	Right Front Outlet Valve
	10	378LFO	Left Front Outlet Valve
	11	—	Not Used
	12	—	Not Used
12-Pin Black X2	1	J1587–	SAE J1587 (–)
	2	376C	ECU Ignition Supply
	3	376B	ECU Supply/Battery
	4	376LI	Warning Light Relay
	5	—	Not Used
	6	376H	Pump Relay
	7	376R	Retarder Relay
	8	376L	ABS Indicator Light and Blink Code Switch
	9	GRD	Ground
	10	376A	Motor Monitor
	11	376B	ECU Supply/Battery
	12	J1587+	SAE J1587 (+)

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Circuit Wire Numbers and Descriptions, "D" Version			
Pin Connector	**Pin Number**	**Acterra Wire Number**	**WABCO Circuit Description**
12-Pin Green X3	1	—	Not Used
	2	—	Not Used
	3	377LR+	Left Rear Sensor
	4	377RF+	Right Front Sensor
	5	377LF+	Left Front Sensor
	6	377RR+	Right Rear Sensor
	7	377RR–	Right Rear Sensor
	8	377LF–	Left Front Sensor
	9	377RF–	Right Front Sensor
	10	377LR–	Left Rear Sensor
	11	—	Not Used
	12	—	Not Used

Table 2, Circuit Wire Numbers and Descriptions, "D" Version

ABS Modulator Assembly Pin Connectors		
Acterra Wire Number	**Pin Number**	**Circuit Description**
1	376LRO	Left Rear Outlet Valve
2	378LRI	Left Rear Inlet Valve
3	GRDE	Ground
4	378RFI	Right Front Inlet Valve
5	378RFO	Right Front Outlet Valve
6	GRDE	Ground
7	GRDE	Ground
8	GRDE	Ground
9	—	Not Used
10	378RRO	Right Rear Outlet Valve
11	378RRI	Right Rear Inlet Valve
12	378LFI	Left Front Inlet Valve
13	378LFO	Left Front Outlet Valve
A	GRD	Pump Ground
B	376A	Pump Power

Table 3, ABS Modulator Assembly Pin Connectors

Erasing a Fault from the ECU Memory

NOTE: An active fault cannot be erased until it has been corrected.

Meritor WABCO recommends that you erase all faults from the ECU memory after they have been noted and corrected.

Stored faults are erased from the ECU memory by doing the following:

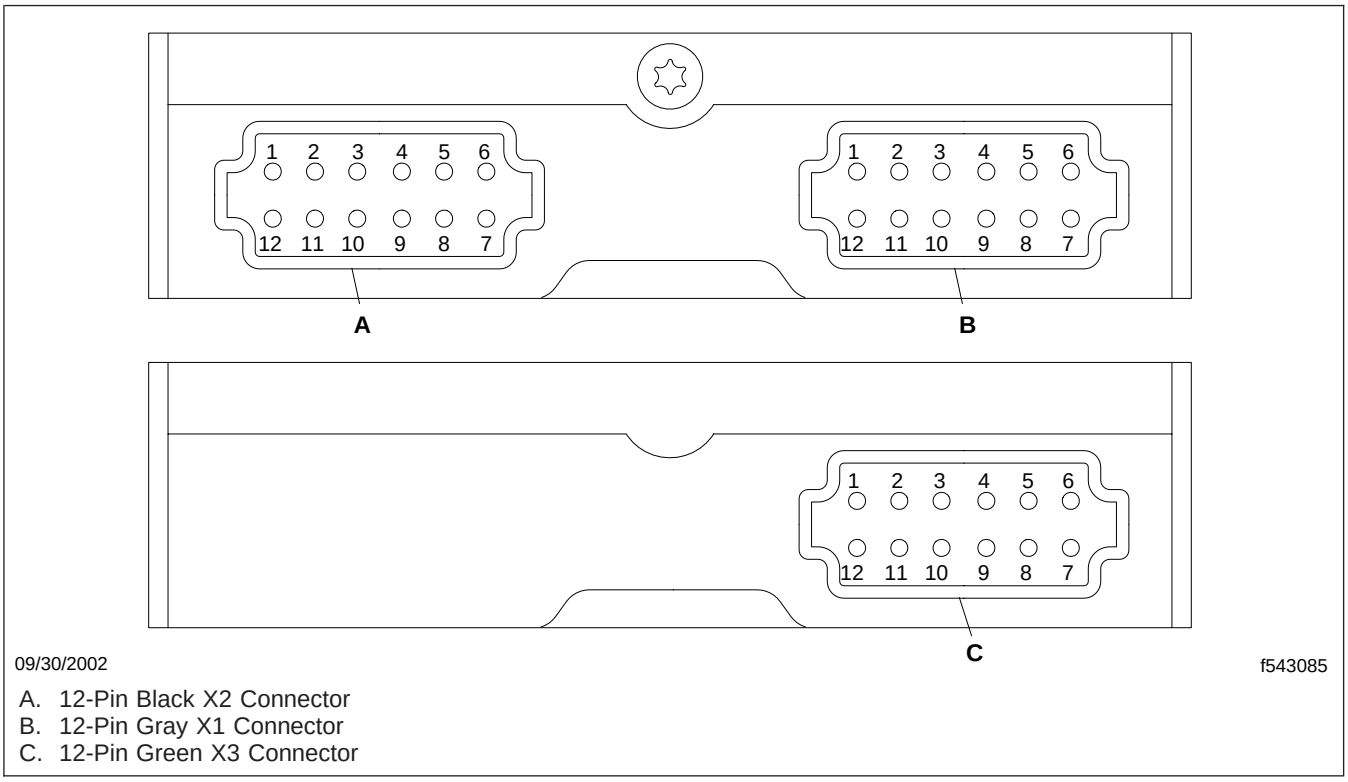
1. Turn the ignition switch on.
2. Press the blink code switch on and hold for 3 seconds.
3. Release the blink code switch.
4. If the ABS light flashes eight times and the system ID code is repeated, all stored faults have been successfully cleared. Turn the ignition OFF.

   Turn the ignition ON. The ABS light stays on because the system is looking for a wheel speed. Drive the vehicle above a speed of 4 mph (6 km/h). Once the ECU senses a wheel speed the light will go out. If the light remains on, there are still active faults.

   If the ABS light does not flash eight times, the active fault still exists. Repair the active fault and repeat the procedure to clear the fault codes.

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Troubleshooting



A. 12-Pin Black X2 Connector
B. 12-Pin Gray X1 Connector
C. 12-Pin Green X3 Connector

Fig. 4, ECU Connectors, "D" Version

Reset Memorized (Learned Components)

The ECU learns whether or not a retarder relay circuit is present. Once the ECU has detected a retarder circuit, it expects to see it every time the vehicle is powered up and will monitor the circuit for faults. If the ECU senses a resistance on the retarder circuit it will automatically learn that the retarder circuit exists. If an engine retarder circuit does not exist, but the ECU has detected one and is indicating faults, something may have been connected (a multimeter, etc.) to the retarder circuit during testing. Moisture, faulty circuit wiring, or moving an ECU from one vehicle to another can also cause the ECU to mistakenly detect a non-existent retarder circuit. If necessary, use the "Reset Memorized" command in the Meritor WABCO TOOLBOX Software to clear the ECU memory of this component. For instructions, see *Meritor WABCO Maintenance Manual No. 39, Rev. 1/00*.

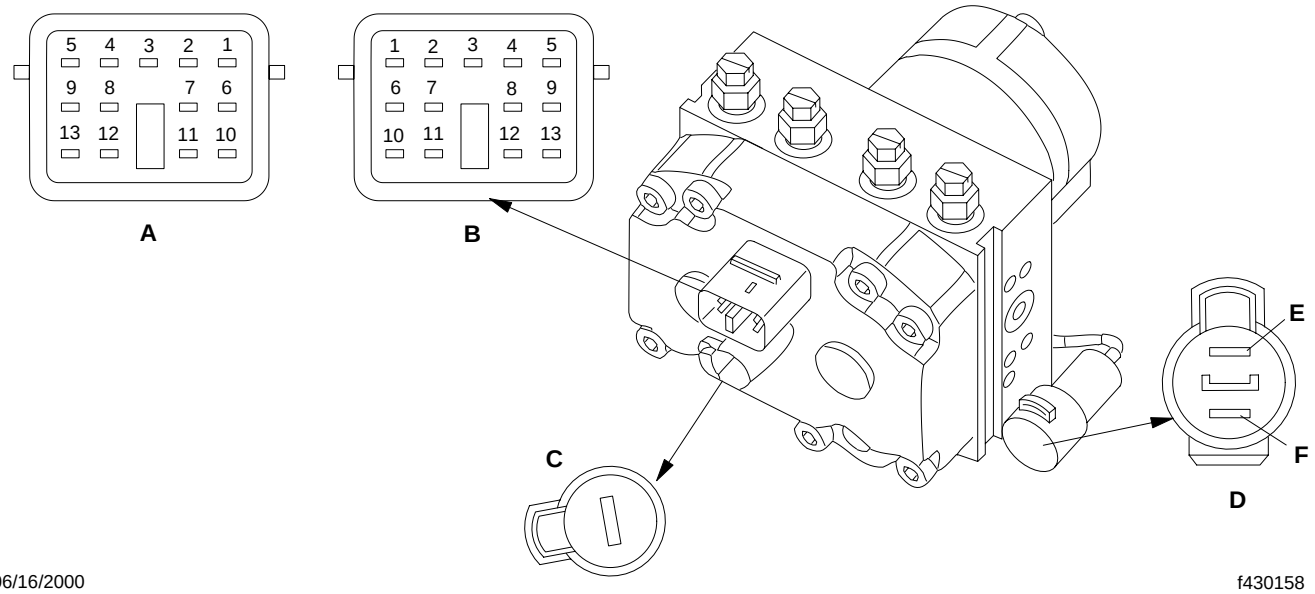
Power Distribution Modules

The cab power distribution module (PDM) is located on the passenger side within the instrument panel. A trim panel covers the PDM and is attached to the instrument panel by quarter-turn fasteners. A decal identifying the location of the fuses, circuit breakers and relays is attached to the back side of the trim panel. See **Fig. 6** for WABCO hydraulic ABS fuses, circuit breakers and relays. See **Group 54** for complete PDM information.

The engine PDM is located in the engine compartment and has a decal identifying the location of fuses, circuit breakers and relays on the outside of the PDM cover. To gain access, open the cover. See **Fig. 7** for WABCO hydraulic ABS fuses, circuit breakers and relays. See **Group 54** for complete PDM information.

Troubleshooting Tables

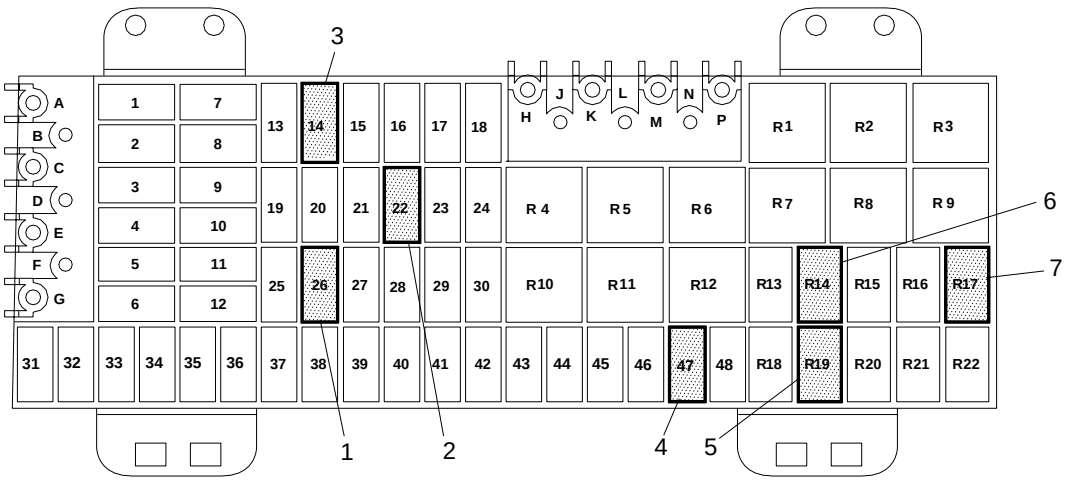
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A. Harness Connector Pinout
B. Modulator Assembly Connector Pinout
C. Main Ground
D. Pump Connector
E. Pin B, Pump Power
F. Pin A, Pump Ground

Fig. 5, ABS Modulator Assembly Pin Connectors, "D" Version



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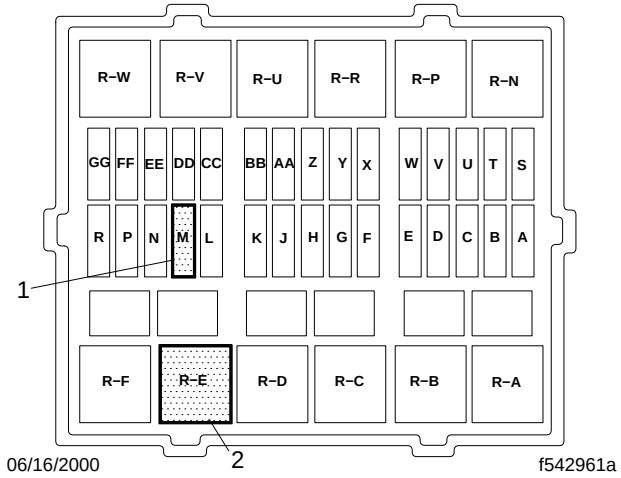
NOTE: The fuses, circuit breakers and relays used for the WABCO hydraulic ABS are shown. See **Group 54** for complete PDM information.

1. Fuse 26, ABS Hydraulic Pump Relay Feed
2. Fuse 22, Ignition Run/Start
3. Fuse 14, ABS
4. Fuse 47, ABS
5. R19, ABS Warning Light Relay
6. R14, Brake Cut-Out
7. R17, Hydraulic Brake Pump Relay

Fig. 6, Cab Power Distribution Module

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Troubleshooting



NOTE: The relays and fuses used for the WABCO hydraulic ABS are shown. See **Group 54** for complete PDM information.

1. Fuse 26, ABS Power 2. ABS Relay

Fig. 7, Engine Power Distribution Module

J1587 Fault 136-001 Left Front Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	001	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across Pins 5 and 8 of the green X3 ECU connector (Circuits 377LF+ and 377 LF–) while rotating the left front wheel 30 rpm.	Voltage greater than 0.2 VAC	Sensor adjustment solved the problem. Clear the stored faults and drive the vehicle 4 mph (6 km/h).	3-2
					Voltage less than 0.2 VAC	Check for excessive wheel bearing end play. Repair as necessary.	

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J1587 Fault 136-001 Left Front Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	001	02	Intermittent open circuit or incorrect sensor resistance NOTE: This SAE J1587 fault code can also be caused by incorrect or mixed tire size. The only way to determine the exact fault is to use blink code diagnostics. If blink code is 5-1, 5-2, 5-3 or 5-4, perform Test 4. If blink code is 4-2, perform Tests 2 and 3.	2. Measure the resistance across Pins 5 and 8 of the green X3 ECU connector (Circuits 377LF– and 377 LF+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377LF+ and 377LF– and repair as necessary. If the problem persists, suspect the ECU is at fault.	4-2
					Resistance reading below 500 or above 2000 ohms	Go to Test 3.	
				3. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377LF+ and 377LF–). Repair as necessary. Go to Test 4.	
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.	
136	001	02	Incorrect or mixed tire size NOTE: This SAE J1587 fault code can also be caused by an intermittent open circuit or incorrect sensor resistance. The only way to determine the exact fault is to use blink code diagnostics. If blink code is 5-1, 5-2, 5-3 or 5-4, perform Test 4. If blink code is 4-2, perform Tests 2 and 3.	4. Check for tire size deviation in excess of 16 percent. Mixed tire sizes can cause this fault.	Correct tire size and size variation does not exceed 16 percent	Perform Test 2 and Test 3 if not already done. If the problem is not found, verify the fault and check the ECU.	5-1 5-2 5-3 5-4
					Incorrect tire size or size variation exceeds 16 percent	Install the correct size tires.	

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Troubleshooting

J1587 Fault 136-001 Left Front Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	001	05	Open circuit	5. Measure the resistance across Pins 5 and 8 of the green X3 ECU connector (Circuits 377LF– and 377LF+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377LF+ and 377LF– and repair as necessary. If the problem persists, suspect the ECU is at fault.	4-2
					Resistance reading below 500 or above 2000 ohms	Go to Test 6.	
				6. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377LF+ and 377LF–). Repair as necessary.	
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.	

Table 4, J1587 Fault 136-001 Left Front Wheel Sensor

J1587 Fault 136-002 Right Front Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	002	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across Pins 4 and 9 of the green X3 ECU connector (Circuits 377RF+ and 377RF–) while rotating the right front wheel 30 rpm.	Voltage greater than 0.2 VAC	Sensor adjustment solved the problem. Clear the stored faults and drive the vehicle 4 mph (6 km/h).	3-1
					Voltage less than 0.2 VAC	Check for excessive wheel bearing end play. Repair as necessary.	

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J1587 Fault 136-002 Right Front Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	002	02	Intermittent open circuit or incorrect sensor resistance	2. Measure the resistance across Pins 4 and 9 of the green X3 ECU connector (Circuits 377RF– and 377RF+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377RF+ and 377RF– and repair as necessary. If the problem persists, suspect the ECU is at fault.	4-1
					Resistance reading below 500 or above 2000 ohms	Go to Test 3.	
				3. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377RF+ and 377RF–). Repair as necessary.	
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.	
136	002	05	Open circuit	4. Measure the resistance across Pins 4 and 9 of the green X3 ECU connector (Circuits 377RF– and 377RF+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377RF+ and 377RF– and repair as necessary. If the problem persists, suspect the ECU is at fault.	4-1
					Resistance reading below 500 or above 2000 ohms	Go to Test 5.	
				5. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377RF+ and 377RF–). Repair as necessary.	
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.	

Table 5, J1587 Fault 136-002 Right Front Wheel Sensor

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Troubleshooting

J1587 Fault 136-003 Left Rear Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	003	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across Pins 3 and 10 of the green X3 ECU connector (Circuits 377LR+ and 377LR–) while rotating the left rear wheel 30 rpm.	Voltage greater than 0.2 VAC	Sensor adjustment solved the problem. Clear the stored faults and drive the vehicle 4 mph (6 km/h).	3-4
					Voltage less than 0.2 VAC	Check for excessive wheel bearing end play. Repair as necessary.	
136	003	02	Intermittent open circuit or incorrect sensor resistance	2. Measure the resistance across Pins 3 and 10 of the green X3 ECU connector (Circuits 377LR– and 377LR+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377LR+ and 377LR– and repair as necessary. If the problem persists, suspect the ECU is at fault.	4-4
					Resistance reading below 500 or above 2000 ohms	Go to Test 3.	
				3. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377LR+ and 377LR–). Repair as necessary.	
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.	

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J1587 Fault 136-003 Left Rear Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	003	05	Open circuit	4. Measure the resistance across Pins 3 and 10 of the green X3 ECU connector (Circuits 377LR– and 377LR+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377LR+ and 377LR– and repair as necessary. If the problem persists, suspect the ECU is at fault.	4-4
					Resistance reading below 500 or above 2000 ohms	Go to Test 5.	
				5. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377LR+ and 377LR–). Repair as necessary.	
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.	

Table 6, J1587 Fault 136-003 Left Rear Wheel Sensor

J1587 Fault 136-004 Right Rear Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	004	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across Pins 6 and 7 of the green X3 ECU connector (Circuits 377RR+ and 377RR–) while rotating the right rear wheel 30 rpm.	Voltage greater than 0.2 VAC	Sensor adjustment solved the problem. Clear the stored faults and drive the vehicle 4 mph (6 km/h).	3-3
					Voltage less than 0.2 VAC	Check for excessive wheel bearing end play. Repair as necessary.	

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Troubleshooting

J1587 Fault 136-004 Right Rear Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	004	02	Intermittent open circuit or incorrect sensor resistance	2. Measure the resistance across Pins 6 and 7 of the green X3 ECU connector (Circuits 377RR– and 377RR+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377RR+ and 377RR– and repair as necessary. If the problem persists, suspect the ECU is at fault.	4-3
					Resistance reading below 500 or above 2000 ohms	Go to Test 3.	
				3. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377RR+ and 377RR–). Repair as necessary.	
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.	
136	004	05	Open circuit	4. Measure the resistance across Pins 6 and 7 of the green X3 ECU connector (Circuits 377RR– and 377RR+).	Resistance reading between 500 and 2000 ohms	Check for intermittent, loose or poor connections in Circuits 377RR+ and 377RR– and repair as necessary. If the problem persists, suspect the ECU is at fault.	4-3
					Resistance reading below 500 or above 2000 ohms	Go to Test 5.	
				5. Disconnect the sensor at the sensor connector. Measure the resistance at the sensor connector (on the sensor side).	Resistance reading between 500 and 2000 ohms	Check the wiring between the ECU and the wheel sensor (Circuits 377RR+ and 377RR–). Repair as necessary.	
					Resistance reading below 500 or above 2000 ohms	Replace the wheel sensor.	

Table 7, J1587 Fault 136-004 Right Rear Wheel Sensor

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J1587 Fault 136-013 Retarder							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	013	03	Short to power	1. Disconnect the black X2 connector at the ECU. With the ignition ON, measure the voltage between Pin 7 of the black X2 ECU connector and a good chassis ground.	Voltage zero	Check for an intermittent short to power in Circuit 376R. If the problem persists, suspect the ECU is at fault.	7-3
					Voltage not zero	Check for a short to power in Circuit 376R. Repair as necessary.	
136	013	05	Open circuit	2. Disconnect the black X2 connector at the ECU. With the ignition OFF, measure the resistance between Pin 7 of the black X2 ECU connector and a good chassis ground.	Resistance between 50 and 200 ohms	Check Circuit 376R for an intermittent open circuit. Repair as necessary. If the problem persists, suspect the ECU is at fault.	
					Resistance above 200 ohms	Check Relay R14 for an open circuit across the relay coil. Check for an open in Circuit 376R. Repair as necessary.	
136	013	06	Short to ground	3. Disconnect the black X2 connector at the ECU. With the ignition OFF, measure the resistance between Pin 7 of the black X2 ECU connector and a good chassis ground.	Resistance between 50 and 200 ohms	Check Circuit 376R for an intermittent short to ground circuit. Repair as necessary. If the problem persists, suspect the ECU is at fault.	
					Resistance below 50 ohms	Check Relay R14 for a short circuit across the relay coil. Check for a short to ground in Circuit 376R. Repair as necessary.	

Table 8, J1587 Fault 136-013 Retarder

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Troubleshooting

J1587 Fault 136-014 Power							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	014	03	Voltage supplied to ECU with ignition OFF	1. With the ignition OFF, measure the voltage between Pin 2 of the black X2 ECU connector and a good chassis ground.	Voltage zero	Check Circuit 376C for an intermittent short to battery voltage with the ignition OFF. If the problem persists, suspect the ECU is at fault.	8-2 *
					Voltage not zero	Check Circuit 376C for a short to battery voltage and check for proper wiring connections. Repair as necessary.	
136	014	04	No voltage supplied to ECU with ignition ON	2. With the ignition ON, measure the voltage between Pin 2 of the black X2 ECU connector and a good chassis ground.	Voltage between 9.5 and 14 volts	Check Circuit 376C for an intermittent open circuit. If the problem persists, suspect the ECU is at fault.	8-1 *
					Voltage below 9.5 volts	Check Circuit 376C for an open circuit and check Fuse 47. Repair as necessary.	

* There is additional troubleshooting information for this blink code in Table 22.

Table 9, J1587 Fault 136-014 Power

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J1587 Fault 136-023 ABS Warning Light							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	023	05	Open circuit or low current	1. Disconnect the black X2 connector from the ECU. Turn the ignition ON.	ABS light illuminates	Check for intermittent wiring connections in Circuit 376L. If the wiring is OK, suspect the ECU is at fault.	7-4
					ABS light does not illuminate	Go to Test 2.	
				2. Turn the ignition OFF and disconnect the black X2 connector from the ECU. Measure the resistance in Circuit 376L between Pin 8 of the black X2 ECU connector and a good chassis ground.	Close to zero resistance	Go to Test 3.	
					Not close to zero resistance	Check Circuit 376L between the black X2 ECU connector and bulkhead connector C, and between bulkhead connector C and Splice S2. Check for sticking ABS lamp relay and check the ground circuit to the relay. Repair as necessary.	
				3. Replace the ABS light in the instrumentation control unit (ICU3) with a known good one. Leave the black X2 ECU connector disconnected. Turn the ignition ON.	ABS light illuminates	Replace the ABS light.	
					ABS light does not illuminate	Go to Test 4.	
				4. Disconnect the B connector from the back of the ICU3. Measure the resistance in Circuit 376L and 376L1 between ICU3 connector Pin B11 and Pin 8 of the black X2 ECU connector.	Close to zero resistance	Check the ICU3. Replace as necessary.	
					Not close to zero resistance	Check Circuit 376L1 between Splice S2 and the ICU3. Repair as necessary.	

Table 10, J1587 Fault 136-023 ABS Warning Light

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Troubleshooting

J1587 Fault 136-030 Recirculation Pump Relay							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	030	03	Relay shorted to power	1. Disconnect the black X2 ECU connector. With the ignition ON, measure the voltage between Pin 6 and a good chassis ground.	Voltage zero	If the problem persists, suspect the ECU is at fault.	7-8
					Voltage not zero	Circuit 376H is shorted to power. Repair as necessary.	
136	030	05	Relay open circuit	2. Disconnect the black X2 ECU connector. Measure the resistance between Pin 6 and a good chassis ground.	Resistance between 50 and 200 ohms	If the problem persists, suspect the ECU is at fault.	
					Resistance below 50 or above 200 ohms	Check the relay coil, relay coil ground circuit, and Circuit 376H for an open circuit. Repair as necessary.	
136	030	06	Relay short to ground	3. Disconnect the black X2 ECU connector. Measure the resistance between Pin 6 and a good chassis ground.	Resistance between 50 and 200 ohms	If the problem persists, suspect the ECU is at fault.	
					Resistance below 50 or above 200 ohms	Check Circuit 376H for a short to ground. Repair as necessary.	
136	030	07	Pump relay sticks, pump continues to run when ECU deactivates the relay NOTE: The problem may be intermittent and a new relay may be required to correct the fault.	4. If the fault is active, disconnect the black X2 connector from the ECU. With the ignition ON, check to see if the recirculation pump is running.	Pump OFF	The ABS pump relay (R17) may be intermittently sticking. Try a new relay and verify that the problem is solved.	
					Pump ON	The ABS pump relay (R17) is sticking. Replace the relay.	

Table 11, J1587 Fault 136-030 Recirculation Pump Relay

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J1587 Fault 136-042 Left Front Inlet Solenoid Valve							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	042	03 05 06	Shorted to power (inlet valve) Open circuit (inlet valve) Shorted to ground (inlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 3 and 2 of the gray X1 ECU connector (Circuits 378LFI and GRDE).	Resistance reading 6.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.	2-2
					Resistance reading not 6.5±0.5 ohms	Go to Test 2.	
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.	
					Resistance reading not close to zero	Check and repair the ground circuit.	
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.	
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.	
				4. Measure the resistance in Circuit 378LFI between modulator connector Pin 12 and connector Pin 3 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.	
					Resistance reading not close to zero	Repair Circuit 378LFI.	
				5. With the modulator valve connector removed, measure the resistance across Pins 12 and 8 on the modulator connector.	Resistance reading 6.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.	
					Resistance reading not 6.5±0.5 ohms	Replace the modulator valve.	

Table 12, J1587 Fault 136-042 Left Front Inlet Solenoid Valve

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Troubleshooting

J1587 Fault 136-043 Right Front Inlet Solenoid Valve							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	043	03 05 06	Shorted to power (inlet valve) Open circuit (inlet valve) Shorted to ground (inlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 4 and 2 of the gray X1 ECU connector (Circuits 378RFI and GRDE).	Resistance reading 6.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.	2-1
					Resistance reading not 6.5±0.5 ohms	Go to Test 2.	
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.	
					Resistance reading not close to zero	Check and repair the ground circuit.	
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.	
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.	
				4. Measure the resistance in Circuit 378RFI between modulator connector Pin 4 and connector Pin 4 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.	
					Resistance reading not close to zero	Repair Circuit 378RFI.	
				5. With the modulator valve connector removed, measure the resistance across Pins 4 and 8 on the modulator connector.	Resistance reading 6.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.	
					Resistance reading not 6.5±0.5 ohms	Replace the modulator valve.	

Table 13, J1587 Fault 136-043 Right Front Inlet Solenoid Valve

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J1587 Fault 136-044 Left Rear Inlet Solenoid Valve							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	044	03 05 06	Shorted to power (inlet valve) Open circuit (inlet valve) Shorted to ground (inlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 5 and 2 of the gray X1 ECU connector (Circuits 378LRI and GRDE).	Resistance reading 6.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.	2-4
					Resistance reading not 6.5±0.5 ohms	Go to Test 2.	
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.	
					Resistance reading not close to zero	Check and repair the ground circuit.	
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.	
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.	
				4. Measure the resistance in Circuit 378LRI between modulator connector Pin 2 and connector Pin 5 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.	
					Resistance reading not close to zero	Repair Circuit 378LRI.	
				5. With the modulator valve connector removed, measure the resistance across Pins 2 and 8 on the modulator connector.	Resistance reading 6.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.	
					Resistance reading not 6.5±0.5 ohms	Replace the modulator valve.	

Table 14, J1587 Fault 136-044 Left Rear Inlet Solenoid Valve

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Troubleshooting

J1587 Fault 136-045 Right Rear Inlet Solenoid Valve							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	045	03 05 06	Shorted to power (inlet valve) Open circuit (inlet valve) Shorted to ground (inlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 6 and 2 of the gray X1 ECU connector (Circuits 378RRI and GRDE).	Resistance reading 6.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.	2-3
					Resistance reading not 6.5±0.5 ohms	Go to Test 2.	
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.	
					Resistance reading not close to zero	Check and repair the ground circuit.	
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.	
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.	
				4. Measure the resistance in Circuit 378RRI between modulator connector Pin 11 and connector Pin 6 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.	
					Resistance reading not close to zero	Repair Circuit 378RRI.	
				5. With the modulator valve connector removed, measure the resistance across Pins 11 and 8 on the modulator connector.	Resistance reading 6.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.	
					Resistance reading not 6.5±0.5 ohms	Replace the modulator valve.	

Table 15, J1587 Fault 136-045 Right Rear Inlet Solenoid Valve

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J1587 Fault 136-048 Left Front Outlet Solenoid Valve							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	048	03 05 06	Shorted to power (outlet valve) Open circuit (outlet valve) Shorted to ground (outlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 10 and 2 of the gray X1 ECU connector (Circuits 378LFO and GRDE).	Resistance reading 3.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.	2-2
					Resistance reading not 3.5±0.5 ohms	Go to Test 2.	
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.	
					Resistance reading not close to zero	Check and repair the ground circuit.	
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.	
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.	
				4. Measure the resistance in Circuit 378LFO between modulator connector Pin 13 and connector Pin 10 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.	
					Resistance reading not close to zero	Repair Circuit 378LFO.	
				5. With the modulator valve connector removed, measure the resistance across Pins 13 and 8 on the modulator connector.	Resistance reading 3.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.	
					Resistance reading not 3.5±0.5 ohms	Replace the modulator valve.	

Table 16, J1587 Fault 136-048 Left Front Outlet Solenoid Valve

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Troubleshooting

J1587 Fault 136-049 Right Front Outlet Solenoid Valve							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	049	03 05 06	Shorted to power (outlet valve) Open circuit (outlet valve) Shorted to ground (outlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 9 and 2 of the gray X1 ECU connector (Circuits 378RFO and GRDE).	Resistance reading 3.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.	2-1
					Resistance reading not 3.5±0.5 ohms	Go to Test 2.	
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.	
					Resistance reading not close to zero	Check and repair the ground circuit.	
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.	
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.	
				4. Measure the resistance in Circuit 378RFO between modulator connector Pin 5 and connector Pin 9 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.	
					Resistance reading not close to zero	Repair Circuit 378RFO.	
				5. With the modulator valve connector removed, measure the resistance across Pins 5 and 8 on the modulator connector.	Resistance reading 3.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.	
					Resistance reading not 3.5±0.5 ohms	Replace the modulator valve.	

Table 17, J1587 Fault 136-049 Right Front Outlet Solenoid Valve

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J1587 Fault 136-050 Left Rear Outlet Solenoid Valve							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	050	03 05 06	Shorted to power (outlet valve) Open circuit (outlet valve) Shorted to ground (outlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 8 and 2 of the gray X1 ECU connector (Circuits 378LRO and GRDE).	Resistance reading 3.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.	2-4
					Resistance reading not 3.5±0.5 ohms	Go to Test 2.	
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.	
					Resistance reading not close to zero	Check and repair the ground circuit.	
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.	
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.	
				4. Measure the resistance in Circuit 378LRO between modulator connector Pin 1 and connector Pin 8 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.	
					Resistance reading not close to zero	Repair Circuit 378LRO.	
				5. With the modulator valve connector removed, measure the resistance across Pins 1 and 8 on the modulator connector.	Resistance reading 3.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.	
					Resistance reading not 3.5±0.5 ohms	Replace the modulator valve.	

Table 18, J1587 Fault 136-050 Left Rear Outlet Solenoid Valve

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Troubleshooting

J1587 Fault 136-051 Right Rear Outlet Solenoid Valve							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	051	03 05 06	Shorted to power (outlet valve) Open circuit (outlet valve) Shorted to ground (outlet valve) NOTE: Check for an open circuit in the wiring between the ECU and the modulator valve. Check the ground circuit to the modulator valve.	1. Measure the resistance across Pins 7 and 2 of the gray X1 ECU connector (Circuits 378RRO and GRDE).	Resistance reading 3.5±0.5 ohms	Check for intermittent wiring connections. If the wiring is OK, suspect the ECU is at fault.	2-3
					Resistance reading not 3.5±0.5 ohms	Go to Test 2.	
				2. Check the ground circuit by measuring the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance reading close to zero	Go to Test 3.	
					Resistance reading not close to zero	Check and repair the ground circuit.	
				3. With the modulator valve connector removed, measure the resistance between Pin 8 on the modulator connector and a good chassis ground.	Resistance reading close to zero	Go to Test 4.	
					Resistance reading not close to zero	Check the modulator ground circuit, repair as necessary.	
				4. Measure the resistance in Circuit 378RRO between modulator connector Pin 10 and connector Pin 7 on the gray X1 ECU connector.	Resistance reading close to zero	Go to Test 5.	
					Resistance reading not close to zero	Repair Circuit 378RRO.	
				5. With the modulator valve connector removed, measure the resistance across Pins 10 and 8 on the modulator connector.	Resistance reading 3.5±0.5 ohms	Repeat Tests 1 through 5. The problem may be intermittent. If the wiring is OK, suspect the ECU is at fault.	
					Resistance reading not 3.5±0.5 ohms	Replace the modulator valve.	

Table 19, J1587 Fault 136-051 Right Rear Outlet Solenoid Valve

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J1587 Fault 136-054 Recirculation Pump							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	054	03	Recirculation pump on without being activated by ECU NOTE: In this case the ECU is sensing voltage on the pump monitor circuit (Pin 10 of the black X2 connector) when the pump relay was not activated by the ECU (Pin 6 of the black X2 connector).	1. Remove the black X2 connector from the ECU. With the ignition ON, measure the voltage between Pin 10 and a good chassis ground.	Voltage zero	Check the ECU and verify the fault.	7-7
					Voltage not zero	Go to Test 2.	
				2. Remove the ABS pump relay (R17) and repeat Test 1.	Voltage zero	Check Relay R17; it may be sticking or shorted.	
					Voltage not zero	Check for a short to power in Circuit 376A causing the pump to run when it should not be. Repair as necessary.	
136	054	04	Recirculation pump does not switch on when activated by the ECU NOTE: In this case the ECU does not sense voltage on the pump monitor circuit (Pin 10 of the black X2 ECU connector) when the pump relay was activated by the ECU (Pin 6 of the black X2 ECU connector).	3. Remove the black X2 connector from the ECU. With the ignition ON, link Pins 6 and 3 while measuring the voltage between Pin 10 and a good chassis ground. The pump should run (do not hold for more than 1 minute).	Voltage between 9.5 and 14 volts	Check for intermittent connections in Circuit 376A and check Relay R17 for intermittent operation. Repair as necessary.	
					Voltage below 9.5 or above 14 volts	Check Circuit 376A and check Relay R17. Repair as necessary.	
136	054	07	Recirculation pump sticks or is locked NOTE: In this case, the ECU senses high current on the pump monitor circuit (Pin 10 of the black X2 ECU connector) indicating the pump motor is locked.	4. Remove the black X2 connector from the ECU. With the ignition ON, momentarily link Pins 6 and 3. The pump should run (do not hold for more than 1 minute).	Pump runs	Repeat the test to verify. If the fault persists, suspect a problem with the ECU.	
					Pump does not run	Replace the recirculation pump.	

Table 20, J1587 Fault 136-054 Recirculation Pump

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Troubleshooting

J1587 Fault 136-055 ECU							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	055	02	Reference to ground interrupted	1. With the ignition OFF, measure the voltage between Pin 2 of the gray X1 ECU connector (Circuit GRDE) and a good chassis ground.	Voltage zero volts	Go to Test 2.	2-7
					Voltage not zero volts	Check the ground circuit for a short to positive voltage.	
				2. Measure the resistance between Pin 2 of the gray X1 ECU connector and a good chassis ground.	Resistance near zero ohms	Check the ECU ground circuit (GRDE) for an intermittent or loose connection. Check ground Splice S2. If the problem persists, suspect the ECU is at fault.	
					Resistance above zero ohms	Check the ECU ground circuit (GRDE). Repair as necessary.	

Table 21, J1587 Fault 136-055 ECU

J1587 Fault 136-251 Low Voltage							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	251	03	Voltage too high NOTE: Voltage to the ABS ECU must be between 9.5 and 14 volts to function properly.	1. Disconnect the black X2 ECU connector. Start the engine and run it at governed speed while measuring the voltage between Pins 9 and 3.	Voltage between 9.5 and 14 volts	Check the electrical system. If the problem persists, suspect the ECU is at fault.	8-2 *
					Voltage below 9.5 or above 14 volts	Check the batteries and charging system for malfunction. Repair as necessary.	
136	251	04	Low voltage to ABS solenoid valves NOTE: Voltage to the ABS ECU must be between 9.5 and 14 volts to function properly.	2. Disconnect the black X2 ECU connector. Start the engine and run it at idle while measuring the voltage between Pins 3 and 9 of the black X2 ECU connector.	Voltage between 9.5 and 14 volts	Verify that the batteries were not drained or the charging system was not overloaded when the fault occurred. If the problem persists, suspect the ECU is at fault.	8-1 *
					Voltage below 9.5 or above 14 volts	Check the batteries and charging system for malfunction. Repair as necessary.	

* There is additional troubleshooting information for this blink code in Table 9.

Table 22, J1587 Fault 136-251 Low Voltage

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J1587 Fault 136-253 Internal Tire Parameter							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	253	02	Incorrect internal tire parameter	—	—	Contact Meritor WABCO (1-800-535-5560).	8-4

Table 23, J1587 Fault 136-253 Internal Tire Parameter

J1587 Fault 136-254 ECU Internal Fault							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	254	12	Internal ECU Fault	—	—	Replace the ECU.	8-3

Table 24, J1587 Fault 136-254 ECU Internal Fault

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For a full view of the "D" version wiring diagram, see **Fig. 1**.

For partial (detailed) views of the "D" version wiring diagram, see **Fig. 2** and **Fig. 3**.

For the hydraulic pump circuit, see **Fig. 4**.

For the exhaust brake circuit, see **Fig. 5**.

For a full view of the "D" version engine power distribution module (PDM) harness, see **Fig. 6**.

For partial (detailed) views of the "D" version engine PDM harness, see **Fig. 7** and **Fig. 8**.

For the wheel sensor harness assembly, see **Fig. 9**.

For the ABS chassis harness assembly, see **Fig. 10**.

For a plumbing diagram of the "D" version hydraulic ABS system, see **Fig. 11**.

For the "D" version ECU harness assembly, see **Fig. 12**.

For the dash overlay harness, see **Fig. 13**.

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Specifications

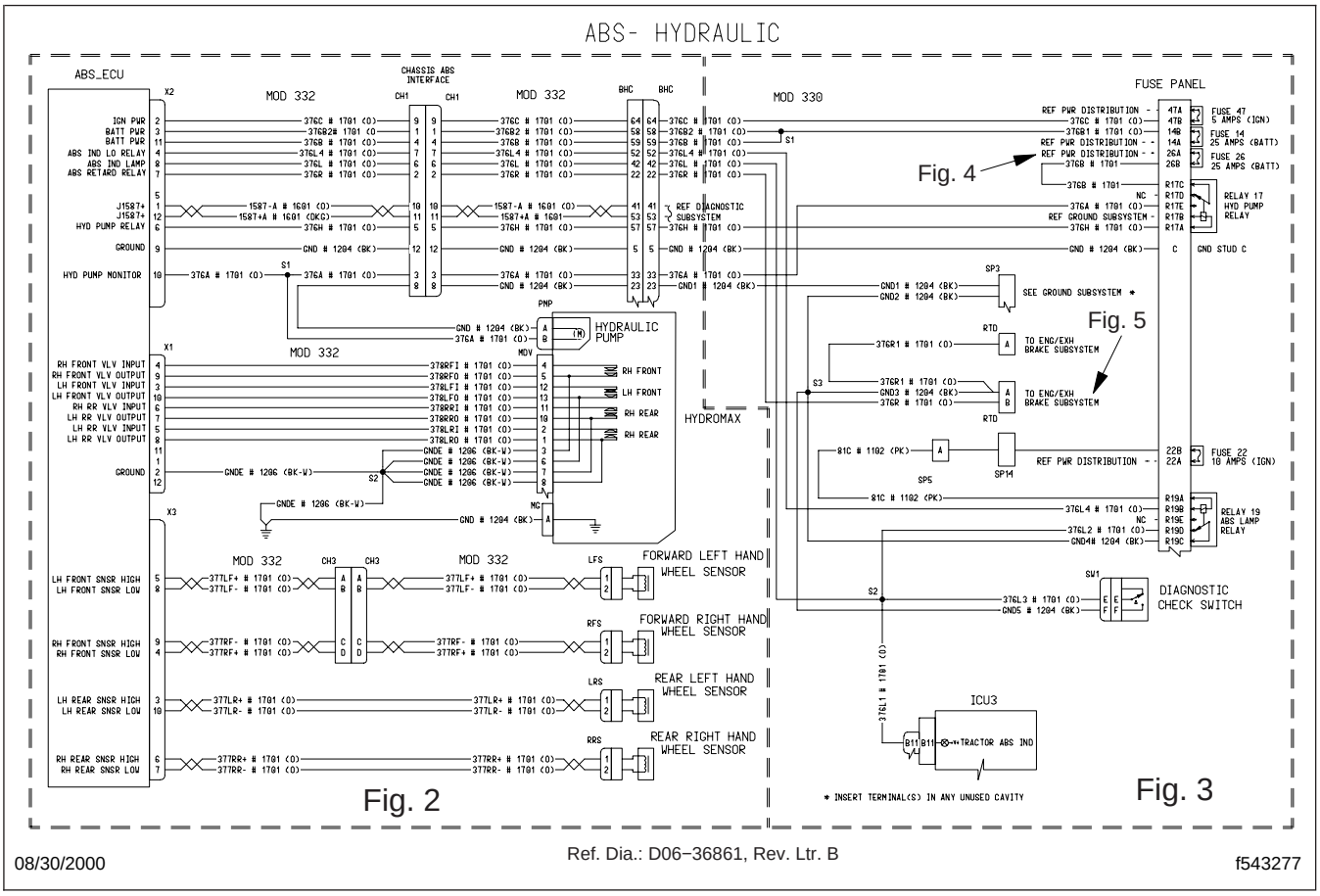


Fig. 1, Wiring Diagram, "D" Version (full view)

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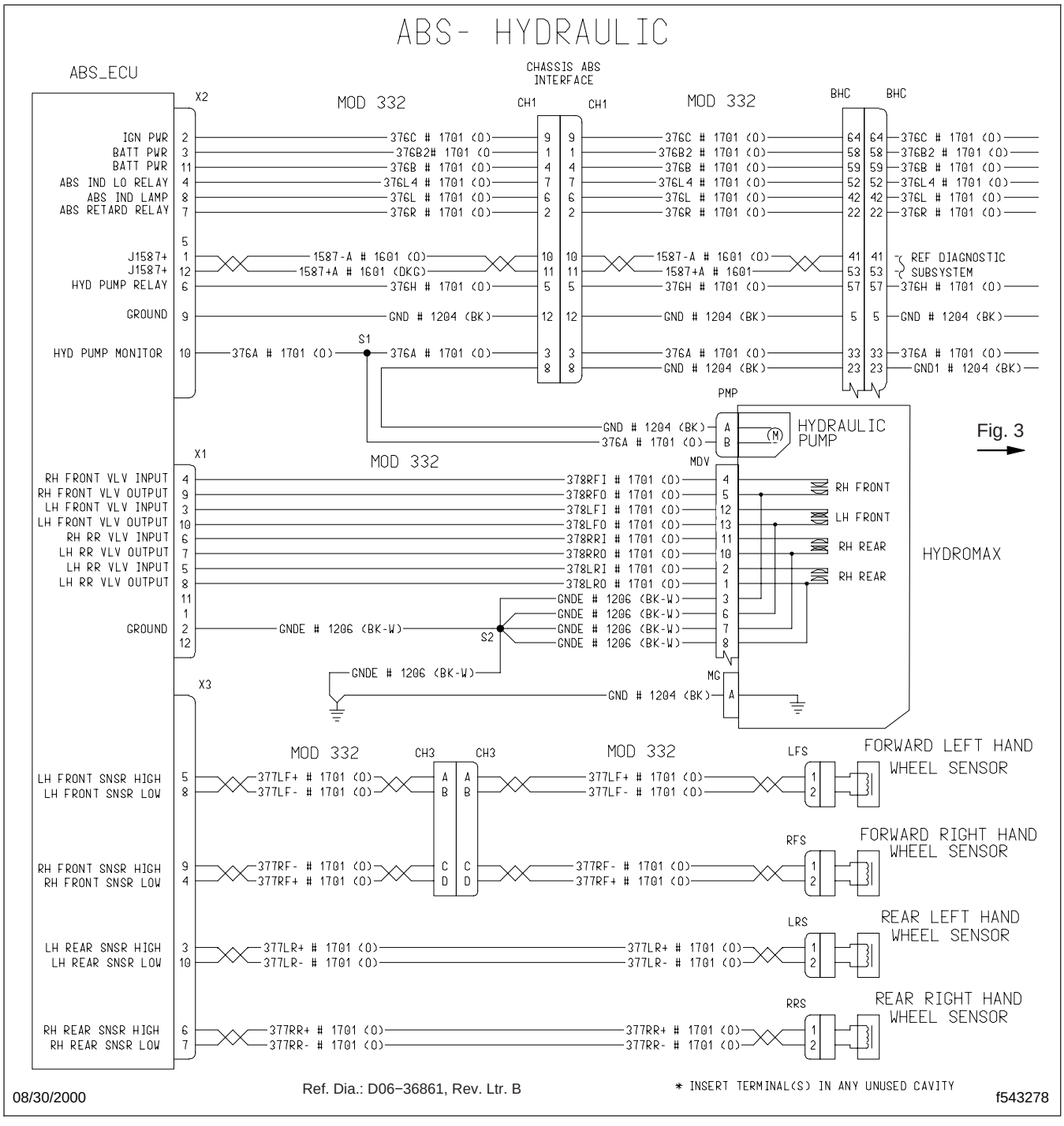


Fig. 2, Wiring Diagram, "D" Version (partial view)

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Specifications

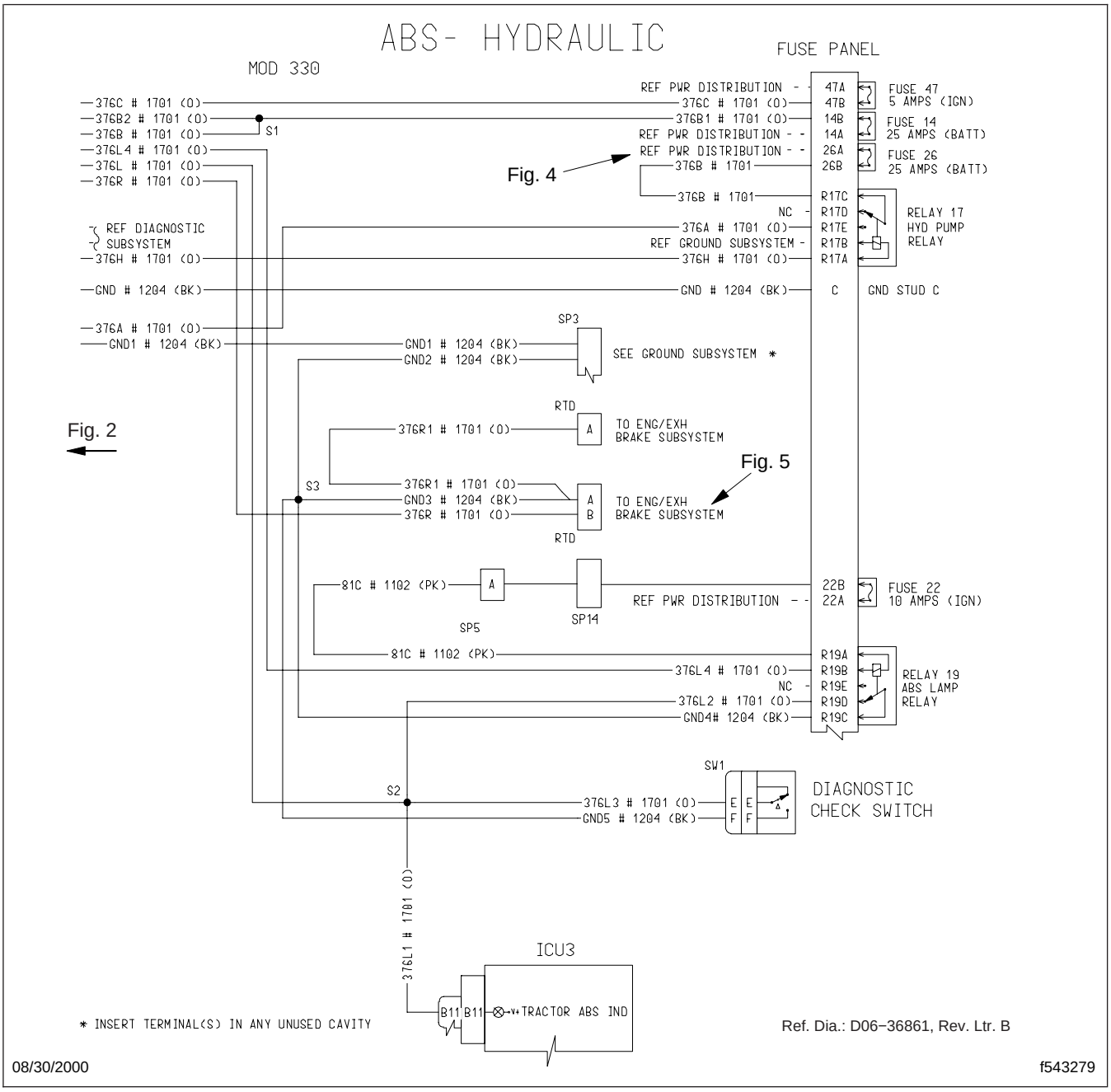
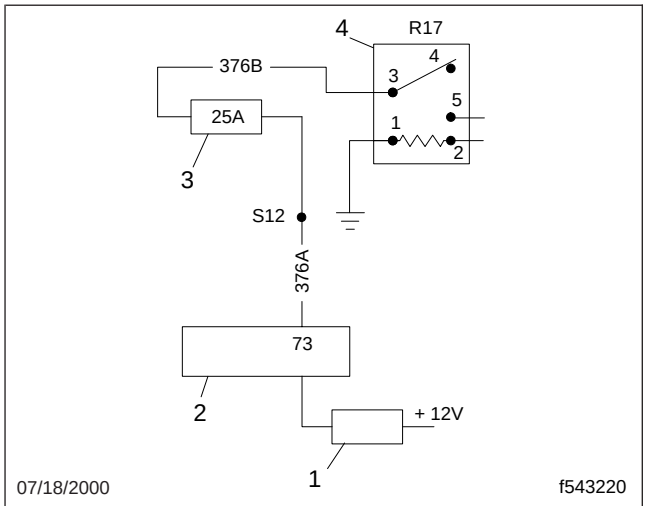


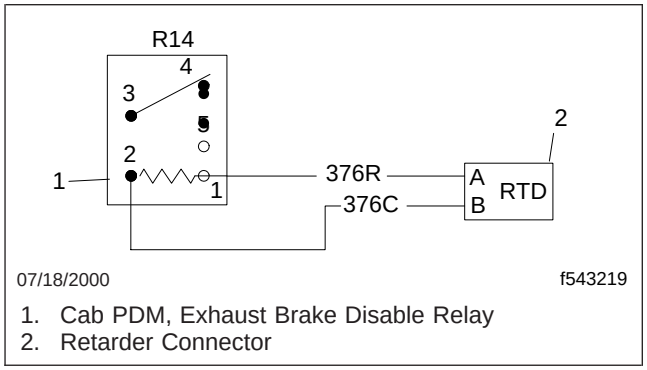
Fig. 3, Wiring Diagram, "D" Version (partial view)

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1. Engine PDM, Fuse M, ABS Power
2. Bulkhead Connector B (BHB)
3. Cab PDM, Fuse 26, Pump Relay Feed
4. Cab PDM, Pump Relay

Fig. 4, Hydraulic Pump Circuit



1. Cab PDM, Exhaust Brake Disable Relay
2. Retarder Connector

Fig. 5, Exhaust Brake Circuit

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Specifications

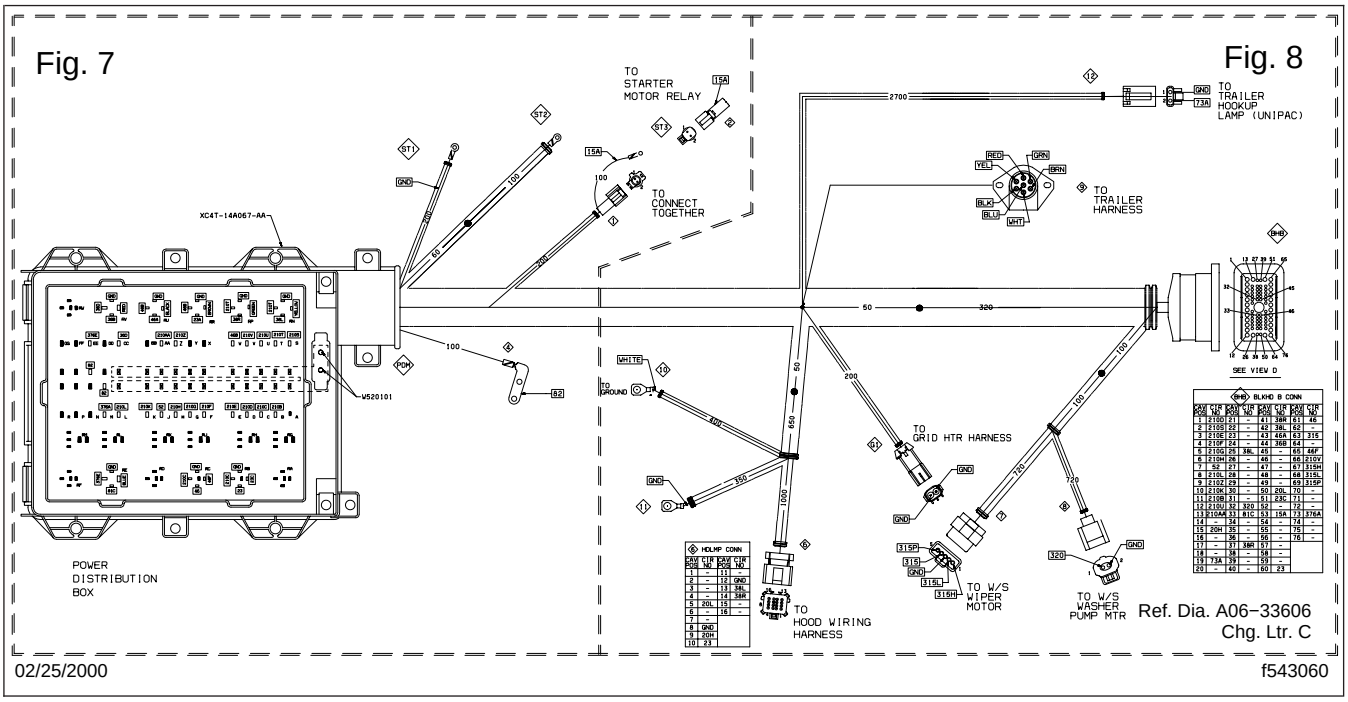


Fig. 6, Engine PDM Harness, "D" Version (full view)

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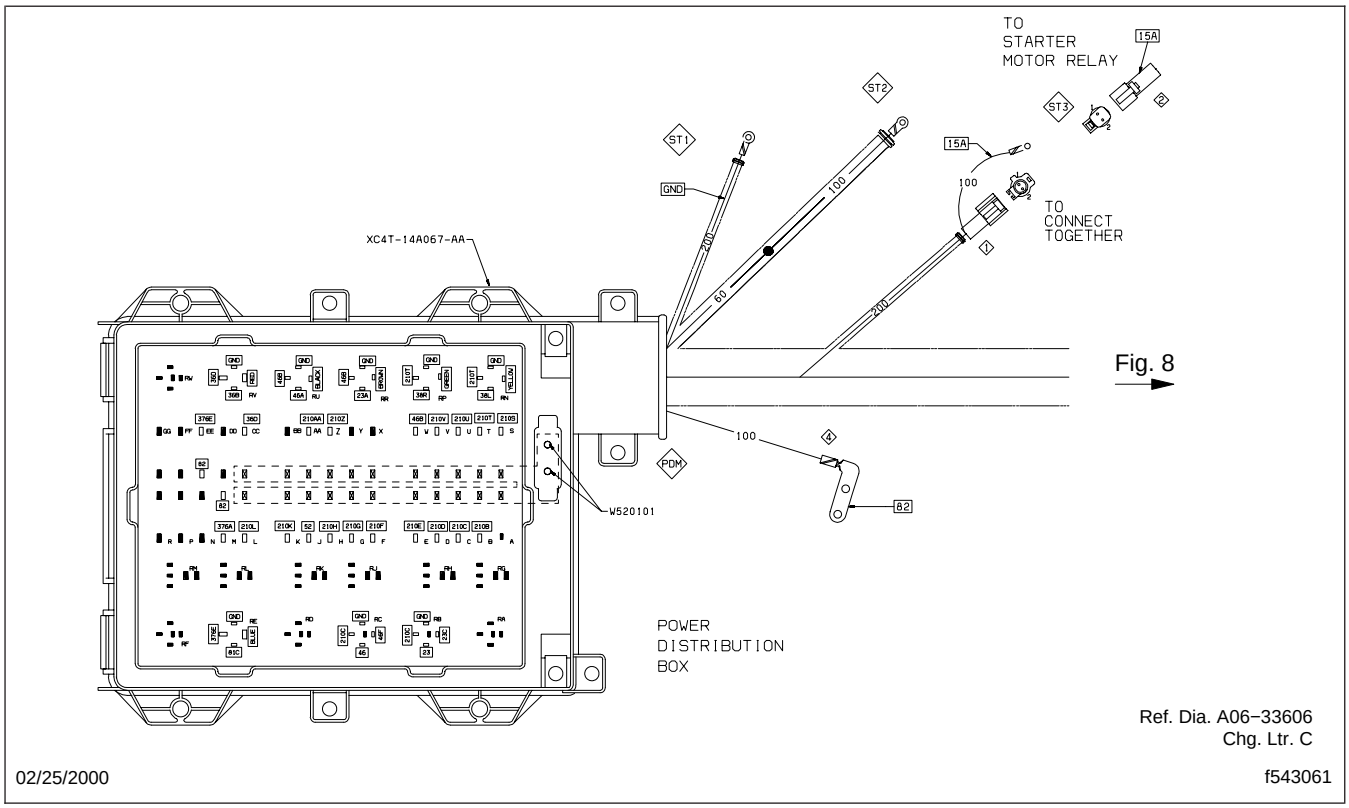


Fig. 7, Engine PDM Harness, "D" Version (partial view)

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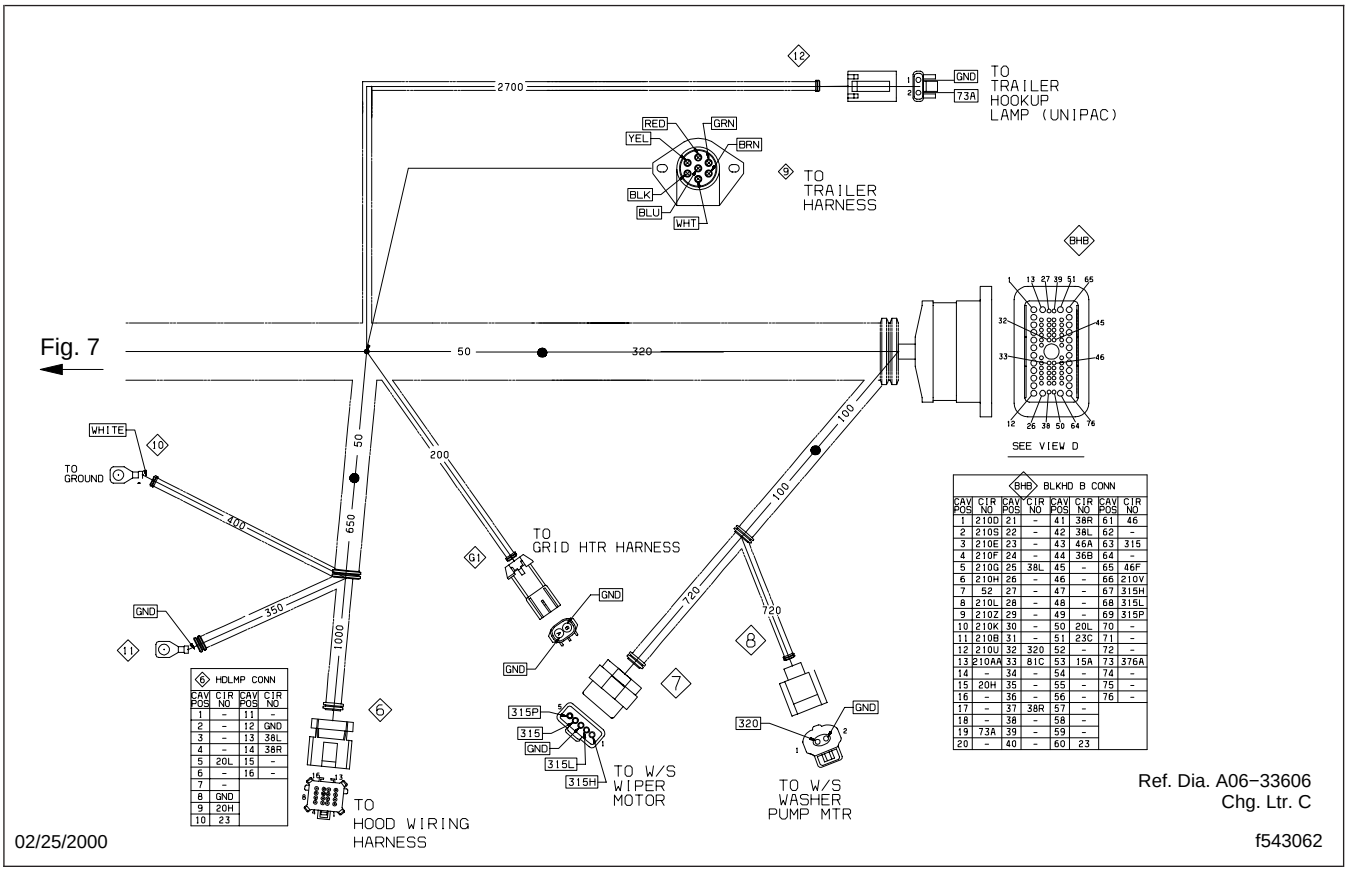


Fig. 8, Engine PDM Harness, "D" Version (partial view)

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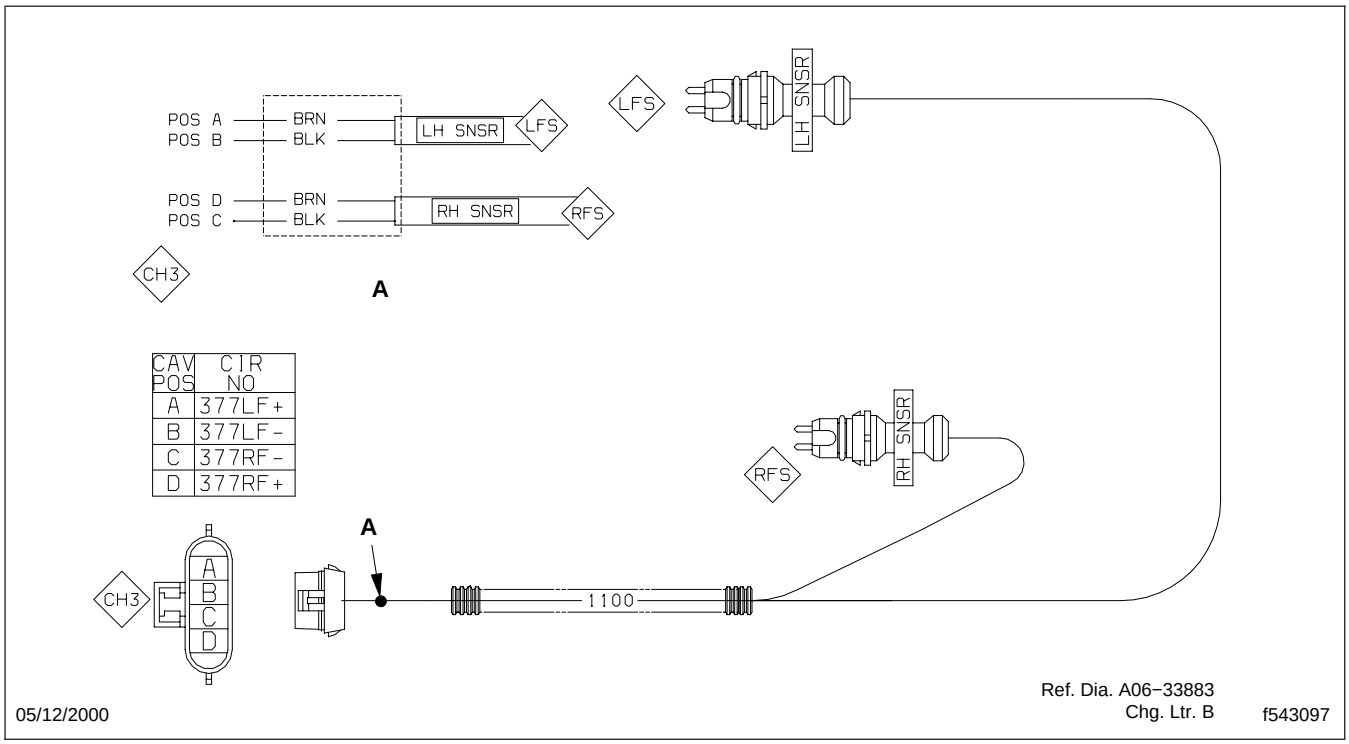


Fig. 9, Wheel Sensor Harness Assembly

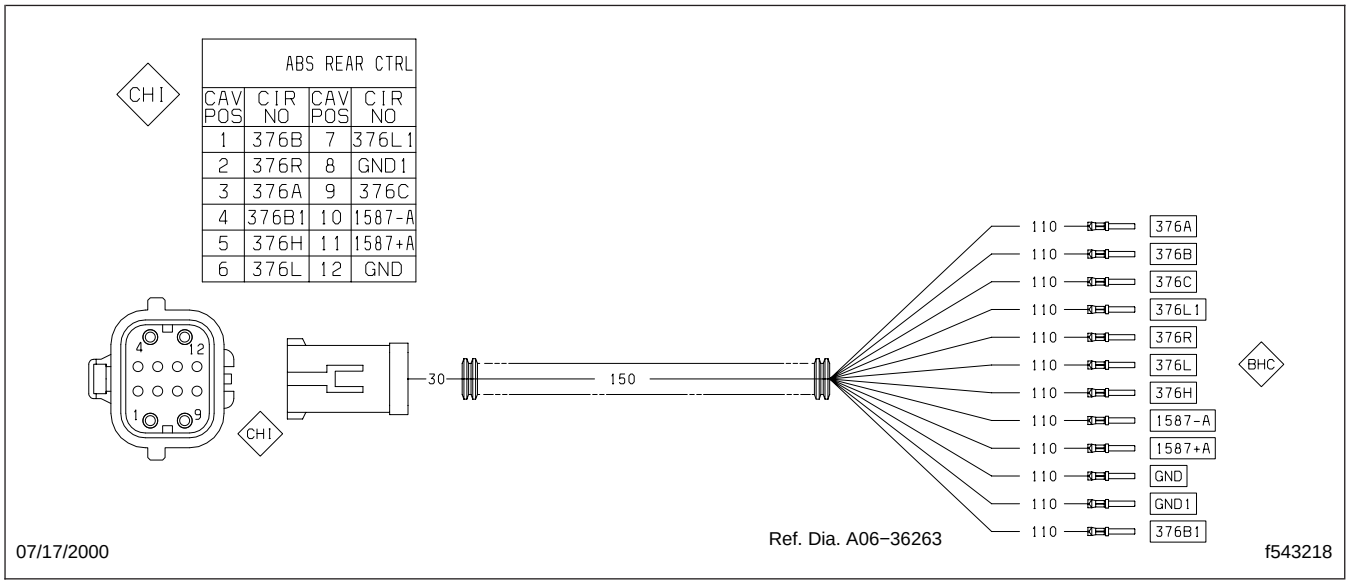
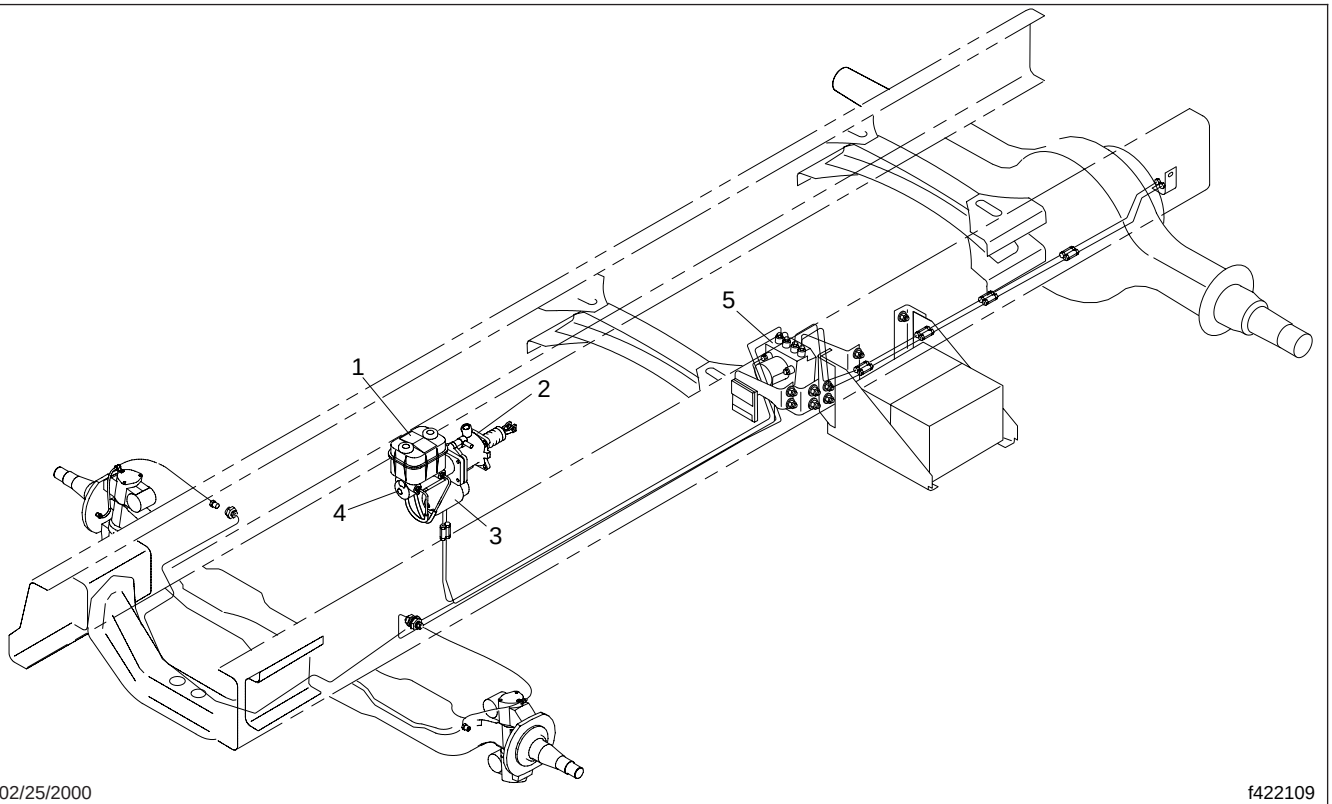


Fig. 10, ABS Chassis Harness Assembly

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Specifications



1. Reservoir
2. Power Booster
3. Electric Pump
4. Master Cylinder
5. Brake Pressure Modulator

Fig. 11, Hydraulic ABS Plumbing, "D" Version

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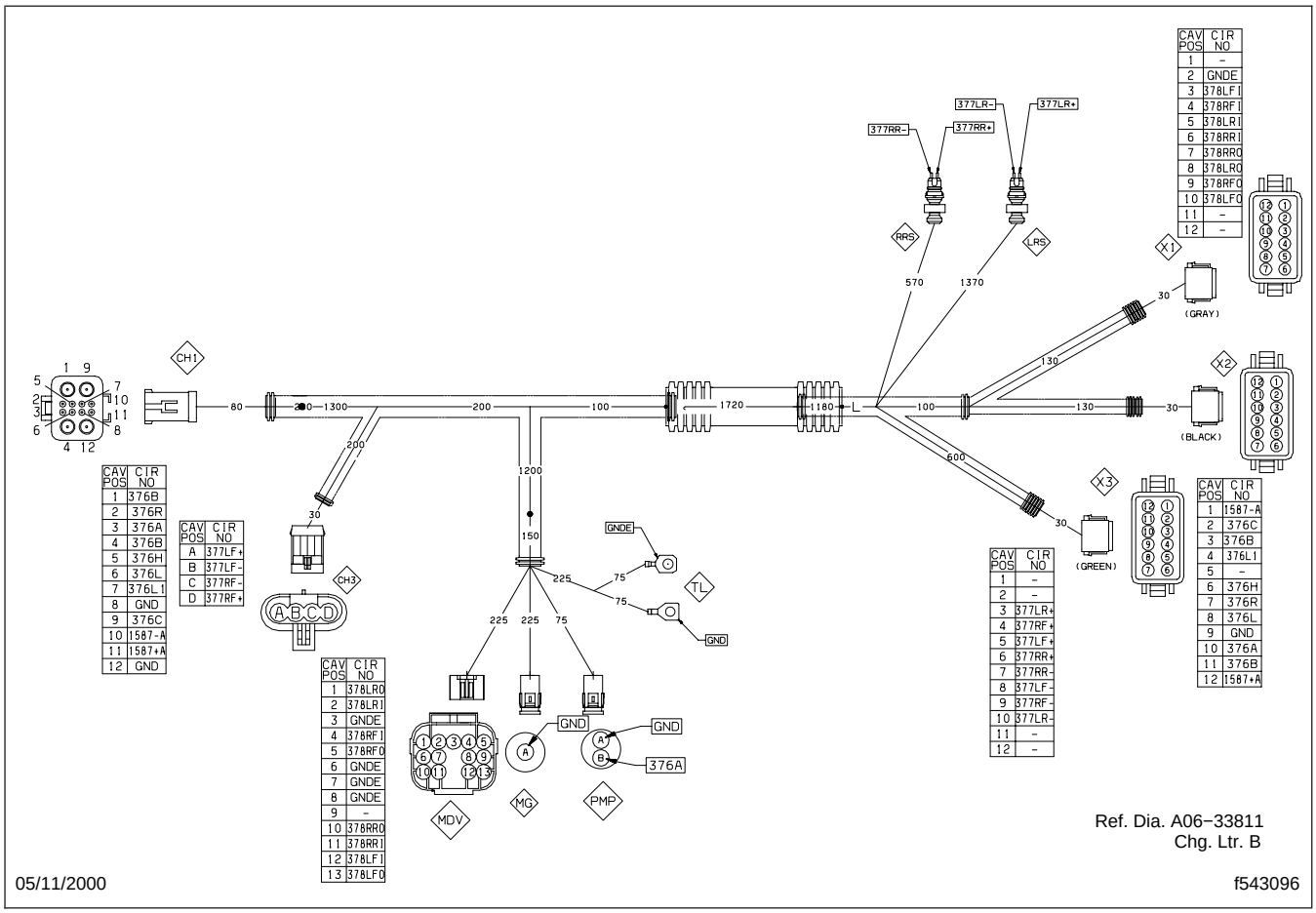


Fig. 12, "D" Version ECU Harness Assembly

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Specifications

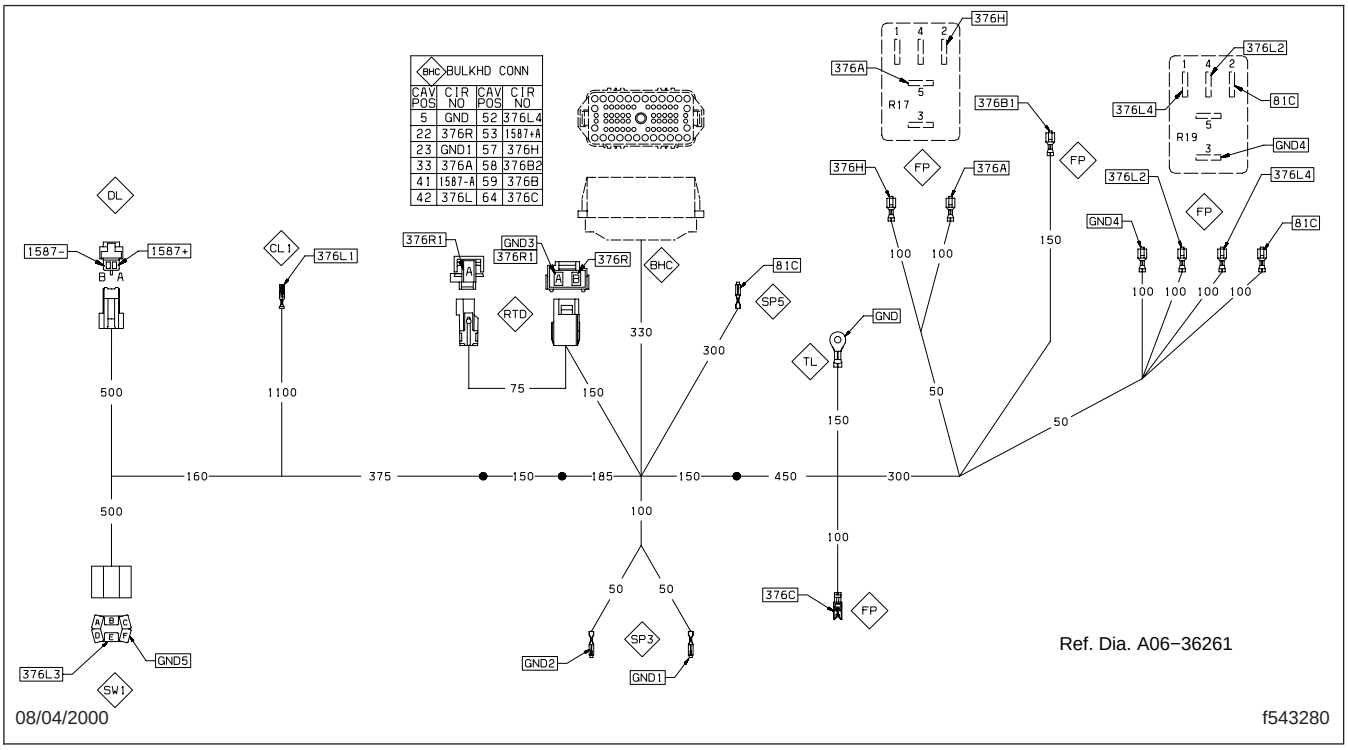


Fig. 13, Dash Overlay Harness

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General Information

The driveline parking brake is designed to hold the vehicle on a grade and to stop a slow moving vehicle if the service brakes are not working. The parking brake is manually operated and has a mechanical linkage; it does not rely on hydraulic or air pressure. It is installed only on vehicles with hydraulic brakes.

The parking brake is mounted either on the rear of the transmission, between it and the driveshaft (**Fig. 1**), or on the rear drive axle (**Fig. 2**). The main parts of the brake are the drum, brake shoes, return springs, support plate (Bosch) or backing plate (Meritor), cam, actuator strut (Meritor), actuating lever, brake cable and brake lever assembly.

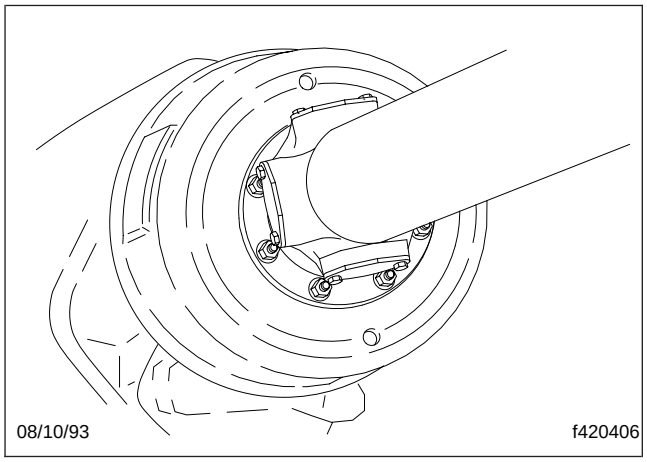


Fig. 1, Parking Brake Mounted Between Transmission and Driveshaft

For Meritor, the brake drum is bolted onto the driveline companion flange and the backing plate is bolted to the rear of the transmission, or on the rear axle. The brake shoes are held in place by the return springs. See **Fig. 3**.

For Bosch, the brake drum and the driveline companion flange are bolted to the transmission companion flange which is attached to the transmission shaft. The support plate is bolted to the rear of the transmission. The brake shoes are held in place by the return springs, the shoe-to-shoe spring and by the support plate. See **Fig. 4** and **Fig. 5**.

The brake cable runs from the actuating lever to inside the cab, where it is controlled by the parking brake lever assembly. See **Fig. 6**. A ring at the end

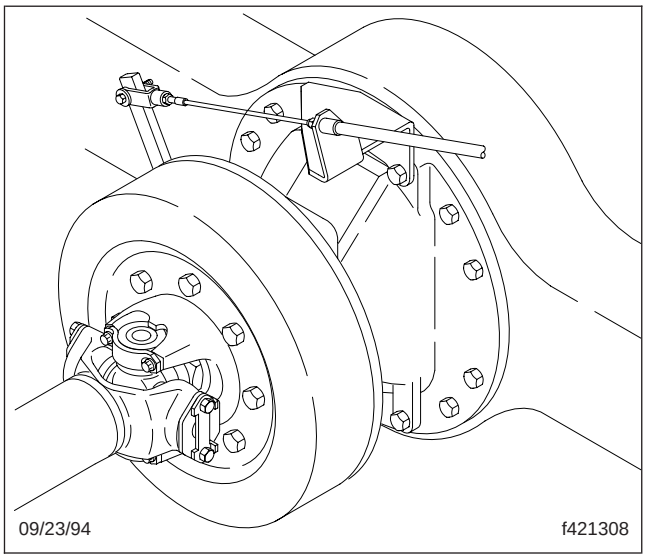


Fig. 2, Parking Brake Mounted on Rear Drive Axle

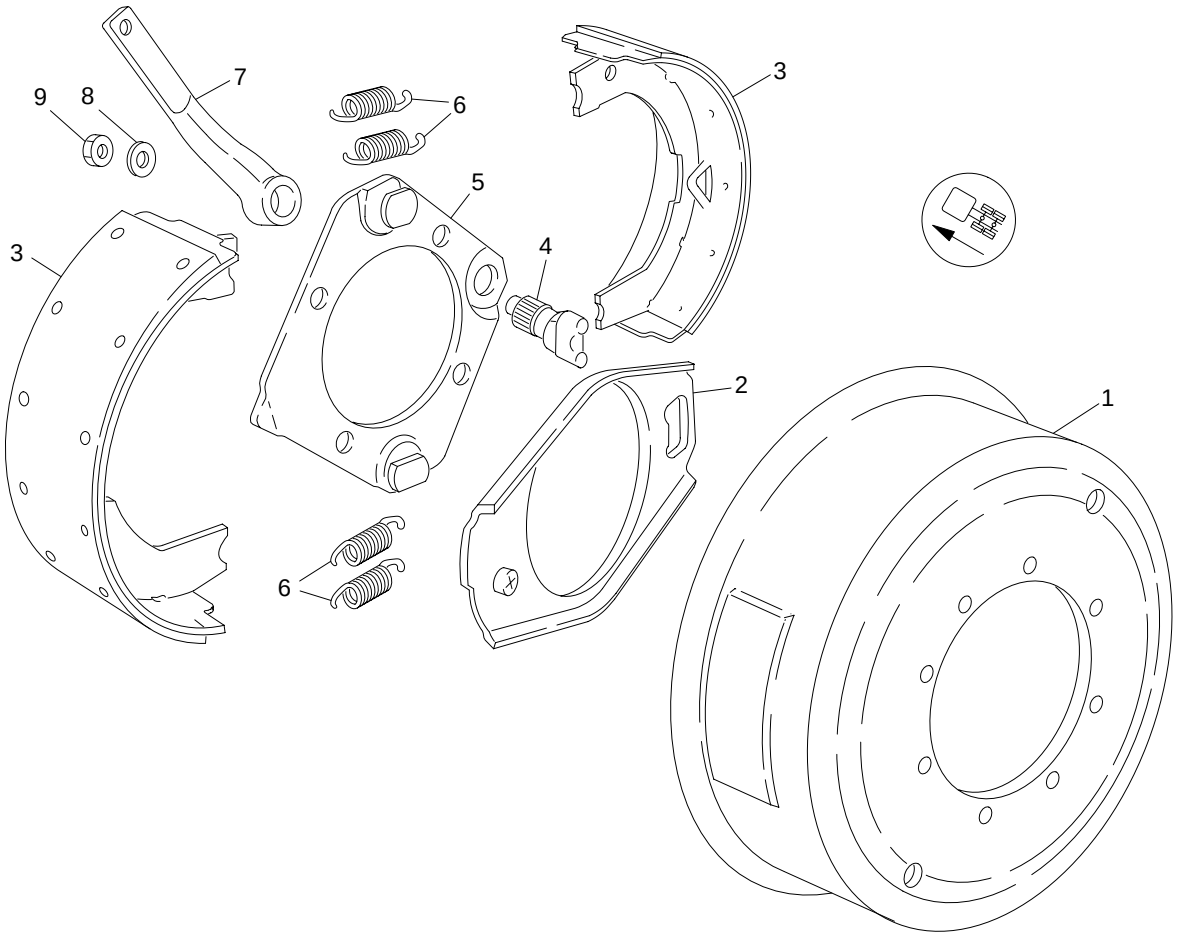
of the parking brake lever is used to adjust the cable length to compensate for brake shoe wear.

When the brake lever is pulled up, the brake cable pulls the actuating lever, turning the cam. For Meritor, the cam fits into an oblong hole in the actuator strut and rotates the strut slightly. This pushes the brake shoes outward against the brake drum. See **Fig. 7**. For Bosch, the cam pushes the brake shoes outward against the brake drum. See **Fig. 8**. Because the backing plate (Meritor) or the support plate (Bosch) and the brake shoes are mounted in a fixed position on either the transmission or rear axle, and the drum is attached to the end of the driveshaft, the driveshaft is prevented from turning. This keeps the vehicle from rolling.

When the parking brake lever is released, the tension on the cable is removed. The actuating lever, cam and actuator strut (Meritor) all return to their original positions. The brake return springs and shoe-to-shoe spring (Bosch) pull the brake shoes away from the brake drum. The driveshaft is then free to move and the vehicle can be moved.

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General Information

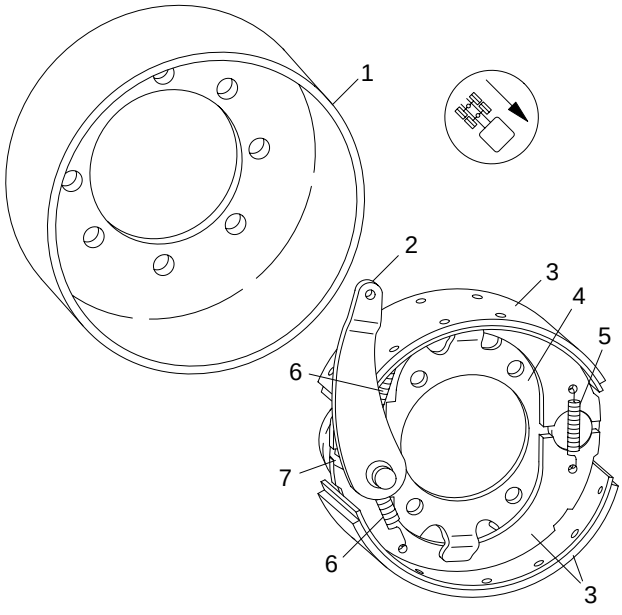


NOTE: Not all parts are shown.

1. Drum
2. Actuator Strut
3. Brake Shoe
4. Cam
5. Backing Plate
6. Return Springs
7. Actuating Lever
8. Washer
9. Nut

Fig. 3, Meritor Parking Brake (exploded view)

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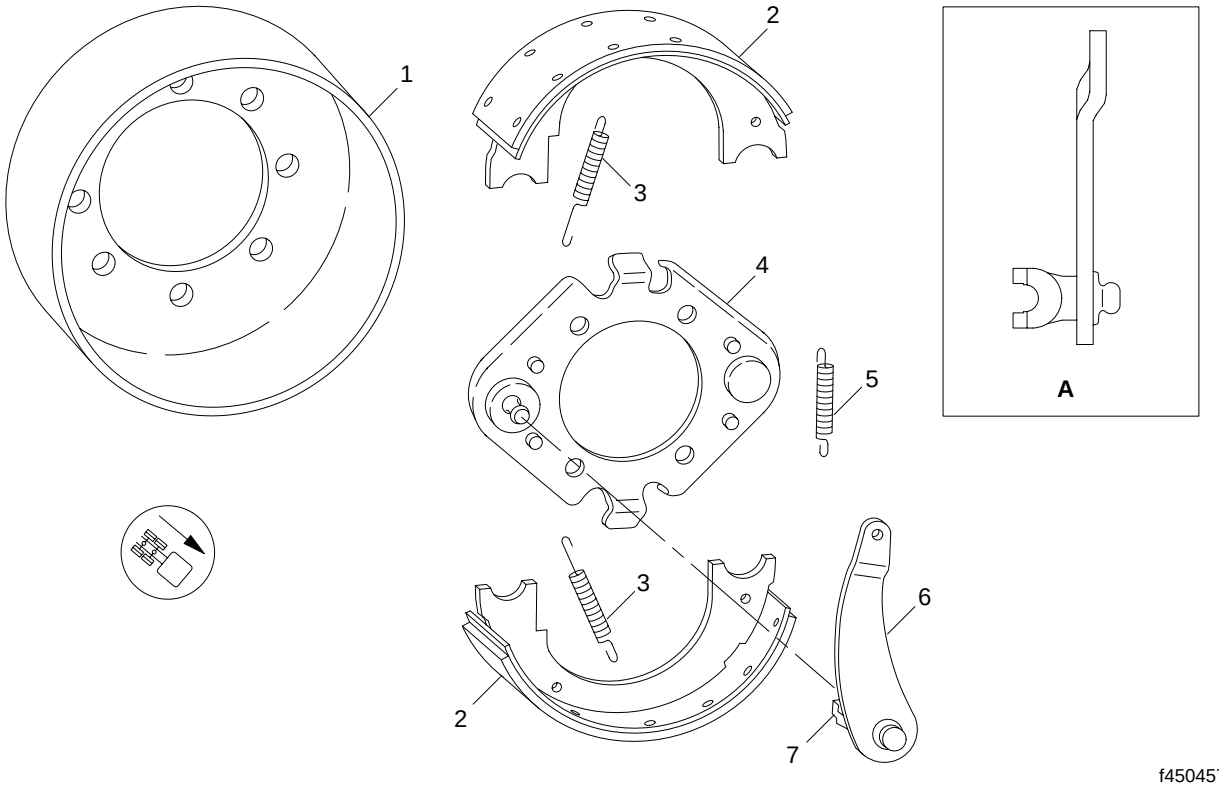
NOTE: Not all parts are shown.

1. Brake Drum
2. Actuating Lever
3. Brake Shoe
4. Support Plate
5. Shoe-to-Shoe Spring
6. Return Spring (2 qty.)
7. Cam

Fig. 4, Bosch Parking Brake (assembled parts)

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General Information



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NOTE: Not all parts are shown.

A. Top View of Actuating Lever

1. Brake Drum
2. Brake Shoe
3. Return Spring
4. Support Plate
5. Shoe-to-Shoe Spring
6. Actuating Lever
7. Cam

Fig. 5, Bosch Parking Brake (exploded view)

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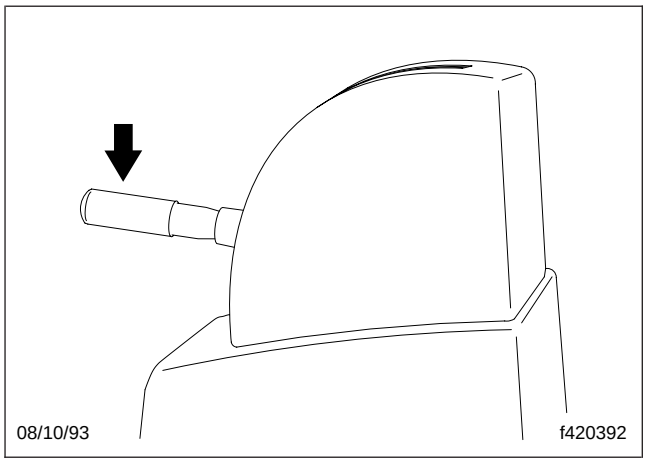
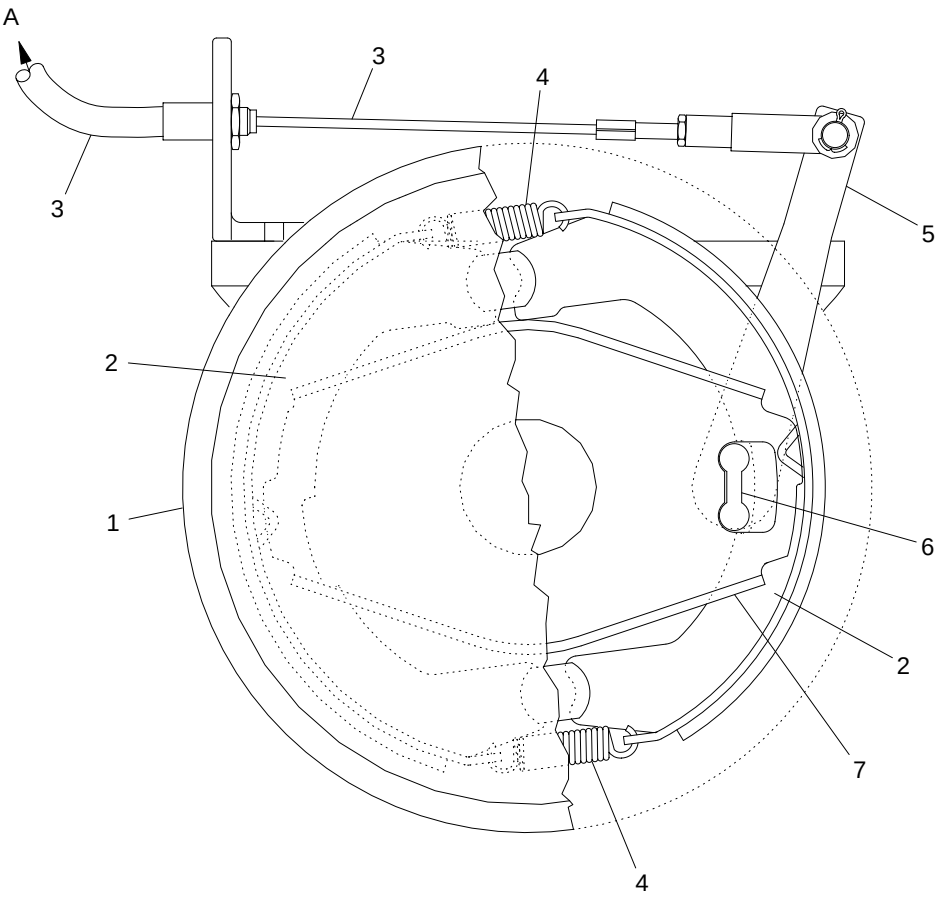


Fig. 6, Parking Brake Lever Handle

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General Information



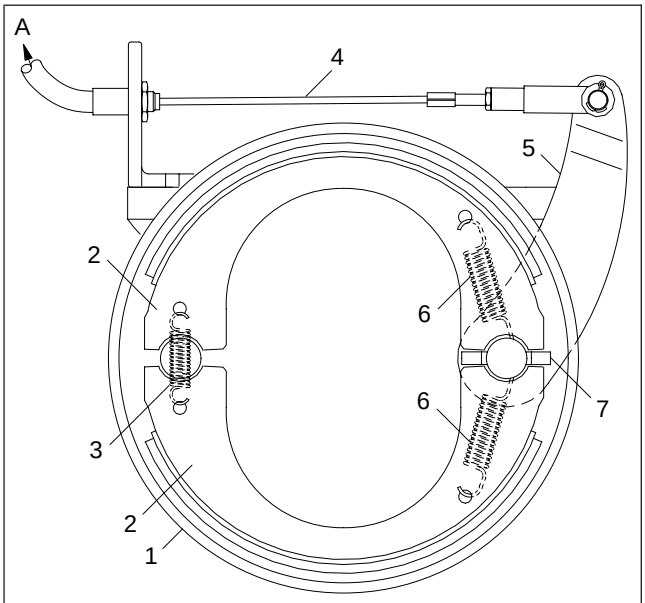
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A. To parking brake lever in the cab.

1. Brake Drum (shown cut away)
2. Brake Shoe
3. Brake Cable
4. Return Springs
5. Actuating Lever
6. Cam
7. Actuator Strut

Fig. 7, Meritor Transmission-Mounted Parking Brake

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NOTE: Not all parts are shown.

A. To parking brake lever in the cab.

1. Brake Drum
2. Brake Shoe
3. Shoe-to-Shoe Spring
4. Brake Cable
5. Actuating Lever
6. Return Spring
7. Cam

Fig. 8, Bosch Parking Brake on Eaton® Fuller® Transmission

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Safety Precautions

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the parking brake, starting with removal of the brake drum and continuing through assembly.

Because most brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Because medical experts believe that long-term exposure to some non-asbestos fibers could also be a health hazard, also observe the following precautions if servicing non-asbestos brake linings.

Exposure to airborne brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

During brake servicing, wear an air purifying respirator with high-efficiency filters. The respirator and filter must be approved by NIOSH or MSHA and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly and the dirty air is removed from the cylinder by the vacuum.

If such an enclosed system is not available, or cannot be used, clean the brake assembly in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with an HEPA filter system, remove dust from all the brake parts. After vacuuming, remove any remaining dust using a rag soaked in water and wrung until nearly dry.

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Removal

WARNING

Before starting the procedure below, see "Safety Precautions" in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

1. Park the vehicle on a level surface. Set the parking brake to keep the brake drum in place when the driveline is disconnected. Shut down the engine. Chock the tires.
2. Remove the driveline midship bearing carrier from the frame crossmember.
   - 2.1 Put a jackstand under the driveline at the rear of the midship bearing.
   - 2.2 Remove the bolts holding the midship bearing carrier to the bracket on the frame crossmember. See Fig. 1.

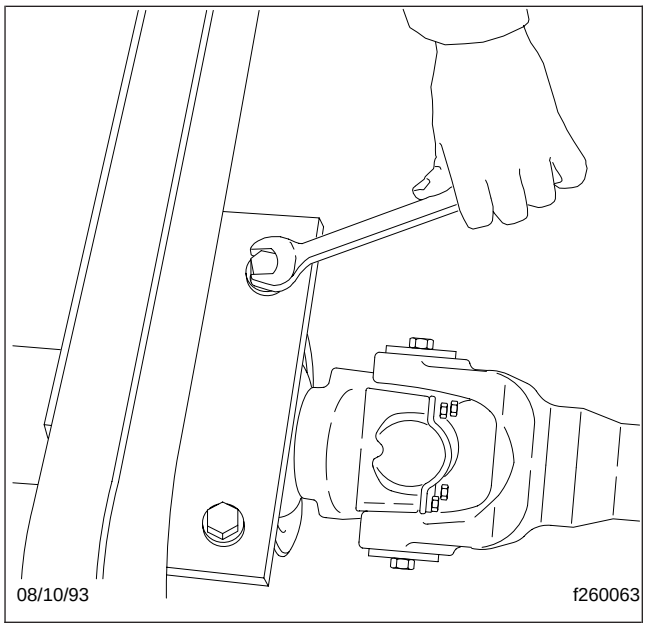


Fig. 1, Bracket Bolts Holding Midship Bearing Carrier

   - 2.3 Lower the driveline and midship bearing carrier onto the jackstand. It should rest securely on the jackstand.
3. Disconnect the driveline companion flange from either the transmission or rear axle companion flange. See Fig. 2.

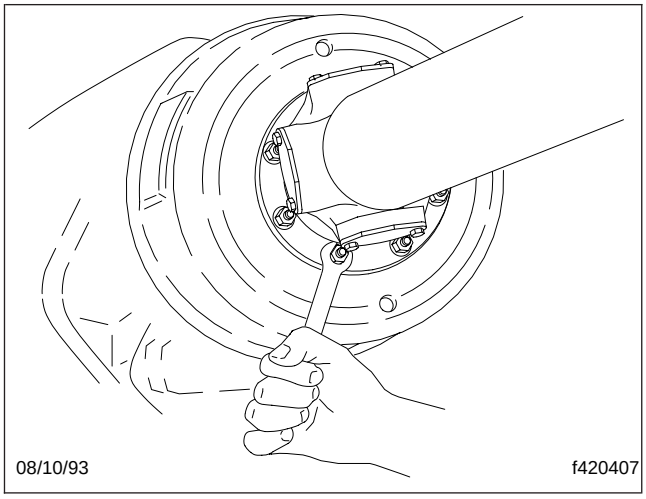


Fig. 2, Driveline Companion Flange Bolts

4. Slide out the driveline and lower it to the floor. See Fig. 3.

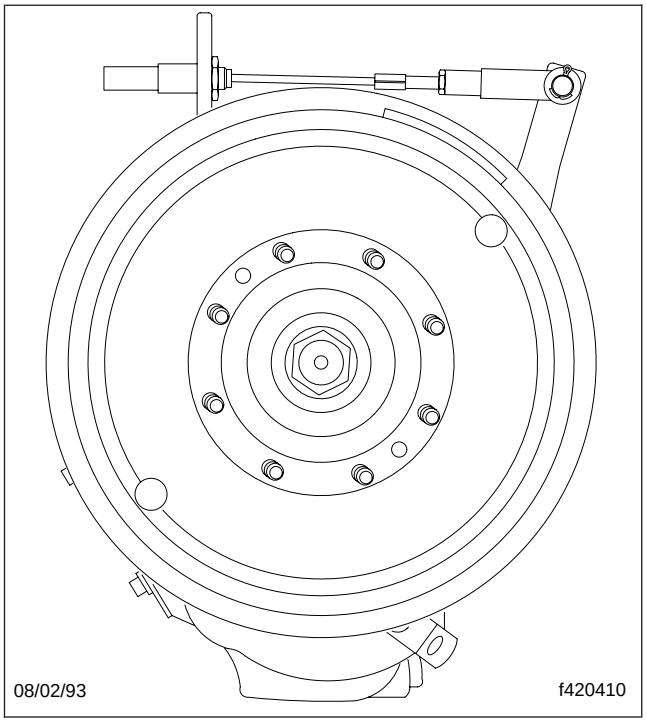


Fig. 3, Driveline Removed (transmission-mounted parking brake shown)

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Meritor Removal and Installation

5. Release the parking brake.
6. Disconnect the brake cable from the actuating lever. See **Fig. 4**.

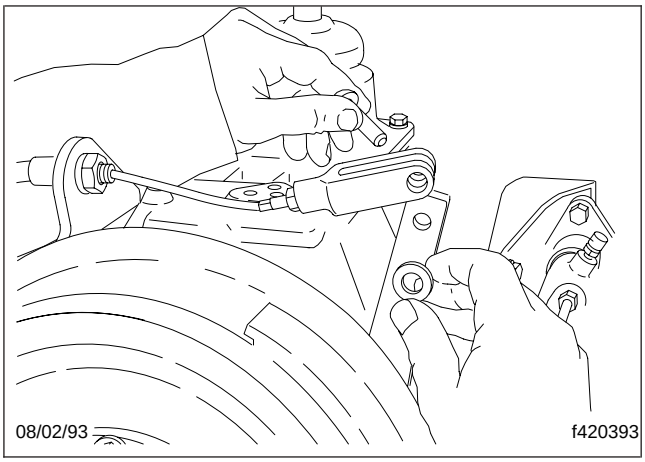


Fig. 4, Disconnecting the Brake Cable from the Actuating Lever

7. Pull the brake drum off either the transmission or rear axle companion flange. See **Fig. 5**.

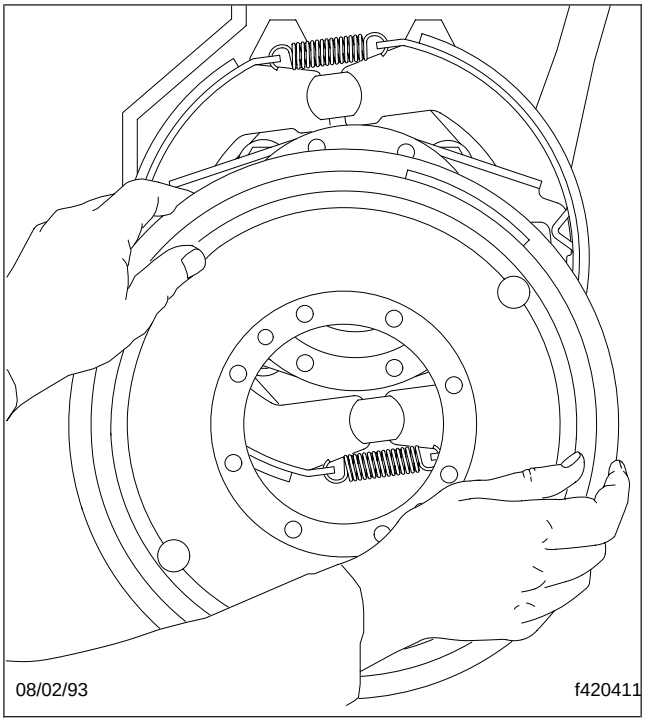


Fig. 5, Brake Drum Removal

8. Remove the brake shoes.
   - 8.1 Carefully remove the lower brake shoe return springs. See **Fig. 6**.

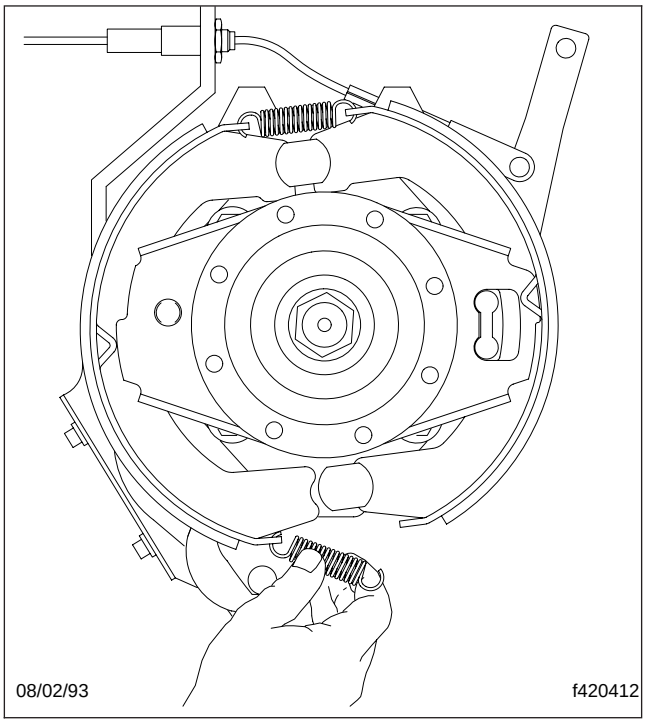


Fig. 6, Lower Brake Shoe Return Spring

   - 8.2 Pull the bottom of one brake shoe out, releasing the pressure on the upper return springs. See **Fig. 7**. Remove the upper return springs.
   - 8.3 Remove both brake shoes.
9. Remove the actuator strut.
   - 9.1 Remove the large end-nut from either the transmission or rear axle shaft. See **Fig. 8**.
   - 9.2 Remove the companion flange that holds the actuator strut in place. See **Fig. 9**.
   - 9.3 Remove the actuator strut. See **Fig. 10**.
10. Remove the four hexbolts, washers and nuts holding the backing plate to the square adapter on the end of the transmission (or rear axle). Remove the backing plate. See **Fig. 11** and **Fig. 12**.
11. If replacing the actuating lever or cam, remove them from the backing plate.

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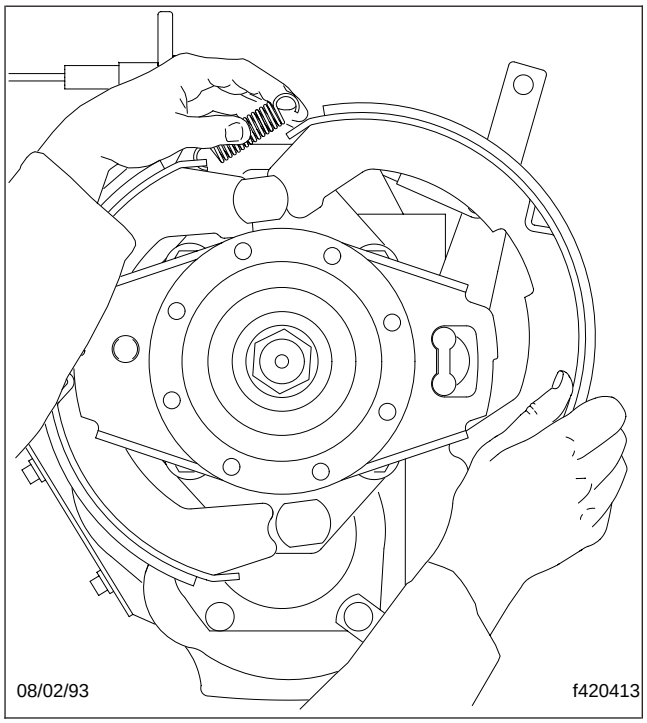


Fig. 7, Upper Return Spring Removal

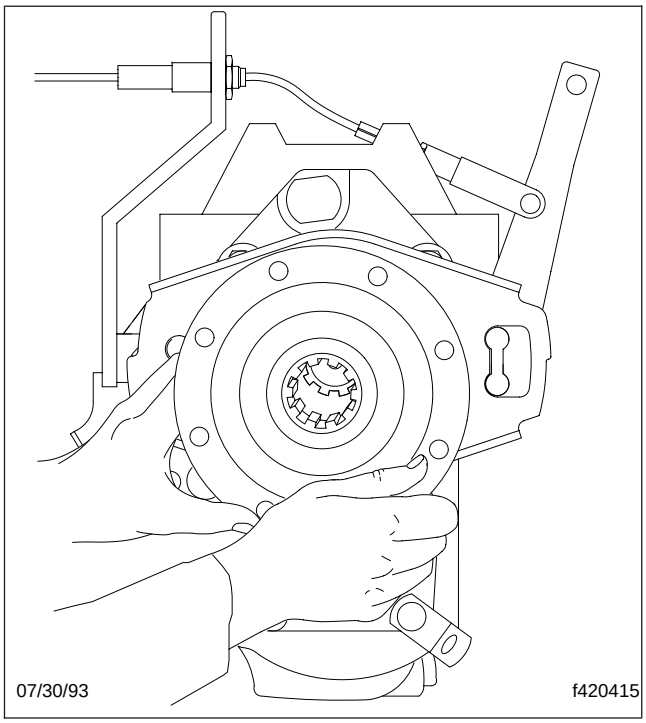


Fig. 9, Removal of Companion Flange

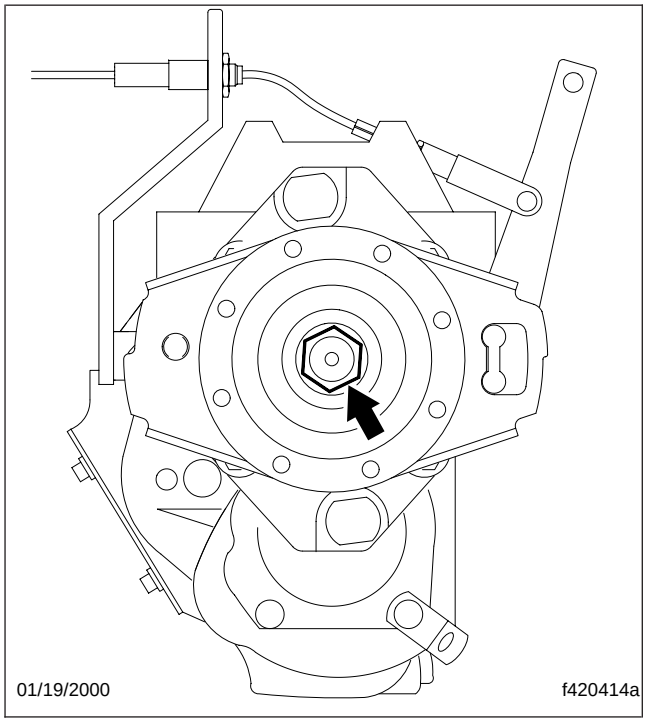


Fig. 8, End Nut

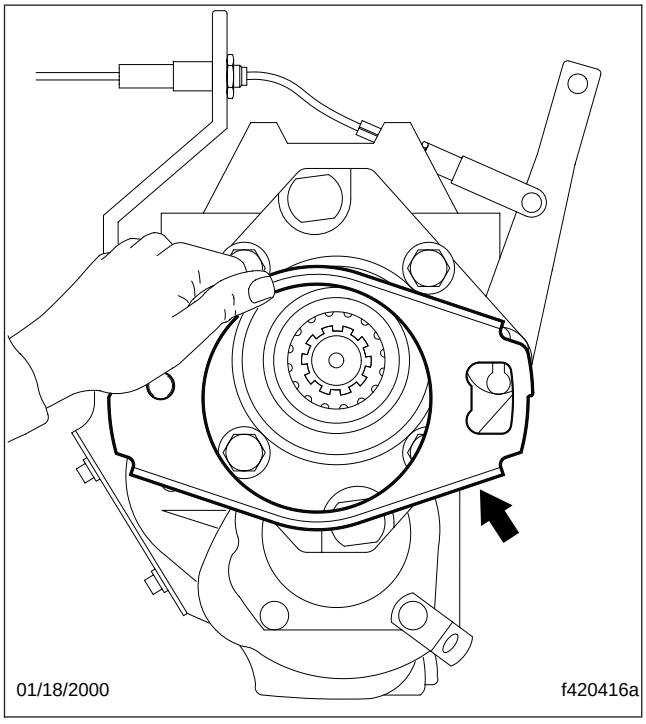


Fig. 10, Removal of Actuator Strut

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Meritor Removal and Installation

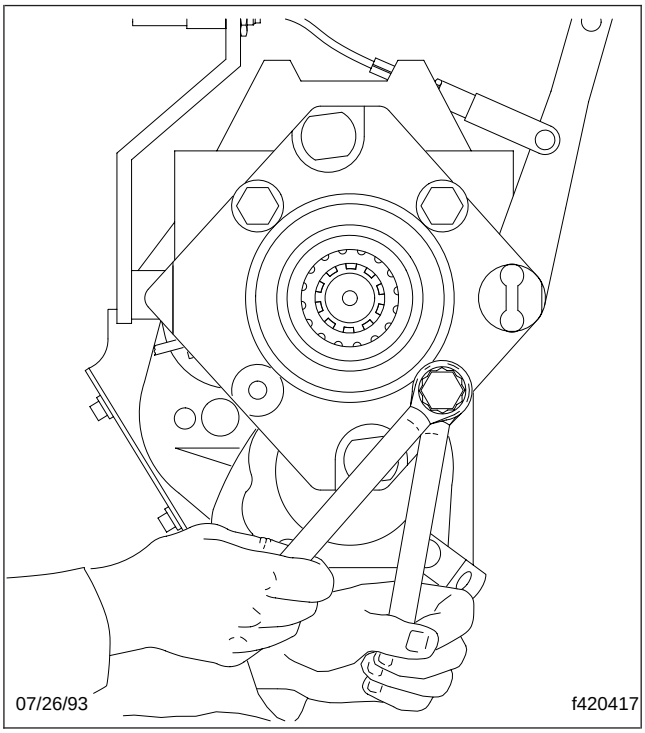


Fig. 11, Removal of Hexbolts on Backing Plate

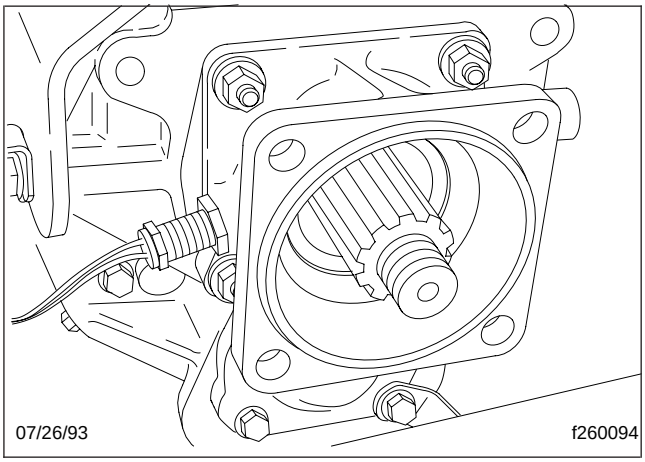


Fig. 12, Backing Plate Removed

11.1 Mark the splines of the lever and cam for later reference.

11.2 Put the backing plate in a padded vise. Remove the nut and washer holding the lever and the cam together. Remove them from the backing plate. See **Fig. 13** and **Fig. 14**.

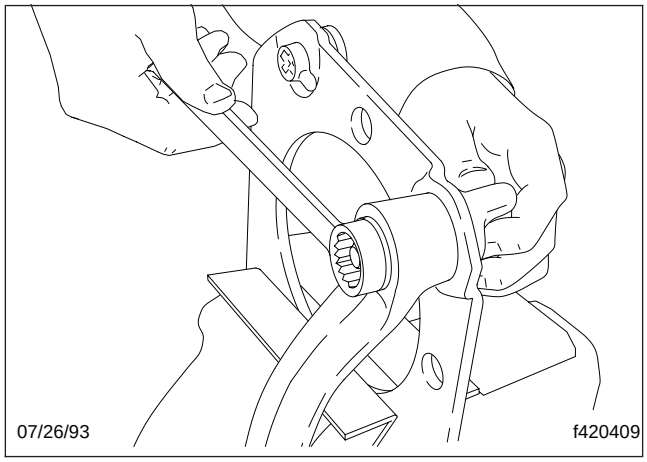


Fig. 13, Removal of Lever Nut and Washer

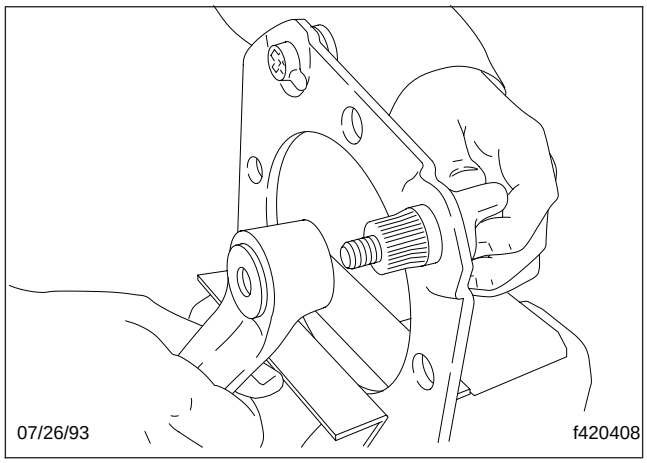


Fig. 14, Lever Removed from Backing Plate

Installation

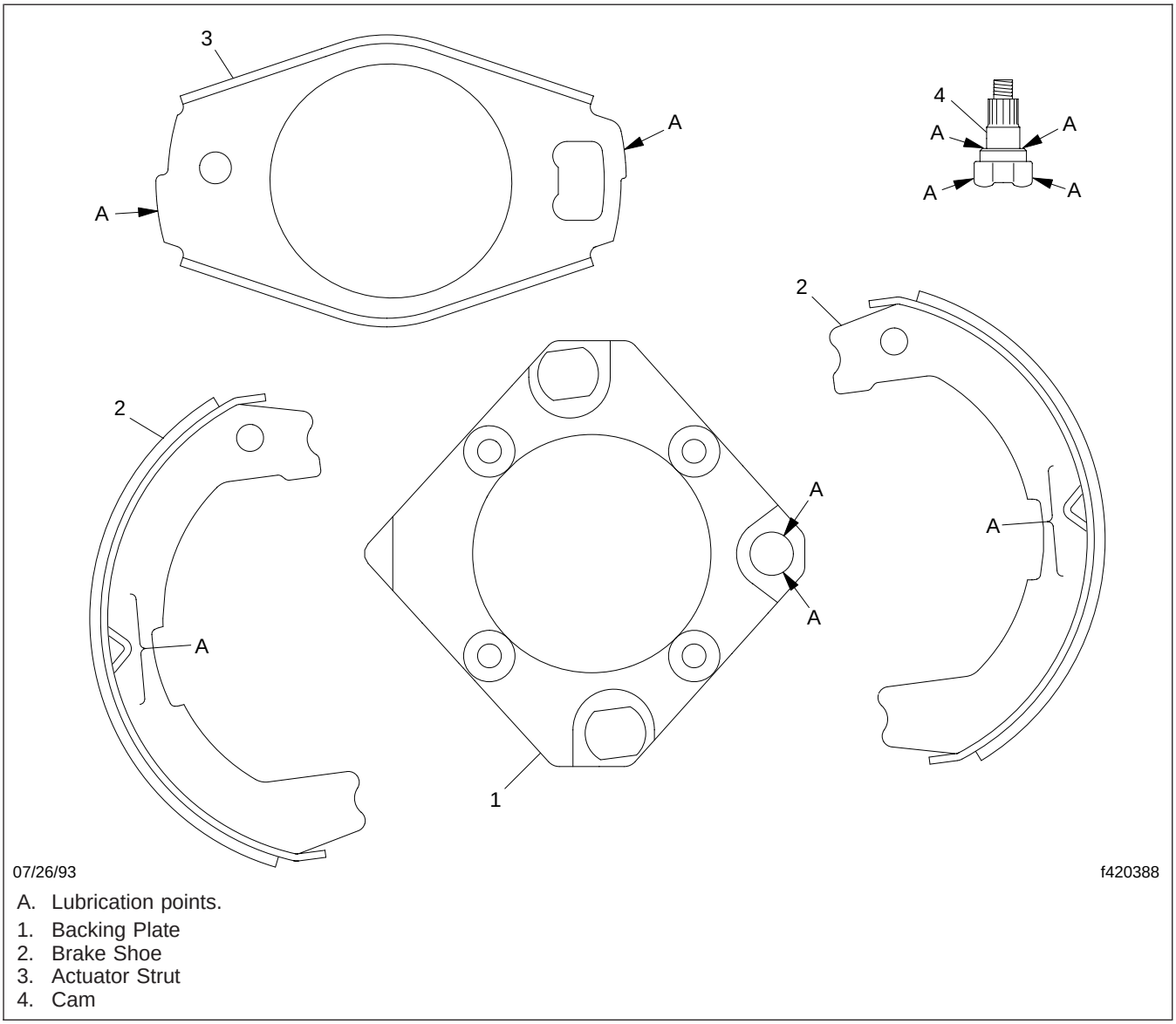
1. Clean all the parts. Check for damage and corrosion, and replace parts if needed. Check the backing plate for cracks or bending. Replace it if needed.

⚠ CAUTION

Do not let any grease get on the brake drum or linings. Grease on these parts will reduce the effectiveness of the driveline parking brake. If brake linings become contaminated, replace them.

2. Using NLGI grade 2 brake grease, lubricate (see **Fig. 15**):

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A. Lubrication points.
1. Backing Plate
2. Brake Shoe
3. Actuator Strut
4. Cam

Fig. 15, Brake Shoes and Backing Plate

- The cam head face and journals;
- The mating surfaces of the brake shoe webs and the actuator strut;
- Both sides of the cam hole in the backing plate.

3. If the cam and actuating lever were removed, install them on the backing plate.

3.1 Put the cam through the hole in the backing plate. See **Fig. 14**.

3.2 Using the reference marks made during removal, align the splines of the actuating lever with those of the cam. Install the lever on the cam.

3.3 Install the nut and washer on the cam. See **Fig. 13**. Tighten the nut until there is 0.001 to 0.010 inch (0.025 to 0.25 mm)

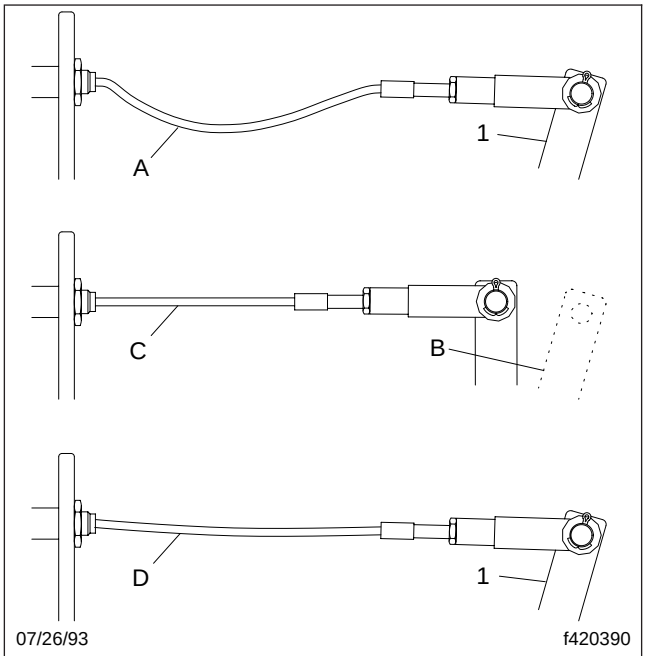
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Meritor Removal and Installation

clearance between the actuating lever and the backing plate.

4. Using the four hexbolts, nuts and washers, install the backing plate on the transmission or rear axle. See **Fig. 11**. Tighten the nuts:
   - 170 to 185 lbf·ft (230 to 251 N·m) if mounted on Eaton® Fuller® transmissions;
   - 150 to 165 lbf·ft (203 to 224 N·m) if mounted on Allison transmissions;
   - 150 to 165 lbf·ft (203 to 224 N·m) if mounted on the rear axle.
5. Install the brake shoes on the backing plate so that the web ends are up against the bosses on the backing plate.
6. Install four new brake return springs.
7. Install the actuator strut on the backing plate.
   - 7.1 Put the actuator strut on the backing plate so its pressure points are against those of the brake shoe webs, and so the slot in the actuator strut will go over the cam.
   - 7.2 Install the companion flange over the splines of the transmission shaft (or rear axle shaft). See **Fig. 9**.
   - 7.3 Install the large end-nut on the end of the transmission or rear axle shaft. See **Fig. 8**. Tighten the nut:
     - 325 lbf·ft (440 N·m) if mounted on Eaton® Fuller® transmissions;
     - 700 lbf·ft (950 N·m) if mounted on Allison transmissions;
     - 740 to 920 lbf·ft (1000 to 1250 N·m) if mounted on the rear axle.
8. Install the brake drum onto the studs of the transmission (or rear axle) companion flange. See **Fig. 5**.
9. Connect the driveline companion flange to the transmission (or rear axle) companion flange.
   - 9.1 Place the driveline companion flange so its holes fit over the studs on the transmission (or rear axle) companion flange.
   - 9.2 Install the eight nuts and washers on the studs. See **Fig. 3**. Tighten them 45 lbf·ft (61 N·m).
10. Connect the brake cable to the brake lever.
    - 10.1 Check the length of the brake cable. It should be just long enough to let the clevis hole align with the hole in the actuating lever without moving the actuating lever. See **Fig. 16**.

      If the brake cable is too loose or too tight, screw the clevis in or out until the its holes line up with the hole in the actuating lever (without moving the lever). See **Fig. 17**.



A. Too Loose.
B. Correct position of actuating lever.
C. Too Tight.
D. Correct cable adjustment.
1. Actuating Lever

Fig. 16, Brake Cable Tightness

    - 10.2 Install the clevis pin through the clevis and actuating lever holes.
    - 10.3 Install the washer and a new cotter pin on the clevis pin.
    - 10.4 Check the brake cable again for any slack. If it still needs adjusting, do it in the cab by turning the ring on the handle of the parking brake lever. See **Fig. 18**.

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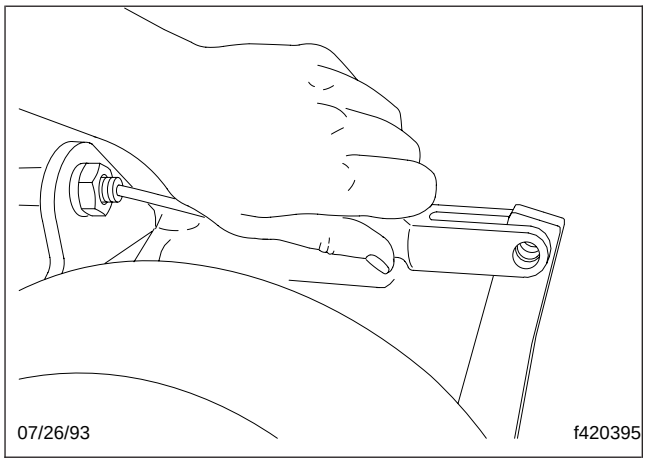


Fig. 17, Brake Cable Adjustment

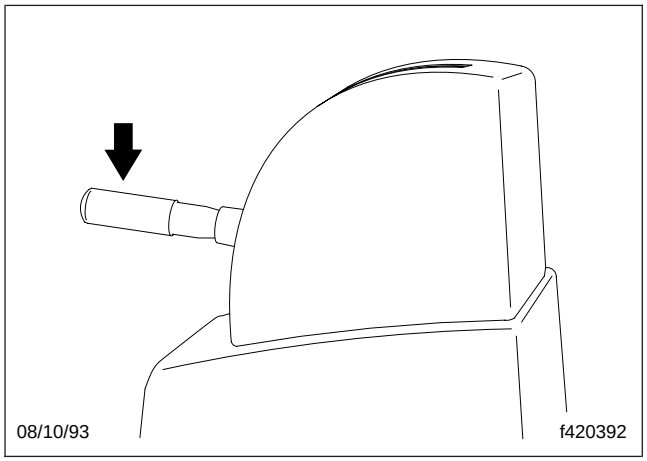


Fig. 18, Ring on Handle of Parking Brake Lever

11. Attach the driveline midship bearing carrier to the bracket on the frame crossmember. Tighten the fasteners 91 lbf·ft (123 N·m).
12. Remove the chocks from the tires.

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Removal

⚠ WARNING

Before starting the procedure below, see "Safety Precautions" in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

1. Park the vehicle on a level surface. Set the parking brake to keep the brake drum in place when the driveline is disconnected. Shut down the engine. Chock the tires.
2. Remove the driveline midship bearing carrier from the frame crossmember.
   - 2.1 Put a jackstand under the driveline at the rear of the midship bearing.
   - 2.2 Remove the bolts holding the midship bearing carrier to the bracket on the frame crossmember. See **Fig. 1**.

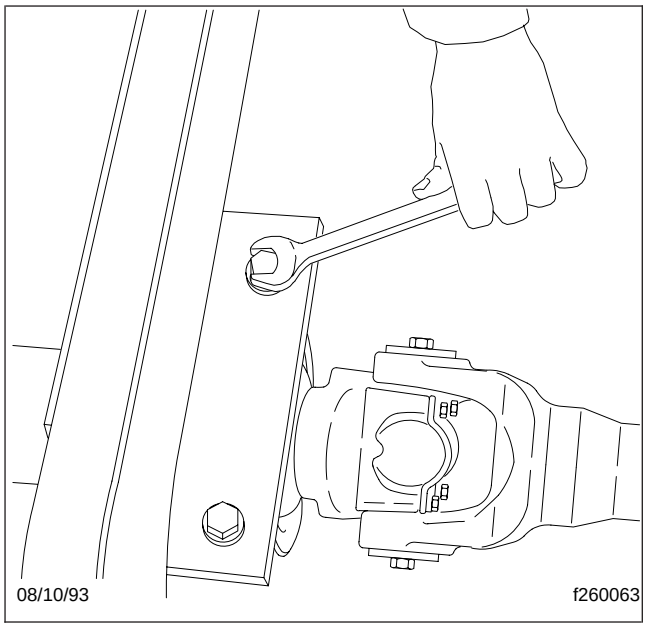


Fig. 1, Bracket Bolts Holding Midship Bearing Carrier

   - 2.3 Lower the driveline and midship bearing carrier onto the jackstand. It should rest securely on the jackstand.
3. Disconnect the driveline companion flange from the transmission companion flange. See **Fig. 2**.

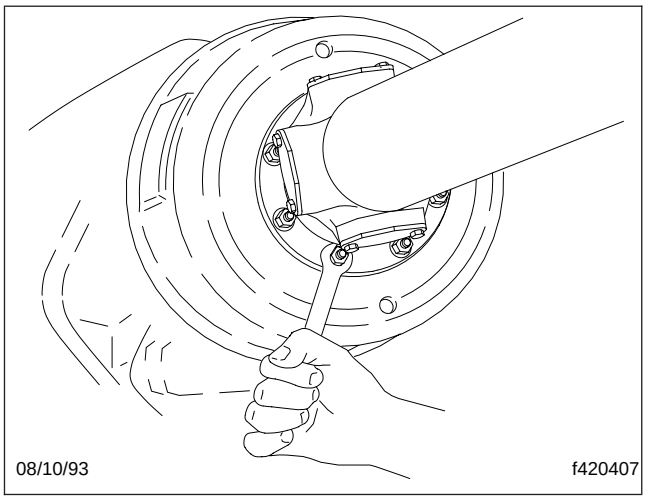


Fig. 2, Driveline Companion Flange Bolts

4. Slide out the driveline and lower it to the floor. See **Fig. 3**.

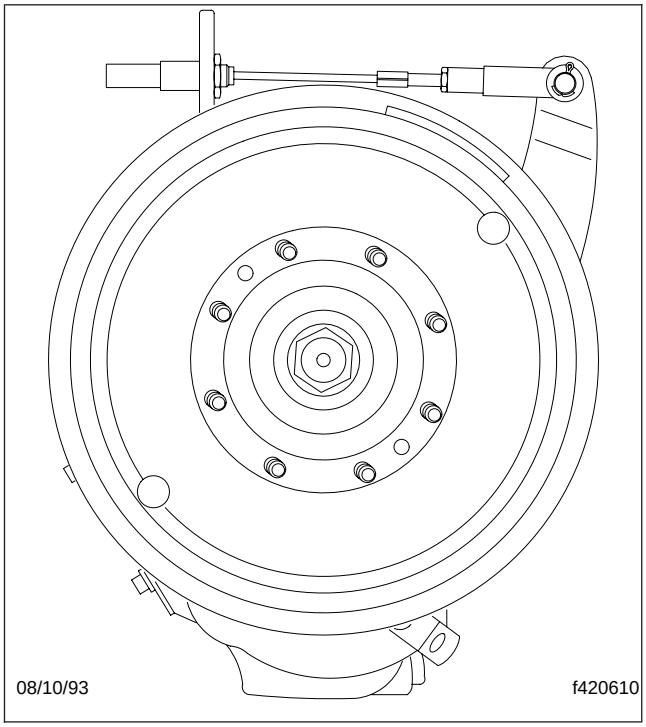


Fig. 3, Driveline Removed

5. Release the parking brake.
6. Pull the brake drum off the transmission companion flange. See **Fig. 4**.

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Bosch Removal and Installation

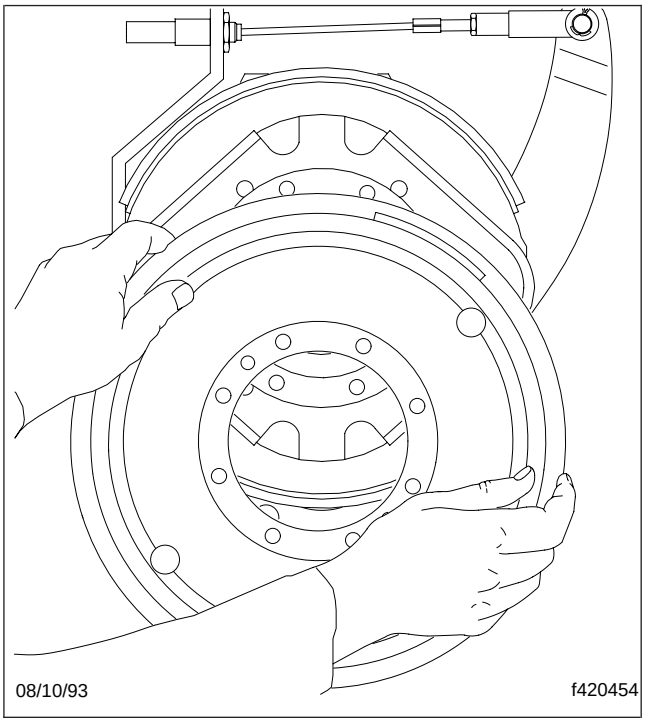


Fig. 4, Brake Drum Removed

7. Disconnect the brake cable from the actuating lever. See **Fig. 5**.

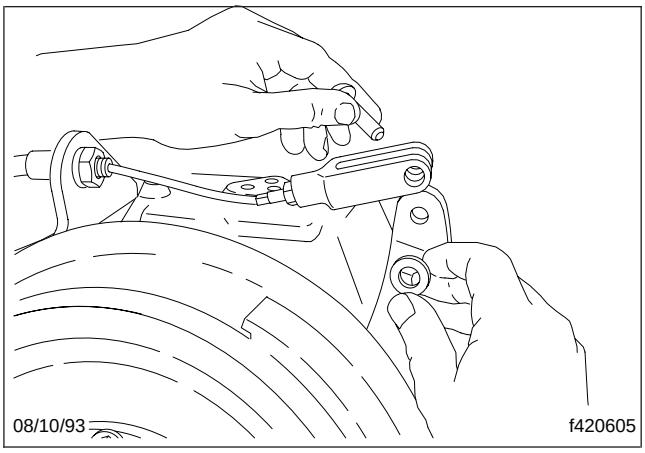


Fig. 5, Brake Line Disconnected

8. Remove the large end-nut from the transmission shaft. See **Fig. 6**. Remove the companion flange.
9. Remove the supporting plate and brake shoes as a unit.
10. Disassemble the brake parts. See **Fig. 7**.

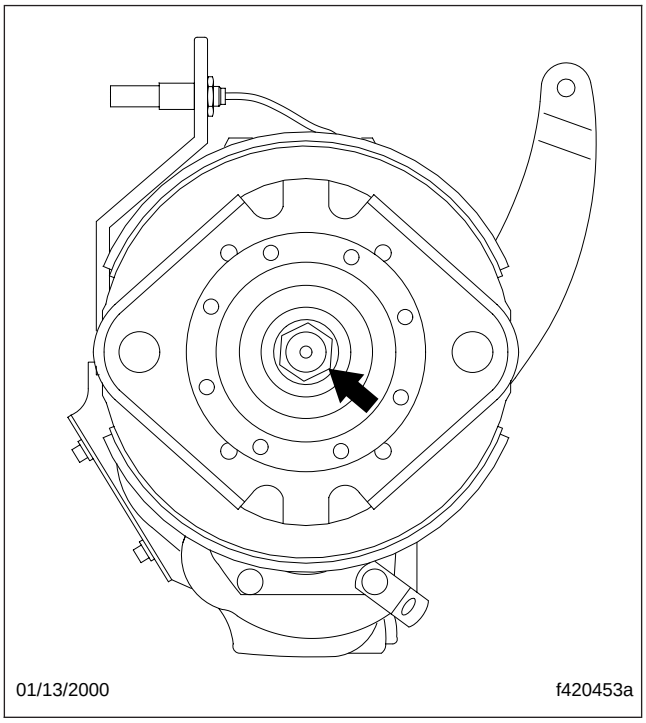


Fig. 6, End Nut

10.1 Remove the actuating lever and cam assembly.

10.2 Remove the brake shoes from the supporting plate.

⚠ WARNING

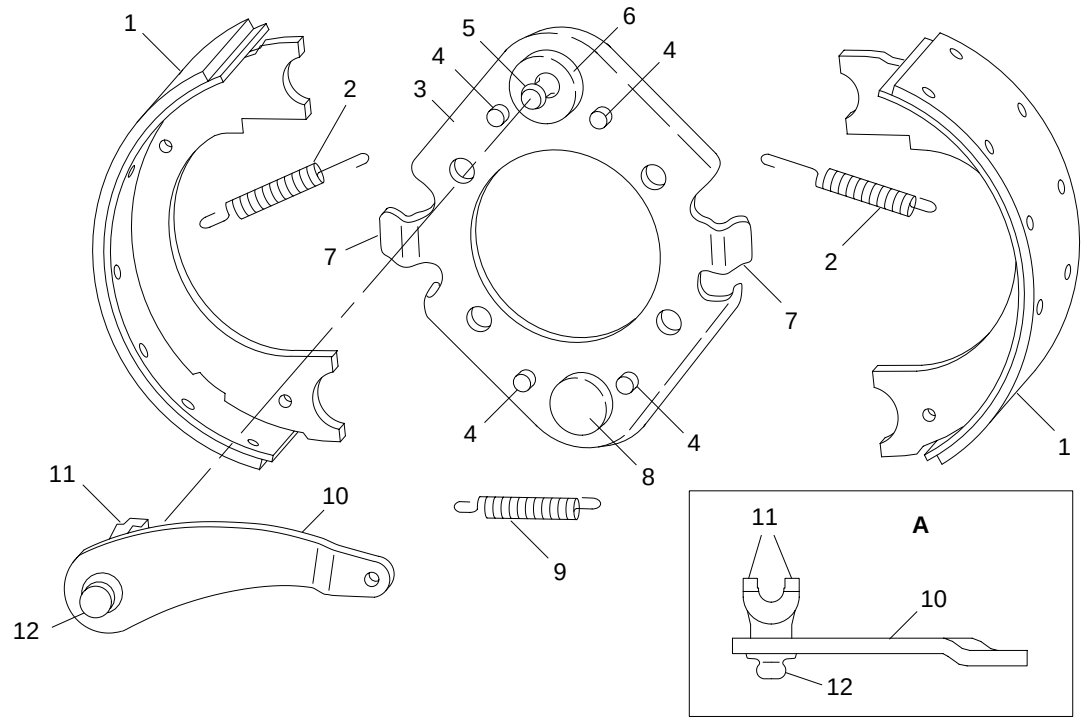
Brake shoe return springs are under tension and may release unexpectedly, which could cause injury. Wear safety glasses when removing them.

10.3 Using a suitable spring removal tool, carefully remove the two brake shoe return springs.

10.4 Spread the brake shoes apart to release tension on the shoe-to-shoe spring.

10.5 Remove both brake shoes from the support plate. Remove the shoe-to-shoe spring.

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A. Top view of actuating lever.

1. Brake Shoe
2. Return Spring
3. Support Plate
4. Shoe Bearing Surface
5. Nib
6. Upper Anchor Pin
7. Support Plate Lug
8. Lower Anchor Pin
9. Shoe-to-Shoe Spring
10. Actuating Lever
11. Cam Lugs
12. Cam Ball

Fig. 7, Parking Brake Components (exploded view)

Installation

1. Clean all the parts. Check for damage and corrosion and replace parts if needed. Check the support plate for cracks or bending. Replace it if needed.

CAUTION

Do not let any grease get on the brake drum or linings. Grease on these parts will reduce the effectiveness of the driveline parking brake. If brake linings become contaminated, replace them.

2. Using NLGI grade 2 brake grease, lightly grease (**Fig. 7**):
   - The cam lugs and ball;
   - The mating surfaces of the brake shoe webs and the support plate lugs;
   - The support plate anchor pins;
   - The shoe bearing surfaces;
   - The ends of the brake shoe webs.
3. Install new brake shoes. See **Fig. 7** and **Fig. 8**.
   3.1 Position the brake shoes on the support plate.

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Bosch Removal and Installation

NOTE: Position the support plate so the anchor pin with the nib is at the top.

3.2 Install a new shoe-to-shoe spring in the hole of each brake shoe.

3.3 Using a twisting motion, install the lower ends of the brake shoes over the lower anchor pin.

3.4 Put the upper ends of the brake shoes against the upper anchor pin making sure the shoe webs are underneath the guide lugs of the support plate.

3.5 Install two new return springs on the nib of the upper anchor pin and in the hole of each brake shoe.

3.6 Install the actuating lever and cam assembly on the anchor pin with the nib.

4. Using the four hexbolts, nuts, and washers, position the support plate and brake shoe assembly on the transmission adapter. See **Fig. 8**. Tighten the nuts 115 N·m (85 lbf·ft).
5. Install the transmission companion flange over the splines of the transmission shaft.
6. Install the large end-nut on the end of the transmission shaft. See **Fig. 6**. Tighten the nut:
   - 325 lbf·ft (440 N·m) on Eaton® Fuller® transmissions;
   - 145 lbf·ft (197 N·m) on Allison transmissions.
7. Install the brake drum onto the studs of the transmission companion flange.
8. Connect the driveline companion flange to the transmission companion flange.

   8.1 Place the driveline companion flange so its holes fit over the studs on the transmission companion flange.

   8.2 Install the eight nuts and washers on the studs. See **Fig. 2**. Tighten them 45 lbf·ft (61 N·m).
9. Connect the brake cable to the brake lever.

   9.1 Check the length of the brake cable. It should be just long enough to let the clevis hole align with the hole in the brake lever without moving the actuating lever. See **Fig. 9**.

   If the brake cable is too loose or too tight, loosen the jam nut. Screw the clevis in or out until its holes line up with the hole in the actuating lever (without moving the lever). See **Fig. 10**.

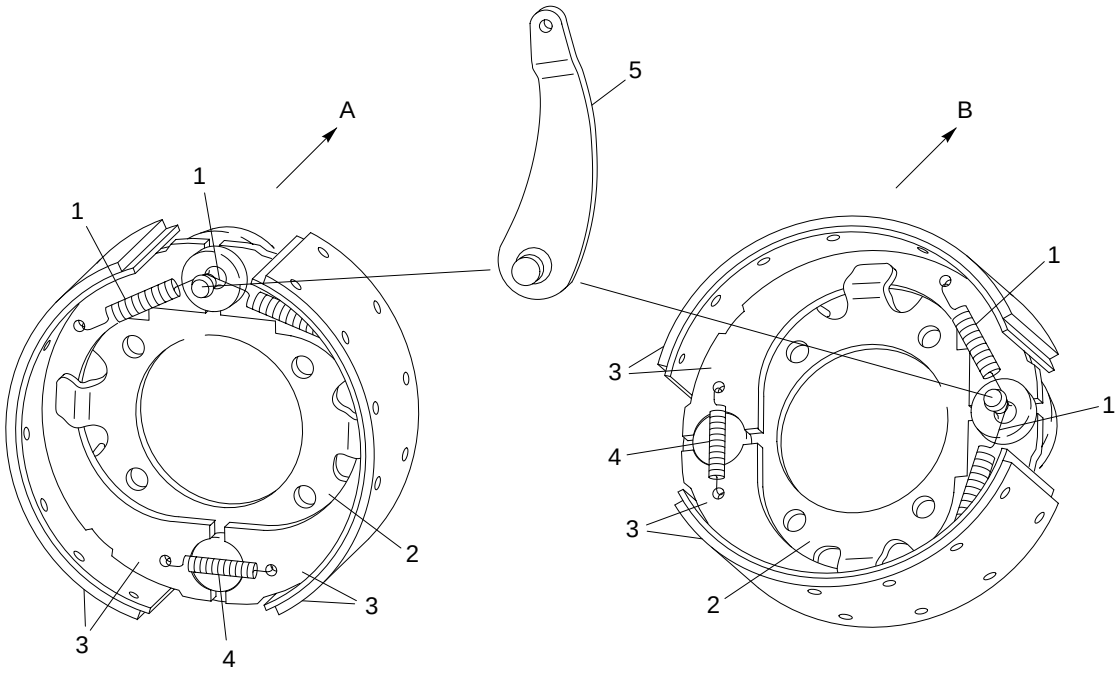
   9.2 Tighten the jam nut firmly.

   9.3 Install the clevis pin through the clevis and actuating lever holes.

   9.4 Install the washer and a new cotter pin on the clevis pin.

   9.5 Check the brake cable again for any slack. If it still needs adjusting, do it in the cab by turning the ring on the handle of the parking brake lever. See **Fig. 11**.
10. Attach the driveline midship bearing carrier to the bracket on the frame crossmember. Tighten the fasteners 91 lbf·ft (123 N·m).
11. Remove the chocks from the tires.

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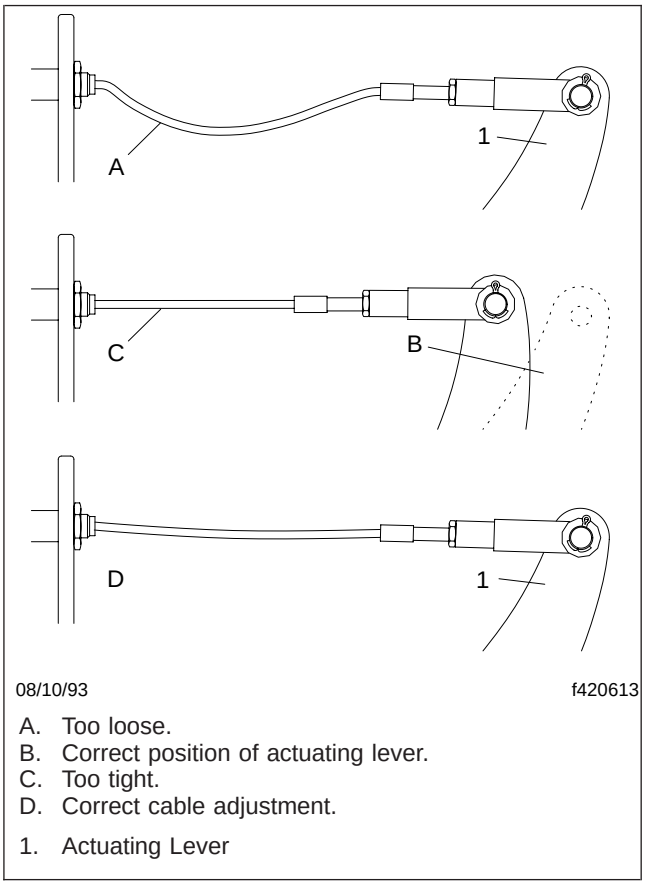
A. To Allison transmission.
B. To Fuller® transmission.

1. Return Spring
2. Support Plate
3. Brake Shoe
4. Shoe-to-Shoe Spring
5. Actuating Lever and Cam Assembly

Fig. 8, Parking Brake Assembly

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Bosch Removal and Installation



A. Too loose.
B. Correct position of actuating lever.
C. Too tight.
D. Correct cable adjustment.

1. Actuating Lever

Fig. 9, Brake Cable Tightness

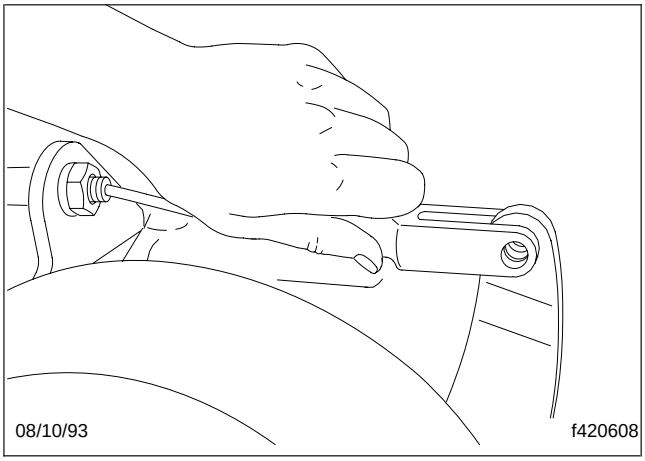


Fig. 10, Clevis Holes Lined Up With Actuating Lever Hole

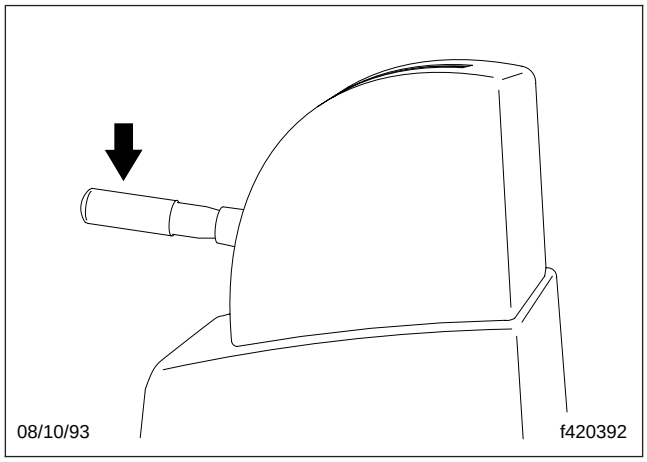


Fig. 11, Ring on Parking Brake Lever Handle

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Replacement

⚠ WARNING

Before starting the procedure below, see "Safety Precautions" in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

1. Park the vehicle on a level surface. Set the parking brake to keep the brake drum in place when the driveline is disconnected. Shut down the engine. Chock the tires.
2. Remove the brake drum. For instructions, see **Subject 110** for the Meritor parking brake and **Subject 120** for the Bosch parking brake.
3. Check the inside of the brake drum for cracking, scoring or other damage. If needed, resurface or replace the drum. If the inside diameter of the drum is more than 12.09 inches (307 mm), replace the drum.
4. Remove the old brake shoes.
   - 4.1 Carefully remove the lower brake shoe return springs. See **Fig. 1**.
   - 4.2 Pull the bottom of one brake shoe out, releasing the pressure on the upper return springs. Remove the upper return springs. See **Fig. 2**.
   - 4.3 Remove both brake shoes.

⚠ CAUTION

Do not let any grease get on the brake drum or linings. Grease on these parts will reduce the effectiveness of the driveline parking brake. If brake linings become contaminated, replace them.

5. Using NLGI grade 2 brake grease, lubricate (see **Fig. 3**):
   - The cam head face and journals;
   - The mating surfaces of the brake shoe webs and the actuator strut;
   - Both sides of the cam hole in the backing plate.
6. Install new brake shoes.

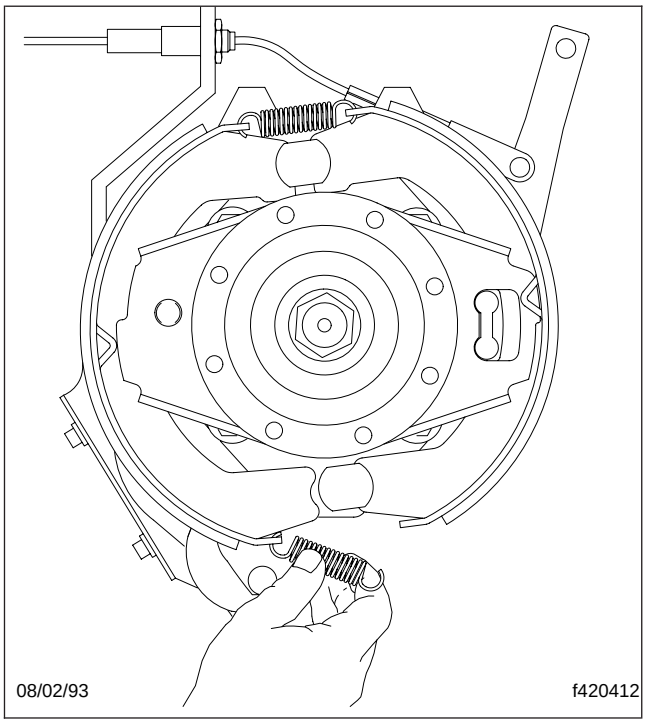


Fig. 1, Removal of Lower Return Spring

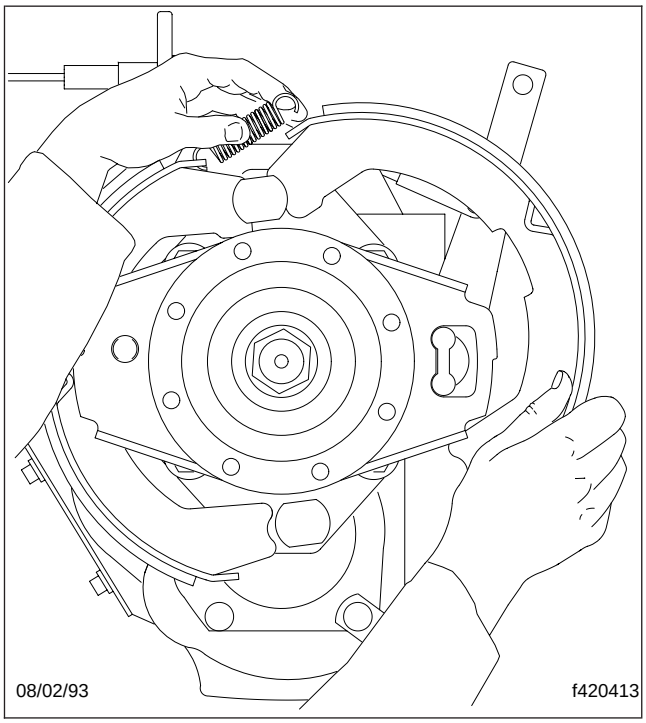
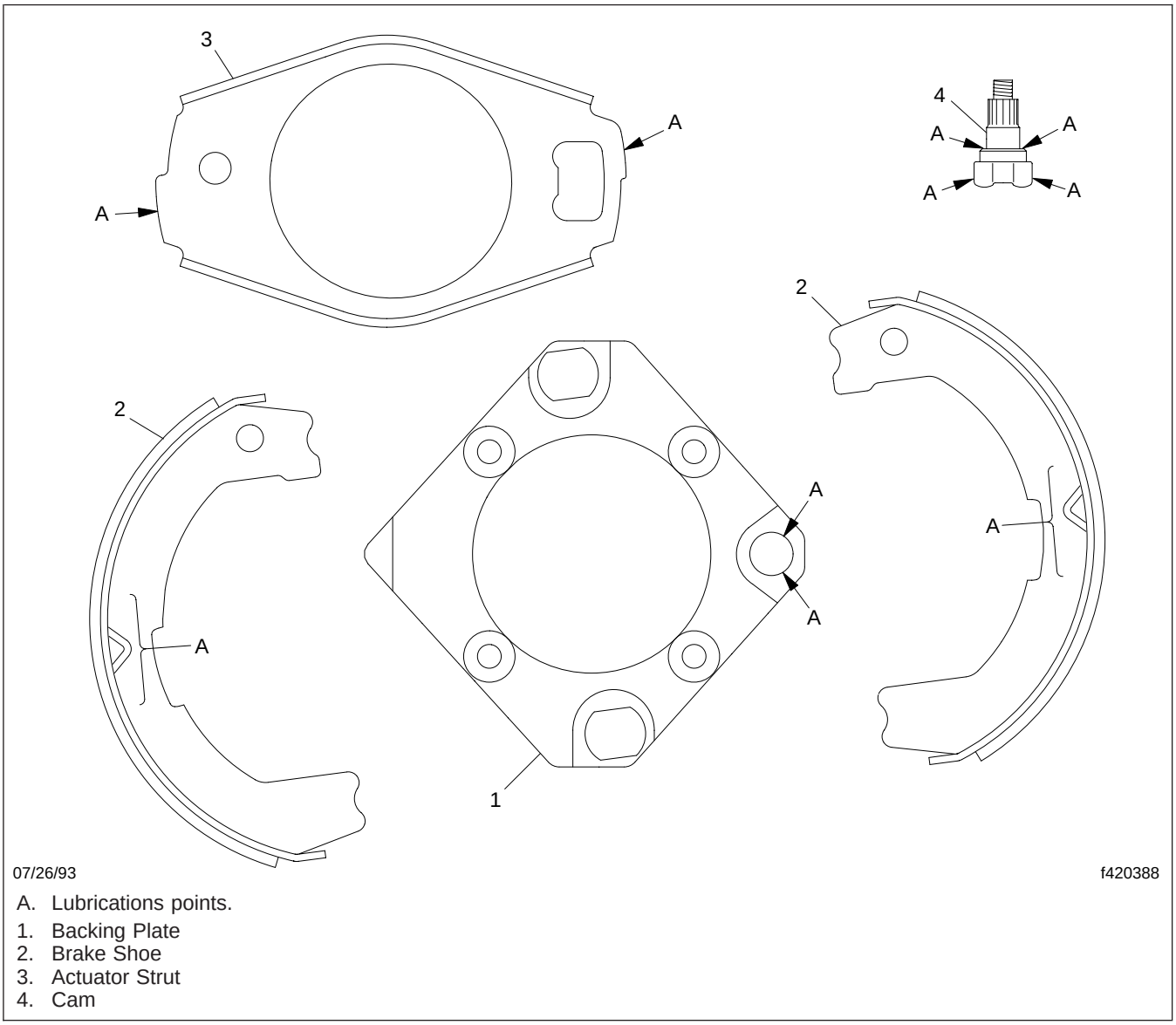


Fig. 2, Removal of Upper Return Spring

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Brake Shoe Replacement



A. Lubrications points.
1. Backing Plate
2. Brake Shoe
3. Actuator Strut
4. Cam

Fig. 3, Brake Shoes and Backing Plate

6.1 Install the brake shoes on the backing plate so that the web ends are up against the bosses on the backing plate.

6.2 Install four new brake return springs.

7. Install the brake drum and connect the driveline. For instructions, see **Subject 110** for the Meritor parking brake and **Subject 120** for the Bosch parking brake.

8. Adjust the brake cable by turning the ring on the end of the parking brake lever in the cab.

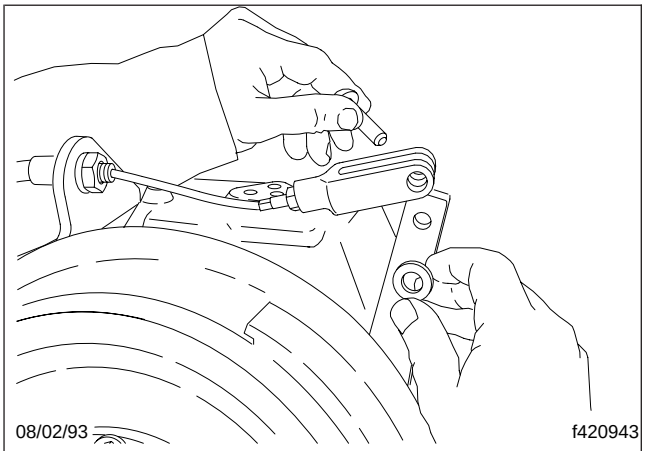
9. Remove the chocks from the tires.

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Parking Brake Cable Replacement

Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front and rear tires.
2. Release the parking brake.
3. At the driveline end, disconnect the brake cable from the actuating lever. See **Fig. 1**.



NOTE: Meritor parking brake shown.

Fig. 1, Brake Cable Disconnected

4. Unscrew the clevis from the cable; put the clevis aside. See **Fig. 2**.

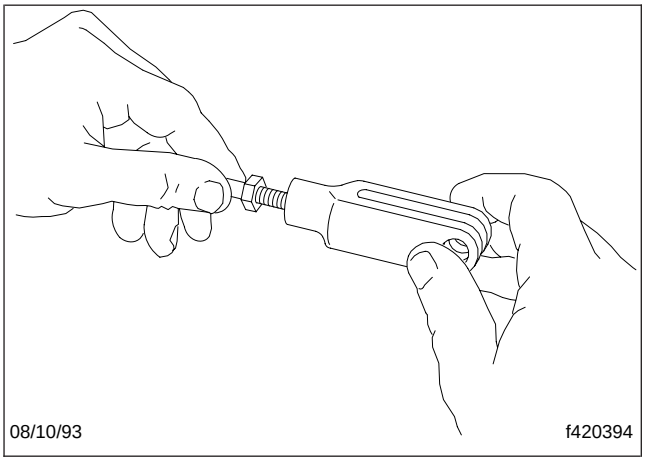
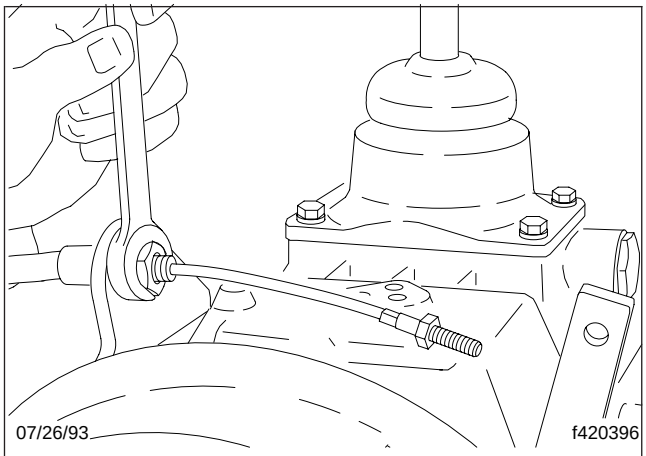


Fig. 2, Clevis Removal from Brake Cable

5. Remove and save the small jam nut from the threaded end of the cable that was installed in the clevis.
6. Remove the brake cable jam nut and lock washer from the cable bracket on top of the transmission. See **Fig. 3**.



NOTE: Meritor parking brake with Eaton® Fuller® transmission shown.

Fig. 3, Jam Nut

7. Push the brake cable end through the "D" hole in the bracket. See **Fig. 4**.

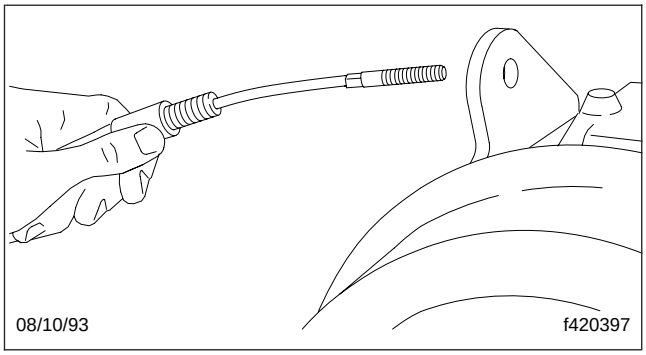


Fig. 4, Brake Cable Removed from Bracket

8. In the cab, remove the plastic boot covering the brake lever assembly.
9. Remove the nut from the double cable clamp on the side of the transmission. See **Fig. 5**. Remove the brake cable from its half of the clamp.
10. Disconnect the parking brake cable from the parking brake lever. See **Fig. 6**.
11. Remove the parking lever assembly from the cab deck.

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Parking Brake Cable Replacement

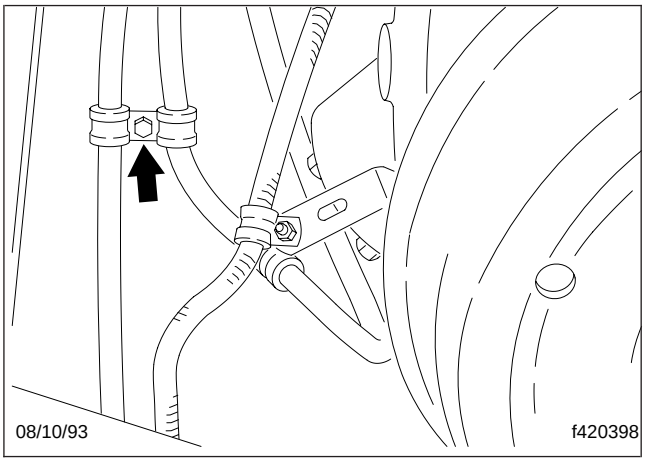


Fig. 5, Double Cable Clamp Nut

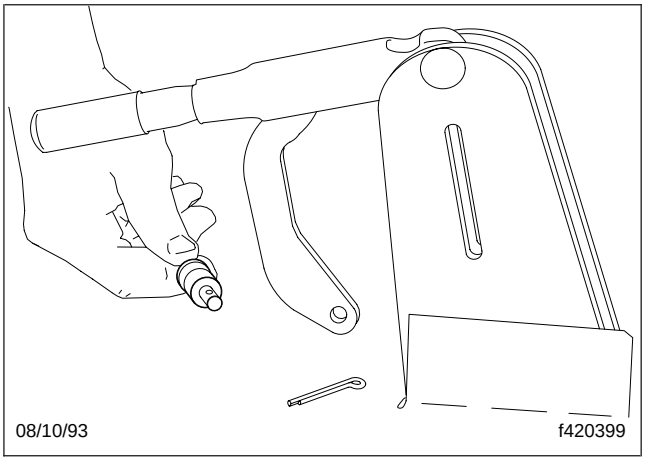


Fig. 6, Cable Disconnected from Lever

11.1 Disconnect the electrical wire from the right side of the parking brake lever assembly. See **Fig. 7**.

11.2 Remove the four mounting bolts and washers that hold the lever assembly to the cab floor. See **Fig. 8**.

11.3 Lift the lever assembly off the floor and set it aside.

12. Remove the jam nut and lockwasher from the threaded end of the cable sheath coming through the hole in the cab deck. See **Fig. 9**.

13. Remove the baseplate by sliding the parking brake cable through the slot in the baseplate. See **Fig. 10**.

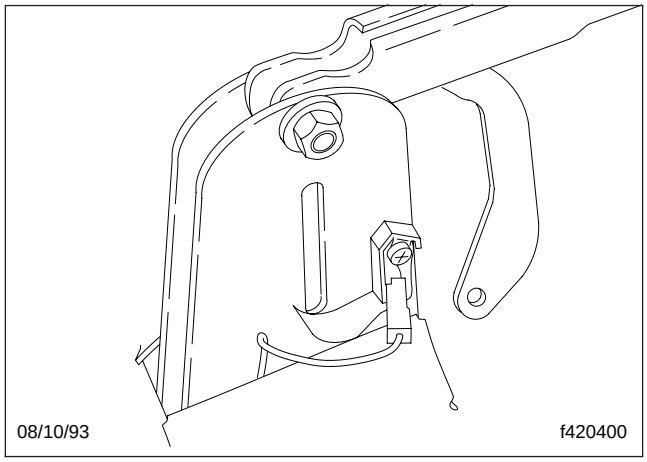


Fig. 7, Electrical Wire on Parking Brake Lever Assembly

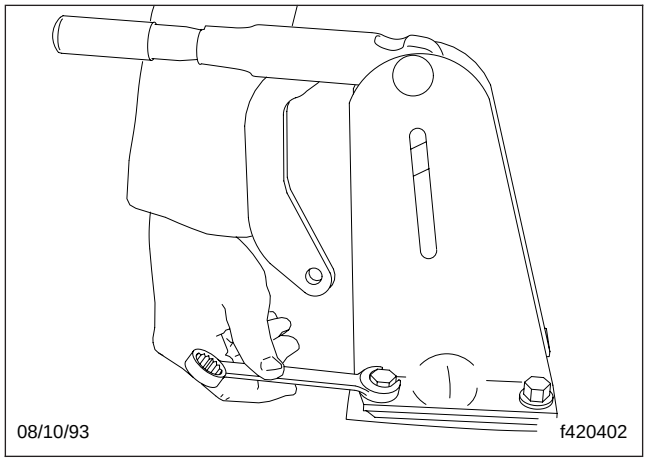


Fig. 8, Lever Assembly Mounting Bolts

14. Pull the entire length of the parking brake cable up through the hole in the cab deck.

15. Check the parking brake lever assembly for wear and damage. Replace it if needed.

16. Put the clevis end of the new parking brake cable assembly in the slot of the baseplate so that the jam nut and washer are on top of the base plate. See **Fig. 10**.

17. Install the lockwasher and jam nut on the cable sheath. Tighten the nut firmly. See **Fig. 9**.

18. Install the free end of the parking brake cable through the hole in the deck. Pull about a foot of the cable up through the sheath.

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Parking Brake Cable Replacement

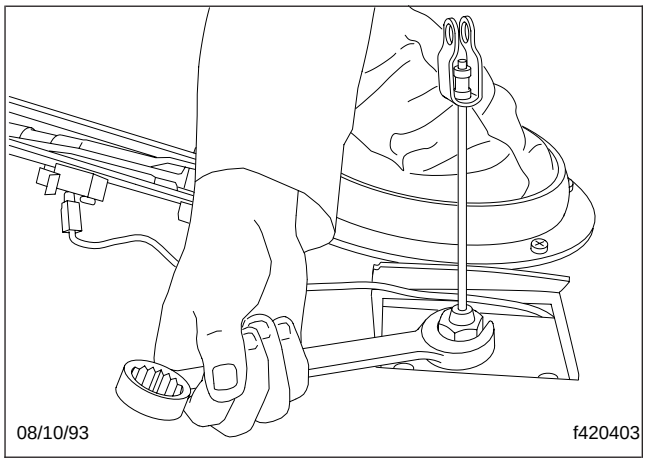


Fig. 9, Jam Nut on Cable Sheath (threaded end)

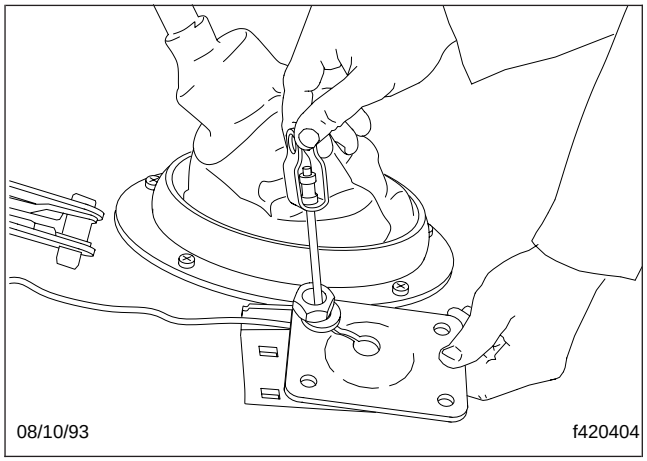
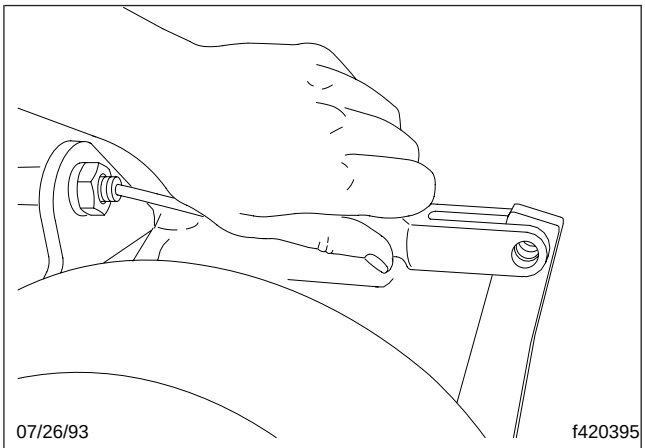


Fig. 10, Removal of Baseplate

19. Connect the new cable to the parking brake lever assembly.
    - 19.1 Install the bushing on the clevis pin. See **Fig. 6**.
    - 19.2 Put the clevis end of the cable up through the middle of the parking brake lever assembly.
    - 19.3 Put the curved brake lever arm into the middle of the brake lever assembly and into the clevis. See **Fig. 6**.
    - 19.4 Line up the slots in the brake lever assembly, the hole in the curved arm and the holes in the clevis.
    - 19.5 Install the clevis pin (with the bushing on it) from the side of the lever assembly with the electric wire connector. See **Fig. 7**.
    - 19.6 Install the washer and cotter pin on the clevis pin.
20. Install the parking brake lever assembly on the cab deck.
    - 20.1 Put the baseplate on the deck lining up the holes in the plate with those in the deck.
    - 20.2 Put the lever assembly in place so that its holes and those of the baseplate and the deck all line up.
    - 20.3 Install the four mounting bolts and washers. Tighten the fasteners firmly.
21. Connect the electrical wire to the right side of the parking brake lever assembly. See **Fig. 7**.
22. Underneath the cab, route the parking brake cable through the double cable clamp on the side of the transmission and up to the cable bracket on the top of the transmission (or rear axle). See **Fig. 5**.
23. Put the cable through the "D" hole in the bracket. Install the lockwasher and jam nut on the threaded end of the cable sheath. Do not tighten the nut all the way. See **Fig. 3**.
24. Connect the parking brake cable to the parking brake actuating lever.
    - 24.1 Screw the threaded end of the cable into the clevis far enough so the clevis holes will line up with the hole in the actuating lever. There should be no slack in the cable. See **Fig. 11**.
    - 24.2 Install the clevis pin in the holes of the clevis and that of the actuator lever.
    - 24.3 Tighten the jam nut (installed previously) 80 lbf·in (900 N·cm).
    - 24.4 Install the washer and a new cotter pin.
25. If a final cable adjustment is needed, make it in the cab by turning the ring on the parking brake lever. See **Fig. 12**.
26. Remove the chocks from the tires.

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Parking Brake Cable Replacement



NOTE: Meritor parking brake shown.

Fig. 11, Clevis Holes Lined Up with Hole in Actuating Lever

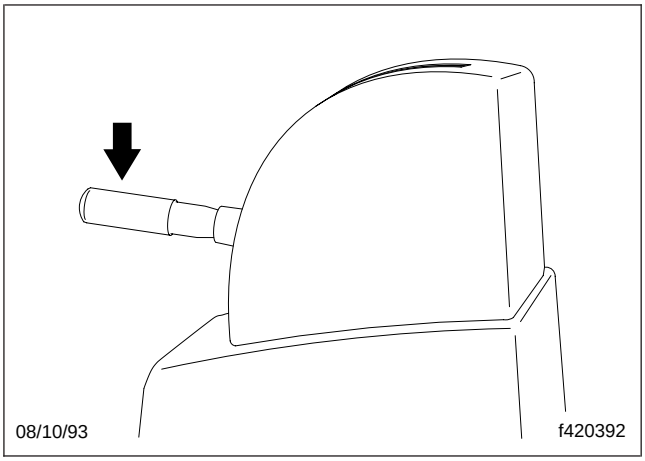


Fig. 12, Handle Ring on Parking Brake Lever

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Troubleshooting Tables

Problem—The Parking Brake Will Not Hold the Vehicle on a Grade

Problem—The Parking Brake Will Not Hold the Vehicle on a Grade	
Possible Cause	**Remedy**
Worn down brake shoe linings	Replace the brake shoes.
Cracked brake drum	Replace the drum.
Worn down or heavily scored brake drum lining	Replace the drum.
Binding brake cable	Repair or replace the cable.
Too much slack in the brake cable	Adjust the brake cable.
Grease on brake shoe linings	Replace the brake shoes. Clean the inside of the drum.

Problem—The Parking Brake Will Not Release

Problem—The Parking Brake Will Not Release	
Possible Cause	**Remedy**
Brake cable is too tight	Adjust the brake cable.
Missing, detached or broken brake shoe return springs	Check the return springs. Install them or replace them as needed.
Corroded or dirty contact points between the brake shoe webs and the actuator strut	Check the area, and clean and lubricate as needed.
Binding parking brake lever in the cab	Check the parking brake lever assembly for damage or corrosion. Repair or replace as needed.

Problem—The Parking Brake Makes Noises While the Vehicle is Moving

Problem—The Parking Brake Makes Noises While the Vehicle is Moving	
Possible Cause	**Remedy**
Loose parking brake drum	Check the brake drum mounting bolts. Tighten as needed.
Loose brake shoes or backing plate	Check the brake shoes, return springs, and backing plate mounting bolts. Tighten, repair, or replace, as needed.
Dirt inside the brake drum	Remove the brake drum and clean it. Also clean other brake parts.

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Specifications

Fastener Torques		
Description	**Torque**	
	lbf·ft (N·m)	**lbf·in (N·cm)**
Transmission End-Nut: Eaton® Fuller® Allison	325 (440) 700 (950)	—
Rear Axle End-Nut (Input Shaft)	740–920 (1000–1250)	—
Backing Plate Mounting Bolts (Meritor): Eaton® Fuller® Transmissions Allison Transmissions Rear Axle	 170–185 (230–251) 150–165 (203–224) 150–165 (203–224)	—
Support Plate Mounting Bolts (Bosch)	85 (115)	—
Brake Drum Mounting Bolts	45 (61)	—
Midship Bearing Carrier Mounting Bolts	91 (123)	—
Cable Bracket Jam Nut (on top of transmission or rear axle)	—	80 (900)

Table 1, Fastener Torques

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General Information

Meritor Q Plus™ series brakes are actuated by an S-type cam head, which is forged integrally with the camshaft and supported with nylon bushings. Cam pressure is applied through the cam rollers.

These brakes are used on both the front steer axle and rear axles.

Meritor steer axles have seven holes for attaching the spider to the axle flange. There is an eighth hole left open on the brake spider, on both the left and right sides of the steer axle. See **Fig. 1**. The seven holes used for attachment of the spider to the axle flange are 0.656 inch in diameter. The eighth hole is oversized at 0.687 inch in diameter.

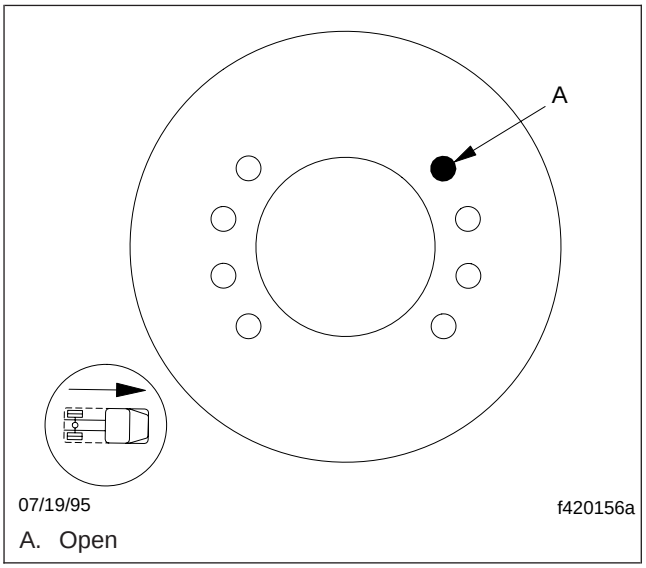


Fig. 1, Brake Spider Holes

Meritor attaches an identifying label to the web of all on-highway shoe and lining assemblies. The label is made of Mylar and is attached with a heat-resistant adhesive. The lining edge code shows the supplier lining designation and the corresponding Meritor designation. See **Table 1**.

Edge Codes		
Vendor Code		**Meritor Designation**
Abex	931–162	R301
	197	R201
	1083–7	R501
	1083–63	R401
	3115–035	R609
	3115–131	R208
Carlisle	E145–A	R202
	NAB–9ML	R302
	NAB10	R502
	NAB11	R402
Ferodo	NAB456	R403
	867	R203

Table 1, Edge Codes

The label includes three lines of information. See **Fig. 2**. The first line identifies the shoe as "Q PLUS". The second line gives the new Meritor aftermarket lining material designation. See "Meritor Designation" in **Table 1**. The third line gives the service part number to use for replacing the shoe and lining assembly.

When the brake pedal is depressed, compressed air enters the brake chamber, causing the diaphragm to move a pushrod assembly.

The pushrod, which is connected to a slack adjuster, turns the slack adjuster and brake camshaft. As the camshaft turns, the S-head, which is between the brake shoe rollers, forces the brake shoes against the brake drum and braking occurs.

When the brakes are released and air is exhausted from the brake chamber, the actuator return spring (within the brake chamber) and the brake shoe return spring, return the camshaft, brake shoes, slack adjuster and the pushrod to their released positions.

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General Information

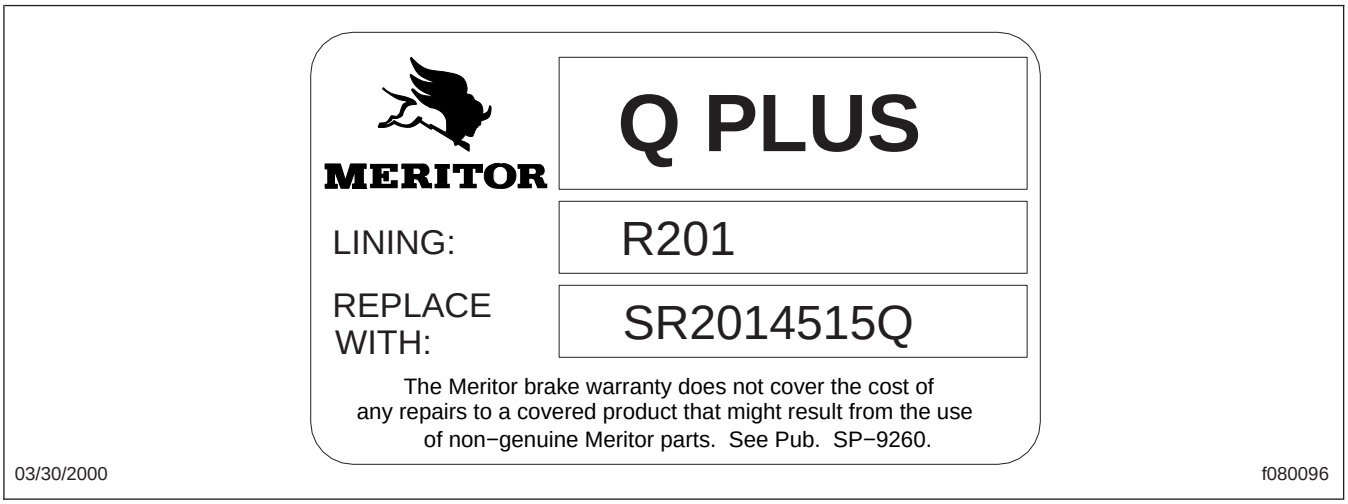


Fig. 2, Sample Meritor Brake Shoe Label

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General Safety Precautions

⚠ WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Asbestos and Non-Asbestos Safety

⚠ WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH.

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

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Safety Precautions

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

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⚠ WARNING

Before starting the procedure below, see "Safety Precautions" in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Raise the front or rear axle. Place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.
3. Remove the wheels and brake drums. For instructions, see **Group 33** or **Group 35** in this manual.

⚠ CAUTION

Before you back off automatic slack adjusters, see Section 42.11 in this manual, or the manufacturer's service information for instructions. Failure to do so could damage the slack adjusters.

4. Back off the slack adjusters. See **Section 42.11** in this manual for instructions on backing off the slack adjuster.
5. Remove the brake shoes.
   - 5.1 Push down on the lower brake shoe. Pull on the roller retaining clip to remove the lower roller. See **Fig. 1**.
   - 5.2 Lift the upper brake shoe and pull on the roller retaining clip to remove the upper roller.
   - 5.3 Lift the lower shoe to release tension on the brake return spring. Remove the spring. See **Fig. 2**.
   - 5.4 Rotate the lower shoe to release tension on the two retaining springs. Remove the springs and the brake shoes. See **Fig. 3**.
6. Inspect the brake shoes and linings for wear or damage. See **Subject 120**.

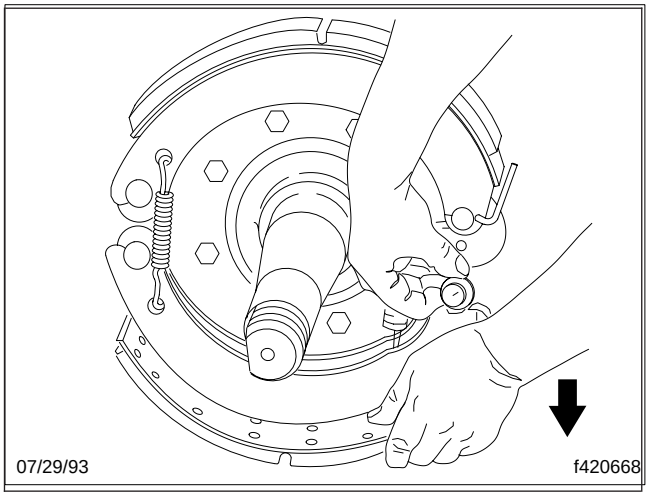


Fig. 1, Lower Cam Roller Removal

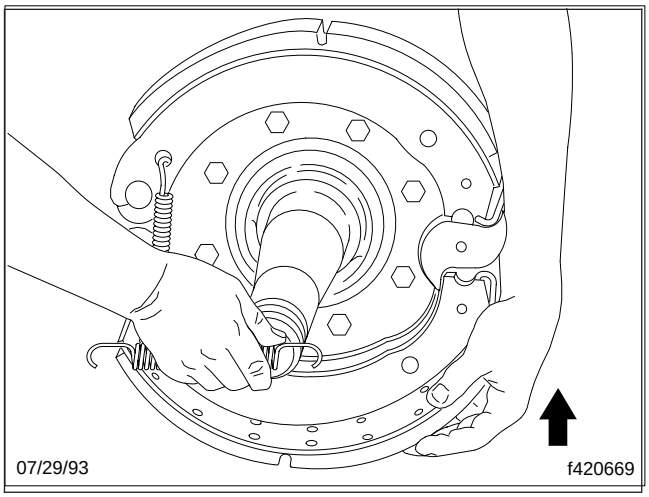


Fig. 2, Return Spring Removal

Installation

IMPORTANT: For best brake performance, do not mix Q and Q Plus™ series brakes. Use the same brake series on the entire vehicle.

IMPORTANT: Do not apply any grease on the outer diameter of the roller that touches the cam head.

1. Apply a thin film of a temperature resistant grease (Meritor 0-616, or an equivalent) on the anchor pins where they touch the brake shoes. Also, apply a multipurpose chassis grease (Meritor 0-617-A or 0-617-B, or an equivalent) on the

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Brake Shoe Removal and Installation

retainer clips, spider, and shoe rollers where they touch the brake shoes.

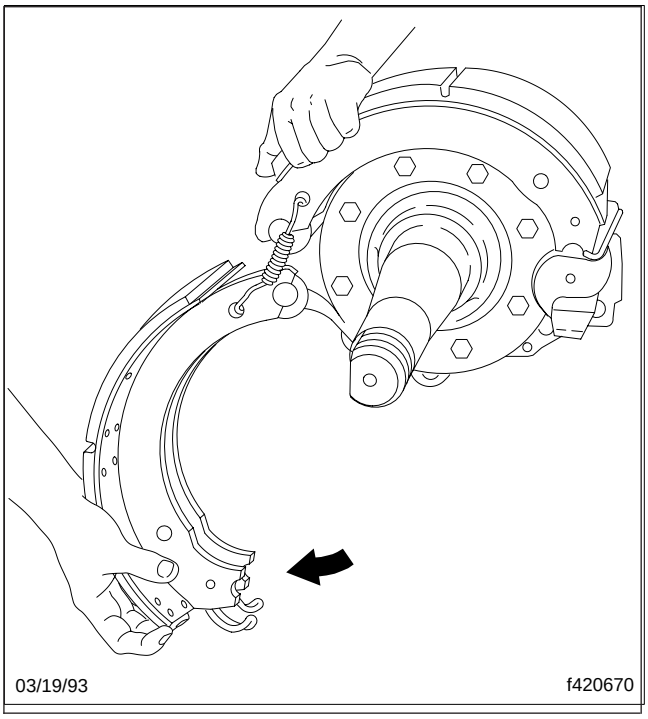


Fig. 3, Lower Shoe Rotated

2. Install the brake shoes.
   - 2.1 Place the upper brake shoe in position on the top anchor pin. Hold the lower brake shoe on the bottom anchor pin and attach two new brake shoe retaining springs. See **Fig. 4**.
   - 2.2 Rotate the lower brake shoe forward and attach a new brake shoe return spring. See **Fig. 5**.
   - 2.3 Pull the upper brake shoe away from the cam to allow enough space to install the cam rollers and retainers. Press the ears of the new retainer together to permit the retainer to fit between the brake shoe webs. See **Fig. 6**.
   - 2.4 Push the retainer into the brake shoe until the ears lock in the holes in the shoe webs. See **Fig. 7**.

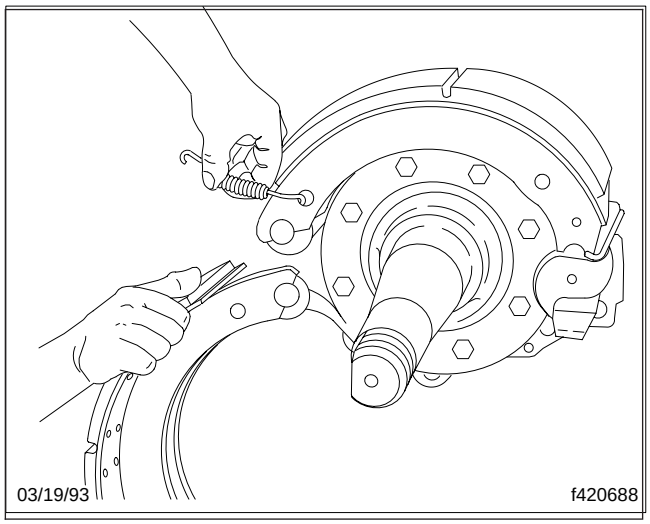


Fig. 4, Lower Brake Shoe on Bottom Anchor Pin

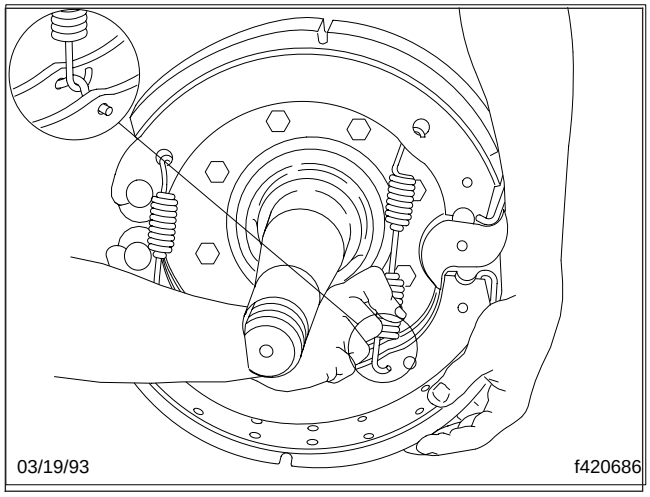
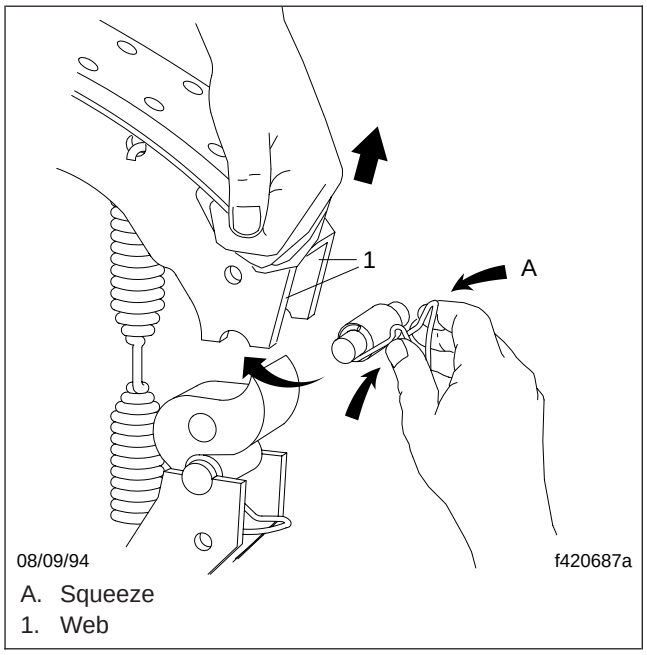


Fig. 5, New Brake Shoe Return Spring

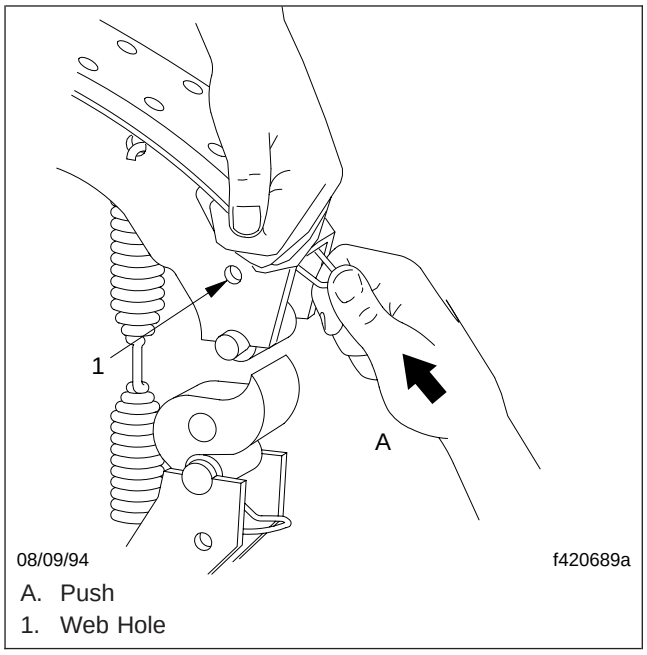
   - 2.5 Repeat these procedures to install the new roller and retainer on the lower brake shoe.
3. Install the wheels and brake drums. For instructions, see **Group 33** or **Group 35** in this manual.
4. Adjust the brakes at the slack adjusters. For instructions, see **Subject 130**.
5. Remove the safety stands, lower the vehicle and remove the chocks from the tires.

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A. Squeeze
1. Web

Fig. 6, Cam Roller and Retainer



A. Push
1. Web Hole

Fig. 7, Retainer in Web Hole

⚠ WARNING

Do not operate the vehicle until you have adjusted the brakes and checked for their proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

6. In a safe area, check for proper brake operation.
   - 6.1 Apply and release the brakes several times to check for air leaks and correct operation of the slack adjusters.
   - 6.2 Do several low-speed stops to ensure correct parts replacement and full vehicle control.
   - 6.3 Make ten 40 to 20 mph (60 to 30 km/h) snubs to seat the linings.
   - 6.4 Make 10 stops from 20 mph (30 km/h) at 50 percent air pressure.
   - 6.5 Make a full-pressure stop from 20 mph (30 km/h).
   - 6.6 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than the others shows a lack of braking effort on those wheels.

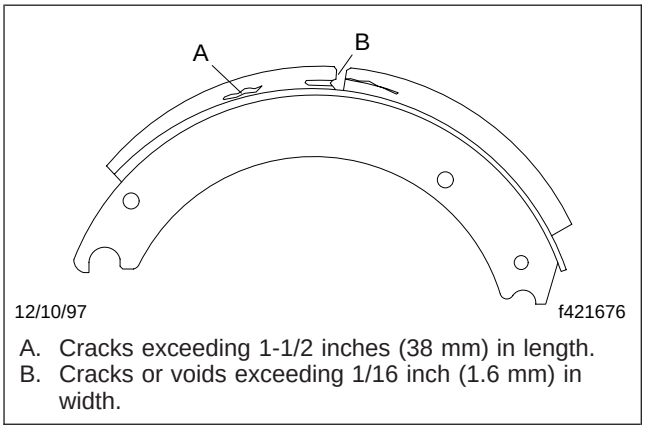
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⚠ WARNING

Before starting the procedure below, see "Safety Precautions" in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

Inspection

1. Remove the brake shoes using the instructions in **Subject 110**.
2. Check the linings.
   - 2.1 If the linings are grease- or oil-soaked, cracked, or worn to less than 1/4-inch (6.4-mm) thickness at any point, replace them.
   - 2.2 Replace the linings if the lining surface is closer than 1/32 inch (0.8 mm) to any rivet head.
   - 2.3 The lining is considered worn-out and the vehicle should not be driven if:
     - Cracks on the lining surface exceed 1/16 inch (1.6 mm);
     - The lining edge shows cracks or voids over 1/16 inch (1.6 mm) in width and 1-1/2 inches (38 mm) in length (see **Fig. 1**);
     - Portions of the lining are missing, exposing a rivet when viewed from the edge (see **Fig. 2**);



A. Cracks exceeding 1-1/2 inches (38 mm) in length.
B. Cracks or voids exceeding 1/16 inch (1.6 mm) in width.

Fig. 1, Cracks and Voids

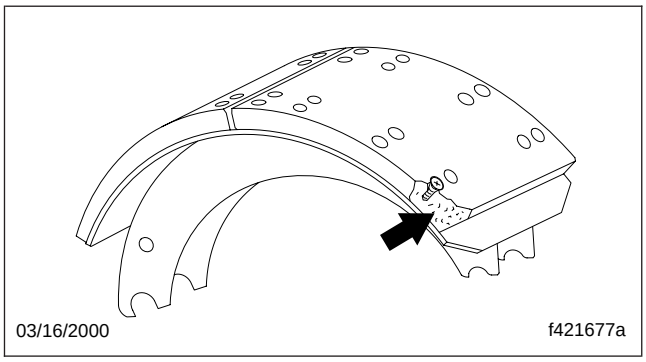


Fig. 2, Rivet Exposed by Missing Brake Lining

     - Cracks extend across the lining face and through the lining edge, or the lining is loose on the shoe (see **Fig. 3**).
   - 2.4 The vehicle is still operational but linings should be replaced as soon as possible if:
     - Horizontal or vertical cracks in the lining edge exhibit no loss of material and do not exceed 1/16 inch (1.6 mm) in width or 1-1/2 inch (38 mm) in length (see **Fig. 4**);
     - Corner portions of the lining are missing with no fastener exposed (see **Fig. 5**);
     - Surface cracks extend from hole to hole or if there is scoring and contamination from road debris (see **Fig. 6**).

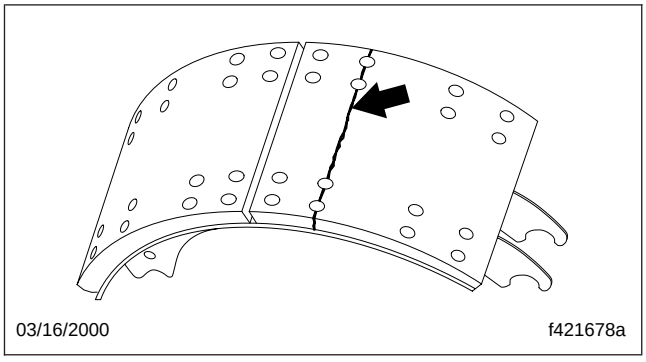


Fig. 3, Crack Extending Through Brake Lining Edge

3. Check the shoes for bent or cracked webs or tables, broken welds, and loose or out-of-round

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Brake Shoe and Lining Inspection

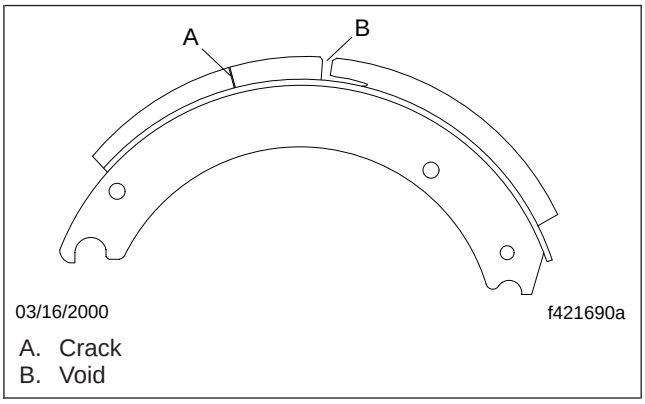


Fig. 4, Cracks and Voids

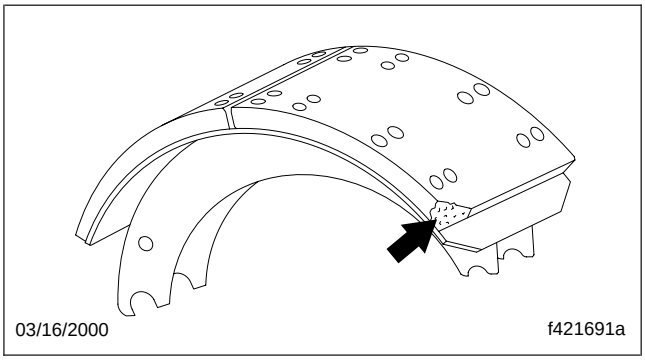


Fig. 5, Corner Segment Missing With No Fastener Exposed

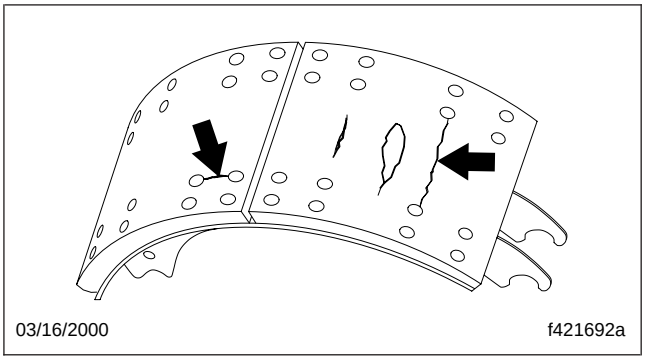


Fig. 6, Cracks Extending From Hole to Hole

rivet or bolt holes. Replace the shoes if any of these conditions exist.

4. Check the anchor pin for looseness and cam roller recesses in the shoe webs for visible wear. Replace the shoe if needed.

5. Check the shoe span. Measure the distances between the centerlines of the anchor pin and the cam roller pin recesses in the shoe web. If the measurement is more than 12-7/8 inches (327 mm), replace the shoe. See **Fig. 7**.

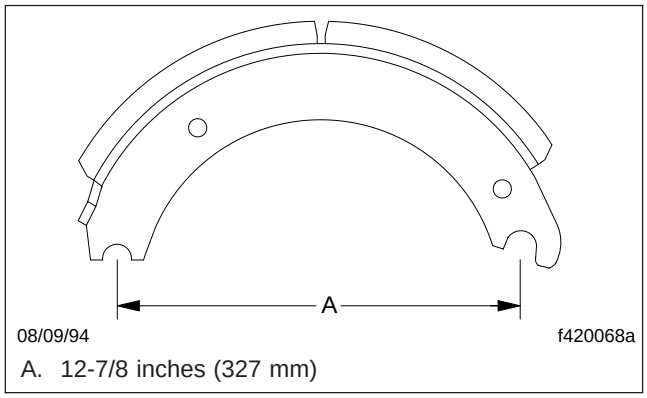


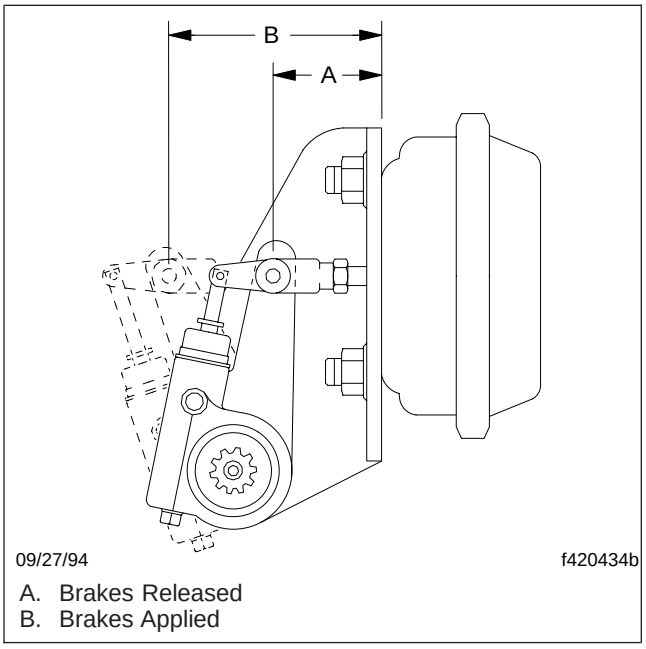
Fig. 7, Measuring the Shoe Span

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Adjustment

1. Check the free-stroke.

   1.1 With the brakes fully released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 1**.



A. Brakes Released
B. Brakes Applied

Fig. 1, Free Stroke Measurements

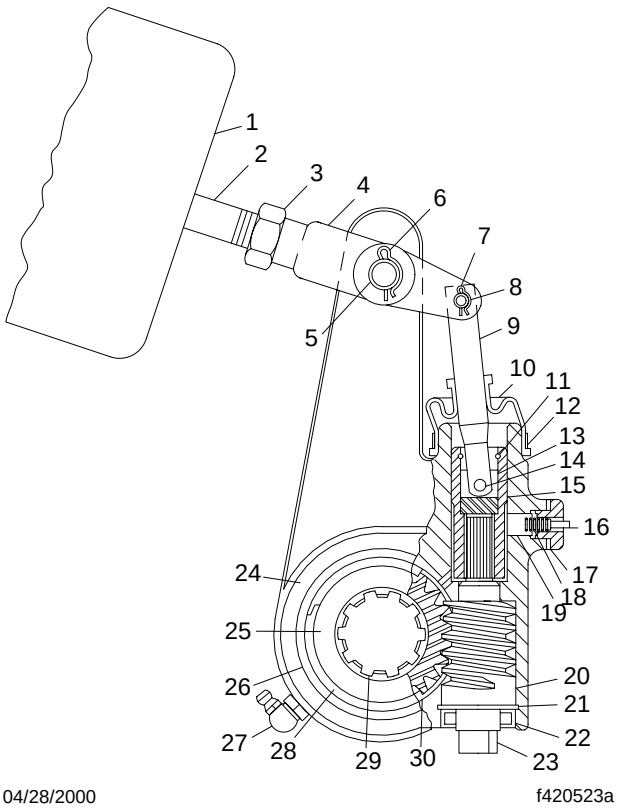
   1.2 Use a pry bar to move the slack adjuster and apply the brakes. Again, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 1**.

   1.3 The difference between the two measurements is the initial free-stroke and sets the clearance between the linings and the drum.

   1.4 The free-stroke must be 5/8 to 3/4 inch (16 to 19 mm).

   If the free-stroke is correct, go to the step for checking brake chamber stroke.

   1.5 If the free-stroke is incorrect, remove the pressure relief capscrew, spring and pawl assembly from the slack adjuster housing. See **Fig. 2**. If equipped with a pull-pawl assembly, carefully insert a screwdriver and raise the relief cap about 1/8 inch (3.2 mm). See **Fig. 3**.

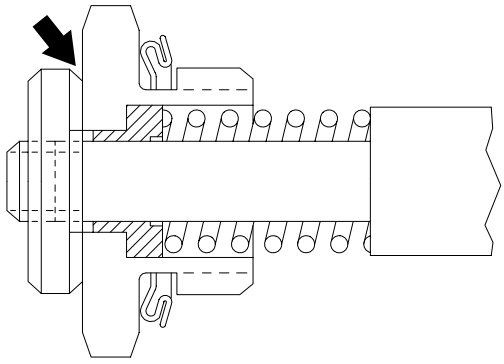


1. Brake Air Chamber
2. Brake Chamber Pushrod
3. Clevis Jam Nut
4. Clevis
5. Clevis Pin (large)
6. Cotter Pin (large)
7. Cotter Pin (small)
8. Clevis (small)
9. Actuator Rod
10. Boot
11. Piston Retaining Ring
12. Boot Retaining Clamp
13. Actuator Piston
14. Roller (Pin)
15. Actuator (Adjusting Screw)
16. Pressure Relief Capscrew
17. Gasket
18. Pawl Spring
19. Pawl Assembly
20. Worm
21. Worm Retaining Snap Ring
22. Worm Seal
23. Manual (Worm) Adjusting Nut End
24. Slack Adjuster
25. Gear
26. Gear Thrustwasher
27. Grease Fitting
28. Gear Retaining Ring
29. Camshaft Splines
30. Gear-to-Body Seal

Fig. 2, Meritor Automatic Slack Adjuster

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Brake Adjustment



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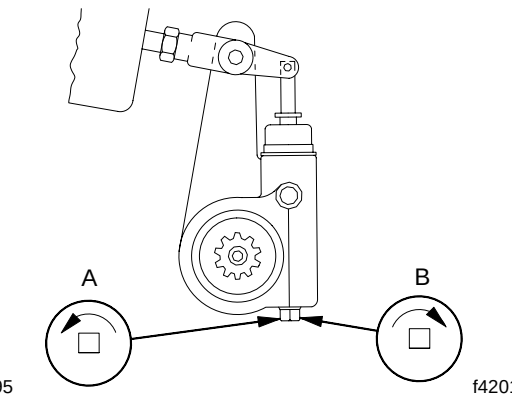
Insert screwdriver where indicated.

Fig. 3, Pull-Pawl Assembly and Screwdriver Position (sectional view)

CAUTION

Before turning the adjusting nut, remove the pressure relief capscrew, spring and pawl assembly. If equipped with a pull-pawl assembly, raise the relief cap about 1/8 inch (3.2 mm). Failure to do so could strip the teeth on the pawl.

1.6 Turn the adjusting nut 1/8 turn. See **Fig. 4**. Measure the stroke again and adjust until it is correct.



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A. Shorten stroke
B. Lengthen stroke

Fig. 4, Nut Adjustment

2. Check for correct brake chamber stroke.

2.1 With the brakes fully released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 1**.

2.2 Build air pressure to 100 psi (689 kPa). Shut down the engine. Fully apply the brakes. Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 1**. The difference between the measurements is the brake chamber stroke.

2.3 The brake chamber stroke must be less than the measurements shown in **Table 1**. If the brake chamber stroke is incorrect, remove the pressure relief capscrew, spring and pawl assembly from the slack adjuster housing. See **Fig. 2**. If equipped with a pull-pawl assembly, carefully insert a screwdriver and raise the relief cap about 1/8 inch (3.2 mm). See **Fig. 3**.

Maximum Adjusted Brake Chamber Stroke	
Chamber Size	**Stroke inch (mm)**
9, 12	Less than 1-3/8 (35)
16, 20, 24	Less than 1-3/4 (44)
24 *, 30	Less than 2 (51)
36	Less than 2-1/4 (57)

* Long Stroke

Table 1, Maximum Adjusted Brake Chamber Stroke

CAUTION

Before turning the adjusting nut, remove the pressure relief capscrew, spring, and pawl assembly. If equipped with a pull-pawl assembly, raise the relief cap about 1/8 inch (3.2 mm). Failure to do so could strip the teeth on the pawl.

2.4 Turn the adjusting nut 1/8 turn, as shown in **Fig. 4**. Measure the stroke again and adjust until correct.

CAUTION

Do not make the adjusted chamber stroke too short. The free-stroke must not be less than 5/8

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to 3/4 inch (16 to 19 mm). If the chamber stroke is too short, the linings can drag and damage the brake.

If the stroke varies or remains greater than the specified range, check the brake components. For instructions, see Subject 150.

2.5 If necessary, replace the slack adjuster. For instructions, see **Section 42.11**.

2.6 If removed, install the pawl assembly, spring, and pressure relief capscrew. Tighten the capscrew 15 to 20 lbf·ft (20 to 27 N·m). Or, remove the screwdriver from the pull-pawl assembly (if equipped).

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⚠ WARNING

Before starting the procedure below, see "Safety Precautions" in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

Replacement

IMPORTANT: For the best brake performance, do not mix brake linings between axles. When relining brake shoes, both wheel ends of each axle must have the same linings. On tandem axles, all four wheel ends must also have the same linings. However, it is not necessary for the steering-axle brakes to have the same linings as the rear drive-axle brakes. Also, when the minimum thickness is reached for any of the brake linings on an axle, reline both brakes on that axle at the same time.

Combination linings with different friction ratings for the primary and secondary shoes are often used. When combination linings are used, install the forward blocks on the primary shoe (following the rotation of the drum, the first shoe after passing the cam or wheel cylinder is the primary shoe).

If the cam is behind the axle, the upper shoe is the primary and the lower shoe is the secondary. See **Fig. 1**. If the cam is in front of the axle, the lower shoe is the primary. See **Fig. 2**.

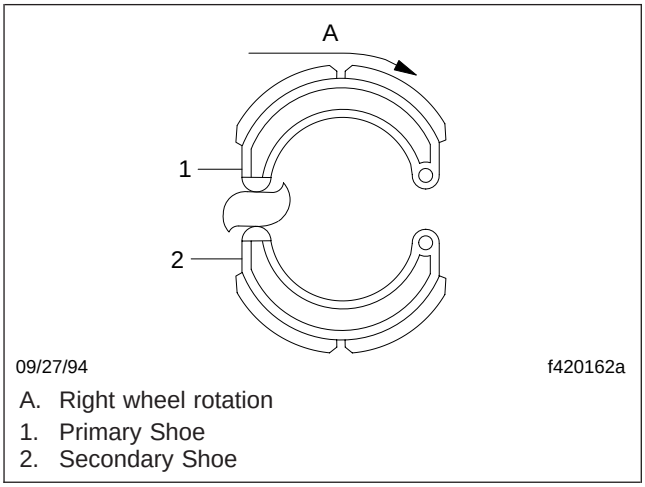


Fig. 1, Camshaft Behind Axle

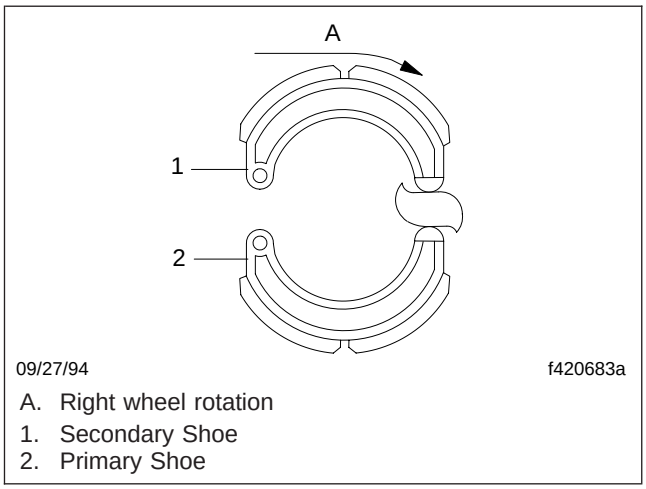


Fig. 2, Camshaft Ahead of Axle

REPLACEMENT USING RIVETS

With the brake shoe removed, do the following:

⚠ CAUTION

Drilling rivets out or cutting off rivet heads with a chisel can cause the rivet hole to become out-of-round. This could damage the brake shoe.

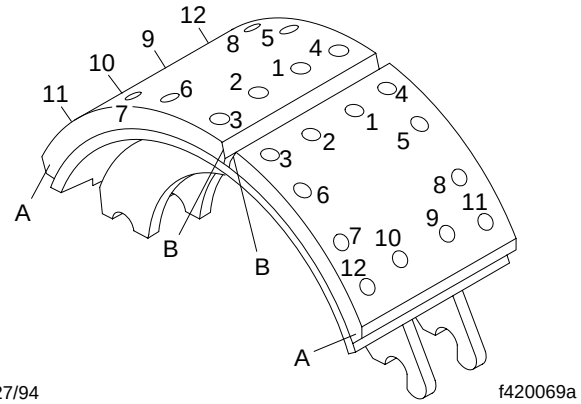
1. Using a suitable riveting mandrel, push the old rivets out.
2. Clean the shoe table. For instructions, see **Subject 150**.
3. Align the brake shoe and lining rivet holes. Using a C-clamp, clamp the lining to the brake shoe.
4. Insert the correct size rivets into all holes and threads, and temporarily hold them in place with masking tape.

IMPORTANT: Use rivets that have the correct material, shank diameter, length, head size and shape. Use tubular rivets that are 1/4-inch diameter by 9/16-inch long, SAE No. 10, made of plated steel or brass.

5. Begin riveting at the center of each heel of the shoe and lining and work toward each toe. Follow the sequence shown in **Fig. 3**.
6. Check for a close fit between the lining and shoe table.

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Brake Shoe Lining Replacement

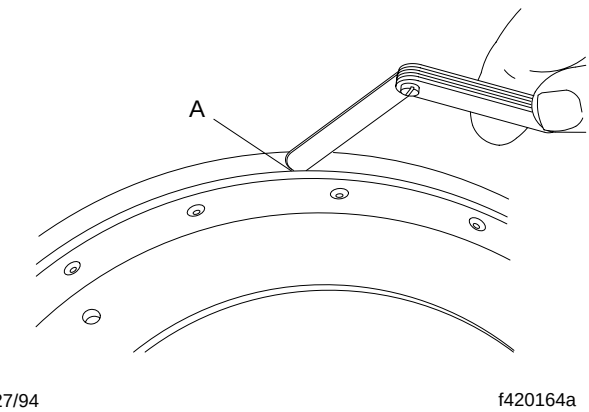


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A. Toe
B. Heel

Fig. 3, Rivet or Bolt Attachment Sequence

Try to insert a 0.010-inch (0.25-mm) feeler gauge between the lining and shoe table along the edges. See **Fig. 4**. It should not be possible to insert the feeler gauge anywhere along the edge, except at each end beyond the last row of rivets. See **Fig. 5**. A larger clearance, up to 0.025 inch (0.64 mm), may exist in these areas.

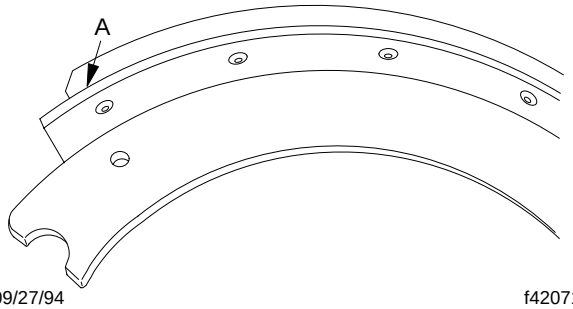


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A. Try to insert a 0.010-inch (0.25-mm) feeler gauge between the lining and shoe table along the edges.

Fig. 4, Feeler Gauge

7. Circle-grind the brake lining to obtain the correct lining-to-drum contact. With the cam in the full-release position, the new brake linings must be ground 0.070 inch (1.8 mm) less than the drum diameter. The cam must be adjusted and the lining ground until there is an 80 percent lining-to-drum contact, which must be continuous and in the center of the lining.



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A. Clearance up to 0.025 inch (0.64 mm), may exist in this area.

Fig. 5, End of Edge

REPLACEMENT USING BOLTS

1. Clean the shoe table. For instructions, see **Subject 150**.
2. Align the brake shoe and lining bolt holes. Using a C-clamp, clamp the lining to the brake shoe.
3. Insert the correct size bolts, and new lockwashers, into all holes and threads. Loosely install the nuts.
4. Tighten the nuts in the sequence shown in **Fig. 3**:
   - 18 to 23 lbf·ft (24 to 31 N·m) for 3/8-inch brass bolts;
   - 80 to 100 lbf·in (900 to 1120 N·cm) for 1/4-inch brass bolts.
5. Circle-grind the brake lining to obtain the correct lining-to-drum contact. With the cam in the full-release position, the new brake linings must be ground 0.070 inch (1.8 mm) less than the drum diameter. The cam must be adjusted and the lining ground until there is an 80 percent lining-to-drum contact, which must be continuous and in the center of the lining.

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Brake Components Disassembly and Inspection, Cleaning, and Assembly

Disassembly and Inspection

(See Fig. 1)

⚠ WARNING

Before starting the procedure below, see "Safety Precautions" in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

1. Check the drum for cracks, heat-checks, glazing, grooving and run-out. See **Fig. 2**. Measure the drum diameter. Replace the drum if it exceeds the maximum diameter stamped on it. Replace cracked drums. Some drums that are glazed, grooved, or out-of-round can be repaired. For detailed instructions, see **Group 33** or **Group 35** in this manual.
2. Disconnect the slack adjuster from the pushrod clevis. For instructions, see **Section 42.11** or the slack adjuster manufacturer's service information for instructions.
3. With the brake shoes removed, use a dial indicator to measure the up-and-down and side-to-side end play of the camshaft. Replace the bushings if there is more than 0.030 inch (0.8 mm) of movement.
4. Remove the slack adjuster.
5. Check the slack adjuster for damage and for binding.
   - 5.1 Check the slack adjuster clevis for cracks or bushing wear. Check the splines for chipped teeth and deformation. Replace as needed.
   - 5.2 Depress the locking sleeve, and turn the adjuster nut with a wrench at least one turn in each direction. If there is binding or if excessive force is needed to turn the slack adjuster, replace it.

IMPORTANT: If any slack adjuster problem is found, repair or replace the unit, depending on the manufacturer's recommendations.

6. Remove the camshaft by grasping its head and pulling the camshaft outboard.
7. Check the camshaft spline end for cracks or worn or deformed splines. Replace the camshaft if damaged.
8. Check the camshaft bushing journals for wear or corrosion. Replace the camshaft if it is worn or if roughness is felt in the journal area.
9. Inspect the camshaft head for brinelling, cracking, or flat spots. Replace the camshaft if a ridge can be felt between the worn area and the cam head surface.
10. Remove the brake chamber stud nuts and lockwashers that attach the brake chamber to the camshaft support bracket.

    Check the chamber for a cracked housing, bent pushrod, loose clamp ring, loose air fitting, air leaks or clogged vent holes. Repair or replace brake chamber parts as needed.
11. Remove and inspect the camshaft support bracket. Remove and discard its gasket.

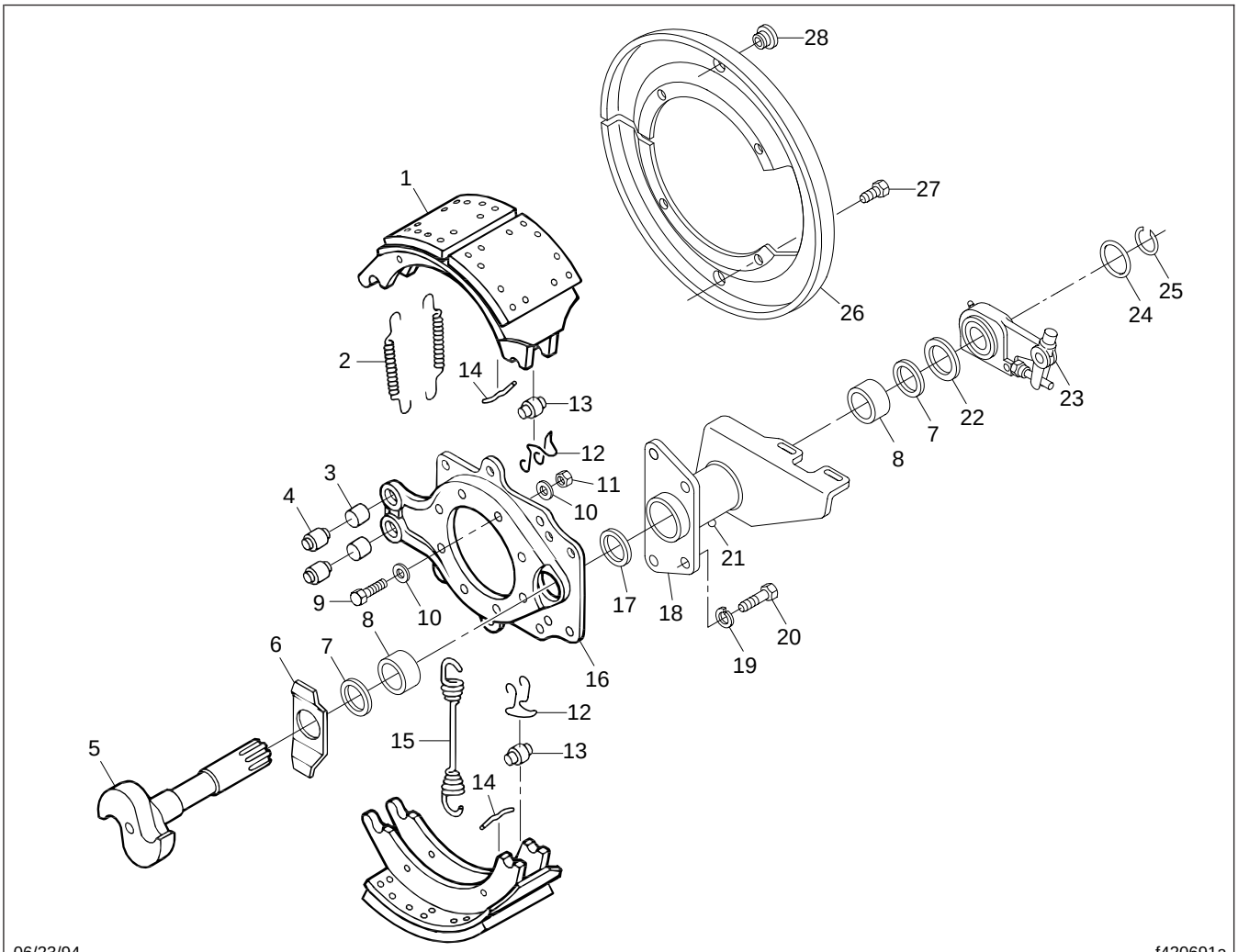
    Check the bracket for a bent, broken or cracked arm, and cracked welds. Replace the bracket if any of these conditions exist.
12. Remove and inspect the old bushing and the grease seal.
    - 12.1 Check the camshaft bushing for wear. The inner surface must be smooth; if rough or abrasive, replace the bushing.
    - 12.2 Inspect the seal. Replace it if the lip is nicked, cut, or distorted.
13. Install the new bushing or seal with a suitable piloted driver.

IMPORTANT: Grease seals are installed in both the bracket and the brake spider so that the seal lip faces the slack-adjuster end of the bracket tube. See **Fig. 3**.

14. Remove the spider-to-axle attaching nuts, hardened washers, and bolts. Remove the spider from the axle flange.
15. If equipped, remove the four capscrews that attach the dust shield to the spider; remove the dust shield.
16. Inspect the spider and parts for damage; replace as needed.

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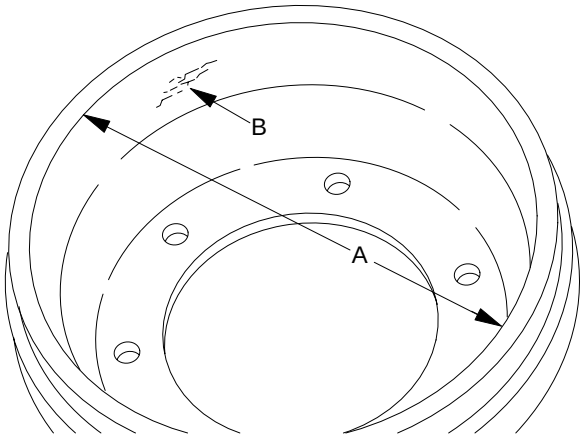
Brake Components Disassembly and Inspection, Cleaning, and Assembly



1. Brake Shoe and Lining Assembly
2. Brake Shoe Retaining Spring
3. Anchor Pin Bushing
4. Brake Shoe Anchor Pin
5. S-Head Camshaft
6. Camhead Washer
7. Camshaft Grease Seal
8. Camshaft, Spider, and Bracket Bushing
9. Spider Mounting Bolt
10. Hardened Washer
11. Nut
12. Brake Shoe Roller Retainer
13. Brake Shoe Roller
14. Brake Shoe Return Spring Pin
15. Brake Shoe Return Spring
16. Brake Spider
17. Camshaft Support Bracket Gasket
18. Camshaft Support Bracket
19. Bracket Capscrew Washers
20. Camshaft Support Bracket Capscrew
21. Grease Fitting
22. Camshaft Washer
23. Automatic Slack Adjuster Assembly
24. Spacing Washer
25. Camshaft Lockring
26. Dust Shield
27. Dust Shield Capscrew
28. Plug

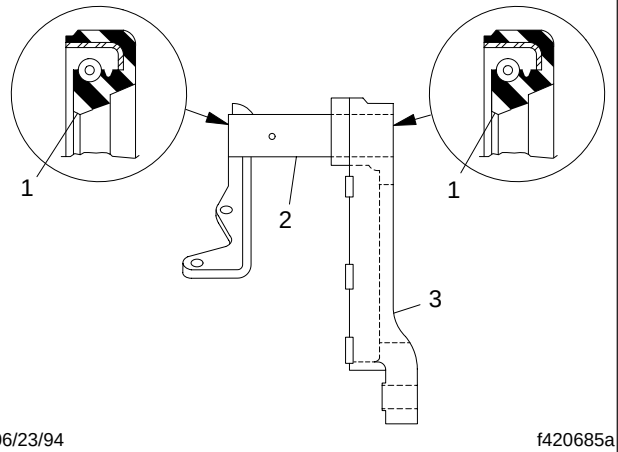
Fig. 1, Q Plus™ Brakes

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A. Check for diameter and for out-of-round.
B. Check for cracks, heat checks, glazing and grooves.

Fig. 2, Brake Drum



NOTE: The seal lip faces the slack adjuster.

1. Seal Lip
2. Camshaft Support Bracket
3. Brake Spider

Fig. 3, Positioning of Seals on the Camshaft

16.1 Check for cracks at the bolt holes, cam area, and around the anchor pin. Replace if damaged.

16.2 Check the anchor pin. If worn or loose, replace it.

16.3 Check the anchor pin and brake spider bushings for wear. The inner surfaces must be smooth. If any surface is rough or abrasive, replace the part.

16.4 Inspect the seal. Replace it if its lip is nicked, cut, or distorted.

17. Using a suitable piloted driver, install the new bushings and seal.

IMPORTANT: Grease seals are installed in both the bracket and the brake spider so that the seal lip is toward the slack-adjuster end of the bracket tube. See **Fig. 3**.

Cleaning

WARNING

Before starting the procedure below, see the "Safety Precautions" in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

After removing the brake parts being serviced, do the following:

1. Wire brush all parts exposed to mud, road dirt, and salt, including the exterior of the drum, spider, brake chamber bracket and dust shields (if equipped). If relining the shoes, thoroughly wire-brush the shoe tables and paint them with a rust inhibitive coating.

CAUTION

A thick layer of oxidation and dirt on the outside of a brake drum acts as an insulator and may hinder normal heat dissipation. Make sure oxidation and dirt are removed by wire brushing or damage to brake components could occur.

2. Using an industrial vacuum cleaner with a HEPA filter system, pick up excessive dust accumulation. Wipe the interior of the drums with a greaseless solvent to remove lining dust.
3. Thoroughly clean all remaining brake parts with a suitable shop solvent. Wipe dry with a clean, lint-free cloth or use low-pressure, filtered and compressed air.

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Brake Components Disassembly and Inspection, Cleaning, and Assembly

Assembly (See Fig. 1)

⚠ WARNING

Before starting the procedure below, see "Safety Precautions" in Subject 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

1. Install the dust shield, if equipped.

   Position the dust shield against the spider, and install the capscrews. Tighten the capscrews to the torque provided in **Specifications, 400**.

2. Install the spider.

   Place the spider on the axle flange. Using a hardened washer under the bolt head and the nut, install the mounting fasteners. Tighten the bolts in a cross pattern to the torque provided in **Specifications, 400**.

3. Install the brake chamber and bracket.

   NOTE: If replacing a brake chamber, make sure that the new chamber is the same size and make as the brake chamber on the other side of the axle.

   3.1 Place the brake chamber on the mounting bracket with the chamber mounting studs through the bracket holes. Install the hardened flatwashers and locknuts. Tighten the nuts to the torque provided in **Specifications, 400**.

   3.2 Place the bracket against the spider and install the lockwashers and capscrews. Tighten the capscrews to the torque provided in **Specifications, 400**.

4. Install the camshaft and parts in the spider; install the slack adjuster.

   4.1 Apply a thin film of chassis grease on the inside of the camshaft bushings and journals. Do not grease the camshaft head area.

   4.2 Apply a thin film of rust-preventive grease (Meritor 0-637, or an equivalent) on the camshaft splines.

   4.3 Carefully slip the camshaft into the spider and the mounting bracket tube.

   4.4 Install the thick camshaft washer on the camshaft.

   4.5 Install the slack adjuster on the camshaft, with the adjuster nut on the side opposite of the brake chamber.

   4.6 Install the outer washers and snap ring.

5. Use a dial indicator to measure the end-play of the camshaft. There should be no more than 0.060 inch (1.5 mm) movement.

6. Pressure lube the camshaft bracket bushings.

   Pump multipurpose chassis grease (NLGI grade 1 or 2) into the chamber bracket until it appears at the slack-adjuster end of the bracket. Use care that no grease enters the drum cavity. If grease leaks out under the camhead, the camshaft grease seal is worn or damaged, or is installed backwards.

NOTE: The use of meter-type fittings, having a maximum 40 psi (276 kPa) pressure relief at shutoff, is recommended.

7. For automatic slack adjusters, see **Section 42.11** or the manufacturer's service information.

8. Install the brake shoes. For instructions, see **Subject 110**.

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Troubleshooting

This troubleshooting guide is designed to help locate causes of problems originating in the air brake system. The corrective measures given are not intended to replace the detailed service information found in other sections of this manual or in the component manufacturer's service manuals.

Before attempting to isolate the causes of an air brake system problem, do the following:

1. Check the operation of the air compressor. See the engine manufacturer's service manual.

   Check the pressure levels of the air reservoirs.
2. Be sure that all relay valves are operating.
3. Check the operation of the brake chambers.
4. Examine all tubing for kinks, dents, and other damage. Replace damaged tubing.
5. Examine all hoses for cracks, drying out, overheating and other damage. Replace damaged hoses.
6. Examine all air line fittings. Tighten loose connections; replace fittings that are damaged.
7. Examine leaking pipe connections for cracks or thread damage; replace as needed. If there is no damage, retighten the fitting.

Problem—Vehicle Does Not Slow Down Quickly Enough With Brakes Applied

Problem—Vehicle Does Not Slow Down Quickly Enough With Brakes Applied	
Possible Cause	**Remedy**
Overloaded vehicle	Observe the recommended maximum load limits.
Low air pressure in the brake system, about 60 psi (413 kPa) or lower	The drain cock on the air reservoir was left open; close the drain cock.
	Check the compressor output pressure; correct as necessary.
	Check the setting of the air governor with an accurate test gauge. Replace the air governor.
Excessively leaking application air lines	Check the application air line, brake valve, and the service and parking brake chambers for air leaks. Repair or replace the damaged component(s).
Below normal brake valve delivery pressure	Lubricate the brake valve parts; overhaul the unit, if necessary.
Worn or glazed brake linings	Install new brake linings on the brake shoes on both sides of the axle.
Brakes need adjustment or lubrication	Adjust or lubricate the brakes.
Inoperative automatic slack adjusters (if equipped)	Lubricate the automatic slack adjusters and check for binding, damaged, or inoperative slack adjuster parts. Replace damaged or inoperative parts, or eliminate the cause of the binding.
Cam has flipped over	Replace the linings and the cam on each end of the axle. Replace the brake drums if needed.
Flat spots or dents on roller surface (possibly caused by skidding of the roller or incorrect handling of the rollers during installation)	Clean and inspect the bearing rollers. Replace the rollers if damaged.
Broken or cracked brake drum(s)	Replace the brake drum(s).
Wrong size brake linings installed	Replace the brake linings with the recommended size.
Wrong size brake chambers installed	Replace the brake chambers with the recommended size.
Bent or broken camshaft bracket or chamber mounting bracket	Replace the camshaft bracket or chamber mounting bracket.
Loose brake chamber mounting stud nuts or brake chamber mounting bracket	Tighten the brake chamber to its mounting bracket or the mounting bracket to the foundation brake housing.

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Troubleshooting

Problem—Vehicle Does Not Slow Down Quickly Enough With Brakes Applied	
Possible Cause	**Remedy**
Ruptured diaphragm in the service brake	Replace the diaphragm.
Glazed brake drums	Turn the brake drums, if possible. If the maximum allowable diameter is exceeded, replace the drum. Do the same for both ends of the axle.

Problem—Service Brakes Release Too Slowly

Problem—Service Brakes Release Too Slowly	
Possible Cause	**Remedy**
Frozen brake shoe anchor pins	Inspect the anchor pins. If damaged, replace them; if not damaged, lubricate them.
Inadequate lubrication of the brake system components	Lubricate those components requiring periodic lubrication.
Incorrectly adjusted brake foot valve pushrod	Readjust the pushrod and/or pedal stop bracket.
Brake foot valve not returning to fully released position	Check for obstructions which might prevent the brake foot valve from returning to the fully released position. Remove any obstructions.
Plugged brake foot valve exhaust port or quick-release valve	Clear the exhaust port of obstructions.
Inoperative brake foot valve or quick-release valve	Overhaul or replace the applicable valve, as needed.
Binding camshaft and bushings	Clean and lubricate the camshaft bushings.
Weak or broken brake shoe return spring	Replace the spring.
Flat spots or dents on roller surface (possibly caused by skidding of the roller or incorrect handling of the rollers during installation)	Clean and inspect the rollers. Replace the rollers if damaged.

Problem—Service Brakes Do Not Apply or Apply Too Slowly

Problem—Service Brakes Do Not Apply or Apply Too Slowly	
Possible Cause	**Remedy**
Lubrication needed to foundation brake assembly	Lubricate those components requiring periodic lubrication.
Insufficient air pressure in brake system	Check all parts of the air pressure system for leaks or inoperative components.
Inoperative brake foot valve or quick-release valve	Repair or replace the brake foot valve or quick-release valve.
Binding camshaft bushings	Clean and lubricate the camshaft bushings.

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Problem—Service Brakes Apply When the Parking Brakes Are Released With Air Pressure

Problem—Service Brakes Apply when the Parking Brakes Are Released With Air Pressure	
Possible Cause	**Remedy**
Air delivery lines to the brake chamber have been reversed	Reverse the connections of the brake chamber air lines.
Leaking pushrod seal	Replace the brake chamber.
Binding braking mechanism	Lubricate the brake mechanism and make sure all parts are aligned with each other and are securely fastened.
	Check for obstructions; remove any obstructions.

Problem—Service Brakes Do Not Release

Problem—Service Brakes Do Not Release	
Possible Cause	**Remedy**
Incorrectly adjusted brake shoes	Adjust the brakes. Also, make sure the slack adjuster is operating correctly. If not, overhaul or replace the slack adjuster.
Brake foot valve may not be fully released	Lubricate the brake foot valve if needed. Check the adjustment of the brake foot valve pushrod.
Inoperative brake foot valve	Overhaul or replace the brake foot valve.
Restriction in tubing, hose, or exhaust port of brake foot valve or quick-release valve	Check for bends or obstructions on the exhaust side of the service brakes. Remove any obstructions; plumb the air lines so that bends are minimal.
Broken power spring may be blocking parking brake piston movement	Replace the power spring or replace the parking brake assembly, whichever is recommended by the parking brake manufacturer.

Problem—Service Brakes Grab or Pull

Problem—Service Brakes Grab or Pull	
Possible Cause	**Remedy**
Not enough weight on vehicle (underloaded)	Add weight to the vehicle, reducing brake sensitivity.
Uneven adjustment of brakes on one axle	Adjust the brakes.
Inadequate lubrication of brake system components	Lubricate those components requiring periodic lubrication.
Binding brake mechanism	Lubricate the brake mechanism and make sure all parts are aligned with each other and are securely fastened.
Binding clevis pin or camshaft at one or more wheels	Clean and lubricate the camshaft bushings.
Loose brake spider	Tighten the mounting bolts or replace the brake spider.
Damaged slack adjuster	Replace the damaged component.
Different length air chamber pushrods or slack adjusters	Replace the components with the correct size and material.
Inoperative brake foot valve	Overhaul or replace the brake foot valve, as needed.

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Troubleshooting

Problem—Service Brakes Grab or Pull	
Possible Cause	**Remedy**
A flat or dent on the S-head camshaft or on the cam roller(s) (if equipped with cam brakes)	Replace the damaged component(s).
Glazed or grease-saturated brake linings	Install a matched set of linings on both sets of brake shoes on that axle. Clean, replace, or turn both brake drums. For instructions on turning drums, see the brake manufacturer's service manual. Find out what is causing the saturation and repair as needed.
Loose or broken brake linings	Install a matched set of linings on both sets of brake shoes on that axle.
Unmatched set of brake linings installed (different friction codes or different brands of brake linings)	Install a new, matched set of brake linings. Clean, replace, or turn both brake drums on that axle. For instructions on turning drums, see the brake manufacturer's service manual.
Distorted or broken brake shoe	Replace the brake shoe. Install a new, matched set of linings on both sets of brake shoes on that axle.
Damaged pilot pads (allowing out-of-round brake drum installation)	Replace the wheel hub.
Brake drum out-of-round to unacceptable limits	Turn both the brake drums on that axle. If the maximum allowable diameter of either drum has been exceeded, replace that drum. For instructions on turning drums, see the brake manufacturer's service manual.
Scored or broken brake drum(s)	Replace both of the drums on that axle.

Problem—Uneven Service Brakes

Problem—Uneven Service Brakes	
Possible Cause	**Remedy**
Wrong brake linings installed or linings not replaced in pairs	Replace the brake linings with the recommended size. Install new linings on both sets of axle brake shoes.
Glazed or grease-saturated brake linings	Install new linings on both axle brake shoes. Clean the brake drums. Find the cause of saturation and repair as needed.
Broken return spring for brake shoe release or service brake	Replace all broken springs.
Brake drum out-of-round to unacceptable limits	Turn the brake drum, if possible. If the maximum allowable diameter of the brake drum has been exceeded, replace the drum. Also, turn or replace the other drum on the axle. For turning the drum, see the brake manufacturer's service manual.
Leaking service brake chamber diaphragm	Tighten the clamp ring. If leaks persist, replace the service brake diaphragm.
Wheel bearings out of adjustment	Adjust the wheel bearings or replace them if damaged. For instructions, see the front axle group or the rear axle group of the vehicle maintenance manual.
Damaged brake spider	Replace the brake spider.
Bent or stretched brake shoes	Replace the axle brake shoes on each wheel.
Grease, oil, or dirt on linings	Replace the linings on each set of axle brake shoes. Clean the brake drums. Find the cause of contamination and remedy it.

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Problem—Dragging Service Brake

Problem—Dragging Service Brake	
Possible Cause	**Remedy**
Broken service brake return spring	Replace the service brake return spring.
Service-application air not exhausting, or not exhausting fast enough, due to control valve, quick-release valve, or limiting and quick-release valve blockage	Test the air system valves for leakage and operation.
Broken brake shoe return spring	Replace the brake shoe return spring.
Binding occurring in camshaft linkage	Lubricate the camshaft linkage. Replace bent or broken parts.
Brake foot valve not returning to fully released position	Check for obstructions which might prevent the brake foot valve from returning to the fully released position. Remove any obstructions.
Incorrectly adjusted brake foot valve pushrod	Readjust the pushrod and/or pedal stop bracket.

Problem—Insufficient Parking Brake Application When Dash Control Valve is Activated

Problem—Insufficient Parking Brake Application When Dash Control Valve is Activated	
Possible Cause	**Remedy**
Parking brake not set for full stroke	Adjust the brakes.
Broken power spring	Replace the parking brake chamber.
Manually caged power spring in a parking brake	Uncage the power spring, using the release bolt.

Problem—Dragging Brakes Due to Parking Brake Mechanism

Problem—Dragging Brakes Due to Parking Brake Mechanism	
Possible Cause	**Remedy**
Insufficient system air pressure to fully release parking brake	Be sure that all air lines are clear. Check that the air governor cutout settings meet recommended specifications.
Ruptured parking brake diaphragm or ineffective piston seal	Replace the diaphragm or parking brake piston seal.
Broken parking brake return spring (double-diaphragm-type brake chambers only)	Replace the parking brake chamber.

Problem—Air Pressure Will Not Rise to Normal

Problem—Air Pressure Will Not Rise to Normal	
Possible Cause	**Remedy**
Inaccurately registering air pressure gauge(s)	Check the dash gauge with an accurate test gauge. Replace the dash gauge(s) as needed.
Excessive leakage (not including air compressor)	Check all valves, air lines, and connections for leakage. Repair or replace valves and lines until leakage is eliminated.

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Troubleshooting

Problem—Air Pressure Will Not Rise to Normal	
Possible Cause	**Remedy**
Inoperative compressor (including excessive leakage from compressor)	Rebuild or replace the compressor.
Air reservoir drain cock left open	Close the drain cock.
Maladjusted air governor cutout setting	Check the setting with an accurate test gauge. If recommended specification is not met, replace the air governor.
Inadequate clearance at compressor unloading valve	Repair or adjust the compressor at the unloading valve.
Slipping compressor drive belt (if equipped)	Adjust or replace the compressor drive belt.
Carbon build-up in compressor cylinder head or discharge line	Remove the carbon. If disassembly is not recommended by the compressor manufacturer, replace the air compressor with a factory rebuilt or a new unit.

Problem—Air Pressure Rises Above Normal

Problem—Air Pressure Rises Above Normal	
Possible Cause	**Remedy**
Inaccurate air reservoir pressure dash gauge	Check the dash gauge with an accurate test gauge. Replace the dash gauge, as needed.
Out-of-adjustment air governor	Check the setting with an accurate test gauge. If recommended specification is not met, replace the air governor.
Inoperative air governor	Replace the air governor.
Too much clearance at air compressor unloading valve	Repair or adjust the compressor at the unloading valve.
Air compressor unloading valve stuck closed	
Air compressor unloading valve cavities or unloading valve passage blocked with carbon	

Problem—Air Pressure Drops Quickly With the Engine Stopped and the Brakes Released

Problem—Air Pressure Drops Quickly With the Engine Stopped and the Brakes Released	
Possible Cause	**Remedy**
Leaking brake foot valve	Repair or replace the brake foot valve.
Leaking air compressor discharge valve	Repair or replace the discharge valve. If disassembly is not recommended by the compressor manufacturer, replace the air compressor with a factory-rebuilt or a new unit.
Leaking air governor	Replace the air governor.
Excessive leakage (not including air compressor)	Check all valves, air lines, and connections for leakage. Repair or replace valves and lines until leakage is eliminated.

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Problem—Air Pressure Drops Quickly With the Engine Stopped and the Brakes Fully Applied

Problem—Air Pressure Drops Quickly With the Engine Stopped and the Brakes Fully Applied	
Possible Cause	**Remedy**
Leaking service or parking brake chamber	Tighten the clamp ring(s). If leaks persist, replace the service brake diaphragm or the parking brake chamber, as applicable.
Leaking brake foot valve or quick-release valve	Repair or replace the component(s) or assembly.
Excessive leakage (not including air compressor)	Check all valves, air lines, and connections for leakage. Repair or replace valves and lines until leakage is eliminated.

Problem—Compressor Knocks (Continuously or Intermittently)

Problem—Compressor Knocks (Continuously or Intermittently)	
Possible Cause	**Remedy**
Loose drive pulley, belt, coupling, or gear (as indicated)	Tighten or replace the component. If applicable, inspect the pulley shaft for damage. Replace the shaft, if damaged.
Backlash in the compressor drive gears on drive coupling	Repair or replace the compressor drive gears or drive coupling.
Damaged or worn air compressor bearings	Replace the bearings.
Carbon deposits in compressor cylinder head	Remove the carbon deposits or replace the compressor.

Problem—Safety Valve Activates

Problem—Safety Valve Activates	
Possible Cause	**Remedy**
Out-of-adjustment safety valve	Adjust the safety valve or install a new one.
Too much air pressure in brake system	See "Problem—Air Pressure Rises Above Normal."
Need to drain air reservoirs more often	Drain the air reservoirs daily.

Problem—Oil or Water in the Brake System

Problem—Oil or Water in the Brake System	
Possible Cause	**Remedy**
Excessive oil passing through air compressor	Rebuild or replace the compressor.
Dirty air compressor air strainer (if equipped)	Clean the strainer or install a new one.

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See **Fig. 1** for a full view of the air brake system wiring.

See **Fig. 2** and **Fig. 3** for partial views of the air brake system wiring.

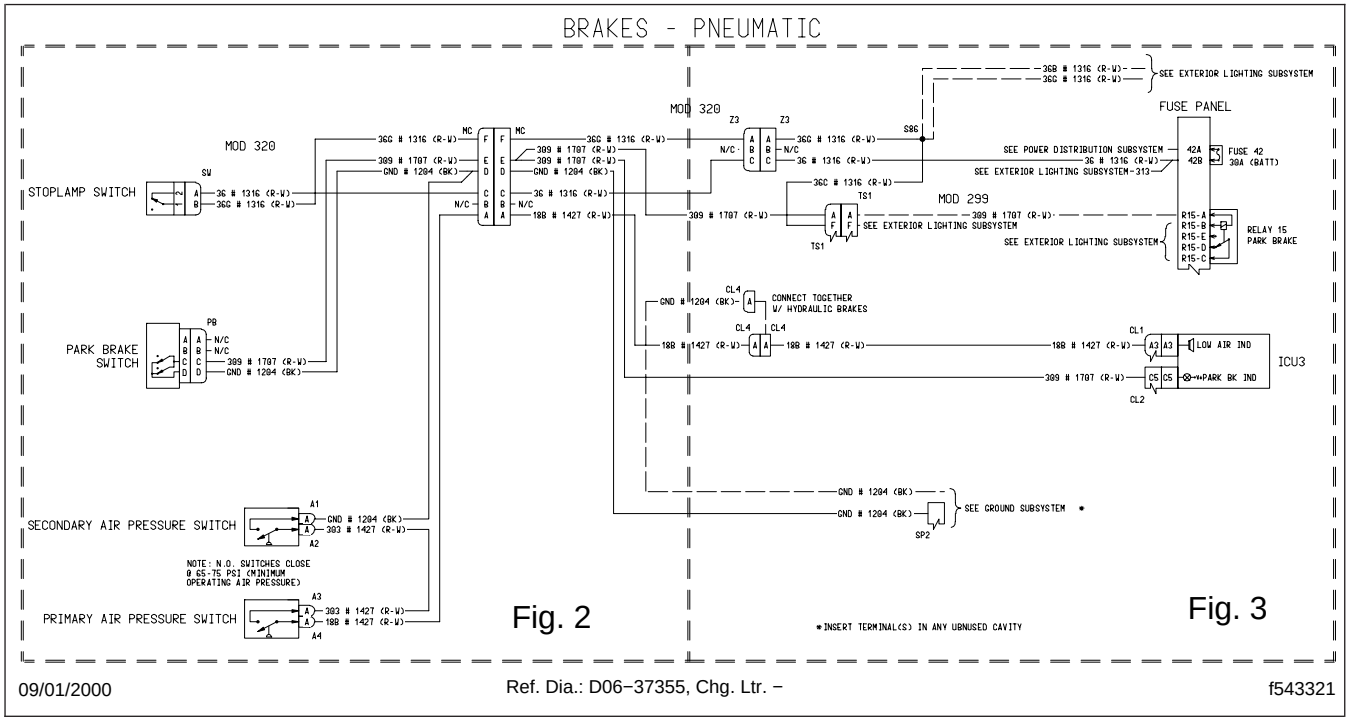


Fig. 1, Air Brake System Wiring (full view)

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Specifications

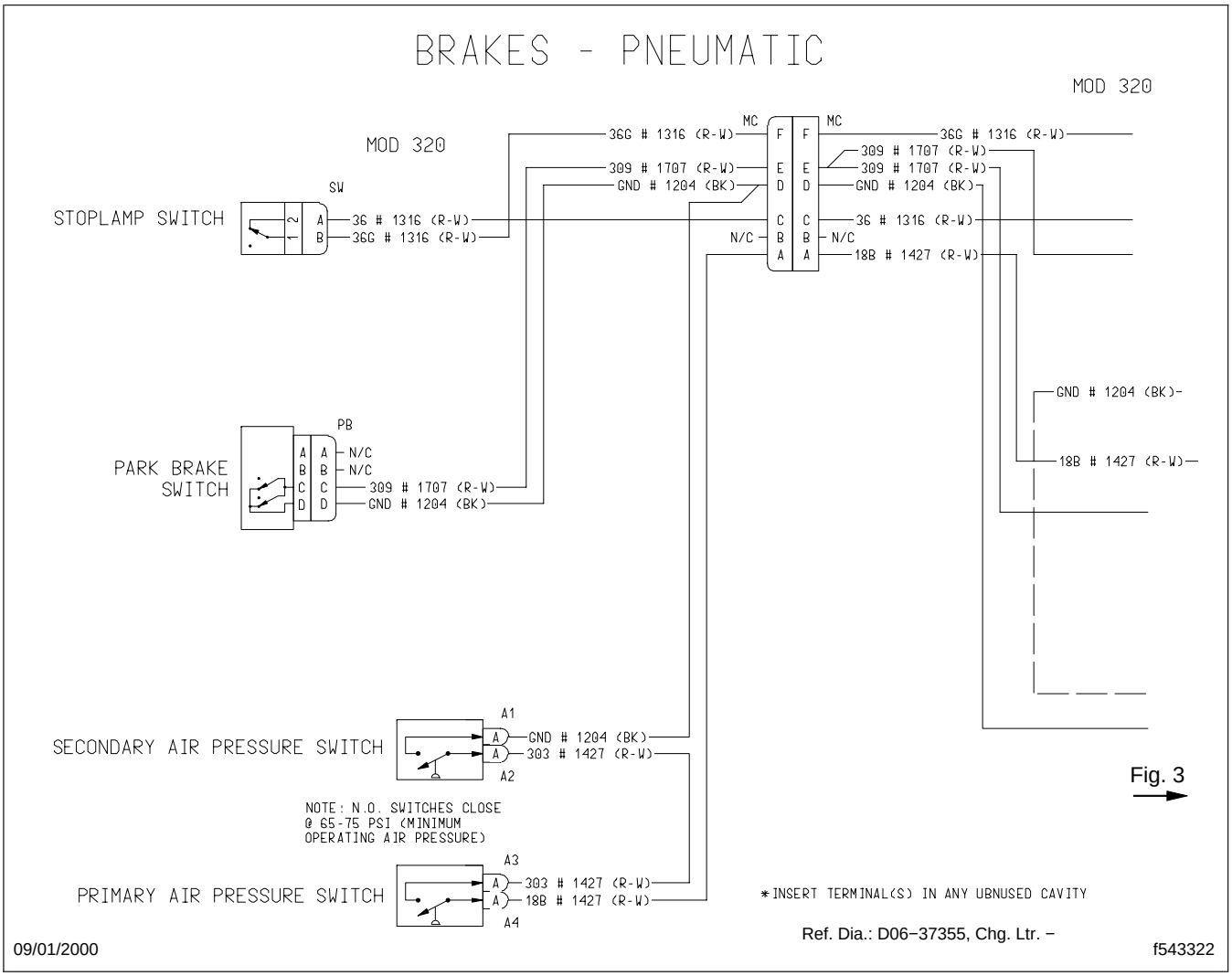


Fig. 2, Air Brake System Wiring (partial view)

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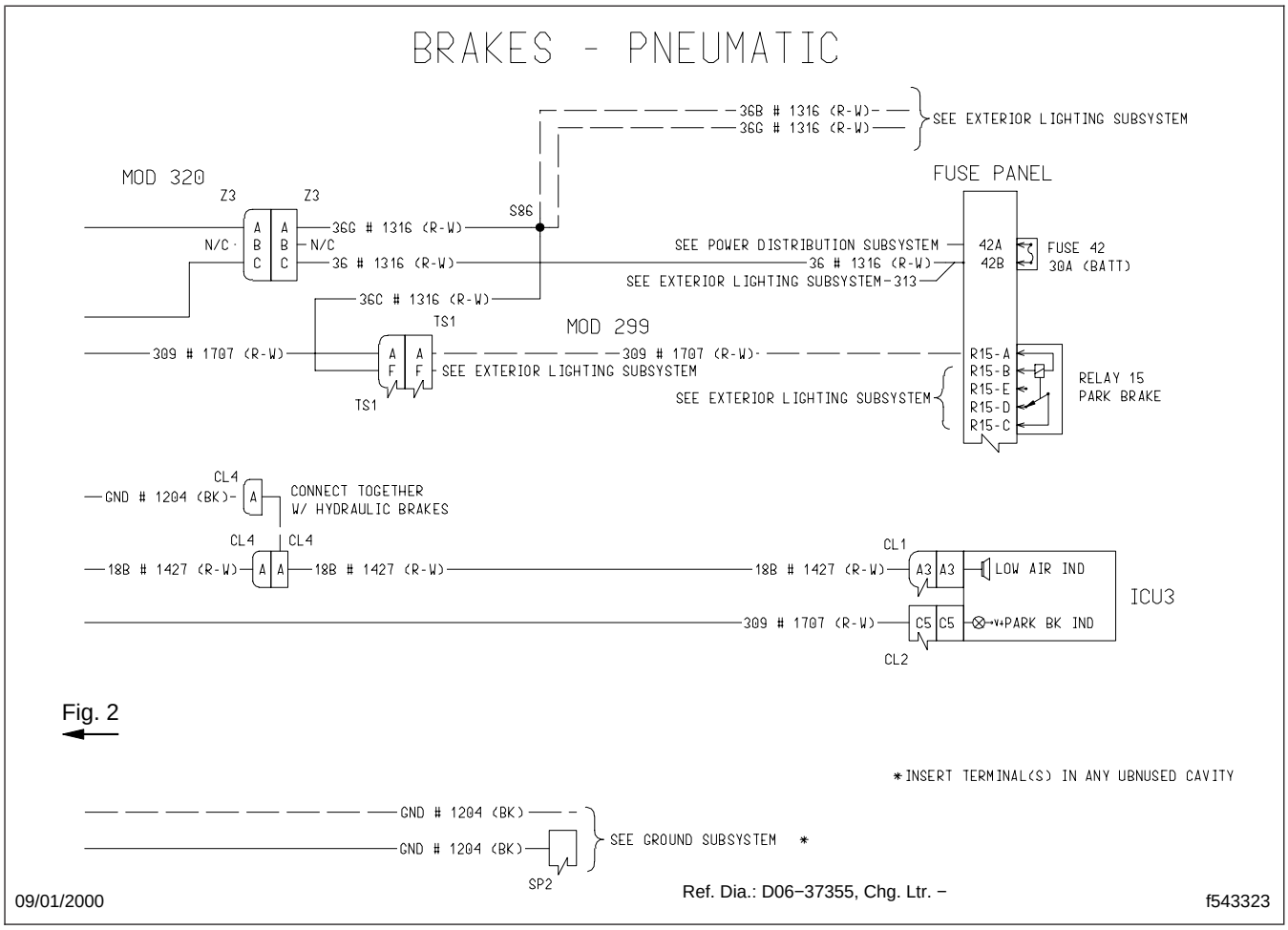


Fig. 3, Air Brake System Wiring (partial view)

Brake Fastener Torque Values				
Description	**Grade**	**Size**	**Torque**	
			lbf·in (N·cm)	**lbf·ft (N·m)**
Brake Shoe Lining Nuts	—	3/8	—	18–23 (24–31)
		1/4	80–100 (900–1120)	—
Dust Shield Capscrews	5	3/8–16	—	25–35 (34–47)
	8			35–50 (47–68)
Spider Mounting Bolts: Customary Thread Capscrew	8	1/2–13	—	60–80 (81–108)
Hexhead Capscrew		5/8–11		130–160 (176–217)
Flanged Hexhead Capscrew		5/8–11		160–200 (217–271)

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Specifications

Brake Fastener Torque Values				
Description	**Grade**	**Size**	**Torque**	
			lbf·in (N·cm)	**lbf·ft (N·m)**
Midland™ Brake Chamber Mounting-Stud Locknuts (chamber size in^2)				
12	8	7/16–14 stud	—	38–43 (52–58)
16		7/16–14 stud		38–43 (52–58)
16		1/2–13 stud		60–65 (81–88)
16		1/2–20 stud		65–70 (88–95)
20		5/8–11 stud		120–130 (162–176)
24		5/8–11 stud		120–130 (162–176)
MGM® Brake Chamber Mounting-Stud Locknuts (chamber size in^2)				
16	8	7/16–14 stud	—	35–40 (47–54)
20		5/8–11 stud		100–115 (136–156)
24		5/8–11 stud		100–115 (136–156)
Brake Chamber Bracket-to-Spider Capscrews	8	1/2–13	—	60–80 (81–108)
		5/8–11		105–145 (142–196)

Table 1, Brake Fastener Torque Values

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General Information

⚠ CAUTION

The size of the tires installed at the factory is programmed into the electronic control unit (ECU). Installing different size tires could result in a reduced braking force, leading to longer stopping distances and possibly resulting in personal injury or property damage.

Acterra vehicles are equipped with the Meritor WABCO "D" version pneumatic antilock brake system (ABS) with a frame-mounted ECU.

The ABS is an electronic wheel speed monitoring and control system that works with the standard air brake system. It passively monitors vehicle wheel speed at all times and controls wheel speed during emergency stops. As a result, the driver has full control of braking until the ECU senses that a lockup is about to occur.

The ABS includes signal-generating sensors activated by tone (tooth) wheels located on the hubs of the monitored wheels. See **Fig. 1**. The sensors transmit vehicle wheel speed information to the ECU. According to programmed specifications, the ECU signals the appropriate modulator valve to increase, reduce, or maintain air pressure in the brake chamber. This prevents front and rear wheel lockup, and enhances steering control during emergency braking situations.

Acterra vehicles are available with four wheel speed sensors and four modulator valves (4S/4M).

During normal braking conditions, the standard air brake system is in effect. If the vehicle is equipped with automatic traction control (ATC), wheel spin is controlled during reduced-traction start-up and acceleration.

The ABS has an ECU that serves as its information processing and command center. The ECU is a digital microcomputer that receives and processes vehicle wheel speed information from the sensors. During emergency brake applications, the ECU regulates the braking force applied to each wheel by sending control signals to the modulator valves.

The major components of the Meritor WABCO pneumatic ABS are:

- Wheel speed sensors;
- An ECU;
- Modulator valves (solenoid control valves);
- An ATC valve (optional);
- ABS warning and wheel-spin indicator lights;
- A retarder relay.

Wheel Speed Sensors

The wheel speed sensor assembly is a signal-generating device. The assembly includes a sensor (coil wrapped around a magnet), a tone wheel, and a sensor clip that holds the sensor in position near the tone wheel. See **Fig. 2**.

Each ABS-controlled wheel has a wheel speed sensor assembly with a tone wheel mounted on the hub. When the vehicle is moving, the teeth on the tone wheel cause interruptions in the magnetic field created by the sensor. The interruptions create electrical pulses that are sent to the ECU where they are used to determine the wheel speed.

Electronic Control Unit (ECU)

The ECU contains microcomputers to monitor the front and rear control channels. See **Fig. 3**. It is mounted on the right-hand frame rail.

The ECU receives signals from the wheel speed sensors and uses them to calculate wheel speed and a vehicle reference speed. The unit is programmed to determine whether the wheels are slowing at a normal braking rate or at a higher rate, requiring ABS braking control. If the ECU senses wheel slip or lockup, the appropriate control circuit signals the modulator valve(s) to release, hold, or reapply braking pressure.

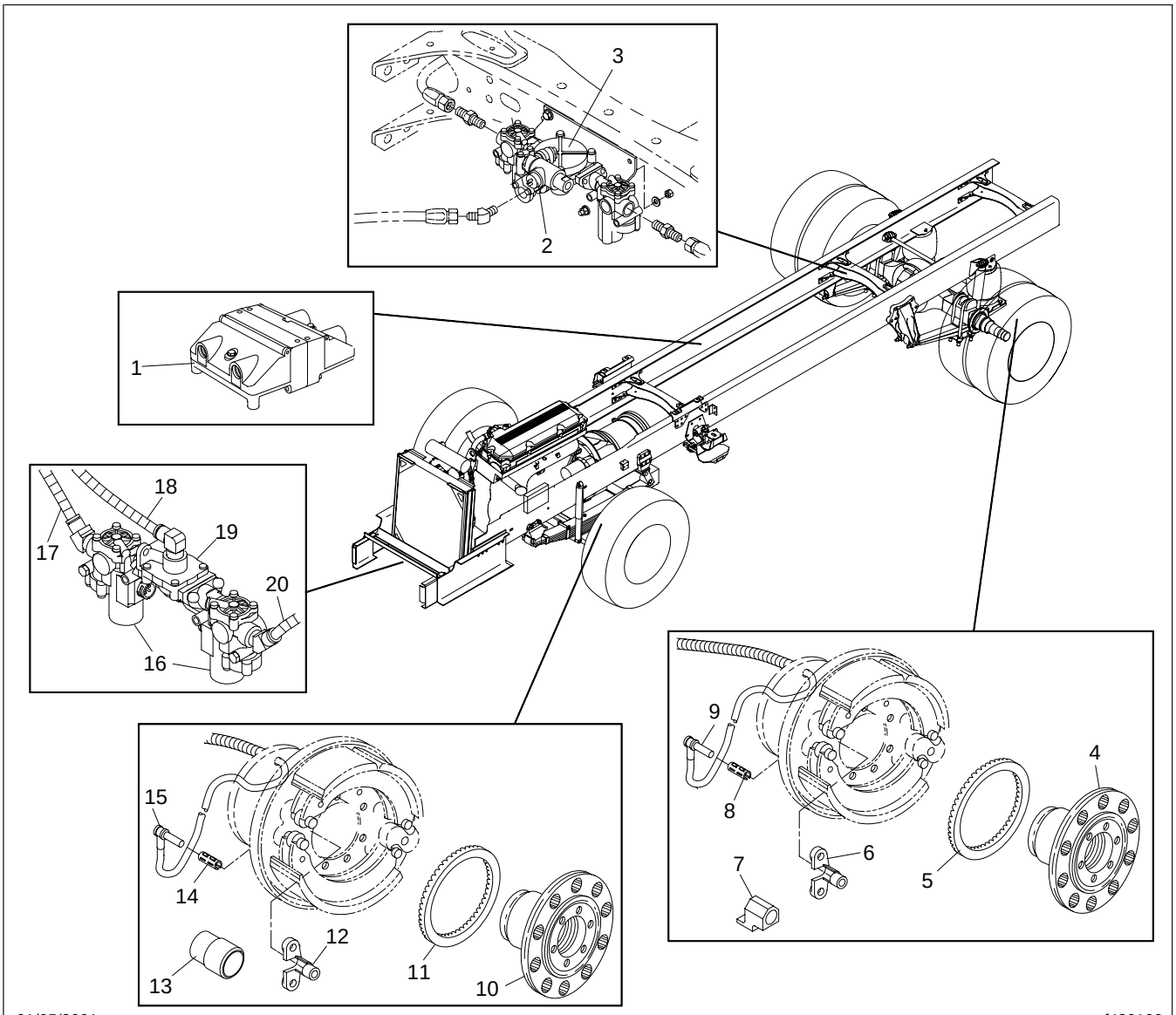
The ECU also shuts down the engine brake and the exhaust brake, if equipped, when a wheel approaches a slip or lockup condition. When the wheels return to a normal rate of speed, the engine and exhaust brakes are reactivated automatically.

The ECU constantly monitors the wheel sensors, modulator valves, ATC valve (if equipped), and the electrical circuitry. After the ignition switch is turned on, the ABS warning light (TRACTOR ABS or TRAILER ABS) and the ATC wheel spin indicator light (WHEEL SPIN) on the dash illuminate for about 3 seconds. See **Fig. 4**.

During the self-test, the modulator valves and the ATC valve cycle on and off, creating clicking noises that may be heard inside the cab. These clicking

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General Information

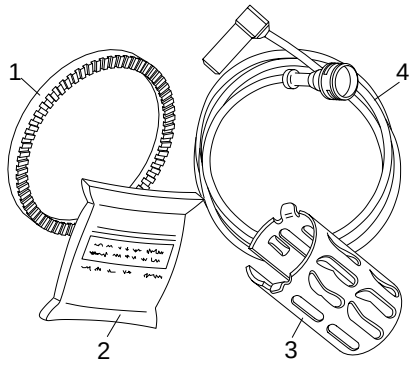


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1. ECU
2. ATC Valve (optional)
3. Rear Modulator Valve Assembly
4. Rear Wheel Hub
5. Rear Wheel Tone Wheel
6. Rear Wheel Sensor Holder (bolted on)
7. Rear Wheel Sensor Mounting Block (welded on)
8. Rear Wheel Sensor Clip
9. Rear Wheel Sensor
10. Front Wheel Hub
11. Front Wheel Tone Wheel
12. Front Wheel Sensor Holder (bolted on)
13. Front Wheel Sensor Bushing (welded on)
14. Front Wheel Sensor Clip
15. Front Wheel Sensor
16. Front Modulator Valves
17. Air Line-to-Right-Side Brake Chamber
18. Supply Air Line
19. Quick-Release Valve
20. Air Line-to-Left-Side Brake Chamber

Fig. 1, ABS Component Location (4-channel, 4S/4M system shown)

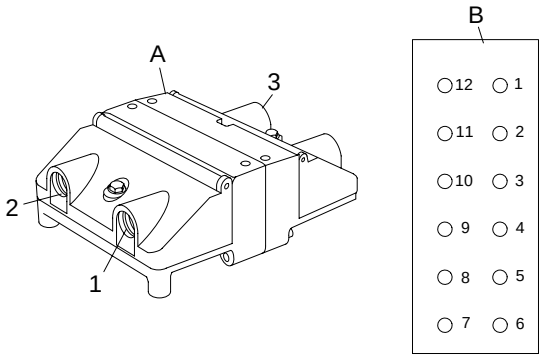
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1. Tone Wheel
2. Lubricant
3. Sensor Spring Clip
4. Sensor

Fig. 2, Wheel Speed Sensor Components



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A. Frame-mounted ECU.
B. ECU connector pin locations.

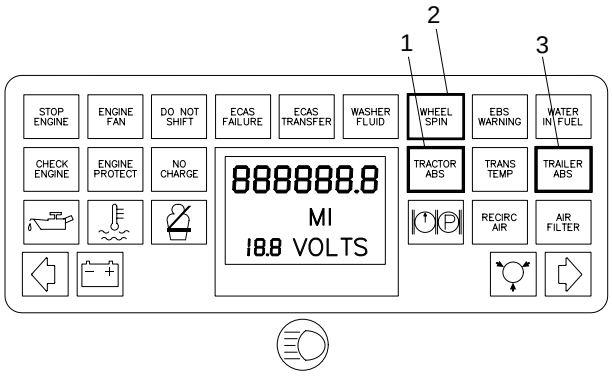
1. Gray X1 Connector
2. Black X2 Connector
3. Green X3 Connector

Fig. 3, Frame-Mounted ECU and Pin Locations

noises are normal and do not indicate an ABS problem. After about 3 seconds, the lights go off only if all of the ABS and ATC components are functioning correctly.

After the self-test, on vehicles with ATC, the ATC indicator light illuminates if a drive wheel spins during start-up or acceleration.

A problem in the traction control system will cause the ATC indicator light to remain illuminated.



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NOTE: Light positions may vary between vehicles.

1. Wheel Spin Indicator (optional)
2. Tractor ABS Warning
3. Trailer ABS Warning (optional)

Fig. 4, ABS and ATC Lights

IMPORTANT: If the ABS warning light and the ATC indicator light do not work as described above, repair the ABS or ATC. See **Troubleshooting, 300** for fault diagnosis.

If, during vehicle operation, the safety circuit senses a failure in any part of the ABS (such as a sensor, modulator valve, wiring connection, or short circuit), the ABS warning light illuminates. A fault is stored in the ECU memory and the control circuit where the failure occurred is switched to normal braking action. The remaining control circuit retains the ABS effect.

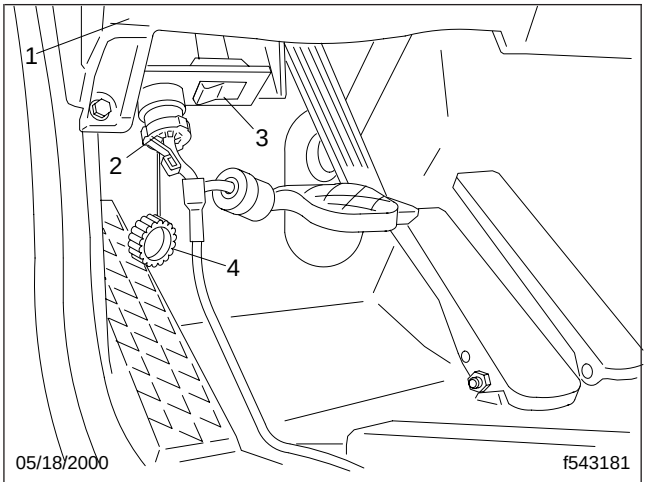
Even if the ABS is completely inoperative, normal braking is maintained. An exception would be if a modulator valve or valve assembly is damaged and inoperative. These components are an integral part of the air brake system so normal braking may be impaired or inoperative.

For troubleshooting purposes, the ECU can communicate with the troubleshooting tools through the J1587 diagnostic datalink connector. The connector is located below the dash on the driver's side. See **Fig. 5**. The Sterling-recommended troubleshooting tools are the Meritor WABCO TOOLBOX Software or ServiceLink. The hand-held Pro-Link® 9000 electronic diagnostic tool or blink codes may also be used.

NOTE: Blink codes are not as descriptive as J1587 fault codes and may require longer diagnostic time.

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IMPORTANT: Do not open the ECU. Opening the ECU to gain access to the internal components will void the warranty.



1. Driver's Side Lower Dash
2. J1587 Datalink Diagnostic Connector
3. Diagnostic Switch
4. Connector Cap (tethered)

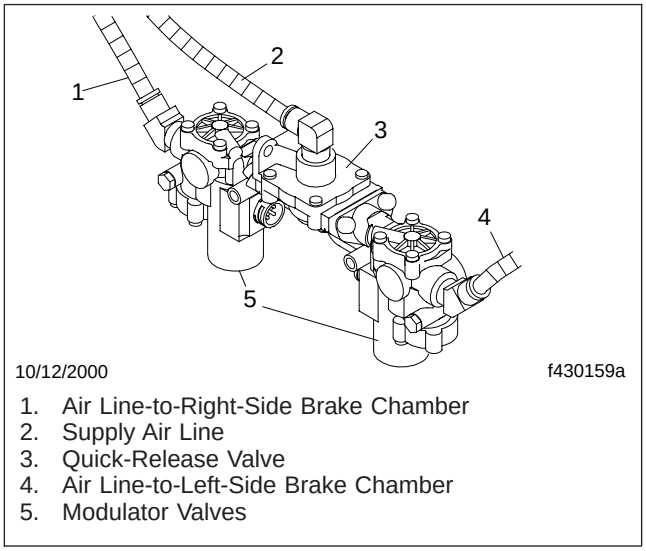
Fig. 5, J1587 Datalink Diagnostic Connector

Modulator Valves

Modulator valves control the air pressure in each affected brake chamber during an ABS operation. Depending on the signal received from the ECU, modulator valves prevent wheel lockup by reducing, maintaining, or increasing brake pressure. During normal braking applications, the ABS is inactive and compressed air flows freely through the modulator valves to the brake chambers.

Each ABS-monitored wheel has its own modulator valve. The front modulator valve assembly, mounted on the front crossmember, includes two modulator valves connected to a quick-release valve. See **Fig. 6**.

The rear modulator valve assembly is mounted on a crossmember near the rear brake chambers. See **Fig. 1**. The assembly includes two modulator valves; one mounted on each side of a service relay valve. If the vehicle is equipped with ATC, the ATC valve is mounted on the control port of the rear service relay valve.



1. Air Line-to-Right-Side Brake Chamber
2. Supply Air Line
3. Quick-Release Valve
4. Air Line-to-Left-Side Brake Chamber
5. Modulator Valves

Fig. 6, Front Modulator Valve Assembly

Vehicles with tandem rear axles and a 4S/4M ABS share modulator valves. One wheel is sensed but the modulator valve controls both wheels.

Each modulator valve includes two solenoid control valves (one supply and one exhaust) and two diaphragms (see **Fig. 7**):

- The supply diaphragm opens and closes an air passage between the supply port and delivery port. It is controlled by the supply solenoid valve.
- The exhaust diaphragm opens and closes an air passage between the exhaust port and the delivery port. It is controlled by the exhaust solenoid valve.

The ECU energizes different combinations of these solenoid valves to perform four functions: normal braking (without ABS control), ABS brake release (exhaust), ABS brake hold, and normal brake reapply.

Normal Brake Control

The normal brake function (without ABS control) operates as follows:

1. Before braking, the supply pilot chamber is open to the atmosphere through the exhaust port.
2. When the brakes are applied, both solenoid valves in the ABS modulator valve are closed (de-energized). See **Fig. 7**.

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3. Increased air pressure entering the supply port unseats the supply diaphragm by increasing the pressure under the diaphragm. This opens the passage to the delivery port and allows air to flow directly through the valve and into the brake chamber.
4. Air also flows through the exhaust valve. The increased pressure under the exhaust diaphragm seats the diaphragm, which closes the passage between the exhaust port and the delivery port.
5. When the brake pedal is released, air pressure at the supply port decreases and the higher pressure in the brake chamber reverses the flow of air in the modulator valve. Air now flows from the delivery port to the supply port until the pressure is balanced. This releases the supply diaphragm and closes the passage between the two ports.
6. The reduced pressure unseats the exhaust diaphragm and air is vented through the exhaust port to the atmosphere.

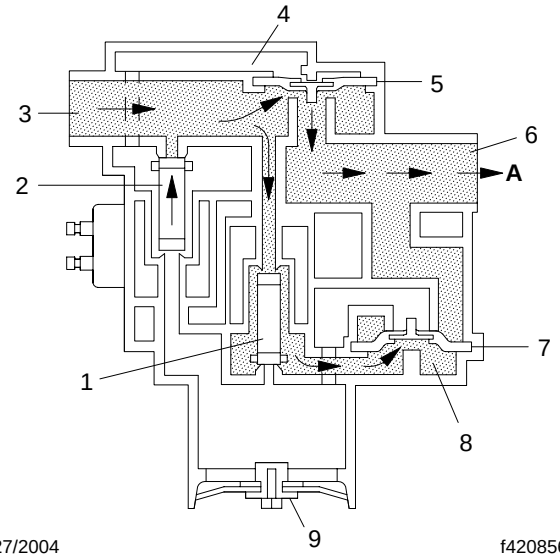
Brake Release (ABS Active)

The ABS brake release (exhaust) function is triggered when the ECU determines that the brakes are about to lock.

1. When a wheel is going to lock, the ECU opens (energizes) both solenoid valves in the ABS modulator valve. See **Fig. 8**.
2. The open supply valve allows compressed air to enter the supply pilot chamber above the supply diaphragm. The increased pressure seats the diaphragm and stops air from entering the brake chamber.
3. The open exhaust valve shuts off the supply of air entering the exhaust pilot chamber. It also creates an opening between the pilot and exhaust chambers.
4. Air from the brake chamber enters through the delivery port. The pressure unseats the exhaust diaphragm, creating an opening between the delivery and exhaust chambers. Brake-chamber air is then released through the exhaust port.

Brake Hold Control (ABS Active)

The ABS brake hold function takes control during an emergency stop when the pedal control valve delivers more air than the brakes can handle without locking. The hold function occurs after the ABS has started to control the pressure in the brake chamber by releasing some of the air.



NOTE: Both solenoid valves are closed. The modulator valve is shown in the braking configuration with increased air pressure at the supply port (supply diaphragm unseated, exhaust diaphragm seated).

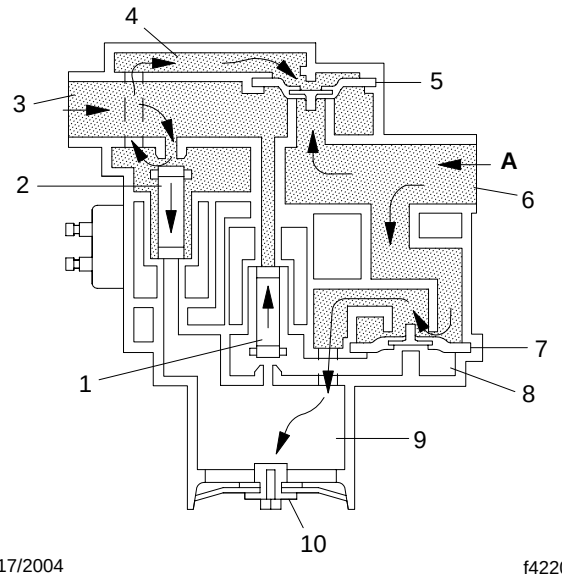
A. Air to brake chamber.

1. Exhaust Valve (closed)
2. Supply Valve (closed)
3. Supply Port
4. Supply Diaphragm (unseated)
5. Delivery Port
6. Exhaust Diaphragm (seated)
7. Exhaust Port

Fig. 7, Modulator Valve With Brake Applied, Normal Brake Control

1. When enough air is released through the exhaust port to stop the wheel from locking (ABS brake release), the exhaust valve is closed and air pressure is allowed to flow into the exhaust pilot chamber. See **Fig. 9**.
2. The increased pressure under the exhaust diaphragm seats the diaphragm, which closes the passage between the exhaust port and the delivery port. This stops the flow of air from the brake chamber to the exhaust port.
3. The supply valve stays open to maintain pressure in the supply pilot chamber and to keep the

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NOTE: Both solenoid valves are open.

A. Air from brake chamber.

1. Exhaust Valve (open)
2. Supply Valve (open)
3. Supply Port
4. Supply Pilot Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Diaphragm (unseated)
8. Exhaust Pilot Chamber
9. Exhaust Chamber
10. Exhaust Port

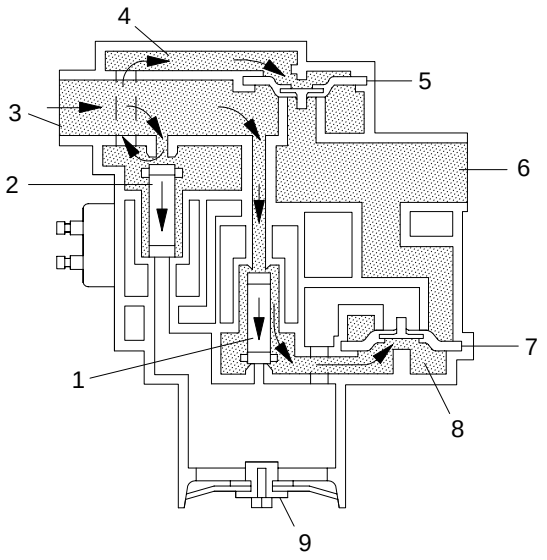
Fig. 8, Modulator Valve, Brake Release (exhaust)

supply diaphragm seated. This prevents further buildup of pressure in the brake chamber.

4. The remaining air pressure in the brake chamber is held and remains constant for stopping the vehicle in the minimum distance.

Reapply Brake Control (ABS Active)

The reapply brake control is the last ABS function. To achieve maximum braking, the ECU determines when to reapply the air pressure that the pedal control valve is delivering. When appropriate, both ABS solenoid valves are closed, which returns the system to the normal brake control state shown in **Fig. 7**.



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NOTE: The supply valve is open; the exhaust valve is closed.

1. Exhaust Valve (closed)
2. Supply Valve (open)
3. Supply Port
4. Supply Pilot Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Port

Fig. 9, Modulator Valve, Brake Hold Control

During an ABS event, the ECU cycles the modulator valve(s) through the sequence of ABS valve states (brake release, hold, and reapply) very rapidly in order to control wheel speed. The effect is similar to manually pumping the brakes on a vehicle without an ABS.

NOTE: The driver always controls the maximum amount of pressure applied to the brakes. Pressure to the brake chamber can never be more than the driver applies with the foot pedal. The ABS can override the pedal pressure to provide less brake pressure but not more.

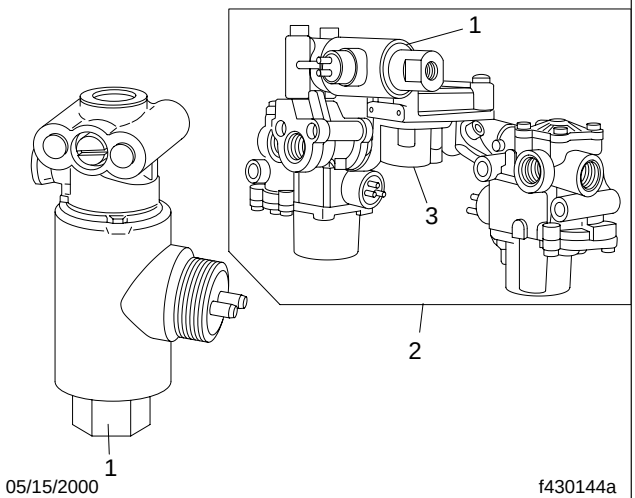
Automatic Traction Control (ATC)

If the vehicle is equipped with ATC, the ABS and ATC automatically reduce wheel spin during low-traction start-up or acceleration.

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If a drive wheel starts to spin faster than the steer-axle wheels, ATC applies air pressure to brake that drive wheel. This transfers engine torque to the wheel or wheels that have better traction (differential braking). If two or more drive wheels spin, the ATC reduces the engine torque to provide improved traction, overriding the throttle pressure from the driver.

The ATC valve controls only the brake chambers for the drive wheels. It is mounted on the service relay valve (rear modulator valve assembly). See **Fig. 10**. The solenoid in the ATC valve controls an on/off air valve, which allows or prevents air flow to the control side of the service relay valve.



1. ATC Valve
2. Rear Modulator Valve Assembly
3. Service Relay Valve

Fig. 10, ATC Valve

If a wheel spin from one side of the vehicle is detected, the ECU signals the ATC valve to open. This allows compressed air to enter the service relay valve and the ABS determines which brake to apply.

An ATC function switch on the dash allows the driver to select from two levels of drive-axle traction control (see **Fig. 11**):

- In the default position, the ATC reduces drive-axle wheel spin on icy, wet, or sand-covered roads.
- Pressing the TRAC MUD/SNOW switch increases the available traction on extra soft surfaces like snow, mud, or gravel by slightly increasing the permissible wheel spin. The greater wheel spin may also be used to help burn through a thin layer of ice.

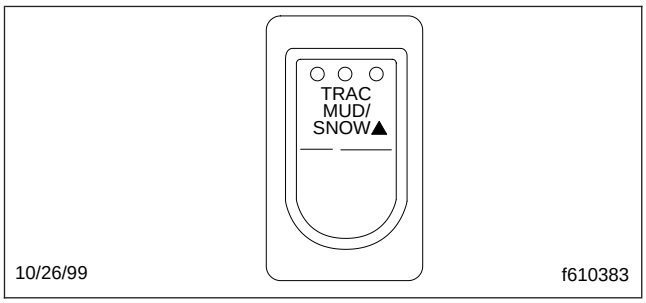


Fig. 11, ATC Switch for Soft Surfaces

The ATC function turns on and off automatically; drivers do not have to select this feature. If a drive wheel spins during start-up or acceleration, the ATC indicator light illuminates, indicating the ATC is active. The light goes out when the drive wheel stops spinning.

The TRAC MUD/SNOW mode overrides the ATC function. It must be manually selected by pressing the TRAC MUD/SNOW spring-loaded switch briefly after the vehicle is started. The ECU indicates the activation by a constant flashing of the WHEEL SPIN light. This mode is disengaged by pressing the TRAC MUD/SNOW switch again or turning the ignition switch off.

ABS Warning and ATC Indicator Lights

The ABS warning light (TRACTOR ABS or TRAILER ABS) receives power whenever the ignition switch is turned on. The ground paths for this indicator are through the ABS ECU and the blink-code switch. During the self-test, and whenever a malfunction occurs, the ECU completes the ground path and the ABS indicator on the dash illuminates. See **Fig. 4**. The light is also used to display blink code diagnostics.

The warning light alerts the driver that the self-test is working or that an ABS malfunction exists. After a wheel-sensor-related fault has been repaired, if the stored faults are cleared, the ABS warning light remains on until the vehicle is driven above a speed of 4 mph (6 km/h).

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General Information

The ATC indicator light also receives power whenever the ignition switch is on. If the drive-axle wheels spin, the ATC indicator light illuminates.

On vehicles equipped with ATC, if the TRAC MUD/SNOW switch (**Fig. 11**) is activated, the ABS ECU allows more wheel spin than normal and the ATC indicator blinks continuously until the switch is deactivated.

If the ATC wheel-spin indicator light illuminates during normal vehicle operation, there is an ATC malfunction.

Tire Size

For proper ABS and ATC operation with the standard ECU, the front and rear tire sizes must be within 14 percent of each other. When the tire-size range is exceeded, system performance can be affected and the warning lamp may come on.

Call Meritor WABCO at 1-800-535-5560 if you plan a tire-size difference greater than 14 percent.

Calculate the percentage difference of the tire sizes with the following equation:

Percentage Difference = {(steer-axle tire rpm ÷ drive-axle tire rpm) – 1} x 100, where rpm equals tire revolutions per mile.

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Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

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Wheel Speed Sensor Replacement

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Replacement

IMPORTANT: Do not attempt to repair the wheel sensor wire (the wire that comes with the sensor). If the wire is damaged, replace the sensor assembly.

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Group 54** for information on special terminals and connectors, and on ordering tools for them.

Front Axle

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Twist and pull the sensor to remove it from the steering knuckle. See **Fig. 1**.
3. Remove the sensor cable from the steering knuckle top cap.
4. Disconnect the sensor cable from the chassis harness.
5. Remove the clamp bushing from the steering knuckle.
6. Connect the new sensor cable to the chassis harness.
7. Attach the sensor cable to the steering knuckle top cap.
8. Press the clamp bushing into the brake spider hole until it stops.
9. Coat the sensor with Mobil HP, Valvoline EP 633, Pennzoil 707L, or an equivalent. Press the sensor into the clamp bushing until it is stopped by the tone wheel.
10. Remove the chocks from the rear tires.

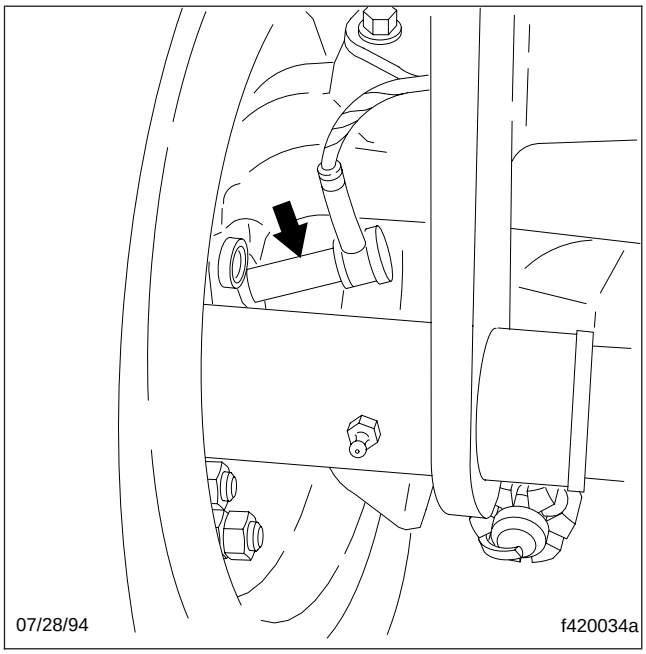


Fig. 1, Front Wheel Speed Sensor Removal

Rear Axle

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires to prevent vehicle movement.
2. Raise the rear of the vehicle until the tires clear the ground. Place safety stands under the axle.
3. Back off the slack adjuster to release the rear axle brake shoes.
4. Remove the wheel and tire assembly from the rear axle. For instructions, see **Group 40**.
5. Remove the brake drum. For instructions, see **Group 35**.
6. Twist and pull the sensor to remove it from the mounting block in the axle housing.
7. Remove the clamp bushing.
8. Remove the capscrew that attaches the sensor cable and the hose clamp to the axle tube.
9. Disconnect the sensor cable from the chassis harness.
10. Connect the new sensor cable to the chassis harness.

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Wheel Speed Sensor Replacement

11. Attach the hose clamp and sensor cable to the axle tube located between the backing plate and the spring plate.
12. Press the clamp bushing into the mounting block until it stops.
13. Coat the sensor with Mobil HP, Valvoline EP633, Pennzoil 707L, or an equivalent. Using your hand, push the sensor into the clamp bushing until it is stopped by the tone wheel.
14. Install the brake drum on the wheel hub. For instructions, see **Group 35**.
15. Adjust the rear axle brakes. For instructions, see **Section 42.03**.
16. Install the wheel and tire assembly, and tighten the wheel nuts. Use the tightening sequence and torque values listed in **Group 40**.
17. Remove the safety stands and lower the vehicle.
18. Remove the chocks from the front tires.

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Adjustment

NOTE: The following adjustment procedure requires the use of special tool T11-17556-000. Use of this tool, available through the PDCs, eliminates the time-consuming task of removing the wheel and tire assembly, and the brake drum. See **Fig. 1**.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front tires.

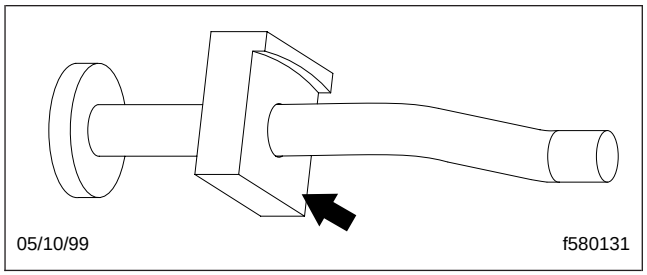
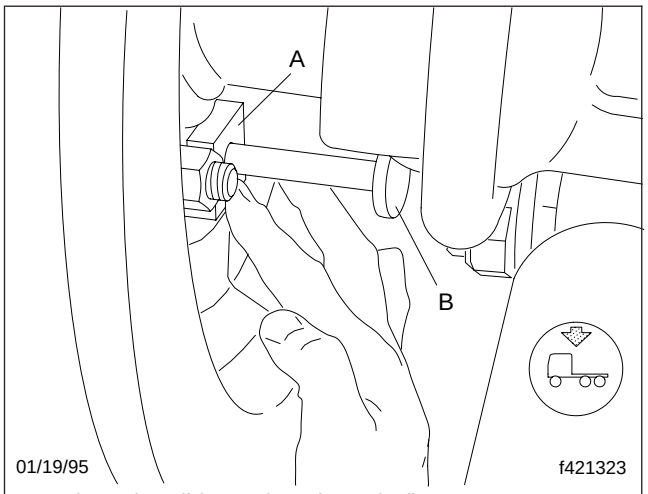


Fig. 1, ABS Sensor Adjustment Tool Slide

2. Find the sensor access hole in the rear-axle flange.
   - 2.1 View the inboard side of the brake drum and axle from the rear. The ABS sensor wiring harness should be visible through a hole in the 12 o'clock position.
   - 2.2 Find the S-cam at either the 3 or 9 o'clock position.
   - 2.3 The sensor access hole is opposite the S-cam. The hole is approximately 3/4 inch (19 mm) in diameter.

IMPORTANT: Do not pry or push the sensor with sharp objects.

3. Insert service tool T11-17556-000 in the sensor access hole.
4. Place the slide of the tool on the axle flange to align the tool. See **Fig. 2**.
5. Tap the tool handle lightly with the palm of your hand. This ensures that the sensor is touching the tone wheel.
6. Remove the tool from the wheel and repeat the procedure on the other rear-axle speed sensor.



A. Place the slide against the axle flange.
B. Tap the handle with your hand.

Fig. 2, Position the Tool

7. Remove the chocks from the tires.

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Modulator Valve Removal and Installation

⚠ WARNING

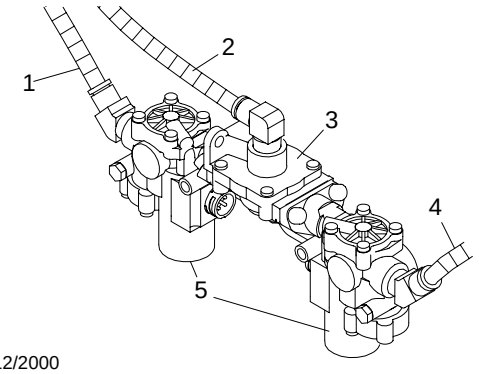
Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Removal

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Group 54** for information on special terminals and connectors, and on ordering tools for them.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the front and rear tires.
2. Release the pressure from the air reservoirs.
3. Mark the electrical connectors for ease of installation. Disconnect the wiring from the applicable front or rear modulator valve assembly.
   - The modulator valves for the front-axle brakes are mounted as an assembly on a bracket on the front crossmember (behind the front bumper). See **Fig. 1**. The assembly includes two modulator valves and a quick-release valve.
   - The rear modulator valve assembly is mounted on a bracket on a crossmember near the rear brake chambers. See **Fig. 2**. The assembly includes two modulator valves and a service relay valve.
4. Mark the air lines for ease of installation. Disconnect the air lines.
5. Remove the fasteners attaching the modulator valve assembly to the mounting bracket. Remove the valve assembly.

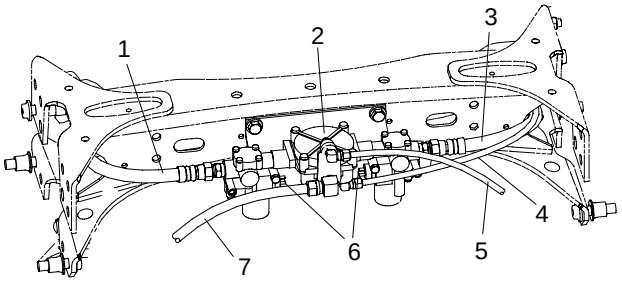
NOTE: The modulator valve assemblies can be disassembled if replacement of the quick-release valve, service relay valve, automatic traction control (ATC) valve (if equipped), or one of the modulator valves is needed. For disassembly and assembly instructions, see **Subject 140**.



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1. Air Line-to-Right-Side Brake Chamber
2. Supply Air Line
3. Quick-Release Valve
4. Air Line-to-Left-Side Brake Chamber
5. Modulator Valves

Fig. 1, Front Modulator Valve Assembly



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1. Delivery Air Line-to-Right-Side Brake Chamber
2. Service Relay Valve
3. Delivery Air Line-to-Left-Side Brake Chamber
4. Anti-Compounding Line (black, to park brake quick-release/relay valve)
5. Control Air Line (green, from foot pedal valve)
6. Modulator Valve Electrical Connections
7. Supply Air Line (green, from primary air reservoir)

Fig. 2, Rear Modulator Valve Assembly

Installation

1. Install the new modulator valve assembly on the bracket on the crossmember. Tighten the fasteners 18 lbf·ft (24 N·m).
2. Connect the air lines to the valves as marked during removal.
3. Connect the electrical cable connectors to the modulator valves and hand-tighten.

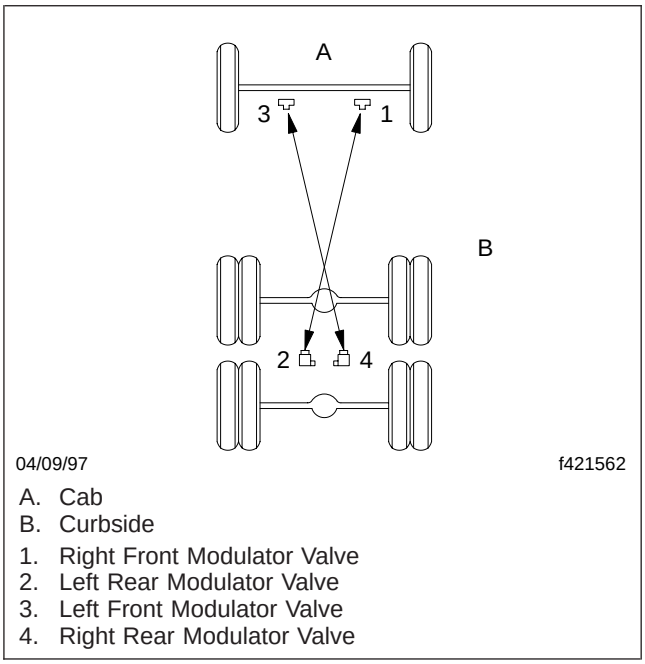
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Modulator Valve Removal and Installation

Installation Checkout

Valves can be tested using Meritor WABCO TOOLBOX Software or the following procedure:

1. Apply the brakes, turn the ignition switch on, and wait for the ABS indicator light to illuminate.
2. When the ABS warning light illuminates, listen for the modulator valves to cycle one by one in order (1, 2, 3 and 4), and then in pairs diagonally (1 and 2 together, and then 3 and 4 together). See **Fig. 3**.



A. Cab
B. Curbside
1. Right Front Modulator Valve
2. Left Rear Modulator Valve
3. Left Front Modulator Valve
4. Right Rear Modulator Valve

Fig. 3, Modulator Valve Self-Test Sequence

3. If a valve fails to cycle, turn the ignition switch off and make sure the electrical connections are tight. Turn the ignition switch on and listen to the valve cycle again.

   If a valve still fails to cycle, check for faults. See **Troubleshooting, 300** for fault identification.
4. Apply the brakes and check the modulator valve fittings for leaks. No air leakage is permitted.
5. Remove the chocks from the tires.
6. Test drive the vehicle to verify that the ABS warning light is functioning correctly.

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Modulator Valve Assembly, Disassembly and Assembly

⚠ WARNING

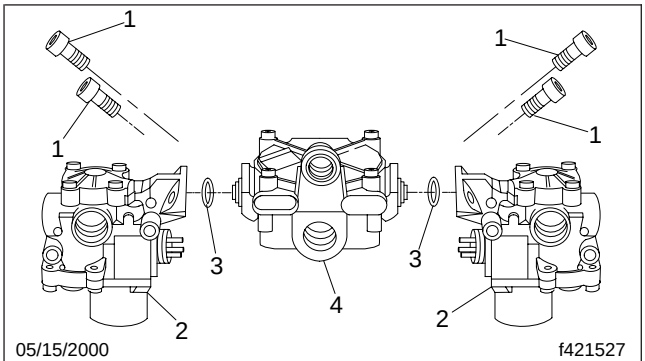
Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Disassembly

NOTE: On vehicles equipped with automatic traction control (ATC), the ATC valve can be replaced without removing the rear modular valve assembly if there is enough room to work.

1. Remove the modulator valve assembly from the crossmember. See **Subject 130** for instructions.
2. Remove the modulator valves from the quick-release or service relay valve.

   2.1 Using a 6-mm Allen wrench, remove the two allen-head capscrews that attach each modulator valve to the quick-release or service relay valve. See **Fig. 1**.



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NOTE: The fasteners are the same for both the front and rear modulator valve assemblies.

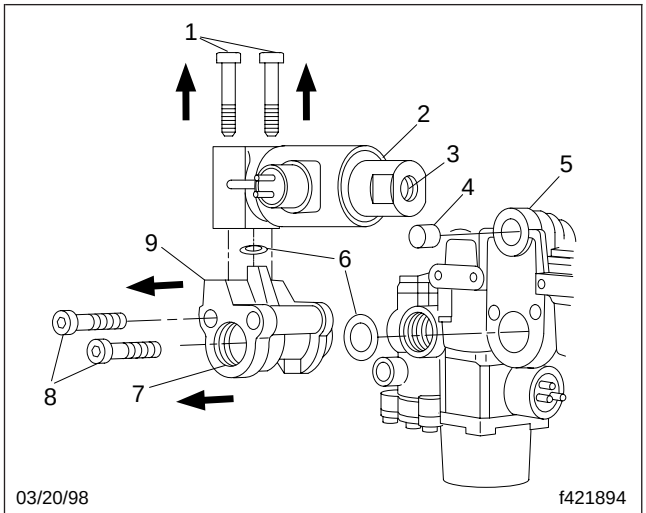
1. Capscrew, M8 Allen-Head
2. Modulator Valve
3. O-Ring
4. Service Relay Valve

Fig. 1, Rear Modulator Valve Assembly

   2.2 Carefully separate the modulator valves from the quick-release or service relay valve.

   2.3 Remove and discard the O-rings.

3. If the vehicle is equipped with ATC, remove the ATC valve from the service relay valve. See **Fig. 2**.



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1. Capscrew, M8 Allen-Head
2. ATC Valve
3. Control Port
4. Seal
5. Service Relay Valve
6. O-Ring
7. Supply Port
8. Capscrew, M6 Allen-Head
9. Adaptor

Fig. 2, ATC Valve Mounting

   3.1 Using a 5-mm Allen wrench, remove the two allen-head capscrews that attach the adaptor to the service relay valve. Remove the adapter/ATC valve assembly.

   3.2 Using a 6-mm Allen wrench, remove the two allen-head capscrews that attach the ATC valve to the adaptor. Separate the valve from the adaptor.

   3.3 Remove and discard the seal and two O-rings.

Assembly

1. If the vehicle is equipped with ATC, install the ATC valve on the service relay valve.

   1.1 Clean the O-ring grooves on the adaptor. Lubricate the small replacement O-ring and install it in the top port in the adaptor.

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Modulator Valve Assembly, Disassembly and Assembly

1.2 Using two new M8 allen-head capscrews, install the ATC valve on the adaptor. Tighten the capscrews 12 to 13 lbf·ft (18 to 20 N·m).

1.3 Lubricate the replacement seal and install it in the control port (upper port) of the service relay valve.

1.4 Lubricate the large replacement O-ring and install it in the groove in the supply port (lower port) of the service relay valve.

1.5 Using two new M6 allen-head capscrews, install the adaptor on the service relay valve. Tighten the capscrews 48 to 60 lbf·in (542 to 678 N·cm).

2. Install the modulator valves on the quick-release or service relay valve.

2.1 Plug any unused ports on the replacement modulator valves.

2.2 Clean the O-ring surfaces on the modulator and quick-release or service relay valves. Lubricate the replacement O-rings and place them in the applicable grooves in the valves.

2.3 Install each modulator valve on the quick-release or service relay valve with two M8 allen-head capscrews. Tighten the capscrews 13 to 15 lbf·ft (18 to 20 N·m).

3. Install the modulator valve assembly on the bracket on the crossmember. For instructions, see **Subject 130**.

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Installation

IMPORTANT: Some antilock braking system (ABS) service hubs do not have a tone (tooth) ring installed on the hub. The tone ring must be ordered separately and installed on the hub before installation of the hub onto the axle. Tone rings are made of a special material and require a specific installation procedure for proper installation.

⚠ WARNING

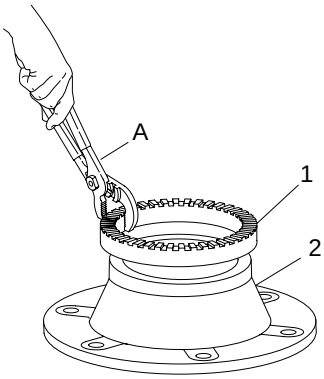
When installing ABS, special ABS hubs must be ordered. Machining older hubs to accommodate the installation of tone rings can cause problems due to insufficient hub bore wall thickness. Machining an older hub with insufficient hub bore wall thickness could result in cracking, causing bearing damage and wheel loss. This could cause an accident resulting in personal injury and property damage.

1. Submerge the tone ring in boiling water or place it in an oven at 250°F (121°C) for approximately 15 minutes.

⚠ CAUTION

Do not attempt to heat the tone ring with a torch as this can damage the ring.

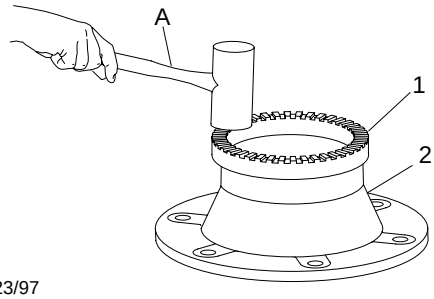
2. Using pliers, remove the tone ring from the boiling water or oven and center it on the machined area of the hub bore. See **Fig. 1**.
3. While the tone ring is still hot, make sure it is properly centered on the machined surface. Using a rubber mallet, tap the tone ring until it bottoms out around the machined surface on the hub. See **Fig. 2**.
4. Install the hub on the axle. Place a dial indicator with a magnetic base so the dial indicator is against the tone-ring teeth. See **Fig. 3**.
5. Rotate the hub and check the ring for runout. The runout should be less than 0.005 inch (0.13 mm). See **Fig. 4**.
6. Install the wheel. For instructions, see **Group 40**.



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A. Use pliers to apply the ring.
1. Tone Ring
2. Hub

Fig. 1, Install the Ring on the Hub



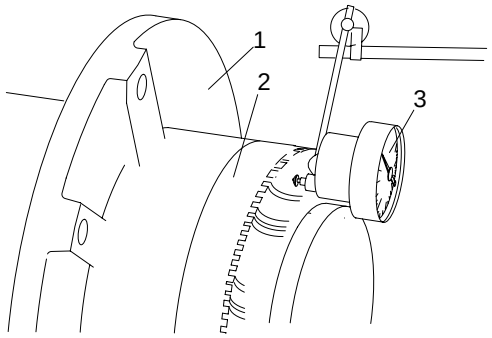
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A. Use a rubber mallet.
1. Tone Ring
2. Hub

Fig. 2, Tap the Tone Ring

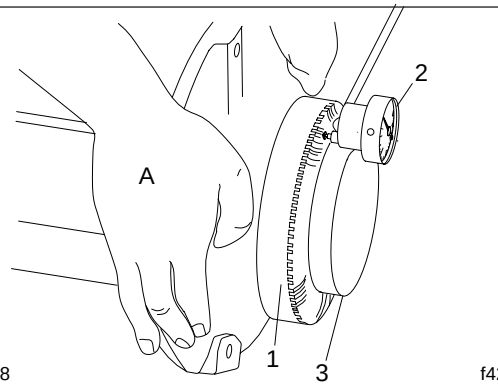
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ABS Tone Ring Installation on Service Hubs



1. Hub
2. Tone Ring
3. Dial Indicator

Fig. 3, Position the Dial Indicator



A. Rotate the hub.
1. Tone Ring
2. Dial Indicator
3. Axle

Fig. 4, Check Tone-Ring Runout

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Dynamometer Testing Vehicles with ATC

⚠ WARNING

Do not test a vehicle equipped with automatic traction control (ATC) on a dynamometer unless ATC is disabled. Activation of ATC on a dynamometer will cause unequal drive-wheel torque that can result in loss of vehicle control and personal injury or death.

Vehicles with ATC must have ATC disabled before testing the vehicle on a dynamometer. Use one of the following methods to disable ATC:

- Use the Meritor WABCO TOOLBOX Software or the Pro-Link® 9000 electronic diagnostic tool to disable ATC.
- Press and hold the blink code switch for a least 3 seconds. Once the system identification code begins, ATC has been disabled. For Acterra vehicles, the system identification code is two flashes (4S/4M system).
- Removing the antilock braking system (ABS) circuit breaker or fuse, or removing the electronic control unit (ECU) power connector, will disable both the ABS and ATC.

The WHEEL SPIN light on the dash comes on and stays on when ATC is disabled.

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Testing

General Information

⚠ WARNING

Before testing a vehicle equipped with automatic traction control (ATC) on a dynamometer, ATC must be disabled. See Subject 160 for instructions. Activation of the vehicle ATC on a dynamometer will cause unequal drive-wheel torque that can result in loss of vehicle control and personal injury or death.

Sensor and valve resistance tests are performed in two steps. Disconnect the applicable cable from the ECU and measure the resistance across the terminals in the cable connector. If the resistance is within the specified range, both the cable and the sensor or valve are operable.

If the resistance reading is not acceptable, disconnect the cable from the sensor or valve and measure the resistance across the sensor or valve terminals. This two-step procedure quickly determines whether the problem is in the cable or the component.

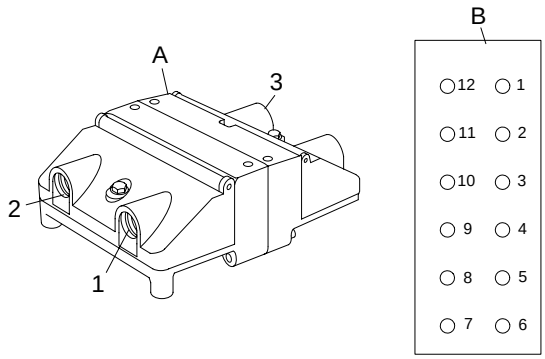
Wire Numbers and Connector Pin Locations

⚠ CAUTION

The ignition switch must be off when connecting or disconnecting connectors from the ECU.

Power applied to the ECU during connector installation or removal could damage the pins.

The WABCO "D" version, frame-mounted ECU has several multi-pin connectors that must be disconnected to test the wheel speed sensors, modulator valves, or ATC valve. To disconnect the electrical connectors from the ABS ECU, remove the capscrews and lift the covers. See **Fig. 1** to identify the pin locations on the ECU connector. **Table 1** provides the wire numbers and circuit descriptions for testing the ABS and ATC components.



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A. Frame-mounted ECU.
B. ECU connector pin locations.
1. Gray X1 Connector
2. Black X2 Connector
3. Green X3 Connector

Fig. 1, Frame-Mounted ECU and Pin Locations

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Testing

ABS/ATC Circuit Pin and Wire Numbers				
Pin Connector	**Pin Number**	**Color**	**Wire Number**	**Circuit Description**
X1 Gray	1	Orange	376C	ECU Positive12-Volt Ignition Supply
	2	Orange	376C*	ECU #2 Positive 12-Volt Ignition Supply
	3	Orange	376T	Wheel Spin Light and ATC Switch
	4	Dark Green	1587+	J1587+
	5	Orange	376R	Retarder Interrupt Signal
	6	Dark Green	1939–/ J1922–	J1939–/J1922–
	7	Yellow	1939+/ J1922+	J1939+/J1922+
	8	—	—	Not Used
	9	Orange	1587–	J1587–
	10	Orange	376L	ABS Light and Blink Code Switch
	11	Black	GRD	ECU Ground
	12	Black	GRD	ECU Ground
X2 Black	1	—	—	Not used
	2	Orange	378LFI	Left Front Modulator Valve, In
	3	Orange	378RF0	Right Front Modulator Valve, Out
	4	Orange	378RFI	Right Front Modulator Valve, In
	5	Orange	377RF+	Right Front Sensor, High
	6	Orange	377RF–	Right Front Sensor, Low
	7	Orange	377LF–	Left Front Sensor, Low
	8	Orange	377LF+	Left Front Sensor, High
	9	Black-White	378RF–	Right Front Modulator Valve, Ground
	10	Orange	378LF0	Left Front Modulator Valve, Out
	11	Black-White	378LF–	Left Front Modulator Valve, Ground
	12	—	—	Not used

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ABS/ATC Circuit Pin and Wire Numbers				
Pin Connector	**Pin Number**	**Color**	**Wire Number**	**Circuit Description**
X3 Green	1	Orange	377LR+	Left Rear Sensor, High
	2	Orange	377LR–	Left Rear Sensor, Low
	3	Orange	377RR+	Right Rear Sensor, High
	4	Orange	377RR–	Right Rear Sensor, Low
	5	Orange	378T+	ATC Valve, High
	6	Orange	378T–	ATC Valve, Low
	7	Orange	378RR0	Right Rear Modulator Valve, Out
	8	Black-White	378RR–	Right Rear Modulator Valve, Ground
	9	Orange	378RRI	Right Rear Modulator Valve, In
	10	Orange	378LR0	Left Rear Modulator Valve, Out
	11	Black-White	378LR–	Left Rear Modulator Valve, Ground
	12	Orange	378LRI	Left Rear Modulator Valve, In

Table 1, ABS/ATC Circuit Pin and Wire Numbers

ECU Supply Voltage/Ground Test

Use Meritor WABCO TOOLBOX Software to check the supply voltage to the ABS ECU. If TOOLBOX Software is not available, use the following procedure to check the voltage:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the gray X1 connector at the ABS ECU.
3. Turn the ignition switch on.
4. Connect a voltmeter between Pin 1 and Pin 12. The voltmeter must indicate 9.5 to 14 volts.
5. Connect a voltmeter between Pin 2 and Pin 11. The voltmeter must indicate 9.5 to 14 volts.
6. Turn the ignition switch off.
7. If the voltage at the ECU is not within the specified range, check the battery voltage and test the wiring to the ECU and to ground.
8. Connect the gray X1 connector to the ECU.
9. Remove the chocks from the tires.

Pneumatic ABS Test

To check for air leaks in the pneumatic ABS, listen for the sound of escaping air at each valve. To confirm a slow air leak, apply a soap-and-water solution to air line fittings and watch for bubbles.

Wheel Speed Sensor Tests

Wheel Speed Sensor and Circuit Resistance

To check the resistance in a wheel speed sensor circuit, perform the following test:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the sensor cable connector from the ABS ECU. See **Table 1**.
3. Connect ohmmeter probes to the sensor connector terminals and read the resistance.
   - If the resistance is between 900 and 2000 ohms, the cable and the sensor circuit are operable. Perform the "Wheel Speed Sensor Voltage" test.
   - If the resistance is less than 900 ohms or greater than 2000 ohms, perform the "Wheel Speed Sensor Resistance" test.

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Wheel Speed Sensor Resistance

To check the resistance in a wheel speed sensor, perform the following test:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the wheel sensor cable from the chassis harness.
3. Connect ohmmeter probes to the pins on the sensor and read the resistance.
    - If the resistance reading is between 900 and 2000 ohms, but the resistance noted in the "Wheel Speed Sensor and Cable Resistance" test was not, repair or replace the chassis harness wiring.
    - If the resistance is less than 900 ohms or greater than 2000 ohms, clean the terminals and check the resistance again.
    - If the resistance reading is still not correct, replace the sensor. See **Subject 110** for instructions.
4. Install the connectors.
5. Remove the chocks from the tires.

Wheel Speed Sensor Voltage

To check the voltage output of a wheel speed sensor, perform the following test:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires of the axle not being tested.
2. Raise the vehicle and put jack stands under the axle so the wheels can rotate.
3. Disconnect the applicable connector from the ABS ECU for the sensor being tested. See **Table 1**.
4. Set a digital multimeter to the AC voltmeter mode. Connect the probes to the cable connector terminals for the sensor being tested.
5. Rotate the wheel by hand at a speed of 30 rpm (one-half revolution per second) and read the voltage output. The wheel speed sensor must generate a minimum of 0.2 volt AC.
    - If the voltage is at least 0.2 volt AC, skip to the next step.
    - If the voltage reading is less than 0.2 volt AC, push the sensor into the holder until the sensor touches the tooth wheel. See **Subject 120** for instructions. Repeat the voltage test.
    - If the sensor output is still less than 0.2 volt AC, replace the sensor.
6. Install the connector on the ECU.
7. Remove the jack stands and lower the vehicle.
8. Remove the chocks from the tires.

Modulator Valve Tests

Modulator Valve Function Check

Valves can be tested using Meritor WABCO TOOLBOX Software or the following procedure:

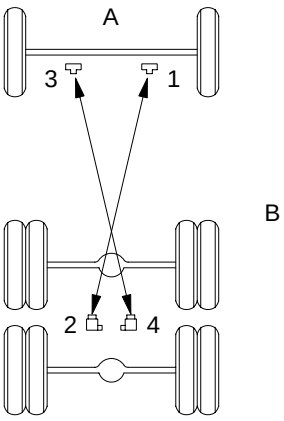
1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Turn the ignition switch to the ON position.
3. When the ABS warning light illuminates, listen for the modulator valves to cycle one by one in order (1, 2, 3 and 4), and then in pairs diagonally (1 and 2 together, and then 3 and 4 together). See **Fig. 2**.
4. If the valves do not all cycle correctly, turn the ignition off and check the connectors for tightness. Repeat the self-test.
5. If the valves still do not cycle correctly, start the engine and check the air line connections to the valves for leaks. Shut down the engine and tighten the air line fittings. Repeat the self-test.
6. If the valves still do not cycle correctly, perform the "Modulator Valve and Cable Resistance" test.

Modulator Valve and Cable Resistance

To check the resistance in a modulator valve and cable circuit, perform the following test:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the modulator valve connector from the ABS ECU. See **Table 1**.

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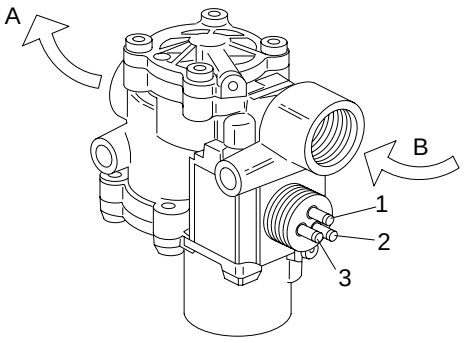


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A. Cab
B. Curbside
1. Right Front Modulator Valve
2. Left Rear Modulator Valve
3. Left Front Modulator Valve
4. Right Rear Modulator Valve

Fig. 2, Modulator Valve Self-Test Sequence

3. Connect ohmmeter probes to the cable supply solenoid and ground pins and read the resistance. Move the probes to the exhaust solenoid and ground pins and read the resistance. See **Fig. 3**.



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A. Delivery Port
B. Supply Port
1. Ground (Common), Black-White Wire
2. Exhaust Solenoid (Out), Orange Wire
3. Supply Solenoid (In), Orange Wire

Fig. 3, Modulator Valve Terminals

4. The resistance in each cable circuit must be between 4 and 8 ohms.
   - If the resistance in each cable circuit is between 4 and 8 ohms, the cable and modulator valve are operable. Install the connector on the ECU and remove the chocks from the tires.
   - If the resistance in either cable circuit is less than 4 ohms or greater than 8 ohms, perform the "Modulator Valve Resistance" test.

Modulator Valve Resistance

To check the resistance in the solenoid coils in an ABS modulator valve, perform the following test:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the cable connector from the modulator valve being tested. See **Table 1**.
3. Connect ohmmeter probes to the modulator valve supply solenoid and ground terminals and read the resistance. Move the probes to the exhaust solenoid and ground terminals and read the resistance. See **Fig. 3**.
4. The resistance in each solenoid coil must be between 4 and 8 ohms.
   - If the resistance in each solenoid coil is between 4 and 8 ohms, but the resistance noted in the "Modulator Valve and Cable Resistance" test was not, repair or replace the chassis harness.
   - If the resistance is less than 4 ohms or greater than 8 ohms, clean the terminals on the modulator valve and check the resistance again.
   - If the resistance is still not correct, replace the valve. See **Subject 130** for instructions.
5. Install the cable connectors.
6. Remove the chocks from the tires.

ATC Valve Tests

ATC Valve and Cable Resistance

To check the resistance in the ATC valve and cable circuit, perform the following test:

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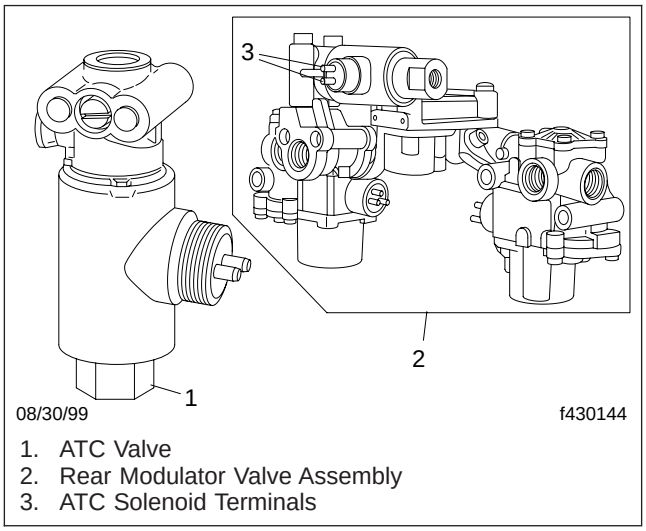
Testing

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the ATC valve connector from the ABS ECU. See **Table 1**.
3. Connect ohmmeter probes to the cable connector pins for the ATC valve and read the resistance.
4. The resistance in the ATC solenoid coil and cable circuit must be between 6.4 and 12 ohms.
    - If the resistance is between 6.4 and 12 ohms, the ATC valve and cable are operable. Install the cable connector on the ECU and remove the chocks from the tires.
    - If the resistance is less than 6.4 ohms or greater than 12 ohms, perform the "ATC Valve Resistance" test.

ATC Valve Resistance

To check the resistance in the solenoid coil in the ATC valve, perform the following test:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the cable connector from the ATC valve. See **Table 1**.
3. Connect ohmmeter probes to the ATC valve terminals and read the resistance. See **Fig. 4**.
4. The resistance of the ATC solenoid coil and its wiring must be between 6.4 and 12 ohms.
    - If the resistance is between 6.4 and 12 ohms, but the resistance noted in the "ATC Valve and Cable Resistance" test was not, repair or replace the electrical cable.
    - If the resistance is less than 6.4 ohms or greater than 12 ohms, clean the terminals on the ATC valve and check the resistance again.
    - If the resistance is still not correct, replace the valve. See **Subject 140** for instructions.
5. Install the connectors.
6. Remove the chocks from the tires.



1. ATC Valve
2. Rear Modulator Valve Assembly
3. ATC Solenoid Terminals

Fig. 4, ATC Valve Terminals

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Troubleshooting

⚠ WARNING

Before testing a vehicle equipped with automatic traction control (ATC) on a dynamometer, ATC must be disabled. See Subject 160 for instructions. Activation of the vehicle ATC on a dynamometer will cause unequal drive-wheel torque that can result in loss of vehicle control and personal injury or death.

The antilock braking system (ABS), and ATC (if equipped), has built-in diagnostics to ensure all components are operating correctly. The first step is an automatic self-test. Under normal conditions, the ABS warning light(s) (TRACTOR ABS or TRAILER ABS) and ATC wheel spin indicator light (WHEEL SPIN) illuminate on the instrument cluster when the ignition is turned on. After about 3 seconds, these lights should go out if all of the vehicle's ABS and ATC components are working properly.

If any of the lights stay on, or come back on later, a problem within the ABS or ATC has occurred. The driver can continue to drive the vehicle, but the ABS could be partially or completely inoperable.

NOTE: The WHEEL SPIN indicator stays lit when ATC is controlling wheel spin and blinks continuously if the ATC switch (TRAC MUD/SNOW) is activated. These are normal conditions and do not indicate a fault.

Troubleshoot to identify the problem(s) indicated by the illuminated light(s) using:

- J1587 codes viewed on a computer with Meritor WABCO TOOLBOX Software installed;
- J1587 codes viewed on a computer with Freightliner's ServiceLink installed;
- Pro-Link® 9000, or;
- Instrument panel blink codes.

NOTE: The J1587-code method provides more information about the specific problem than can be obtained from the blink codes.

To check the type of fault recorded, stop the vehicle and turn off the engine. Turn on the ignition switch, but do not start the engine. If the light stays on after the 3-second self-test, there is an active system fault that must be repaired to ensure proper system operation.

If the light does not stay on, a stored or intermittent fault (indicating a loose connector or broken wire) has been recorded in the ABS electronic control unit (ECU) memory.

If either light does not come on during the self-test, check the bulb, all related circuit breakers in the electrical panel, or the batteries (the ABS and ATC require at least 9.5 volts to function correctly).

Active faults cannot be cleared until they are repaired. A fault that has been repaired will not be cleared from memory (and the light will not go out) until the vehicle has been driven a short distance at 4 mph (6 km/h) to calibrate the system.

Meritor WABCO TOOLBOX Software

The Meritor WABCO TOOLBOX Software can be used to diagnose pneumatic ABS faults. TOOLBOX is packaged with ServiceLink and provides J1587 fault codes, on-screen information, and tests to assist with troubleshooting.

J1587 Codes

Use Freightliner's ServiceLink to diagnose the ABS and ATC if detailed codes are needed or if the diagnosis must be done remotely. Connect a computer, with ServiceLink installed, to the J1587 datalink connector located under the left-hand dash. Follow the instructions found in the ServiceLink manual.

The J1587 codes are eight-digit numbers where:

- The first three digits refer to the message identifier (MID) that indicates the ECU reporting the fault (the MID is 136 for the ABS and ATC ECU);
- The next three digits (preceded by a lowercase "s") represent the subsystem identifier (SID), which indicates the component at fault;
- The last two digits, the failure mode identifier (FMI), represent the specific problem with the component.

See **Table 1** for a list of the J1587 codes with their corresponding components and troubleshooting table references.

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J1587 Codes and Blink Codes Troubleshooting Table Index					
J1587 Code			Blink Code	Description	Troubleshooting Table
MID	SID	FMI			
—	—	—	1-1	No Faults	—
136	001	01–12	3-2, 4-2, 5-2, 6-2	Left Front Wheel Sensor	Table 2
	002	01–12	3-1, 4-1, 5-1, 6-1	Right Front Wheel Sensor	Table 3
	003	01–12	3-4, 4-4, 5-4, 6-4	Left Rear Wheel Sensor	Table 4
	004	01–12	3-3, 4-3, 5-3, 6-3	Right Rear Wheel Sensor	Table 5
	005	—	3-6, 4-6, 5-6, 6-6	Not Used	—
	006	—	3-5, 4-5, 5-5, 6-5	Not Used	—
	007	01, 03, 05, 06	2-2	Left Front Modulator Valve	Table 6
	008	01, 03, 05, 06	2-1	Right Front Modulator Valve	Table 7
	009	01, 03, 05, 06	2-4	Left Rear Modulator Valve	Table 8
	010	01, 03, 05, 06	2-3	Right Rear Modulator Valve	Table 9
	013	03, 05, 06	7-3	Retarder	Table 10
	014	04, 07	8-1, 8-3	Ground Diagonal 1	Table 11
	015	04, 07	8-1, 8-3	Ground Diagonal 2	Table 12
	018	03, 05, 06	7-2	ATC Valve	Table 13
	019	03	7-6	Not Used	Table 14
	023	05	7-4	Warning Light	Table 15
	231, 248	02, 05, 06, 09, 12	7-1, 8-3	J1939 Datalink	Table 16
	251	03	8-2	Voltage Diagonal 1 or 2	Table 17
	253	01, 02, 12	7-5, 8-4	Configuration Errors	Table 18
	254	02, 05, 08, 09, 12	2-1, 7-1, 8-3, 8-4	Miscellaneous Faults	Table 19

Table 1, J1587 Codes and Blink Codes Troubleshooting Table Index

To erase all the stored faults from the ECU memory, see the ServiceLink manual or use the blink code switch. See "Erasing Stored Faults" in this subject. Make sure to note all the stored faults before clearing them. Stored faults cannot be cleared if active faults exist.

Pro-Link® 9000

Pro-Link 9000 is available from Kent-Moore, 1-800-328-6657.

The "D" version cartridge 4.0 or higher must be used with the "D" version ECUs. When troubleshooting the system with Pro-Link 9000, use the instruction booklet that is supplied with the WABCO "D" version ABS cartridge.

Instrument Panel Blink Codes

Use the ABS CHECK switch and the ABS warning light to:

- Display any active or stored faults (press the ABS CHECK switch for 1 second for the "Diagnostic" mode);
- Erase stored faults from the ECU memory or display the system identification code (press

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the ABS CHECK switch for 3 seconds for the "Clear All" mode).

Displaying Blink Codes

NOTE: For simplicity, the ABS warning light (TRACTOR ABS) will be referred to as the ABS light in this procedure.

Blink codes are displayed as follows:

1. With the ignition switch on, press the ABS CHECK switch for about 1 second ("Diagnostic" mode). The ABS light should go out in 1-1/2 seconds. See **Fig. 1**.
2. The ABS light will flash a number of times equal to the first digit of the two-digit blink code. The first digit is a number from one to eight.
3. After a 1-1/2 second pause, the ABS light will flash a number of times equal to the second digit. The second digit is a number from one to six.
4. After a 4-second pause, the cycle repeats an active fault until it is repaired or the ignition switch is turned off. See **Fig. 1**.
5. If there are no active faults, but there is one or more stored fault in the ECU memory, the system will display the stored fault(s). The faults are displayed in sequence starting with the most recent fault. There is a 4-second pause between faults. See **Fig. 2**. Each stored fault is displayed only once. After all faults have been displayed, the light stops blinking.

   For example, after the ABS CHECK switch is pressed for 1 second and released, blink code 2-3 is indicated by two flashes, a pause of 1-1/2 seconds, followed by three flashes and a 4-second pause.
6. If there are no faults in the ECU memory, blink code 1-1 is displayed, meaning the system is clear. See **Fig. 3**.

Identifying Blink Codes

The first digit in a blink code identifies the type of fault; the second digit indicates the specific location of the fault. See **Table 1** to identify the blink codes.

CAUTION

The ignition switch must be off when connecting or disconnecting connectors from the ECU. Power applied to the ECU during connector installation or removal could damage the pins.

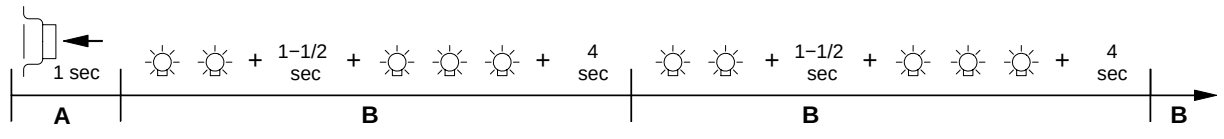
Once a fault code has been identified, use a multimeter to check the electrical harness at the ABS ECU connectors. For wire numbers and connector pin locations on the frame-mounted ECU, see "Wire Numbers and Connector Pin Locations" in **Subject 170**.

See the applicable troubleshooting table for fault codes, pins to be tested, and the correct multimeter readings. Repair or replace the components and/or wiring if the readings are not correct.

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Group 54** for information on special terminals and connectors, and ordering tools for them.

See the wiring diagrams in **Specifications, 400** when troubleshooting the ABS.

After the repair is complete, drive the vehicle at least 4 mph (6 km/h) to calibrate the ABS and ATC. Shut down the engine and turn the ignition switch to the ON position to verify the fault is no longer active.



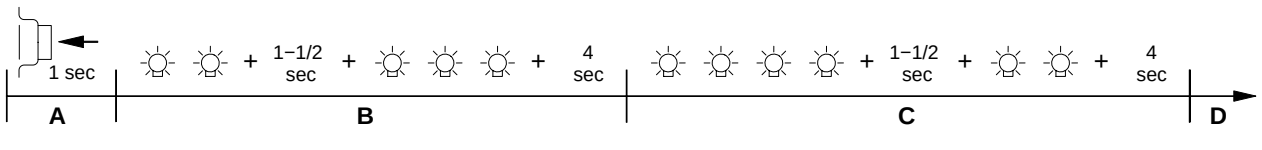
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NOTE: An active fault repeats until the ignition switch is turned off.

A. Press the ABS CHECK switch for 1 second. The ABS light goes out in 1-1/2 seconds.
B. Blink code 2-3: two flashes, a 1-1/2 second pause, three flashes, and a 4-second pause.

Fig. 1, Active Faults Repeat (blink code 2-3 shown)

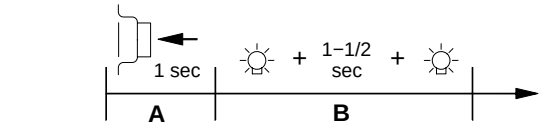
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NOTE: The most recent fault stored is displayed first; each stored fault is displayed once.

A. Press the ABS CHECK switch for 1 second. The ABS light goes out in 1-1/2 seconds.
B. The most recent stored fault is displayed (blink code 2-3 is shown).
C. The second newest stored fault is displayed if one exists (blink code 3-2 is shown).
D. The third newest stored fault is displayed if one exists.

Fig. 2, Stored Faults Display in Sequence



A. Press the ABS CHECK switch for 1 second. The ABS light goes out in 1-1/2 seconds.
B. Blink code 1-1: one flash, a 1-1/2 second pause, and 1 flash.

Fig. 3, No Faults, System OK

After pressing the ABS CHECK switch for 1 second, a 1-1 "no fault" blink code should be displayed if there are no stored faults in the ECU memory.

Erasing Stored Faults

An active fault cannot be erased from ECU memory, but stored faults can be erased all at once without being repaired. Make sure that all stored faults are recorded before they are erased because they should be repaired as soon as possible.

Stored faults can be erased from the ECU memory as follows:

1. Turn the ignition on.
2. Press the ABS CHECK switch for 3 to 6 seconds ("Clear All" mode).
3. After releasing the switch, the ABS light will go out in 1-1/2 seconds.
4. If there were stored faults but no active faults, the ABS light will flash eight times meaning all stored faults have been cleared. See **Fig. 4**. (If there are active faults, only the system identification code will be displayed. See **Fig. 5**.)
5. After a 4-second pause, the ABS light will display the system identification code followed by another 4-second pause repeatedly until the ignition switch is turned off.
6. If there are active faults, only the system identification code will be displayed. See **Fig. 5**.

   The system identification code indicates the number of ABS wheel speed sensors (S) and modulator valves (M) installed on the vehicle. For Acterra vehicles, the system identification code is two flashes (4S/4M system).

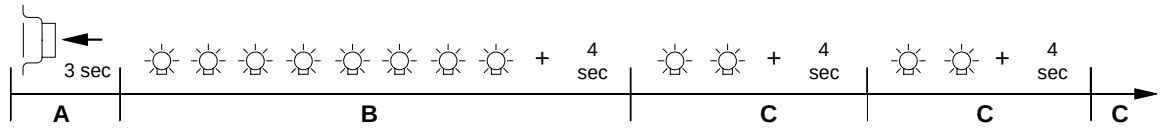
NOTE: If a fault cannot be repaired or erased from ECU memory, contact your Meritor district service manager or call Meritor WABCO at 1-800-535-5560.

Power Distribution Modules

The cab power distribution module (PDM) is located on the passenger side within the instrument panel. A trim panel covers the PDM and is attached to the instrument panel by quarter-turn fasteners. A decal identifying the location of the fuses, circuit breakers and relays is attached to the back side of the trim panel. See **Fig. 6** for WABCO pneumatic ABS fuses, circuit breakers and relays. See **Group 54** for complete PDM information.

The engine PDM is located in the engine compartment and has a decal identifying the location of fuses, circuit breakers and relays on the outside of the PDM cover. To gain access, open the cover. See **Fig. 7** for WABCO pneumatic ABS fuses, circuit breakers and relays. See **Group 54** for complete PDM information.

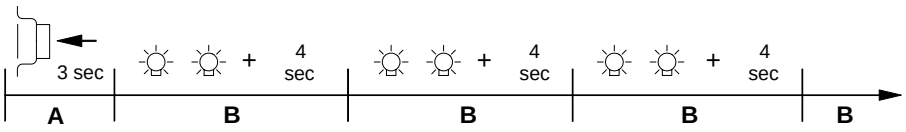
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05/18/2000 f151015

A. Press the ABS CHECK switch for 3 seconds. The ABS light goes out in 1-1/2 seconds.
B. Eight quick flashes followed by a 4-second pause (faults cleared).
C. The system ID code (two flashes for a vehicle with a 4S/4M system), followed by a 4-second pause, repeats until the ignition switch is turned off.

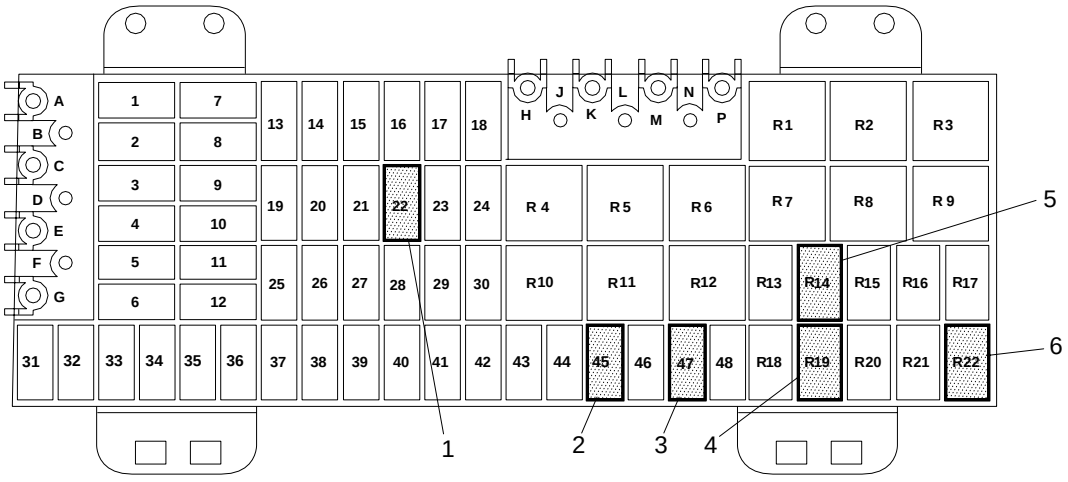
Fig. 4, Stored Faults Cleared



05/18/2000 f151016

A. Press the ABS CHECK switch for 3 seconds. The ABS light goes out in 1-1/2 seconds.
B. The system ID code (two flashes for a vehicle with a 4S/4M system), followed by a 4-second pause, repeats until the ignition switch is turned off.

Fig. 5, Faults Not Cleared, Active Faults Still Exist



10/12/2000 f542963b

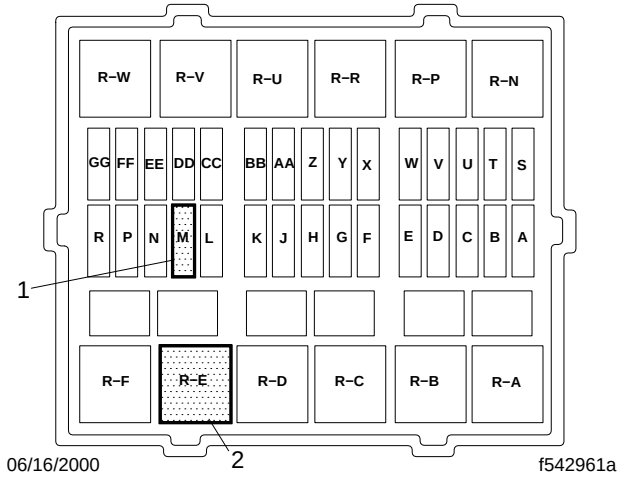
NOTE: The fuses, circuit breakers and relays used for the WABCO pneumatic ABS are shown. See **Group 54** for complete PDM information.

1. Fuse 22, Ignition Run/Start
2. Fuse 45, ABS
3. Fuse 47, ABS
4. R19, ABS Warning Light Relay
5. R14, Retarder Relay
6. R22, Transmission ABS

Fig. 6, Cab Power Distribution Module

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NOTE: The relays and fuses used for the WABCO pneumatic ABS are shown. See **Group 54** for complete PDM information.

1. Fuse M (26), ABS Power
2. Trailer ABS Relay, Constant Power

Fig. 7, Engine Power Distribution Module

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Left Front Wheel Sensor (SID = s001)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	001	01	Incorrect sensor air gap	1. Adjust the sensor. Check AC voltage across Pins 7 and 8 of the black X2 ECU connector while rotating the left front wheel 30 rpm.	Voltage greater than or equal to 0.2 volts AC	Sensor adjustment solved the problem.	3-2
					Voltage below 0.2 volts AC	Check for excessive wheel bearing end play and hub runout. Repair as necessary.	
		02	Incorrect tire size	—	—	Check for the correct tire size and mixed tire sizes. Check for the correct number of teeth on the tone wheel. Correct as necessary.	5-2
		03	Sensor shorted to power	2. Measure the voltage across Pin 7 of the black X2 connector and a good chassis ground. Repeat the test between Pin 8 of the black X2 connector and ground.	Voltage at either pin	Repair the short to power in Circuits 377LF– and 377LF+ in the chassis harness and sensor cable. If the problem is in the sensor harness, replace the sensor.	4-2
					No voltage at either pin	Repeat the test and check for an intermittent short to power in Circuits 377LF+ and 377LF–. Suspect the ECU is at fault if the problem persists.	
		04	Short to ground	3. Measure the resistance between Pin 7 of the black X2 connector and a good chassis ground. Repeat the test between Pin 8 of the black X2 connector and ground.	The resistance between either pin and ground is less than 100,000 ohms	Repair the short to ground in Circuits 377LF+ and 377LF– in the chassis harness or sensor cable. If the problem is in the sensor harness, replace the sensor.	
					The resistance between either pin and ground is more than 100,000 ohms	Repeat the test and check for an intermittent short to ground in Circuits 377LF– and 377LF+. Suspect the ECU is at fault if the problem persists.	

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Troubleshooting

Left Front Wheel Sensor (SID = s001)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	001	05	Open circuit	4. Measure the resistance between Pins 7 and 8 of the black X2 ECU connector.	Resistance is between 900 and 2000 ohms	Repeat the test and check for an intermittent open or short in Circuits 377LF+ and 377LF–. Suspect the ECU is at fault if the problem persists.	4-2
		06	Short circuit				
					Resistance is above 2000 or below 900 ohms	Go to Test 5.	
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is 900 to 2000 ohms	Repair open or short in Circuits 377LF+ and 377LF– in chassis harness.	
					Resistance is above 2000 or below 900 ohms	Replace the sensor.	
		07	Damaged tone ring	—	—	Inspect the tone ring for damage and missing teeth. Make sure the correct tooth wheel is installed (100 tooth normal application). Repair as necessary.	6-2
		08	Excessive wheel slip	—	—	Check the sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.	3-2
		09	Wire mismatch	6. Check for a mixed sensor connection. This can be done using Meritor WABCO TOOLBOX Software by spinning each wheel individually and observing whether the output is from the proper sensor.	—	Correct wiring connections as necessary.	5-2
		10	Intermittent signal	7. Adjust the sensor. Use the wheel sensor output screen in the Meritor WABCO TOOLBOX Software and spin the wheel or drive the vehicle and look for an intermittent or erratic signal.	Signal output normal	Adjustment solved the problem. Make sure brake chatter is not causing the problem.	3-2 5-2
		11	Erratic signal				
					Intermittent or erratic signal output	Check for intermittent wheel sensor circuit connections. The cause could be brake chatter. Repair as necessary.	

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Left Front Wheel Sensor (SID = s001)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	001	12	Frequency too high	8. Check the sensor wiring and connectors for intermittent contact.	Wiring correct	Suspect the ECU is at fault if the problem persists.	5-2
					Wiring not correct	Repair the wheel sensor circuit as necessary.	

Table 2, Left Front Wheel Sensor (SID = s001)

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Troubleshooting

Right Front Wheel Sensor (SID = s002)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	002	01	Incorrect sensor air gap	1. Adjust the sensor. Check AC voltage across Pins 5 and 6 of the black X2 ECU connector while rotating the right front wheel 30 rpm.	Voltage greater than or equal to 0.2 volts AC	Sensor adjustment solved the problem.	3-1
					Voltage below 0.2 volts AC	Check for excessive wheel bearing end play and hub runout. Repair as necessary.	
		02	Incorrect tire size	—	—	Check for the correct tire size and mixed tire sizes. Check for the correct number of teeth on the tone wheel. Correct as necessary.	5-1
		03	Sensor shorted to power	2. Measure the voltage across Pin 5 of the black X2 connector and a good chassis ground. Repeat the test between Pin 6 of the black X2 connector and ground.	Voltage at either pin	Repair the short to power in Circuits 377RF– and 377RF+ in the chassis harness and sensor cable. If the problem is in the sensor harness, replace the sensor.	4-1
					No voltage at either pin	Repeat the test and check for an intermittent short to power in Circuits 377RF+ and 377RF–. Suspect the ECU is at fault if the problem persists.	
		04	Short to ground	3. Measure the resistance between Pin 5 of the black X2 connector and a good chassis ground. Repeat the test between Pin 6 of the black X2 connector and ground.	The resistance between either pin and ground is less than 100,000 ohms	Repair short to ground in Circuits 377RF+ and 377RF– in chassis harness or sensor cable. If the problem is in the sensor harness, replace the sensor.	
					The resistance between either pin and ground is more than 100,000 ohms	Repeat the test and check for an intermittent short to ground in Circuits 377RF– and 377RF+. Suspect the ECU is at fault if the problem persists.	

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Right Front Wheel Sensor (SID = s002)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	002	05	Open circuit	4. Measure the resistance between Pins 5 and 6 of the black X2 ECU connector.	Resistance is between 900 and 2000 ohms	Repeat the test and check for intermittent open or short in Circuits 377RF+ and 377RF–. Suspect the ECU is at fault if the problem persists.	4-1
		06	Short circuit		Resistance is above 2000 or below 900 ohms	Go to Test 5.	
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is between 900 and 2000 ohms	Repair the open or short in Circuits 377RF+ and 377RF– in the chassis harness.	
					Resistance is above 2000 or below 900 ohms	Replace the sensor.	
		07	Damaged tone ring	—	—	Inspect the tone ring for damage and missing teeth. Make sure the correct tooth wheel is installed (100 tooth normal application). Repair as necessary.	6-1
		08	Excessive wheel slip	—	—	Check the sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.	3-1
		09	Wire mismatch	6. Check for a mixed sensor connection. This can be done using Meritor WABCO TOOLBOX Software by spinning each wheel individually and observing whether the output is from the proper sensor.	—	Correct wiring connections as necessary.	5-1
		10	Intermittent signal	7. Adjust the sensor. Use the wheel sensor output screen in the Meritor WABCO TOOLBOX Software and spin the wheel or drive the vehicle and look for an intermittent or erratic signal.	Signal output normal	Adjustment solved the problem. Make sure brake chatter is not causing the problem.	3-1 5-1
		11	Erratic signal		Intermittent or erratic signal output	Check for intermittent wheel sensor circuit connections. The cause could be brake chatter. Repair as necessary.	

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Troubleshooting

Right Front Wheel Sensor (SID = s002)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	002	12	Frequency too high	8. Check the sensor wiring and connectors for intermittent contact.	Wiring correct	Suspect the ECU is at fault if the problem persists.	5-1
					Wiring not correct	Repair the wheel sensor circuit as necessary.	

Table 3, Right Front Wheel Sensor (SID = s002)

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Left Rear Wheel Sensor (SID = s003)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	003	01	Incorrect sensor air gap	1. Adjust the sensor. Check AC voltage across Pins 1 and 2 of the green X3 ECU connector while rotating the left rear wheel 30 rpm.	Voltage greater than or equal to 0.2 volts AC	Sensor adjustment solved the problem.	3-4
					Voltage below 0.2 volts AC	Check for excessive wheel bearing end play and hub runout. Repair as necessary.	
		02	Incorrect tire size	—	—	Check for the correct tire size and mixed tire sizes. Check for the correct number of teeth on the tone wheel. Correct as necessary.	5-4
		03	Sensor shorted to power	2. Measure the voltage across Pin 1 of the green X3 connector and a good chassis ground. Repeat the test between Pin 2 of the green X3 connector and ground.	Voltage at either pin	Repair the short to power in Circuits 377LR– and 377LR+ in the chassis harness and sensor cable. If the problem is in the sensor harness, replace the sensor.	4-4
					No voltage at either pin	Repeat the test and check for an intermittent short to power in Circuits 377LR+ and 377LR–. Suspect the ECU is at fault if the problem persists.	
		04	Short to ground	3. Measure the resistance between Pin 1 of the green X3 connector and a good chassis ground. Repeat the test between Pin 2 of the green X3 connector and ground.	The resistance between either pin and ground is less than 100,000 ohms	Repair the short to ground in Circuits 377LR+ and 377LR– in the chassis harness or sensor cable. If the problem is in the sensor harness, replace the sensor.	
					The resistance between either pin and ground is more than 100,000 ohms	Repeat the test and check for an intermittent short to ground in Circuits 377LR– and 377LR+. Suspect the ECU is at fault if the problem persists.	

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Troubleshooting

Left Rear Wheel Sensor (SID = s003)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	003	05	Open circuit	4. Measure the resistance between Pins 1 and 2 of the green X3 ECU connector.	Resistance is between 900 and 2000 ohms	Repeat the test and check for intermittent open or short in Circuits 377LR+ and 377LR–. Suspect the ECU is at fault if the problem persists.	4-4
		06	Short circuit		Resistance is above 2000 or below 900 ohms	Go to Test 5.	
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is between 900 and 2000 ohms	Repair the open or short in Circuits 377LR+ and 377LR– in the chassis harness.	
					Resistance is above 2000 or below 900 ohms	Replace the sensor.	
		07	Damaged tone ring	—	—	Inspect the tone ring for damage and missing teeth. Make sure the correct tooth wheel is installed (100 tooth normal application). Repair as necessary.	6-4
		08	Excessive wheel slip	—	—	Check the sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.	3-4
		09	Wire mismatch	6. Check for a mixed sensor connection. This can be done using Meritor WABCO TOOLBOX Software by spinning each wheel individually and observing whether the output is from the proper sensor.	—	Correct wiring connections as necessary.	5-4
		10	Intermittent signal	7. Adjust the sensor. Use the wheel sensor output screen in the Meritor WABCO TOOLBOX Software and spin the wheel or drive the vehicle and look for an intermittent or erratic signal.	Signal output normal	Adjustment solved the problem. Make sure brake chatter is not causing the problem.	3-4 5-4
		11	Erratic signal		Intermittent or erratic signal output	Check for intermittent wheel sensor circuit connections. The cause could be brake chatter. Repair as necessary.	

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Left Rear Wheel Sensor (SID = s003)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	003	12	Frequency too high	8. Check the sensor wiring and connectors for intermittent contact.	Wiring correct	Suspect the ECU is at fault if the problem persists.	5-4
					Wiring not correct	Repair the wheel sensor circuits as necessary.	

Table 4, Left Rear Wheel Sensor (SID = s003)

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Right Rear Wheel Sensor (SID = s004)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	004	01	Incorrect sensor air gap	1. Adjust the sensor. Check AC voltage across Pins 3 and 4 of the green X3 ECU connector while rotating the right rear wheel 30 rpm.	Voltage greater than or equal to 0.2 volts AC	Sensor adjustment solved the problem.	3-3
					Voltage below 0.2 volts AC	Check for excessive wheel bearing end play and hub runout. Repair as necessary.	
		02	Incorrect tire size	—	—	Check for correct tire size and mixed tire sizes. Check for the correct number of teeth on the tone wheel. Correct as necessary.	5-3
		03	Sensor shorted to power	2. Measure the voltage across Pin 3 of the green X3 connector and a good chassis ground. Repeat the test between Pin 4 of the green X3 connector and ground.	Voltage at either pin	Repair the short to power in Circuits 377RR– and 377RR+ in the chassis harness and sensor cable. If the problem is in the sensor harness, replace the sensor.	4-3
					No voltage at either pin	Repeat the test and check for an intermittent short to power in Circuits 377RR+ and 377RR–. Suspect the ECU is at fault if the problem persists.	
		04	Short to ground	3. Measure the resistance between Pin 3 of the green X3 connector and a good chassis ground. Repeat the test between Pin 4 of the green X3 connector and ground.	The resistance between either pin and ground is less than 100,000 ohms	Repair the short to ground in Circuits 377RR+ and 377RR– in the chassis harness or sensor cable. If the problem is in the sensor harness, replace the sensor.	
					The resistance between either pin and ground is more than 100,000 ohms	Repeat the test and check for an intermittent short to ground in Circuits 377RR– and 377RR+. Suspect the ECU is at fault if the problem persists.	

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Right Rear Wheel Sensor (SID = s004)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	004	05	Open circuit	4. Measure the resistance between Pins 3 and 4 of the green X3 ECU connector.	Resistance is between 900 and 2000 ohms	Repeat the test and check for an intermittent open or short in Circuits 377RR+ and 377RR–. Suspect the ECU is at fault if the problem persists.	4-3
		06	Short circuit				
					Resistance is above 2000 or below 900 ohms	Go to Test 5.	
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is between 900 and 2000 ohms	Repair the open or short in Circuits 377RR+ and 377RR– in the chassis harness.	
					Resistance is above 2000 or below 900 ohms	Replace the sensor.	
		07	Damaged tone ring	—	—	Inspect the tone ring for damage and missing teeth. Make sure the correct tooth wheel is installed (100 tooth normal application). Repair as necessary.	6-3
		08	Excessive wheel slip	—	—	Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.	3-3
		09	Wire mismatch	6. Check for a mixed sensor connection. This can be done using Meritor WABCO TOOLBOX Software by spinning each wheel individually and observing whether the output is from the proper sensor.	—	Correct wiring connections as necessary.	5-3
		10	Intermittent signal	7. Adjust the sensor. Use the wheel sensor output screen in the Meritor WABCO TOOLBOX Software and spin the wheel or drive the vehicle and look for an intermittent or erratic signal.	Signal output normal	Adjustment solved the problem. Make sure brake chatter is not causing the problem.	3-3 5-3
		11	Erratic signal		Intermittent or erratic signal output	Check for intermittent wheel sensor circuit connections. The cause could be brake chatter. Repair as necessary.	

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Right Rear Wheel Sensor (SID = s004)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	004	12	Frequency too high	8. Check the sensor wiring and connectors for intermittent contact.	Wiring correct	Suspect the ECU is at fault if the problem persists.	5-3
					Wiring not correct	Repair the wheel sensor circuits as necessary.	

Table 5, Right Rear Wheel Sensor (SID = s004)

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Left Front Modulator Valve (SID = s007)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	007	01	Open circuit in inlet or outlet valve circuit	1. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378LFI, 378LFO and 378LF– for an open circuit or poor connections. Repair as necessary.	2-2
					Resistance in either circuit exceeds 8 ohms	Replace the modulator valve.	
		03	Short to power	2. Measure the voltage between Pins 2, 10 and 11 of the black X2 ECU connector and a good chassis ground.	No voltage	Repeat the test. Check Circuits 378LFI, 378LFO and 378LF– for an intermittent short to power. If the problem persists, suspect the ECU is at fault.	
					Voltage	Repair the short to power in Circuit 378LFI, 378LFO or 378LF–.	
		05	Open circuit	3. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378LFI, 378LFO and 378LF– for an open circuit or poor connections. Repair as necessary.	
					Resistance in either circuit exceeds 8 ohms	Replace the modulator valve.	
		06	Short to ground	4. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378LFI and 378LFO for a short to ground. Repair as necessary.	
					Resistance in either circuit is below 4 ohms	Replace the modulator valve.	

Table 6, Left Front Modulator Valve (SID = s007)

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Right Front Modulator Valve (SID = s008)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	008	01	Open circuit in inlet or outlet valve circuit	1. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378RFI, 378RFO and 378RF– for an open circuit or poor connections. Repair as necessary.	2-1
					Resistance in either circuit exceeds 8 ohms	Replace the modulator valve.	
		03	Short to power	2. Measure the voltage between Pins 3, 4 and 9 of the black X2 ECU connector and a good chassis ground.	No voltage	Repeat the test. Check Circuits 378RFI, 378RFO and 378RF– for an intermittent short to power. If the problem persists, suspect the ECU is at fault.	
					Voltage	Repair the short to power in Circuit 378RFI, 378RFO or 378RF–.	
		05	Open circuit	3. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378RFI, 378RFO and 378RF– for an open circuit or poor connections. Repair as necessary.	
					Resistance in either circuit exceeds 8 ohms	Replace the modulator valve.	
		06	Short to ground	4. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378RFI and 378RFO for a short to ground. Repair as necessary.	
					Resistance in either circuit is below 4 ohms	Replace the modulator valve.	

Table 7, Right Front Modulator Valve (SID = s008)

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Left Rear Modulator Valve (SID = s009)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	009	01	Open circuit in inlet or outlet valve circuit	1. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378LRI, 378LRO and 378LR– for an open circuit or poor connections. Repair as necessary.	2-4
					Resistance in either circuit exceeds 8 ohms	Replace the modulator valve.	
		03	Short to power	2. Measure the voltage between Pins 10, 11 and 12 of the green X3 ECU connector and a good chassis ground.	No voltage	Repeat the test. Check Circuits 378LRI, 378LRO and 378LR– for an intermittent short to power. If the problem persists, suspect the ECU is at fault.	
					Voltage	Repair the short to power in Circuit 378LRI, 378LRO or 378LR–.	
		05	Open circuit	3. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378LRI, 378LRO and 378LR– for an open circuit or poor connections. Repair as necessary.	
					Resistance in either circuit exceeds 8 ohms	Replace the modulator valve.	
		06	Short to ground	4. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378LRI and 378LRO for a short to ground. Repair as necessary.	
					Resistance in either circuit is below 4 ohms	Replace the modulator valve.	

Table 8, Left Rear Modulator Valve (SID = s009)

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Right Rear Modulator Valve (SID = s010)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	010	01	Open circuit in inlet or outlet valve circuit	1. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378RRI, 378RRO and 378RR– for an open circuit or poor connections. Repair as necessary.	2-3
					Resistance in either circuit exceeds 8 ohms	Replace the modulator valve.	
		03	Short to power	2. Measure the voltage between Pins 7, 8 and 9 of the green X3 ECU connector and a good chassis ground.	No voltage	Repeat the test. Check Circuits 378RRI, 378RRO and 378RR– for an intermittent short to power. If the problem persists, suspect the ECU is at fault.	
					Voltage	Repair the short to power in Circuit 378RRI, 378RRO or 378RR–.	
		05	Open circuit	3. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378RRI, 378RRO and 378RR– for an open circuit or poor connections. Repair as necessary.	
					Resistance in either circuit exceeds 8 ohms	Replace the modulator valve.	
		06	Short to ground	4. Check the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the "Modulator Valve Resistance" test in **Subject 170**.	Resistance in both circuits is within 4 to 8 ohms	Check harness wiring Circuits 378RRI and 378RRO for a short to ground. Repair as necessary.	
					Resistance in either circuit is below 4 ohms	Replace the modulator valve.	

Table 9, Right Rear Modulator Valve (SID = s010)

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Retarder (SID = s013)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	013	03	Short to power	1. Remove the retarder relay in the main power distribution module (PDM). Turn the ignition switch to ON. Measure the voltage between the relay cavity that corresponds to Terminal 1 of the relay (Circuit 376R) and ground.	No voltage	Go to Test 2.	7-3
					Voltage	Check Circuit 376R between the retarder relay and the ABS ECU for a short to power. Repair as necessary.	
				2. Check for a shorted retarder relay coil. Measure the resistance between relay Terminals 1 and 2.	Resistance is less than 80 ohms	The retarder relay is shorted. Replace the relay.	
					Resistance is between 80 and 100 ohms	Check Circuit 376R between the retarder relay and the ABS ECU for an intermittent short to power. Repeat Test 1 while turning on various accessories (lights, turn signals, etc.). Repair as necessary.	

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Troubleshooting

Retarder (SID = s013)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	013	05	Open circuit	3. Check for an open retarder relay coil. Remove the retarder relay from the main PDM. Measure the resistance between relay Terminals 1 and 2.	Resistance is between 80 and 100 ohms	Go to Test 4.	7-3
					Resistance is greater than 100 ohms	The relay is open. Replace the relay.	
				4. Check for an open in Circuit 376R between the retarder relay and the ABS ECU. Remove the retarder relay in the PDM and remove the gray X1 connector at the ABS ECU. Measure the resistance between the cavity that corresponds to Terminal 1 of the relay (Circuit 376R) and Pin 5 of the gray X1 connector. NOTE: Be sure to touch the meter leads together first to determine the resistance of the meter leads. Subtract this measurement from the test measurement and use this as the test result.	Resistance is greater than 1.4 ohms	Repair high resistance or open in Circuit 376R.	
					Resistance is less than or equal to 1.4 ohms	The resistance in Circuit 376R is acceptable. Check for an open in Circuit 81C (the power side of the retarder relay coil).	
		06	Short to ground	5. Check for a short to ground in Circuit 376R. Remove the retarder relay from the PDM and disconnect the gray X1 connector from the ABS ECU. Check for continuity between the cavity that corresponds to Terminal 1 of the relay and ground.	Continuity	Repair the short to ground in Circuit 376R.	
					No continuity	Check for an intermittent short to ground in Circuit 376R. Check the ABS ECU. Repair or replace as necessary.	

Table 10, Retarder (SID = s013)

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Ground Diagonal 1, Right Front-Left Rear (SID = s014)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	014	04	Low voltage or open circuit	1. Disconnect the gray X1 connector at the ABS ECU. With the ignition ON, measure the voltage between Pins 2 and 11 (Circuits 376C* and GRD).	Voltage is between 9.5 and 14 volts	System voltage is acceptable. Check for intermittent low voltage. Check the batteries and charging system. Voltage may have been temporarily too low. Repair as necessary.	8-1
					Voltage is less than 9.5 volts	Go to Test 2.	
				2. With the ignition ON, measure the voltage between Pin 2 (Circuit 376C*) of the gray X1 connector and a good chassis ground.	Voltage is between 9.5 and 14 volts	Check the ground circuit (GRD) from Pin 11 of the gray X1 connector. Repair as necessary.	
					Voltage is less than 9.5 volts	Check the 5-amp circuit breaker in position 45 of the fuse panel. Check Circuit 376C* between Pin 2 of the gray X1 connector at the ABS ECU and the fuse panel for an open circuit.	
		07	Internal relay fault	—	—	If the fault repeats, replace the ABS ECU.	8-3

Table 11, Ground Diagonal 1, Right Front-Left Rear (SID = s014)

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Ground Diagonal 2, Left Front-Right Rear (SID = s015)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	015	04	Low voltage or open circuit	1. Disconnect the gray X1 connector at the ABS ECU. With the ignition ON, measure the voltage between Pins 1 and 12 (Circuits 376C and GRD).	Voltage is between 9.5 and 14 volts	System voltage is acceptable. Check for intermittent low voltage. Check the batteries and charging system. Voltage may have been temporarily too low. Repair as necessary.	8-1
					Voltage is less than 9.5 volts	Go to Test 2.	
				2. With the ignition ON, measure the voltage between Pin 1 (Circuit 376C) of the gray X1 connector and a good chassis ground.	Voltage is between 9.5 and 14 volts	Check the ground circuit (GRD) from Pin 12 of the gray X1 connector. Repair as necessary.	
					Voltage is less than 9.5 volts	Check the 5-amp circuit breaker in position 47 of the fuse panel. Check Circuit 376C between Pin 1 of the gray X1 connector at the ABS ECU and the fuse panel for an open circuit.	
		07	Internal relay fault	—	—	If the fault repeats, replace the ABS ECU.	8-3

Table 12, Ground Diagonal 2, Left Front-Right Rear (SID = s015)

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ATC Valve (SID = s018)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	018	03	Short to power	1. Disconnect the green X3 connector from the ABS ECU. Disconnect the ATC valve connector. Measure the voltage between Pin 5 of the green X3 connector and a good chassis ground.	Voltage	Circuit 378T+ is shorted to power. Repair as necessary.	7-2
					No voltage	Go to Test 2.	
				2. Measure the voltage between Pin 6 of the green X3 connector and a good chassis ground.	Voltage present	Circuit 378T– is shorted to power. Repair as necessary.	
					Voltage not present	Verify the fault. Check for an intermittent short to power. Check for possible shorts in the ATC and green X3 connectors. Reconfigure the ECU.	
		05	Open circuit	3. Disconnect the ATC valve connector. Measure the resistance across the two pins of the ATC valve.	Resistance is between 6.4 and 12 ohms	Go to Test 4.	
					Resistance is greater than 12 ohms	Replace the ATC valve.	
				4. Reconnect the ATC valve connector. Measure the resistance across Pins 5 and 6 of the green X3 connector.	Resistance is between 6.4 and 12 ohms	Verify the fault. Check for an intermittent open in Circuit 376T+ and 376T–. Reconfigure the ECU.	
					Resistance is greater than 12 ohms	Pinpoint the source of the high resistance in Circuit 376T+ or 376T–. Repair as necessary.	

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ATC Valve (SID = s018)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	018	06	Short to ground	5. Disconnect the ATC valve connector. Measure the resistance across the two pins of the ATC valve.	Resistance is between 6.4 and 12 ohms	Go to Test 6.	7-2
					Resistance is less than 6.4 ohms	The ATC valve is shorted internally. Replace the ATC valve.	
				6. Reconnect the ATC valve connector. Disconnect the green X3 connector from the ABS ECU. Measure the resistance between Pin 5 of the green X3 connector and a good chassis ground.	Resistance is less than 6.4 ohms	Circuit 376T+ is shorted to ground. Repair as necessary.	
					Resistance is between 6.4 and 12 ohms	Circuit 376T– is shorted to ground. Repair as necessary.	

Table 13, ATC Valve (SID = s018)

Not Used (SID = s019)					
MID	**SID**	**FMI**	**Fault Description**	**Action**	**Blink Code**
136	019	03	Short to power	This fault should not appear. Reconfigure the ECU. If the fault continues to appear, check the wiring in the black X2 ABS ECU connector. Pins 1 and 12 of this connector should be unused. Make sure there are no connections to these pins. If incorrect wiring is found, correct it and reconfigure the ECU. If this does not correct the problem, contact Meritor WABCO.	7-6
		06	Short to ground		

Table 14, Not Used (SID = s019)

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Warning Light (SID = s023)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	023	05	Open circuit	1. Was the ABS CHECK switch pressed for longer than 16 seconds?	Yes	This fault can occur if the ABS CHECK switch is pressed for more than 16 seconds. When this happens, the ECU sees no load in the ABS lamp relay control circuit. Clear the fault.	7-4
					No	Go to Test 2.	
				2. With the ignition switch OFF, remove the ABS lamp relay located in the fuse panel (position R19). Measure the resistance across the relay coil (Terminals 1 and 2 of the relay).	Resistance is between 80 and 100 ohms	Go to Test 3.	
					Resistance is greater than 100 ohms	The ABS lamp relay coil is open. Replace the relay.	
				3. With the ABS lamp relay removed, turn the ignition switch to ON and measure the voltage between the relay cavity that corresponds to relay Terminal 2 (Circuit 81C) and a good chassis ground.	Voltage (should be the same as battery voltage)	Make sure the 10-amp circuit breaker in position F11 of the fuse panel is not switching off under load. If it is, locate the problem and correct it. If not, go to Test 4.	
					No voltage	Check the 10-amp circuit breaker in position F11 of the fuse panel. Check for an open or short to ground in Circuit 81C between the breaker and the relay (see the wiring schematics in **Specifications, 400**).	

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Warning Light (SID = s023)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	023	05	Open circuit	4. Disconnect the gray X1 connector from the ABS ECU. With the ABS lamp relay removed, check for continuity between the ABS lamp relay cavity that corresponds to Terminal 1 of the relay (Circuit 376L1) and a good chassis ground.	Continuity	Check for a short to ground in Circuit 376L1 between: • The ABS lamp relay and the ABS check switch; • The ABS check switch and the ABS ECU (376L1 becomes 376L in the chassis harness). Repair as necessary.	7-4
					No Continuity	Go to Test 5.	
				5. With the ABS lamp relay removed and the gray X1 connector at the ABS ECU disconnected, measure the resistance between the cavity that corresponds to Terminal 1 of the relay (Circuit 376L) and Pin 10 of the gray X1 ABS ECU connector. NOTE: Be sure to touch the meter leads together first to determine the resistance of the meter leads. Subtract this measurement from the test measurement and use this as the test result.	Resistance is less than or equal to 1.4 ohms	Make sure the ABS CHECK switch was not depressed for more than 16 seconds. Check for an intermittent open circuit or short to ground in Circuit 376L and 376L1. Check the ECU.	
					Resistance is more than 1.4 ohms	Check for an open in Circuit 376L between the ABS lamp relay and the ABS CHECK switch, and between the ABS CHECK switch and the ABS ECU (376L1 becomes 376L in the chassis harness). Check for ABS CHECK switch stuck or shorted in the ON position.	

Table 15, Warning Light (SID = s023)

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J1939 Datalink (SID = s231 or s248)					
MID	**SID**	**FMI**	**Fault Description**	**Action**	**Blink Code**
136	231 or 248	02	J1939 plausibility error	Check the speedometer calibration. Check for tire size mismatch. The vehicle speed reported on the J1939 databus does not agree with the wheel speed sensors.	7-1
		05	J1939 open/short NOTE: This fault can occur from one of the following: 1. An open in either J1939+ or J1939– 2. J1939+ or J1939– shorted to battery voltage 3. J1939+ shorted to ground 4. J1939+ and J1939– shorted together If items 2, 3 or 4 exist, a J1587 fault of MID 136 SID 248 FMI 06 will occur.	See Freightliner Service Bulletin 54-75 for troubleshooting the J1939 datalink. Repair the J1939 datalink as necessary.	
		06	J1939 short to ground		
		09	J1939 time out NOTE: The ABS ECU is not able to establish communication with the engine.	See Freightliner Service Bulletin 54-75 for troubleshooting the J1939 datalink. Check the engine ECU for J1939 parameter settings and communication. Repair as necessary.	
		12	J1939 internal error	Verify the accuracy of the fault code. Clear the code from the ECU memory. If the fault persists, replace the ABS ECU.	8-3

Table 16, J1939 Datalink (SID = s231 or s248)

Voltage Diagonal 1 or 2 (SID = s251)							
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Test Result**	**Action**	**Blink Code**
136	251	03	Overvoltage NOTE: Voltage to the ECU was too high for more than 5 seconds.	1. Using Meritor WABCO TOOLBOX Software, check the diagonal voltages with the engine running at governed speed, or measure the voltage at the batteries with the engine running at governed speed.	Voltage is between 9.5 and 14 volts	Check for intermittent sources of high voltage. Check the condition of the charging system and batteries. Verify the fault.	8-2
					Voltage is greater than 14 volts	Check the charging system. Repair as necessary.	

Table 17, Voltage Diagonal 1 or 2 (SID = s251)

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Troubleshooting

Configuration Errors (SID = s253)					
MID	**SID**	**FMI**	**Fault Description**	**Action**	**Blink Code**
136	253	01	ATC configuration error NOTE: ATC valve is detected without engine datalink (J1922 or J1939).	Check J1939 for proper wiring. Check the engine ECU for communication. Repair as necessary. Reconfigure the ECU.	7-5
		02	ABS configuration/wheel parameter incorrect	Reconfigure the ECU. If the fault repeats, the wrong ECU is installed. Replace with the current ECU.	8-4
		12	Check sum error	Check parameter setting. Check if the diagnostic device was disconnected during active diagnosis.	

Table 18, Configuration Errors (SID = s253)

Miscellaneous Faults (SID = s254)					
MID	**SID**	**FMI**	**Fault Description**	**Action**	**Blink Code**
136	254	02	Internal error	If the fault persists, replace the ABS ECU.	8-3
		05	ABS and ATC ECU, no loads	No modulator valves are connected. Fault may have resulted from the end of the line testing at the factory.	8-4
		08	Excessive wheel slip	Check the wheel sensor air gaps. One wheel was much faster than the other. May have been caused by testing the vehicle on a dynamometer. May be caused by driver error in vehicles without ATC (excessive tire spinning).	7-1
		09	Modulator valve activated too long	The modulator valve was activated too long (more than 3 minutes). After a delay, function will return to normal.	2-1
		12	Internal error	If the fault persists, replace the ABS ECU.	8-3

Table 19, Miscellaneous Faults (SID = s254)

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Wiring Diagrams

Use the wiring diagrams when troubleshooting the Meritor WABCO "D" version pneumatic ABS and ATC with a frame-mounted ECU.

See **Fig. 1** for a full view of Sheet 1 of the wiring diagram.

See **Fig. 2** for a full view of Sheet 2 of the wiring diagram.

See **Fig. 3** or **Fig. 4** for enlarged partial views of Sheet 2.

See **Fig. 5** for a full view of the wiring assembly dash overlay.

See **Fig. 6** for a full view of the retarder relay circuits.

See **Fig. 7** for a full view of the harness assembly.

See **Fig. 8** for a full view of the chassis harness assembly overlay.

See **Fig. 9** for a full view of the forward chassis harness assembly.

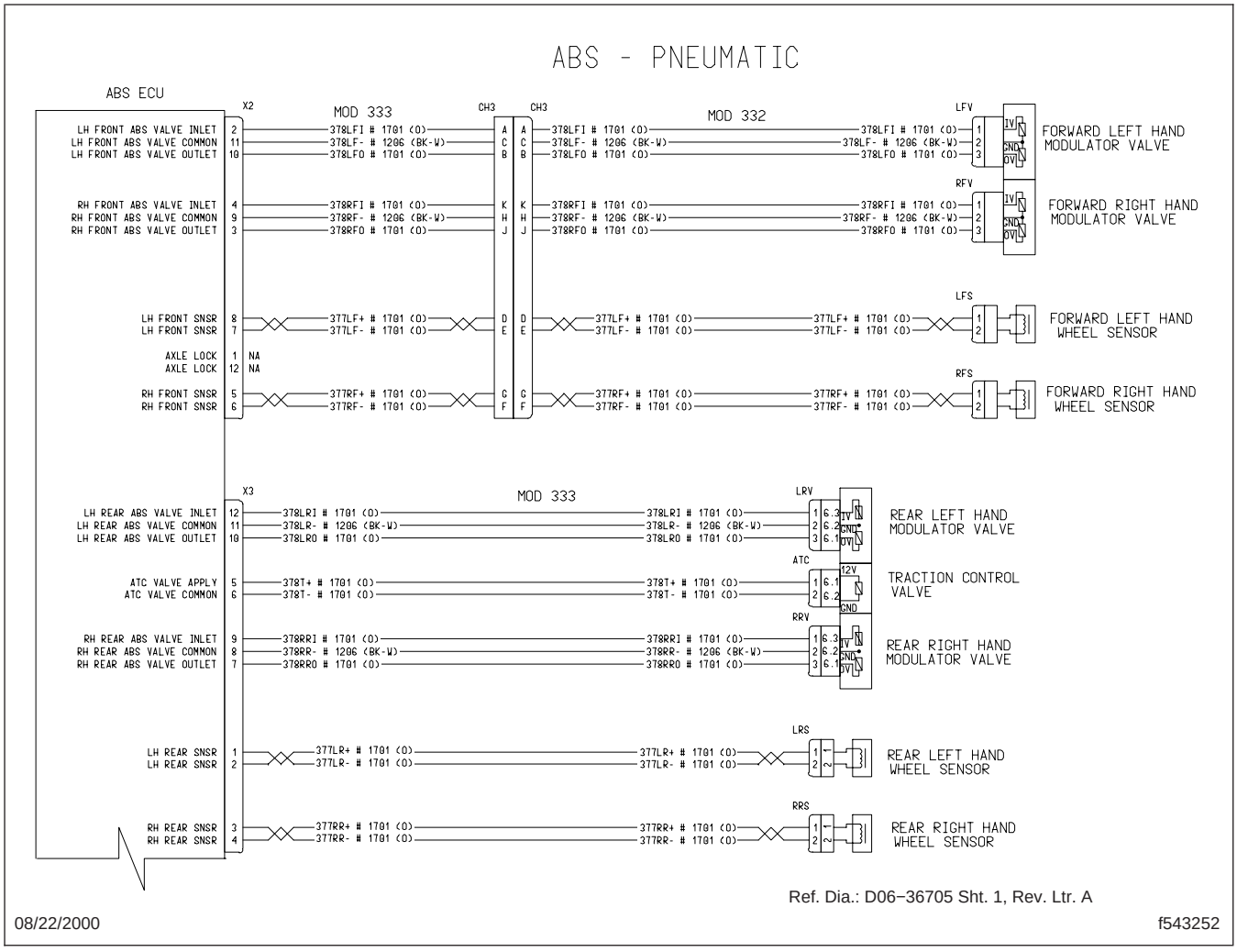
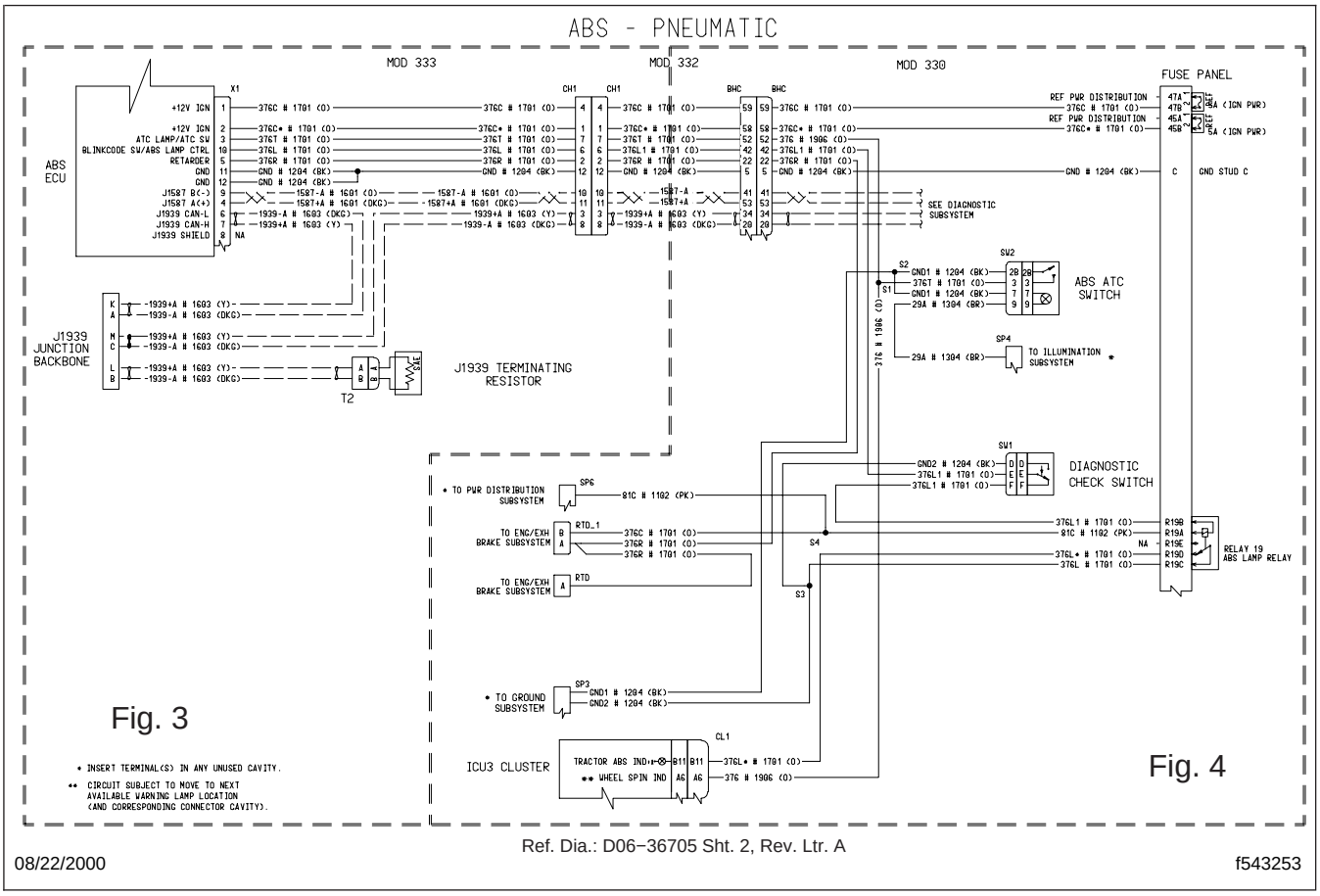


Fig. 1, Wiring Diagram, Sheet 1 (full view)

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Ref. Dia.: D06−36705 Sht. 2, Rev. Ltr. A

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Fig. 2, Wiring Diagram, Sheet 2 (full view)

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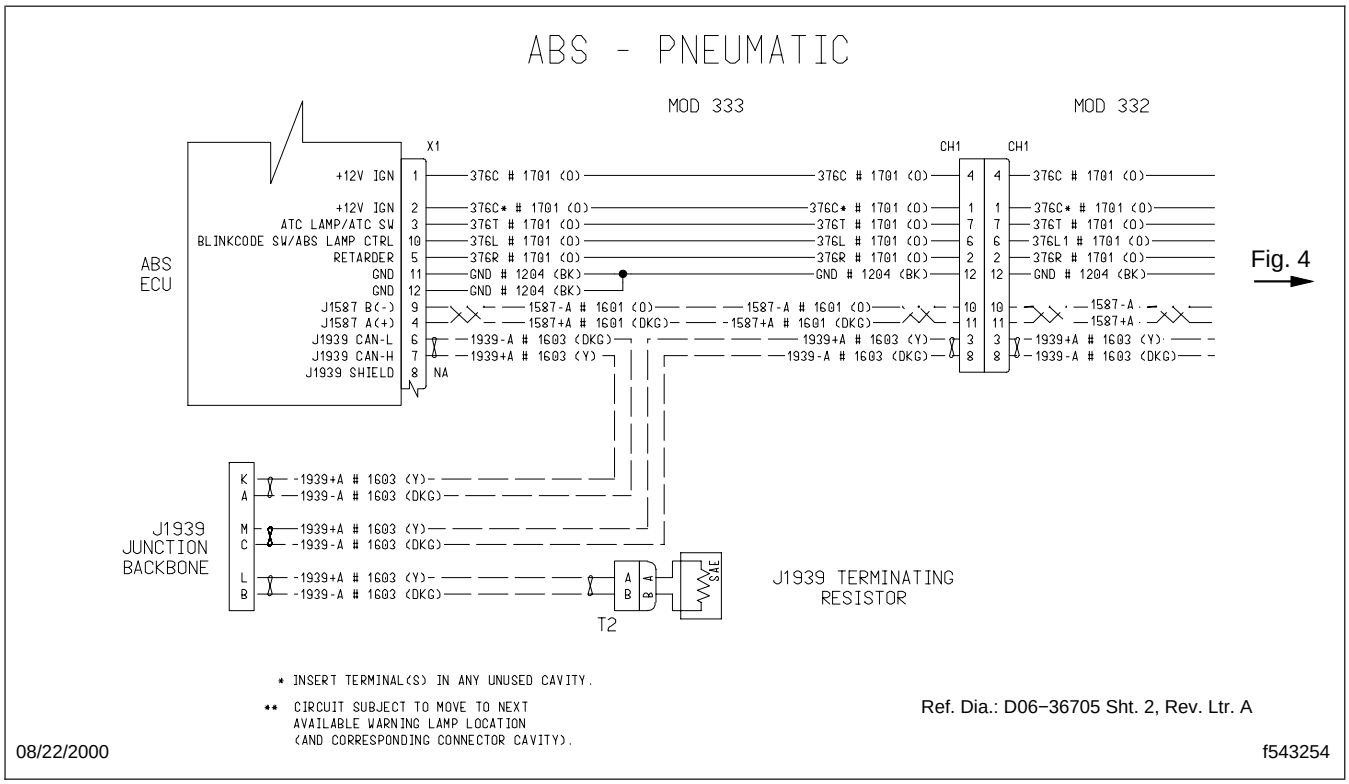


Fig. 3, Wiring Diagram, Sheet 2 (partial view)

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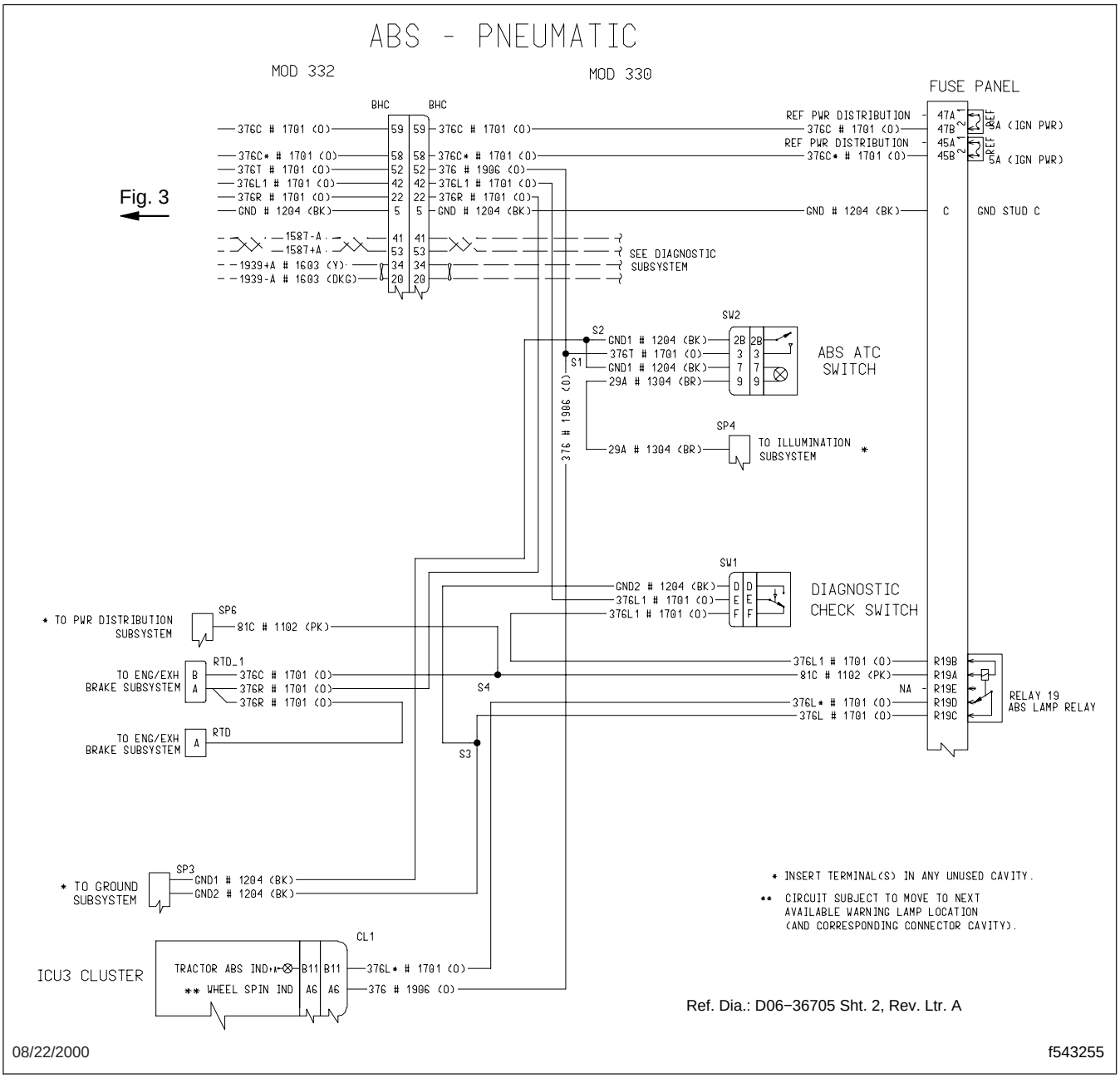
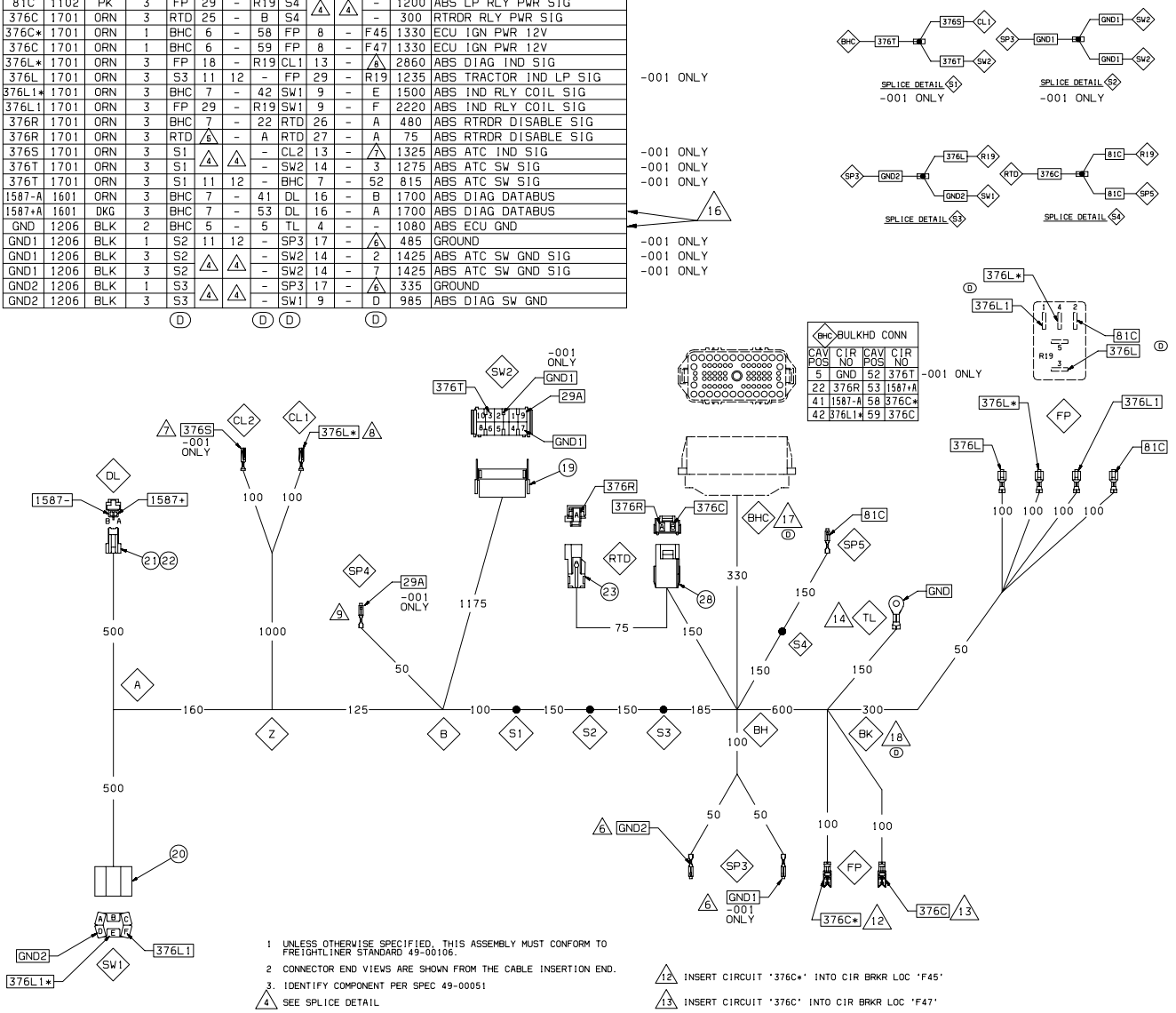


Fig. 4, Wiring Diagram, Sheet 2 (partial view)

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F/L CIR NO	SAE CIR NO	WIRE COLOR	WIRE ITEM NO	FROM LOC	FROM TERM ITEM NO	FROM SEAL INSL NO	FROM CONN CAV POS	TO LOC	TO TERM ITEM NO	TO SEAL INSL NO	TO CONN CAV POS	APPROX LENGTH	CIRCUIT DESCRIPTION	
29A	1304	BR	3	SW2	14	-	9	SP4	30	-	9	1225	ATC SW LP PWR	
81C	1102	PK	3	SP5	30	-	A	S4	11	12	-	150	ABS LP RLY PWR SIG	
81C	1102	PK	3	FP	29	-	R19	S4	4	4	-	1200	ABS LP RLY PWR SIG	
376C	1701	ORN	3	RTD	25	-	B	S4			-	300	RTRDR RLY PWR SIG	
376C*	1701	ORN	1	BHC	6	-	58	FP	8	-	F45	1330	ECU IGN PWR 12V	
376C	1701	ORN	1	BHC	6	-	59	FP	8	-	F47	1330	ECU IGN PWR 12V	
376L*	1701	ORN	3	FP	18	-	R19	CL1	13	-	8	2860	ABS DIAG IND SIG	
376L	1701	ORN	3	S3	11	12	-	FP	29	-	R19	1235	ABS TRACTOR IND LP SIG	-001 ONLY
376L1*	1701	ORN	3	BHC	7	-	42	SW1	9	-	E	1500	ABS IND RLY COIL SIG	
376L1	1701	ORN	3	FP	29	-	R19	SW1	9	-	F	2220	ABS IND RLY COIL SIG	
376R	1701	ORN	3	BHC	7	-	22	RTD	26	-	A	480	ABS RTRDR DISABLE SIG	
376R	1701	ORN	3	RTD	5	-	A	RTD	27	-	A	75	ABS RTRDR DISABLE SIG	
376S	1701	ORN	3	S1	4	4	-	CL2	13	-	7	1325	ABS ATC IND SIG	-001 ONLY
376T	1701	ORN	3	S1			-	SW2	14	-	3	1275	ABS ATC SW SIG	-001 ONLY
376T	1701	ORN	3	S1	11	12	-	BHC	7	-	52	815	ABS ATC SW SIG	-001 ONLY
1587-A	1601	ORN	3	BHC	7	-	41	DL	16	-	B	1700	ABS DIAG DATABUS	
1587+A	1601	DKG	3	BHC	7	-	53	DL	16	-	A	1700	ABS DIAG DATABUS	16
GND	1206	BLK	2	BHC	5	-	5	TL	4	-	-	1080	ABS ECU GND	
GND1	1206	BLK	1	S2	11	12	-	SP3	17	-	6	485	GROUND	-001 ONLY
GND1	1206	BLK	3	S2	4	4	-	SW2	14	-	2	1425	ABS ATC SW GND SIG	-001 ONLY
GND1	1206	BLK	3	S2			-	SW2	14	-	7	1425	ABS ATC SW GND SIG	-001 ONLY
GND2	1206	BLK	1	S3	4	4	-	SP3	17	-	6	335	GROUND	
GND2	1206	BLK	3	S3			-	SW1	9	-	D	985	ABS DIAG SW GND	

(D) (D) (D) (D)



1 UNLESS OTHERWISE SPECIFIED, THIS ASSEMBLY MUST CONFORM TO FREIGHTLINER STANDARD 49-00106.

2 CONNECTOR END VIEWS ARE SHOWN FROM THE CABLE INSERTION END.

3. IDENTIFY COMPONENT PER SPEC 49-00051

4 SEE SPLICE DETAIL

5 SINGLE ITEM USED FOR MULTIPLE WIRES

6 INSERT THIS CIRCUIT INTO GND SPLICE PACK 'SP3'

7 INSERT CIRCUIT '376S' INTO ANY UNUSED GROUND ACTIVATED POSITION. (SEE SWITCH AND GAUGE REPORT).

8 INSERT CIRCUIT '376L*' INTO ICU3 CONNECTOR CAVITY 'B11'

9 INSERT CIRCUIT '29A' INTO ILLUMINATION LAMP FEED SPLICE PACK

12 INSERT CIRCUIT '376C*' INTO CIR BRKR LOC 'F45'

13 INSERT CIRCUIT '376C' INTO CIR BRKR LOC 'F47'

14 INSTALL RING TERMINAL ON PDM GND STUD 'C'

15 DO NOT SOLDER THESE TERMINALS.

16 THE FOLLOWING CIRCUITS TO BE TWISTED TOGETHER A MINIMUM OF 180° TWIST PER 25MM: J1587-A AND J1587+A

(D) 17 LENGTHS ARE MEASURED TO BACK OF BULKHEAD CONNECTOR.

(D) 18 LOC BJ. LENGTHS PAST THE EDGE ARE TO BE DETERMINED BY HARNESS MANUFACTURER.

Ref. Dia.: A06−32583, Rev. Ltr. D

10/19/2000 f543418

Fig. 5, Wiring Assembly Dash Overlay (full view)

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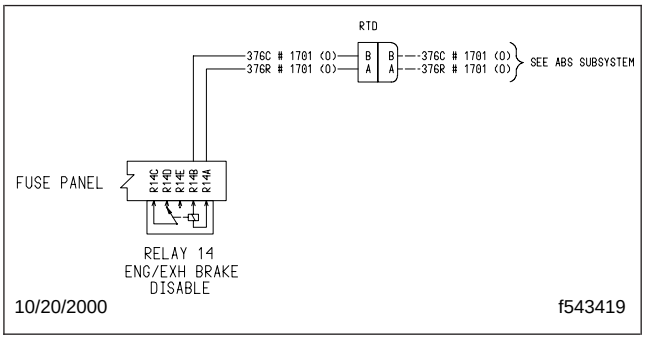


Fig. 6, Retarder Relay Circuits (full view)

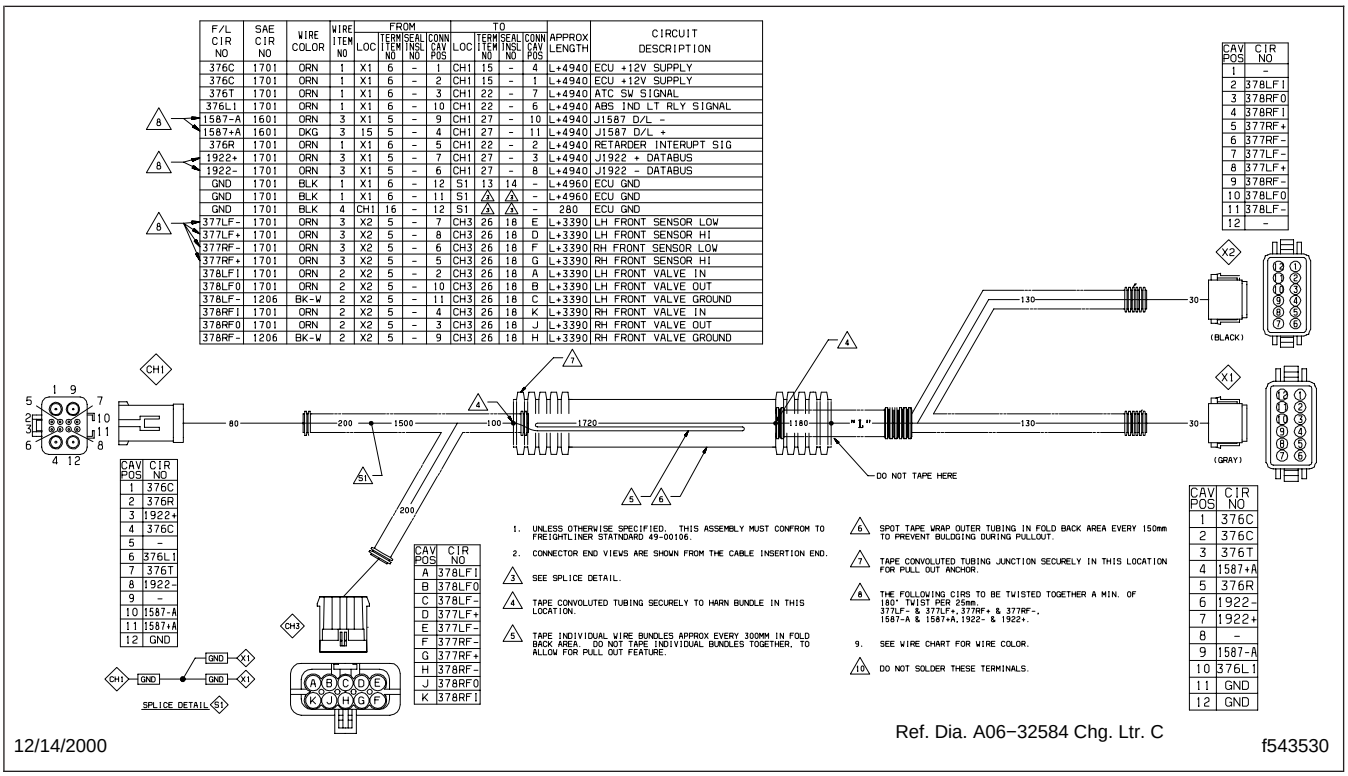
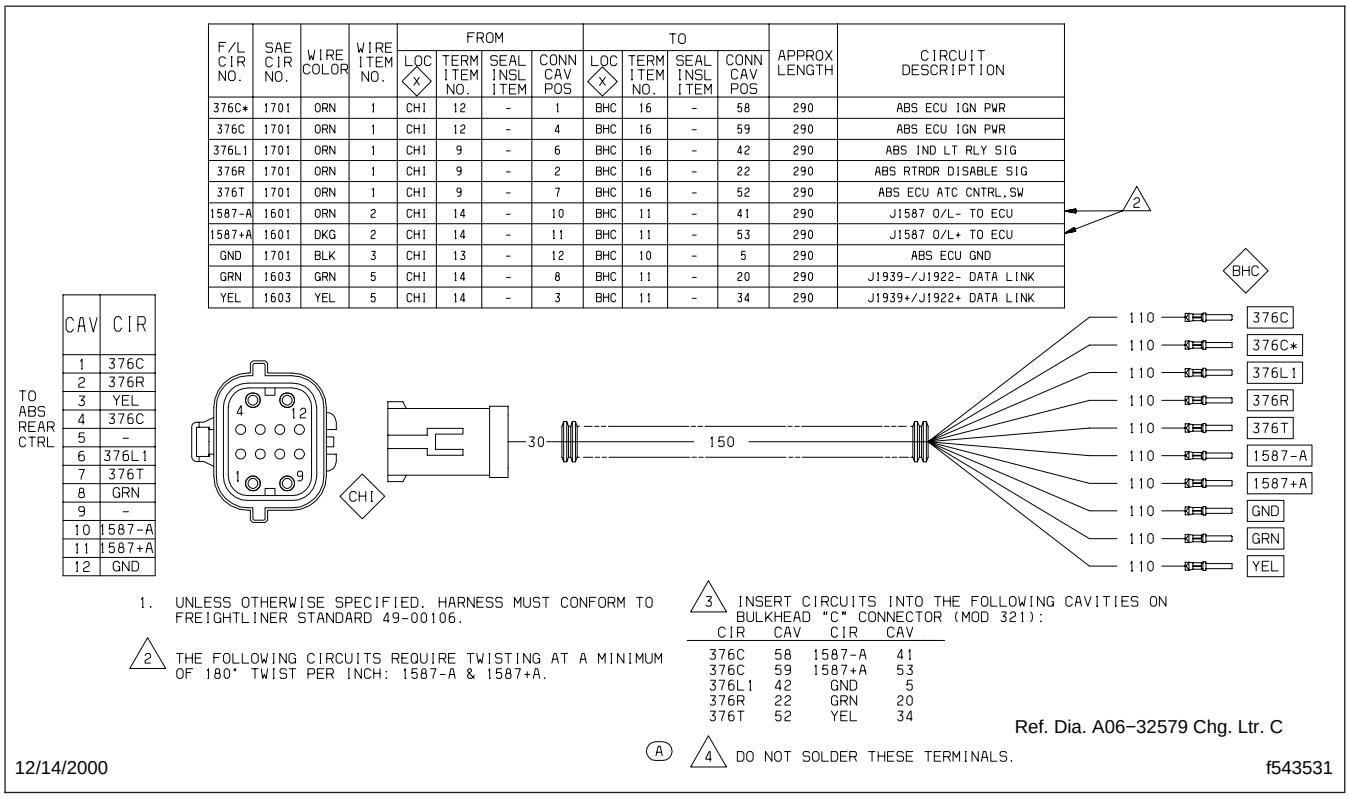


Fig. 7, Harness Assembly (full view)

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F/L CIR NO.	SAE CIR NO.	WIRE COLOR	WIRE ITEM NO.	FROM LOC (X)	FROM TERM ITEM NO.	FROM SEAL INSL ITEM	FROM CONN CAV POS	TO LOC (X)	TO TERM ITEM NO.	TO SEAL INSL ITEM	TO CONN CAV POS	APPROX LENGTH	CIRCUIT DESCRIPTION
376C*	1701	ORN	1	CH1	12	-	1	BHC	16	-	58	290	ABS ECU IGN PWR
376C	1701	ORN	1	CH1	12	-	4	BHC	16	-	59	290	ABS ECU IGN PWR
376L1	1701	ORN	1	CH1	9	-	6	BHC	16	-	42	290	ABS IND LT RLY SIG
376R	1701	ORN	1	CH1	9	-	2	BHC	16	-	22	290	ABS RTRDR DISABLE SIG
376T	1701	ORN	1	CH1	9	-	7	BHC	16	-	52	290	ABS ECU ATC CNTRL.SW
1587-A	1601	ORN	2	CH1	14	-	10	BHC	11	-	41	290	J1587 O/L- TO ECU
1587+A	1601	DKG	2	CH1	14	-	11	BHC	11	-	53	290	J1587 O/L+ TO ECU
GND	1701	BLK	3	CH1	13	-	12	BHC	10	-	5	290	ABS ECU GND
GRN	1603	GRN	5	CH1	14	-	8	BHC	11	-	20	290	J1939-/J1922- DATA LINK
YEL	1603	YEL	5	CH1	14	-	3	BHC	11	-	34	290	J1939+/J1922+ DATA LINK

Fig. 8, Chassis Harness Assembly Overlay (full view)

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F/L CIR NO.	WIRE ITEM NO.	FROM LOC	FROM TERM ITEM NO.	FROM SEAL INSL ITEM	FROM CONN CAV POS	TO LOC	TO TERM ITEM NO.	TO SEAL INSL ITEM	TO CONN CAV POS	APPROX LENGTH -000	APPROX LENGTH -001	CIRCUIT DESCRIPTION
377LF-	4	LFS	-	-	-	CH3	11	12	E	3210	3210	LH FWD SENSOR,LOW
377LF+	4	LFS	-	-	-	CH3	11	12	D	3210	3210	LH FWD SENSOR,HIGH
377RF-	3	RFS	-	-	-	CH3	11	12	F	1410	1410	RH FWD SENSOR,LOW
377RF+	3	RFS	-	-	-	CH3	11	12	G	1410	1410	RH FWD SENSOR,HIGH
378LFI	2	LFV	-	-	-	CH3	11	12	A	2360	4440	LH FWD VALVE,IN
378LFO	2	LFV	-	-	-	CH3	11	12	B	2360	4440	LH FWD VALVE,OUT
378LF-	2	LFV	-	-	-	CH3	11	12	C	2360	4440	LH FWD VALVE,GND
378RFI	1	RFV	-	-	-	CH3	11	12	K	2260	4340	RH FWD VALVE,IN
378RFO	1	RFV	-	-	-	CH3	11	12	J	2260	4340	RH FWD VALVE,OUT
378RF-	1	RFV	-	-	-	CH3	11	12	H	2260	4340	RH FWD VALVE,GND

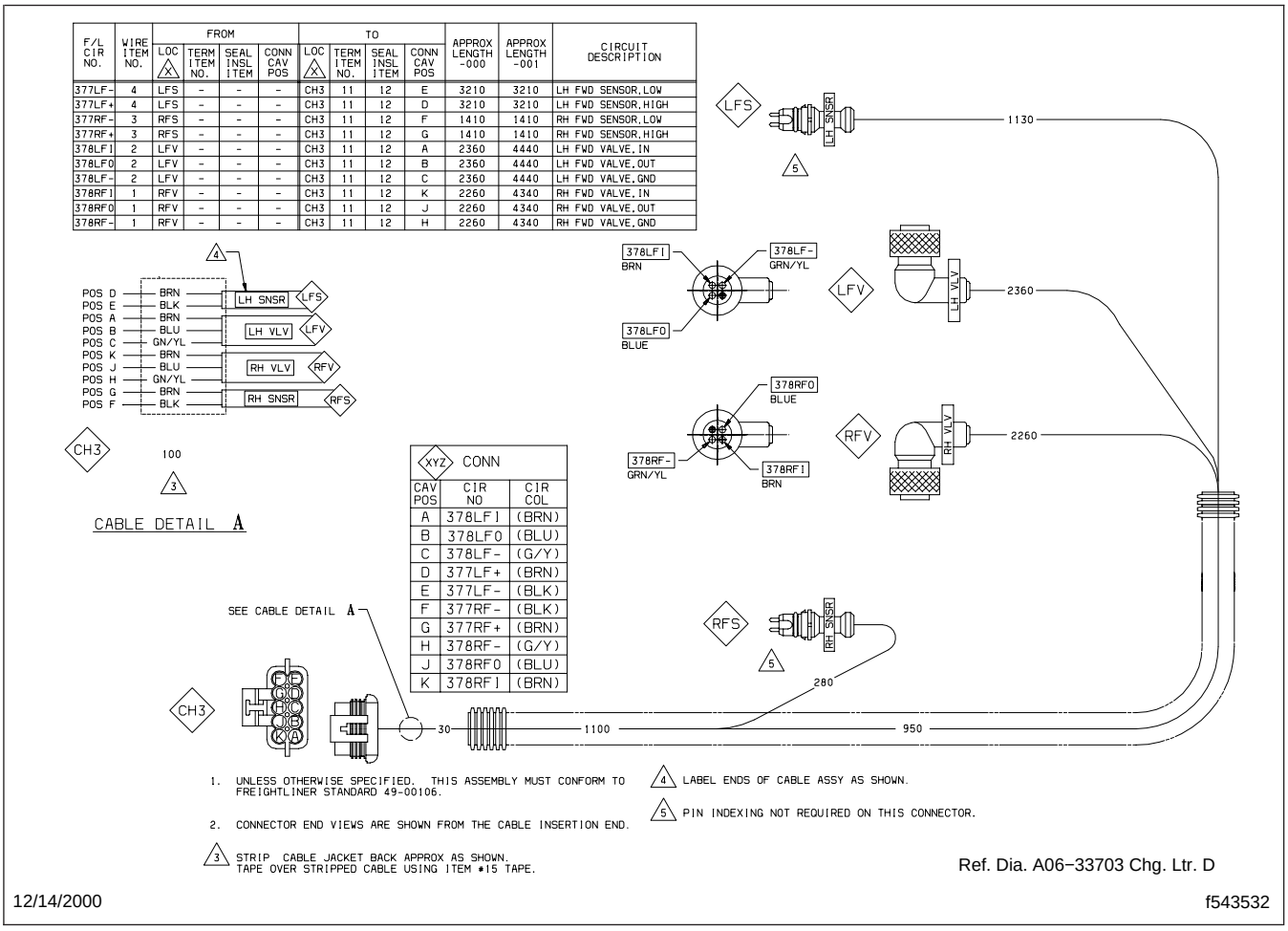


Fig. 9, Forward Chassis Harness Assembly (full view)

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Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Air lines will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

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⚠ WARNING

Make sure the air system has been reduced to 0 psi before attempting to remove an air line. Do not disconnect pressurized air lines as they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

Replacement

⚠ CAUTION

Before working on or around air brake systems and components, see Safety Precautions 100.

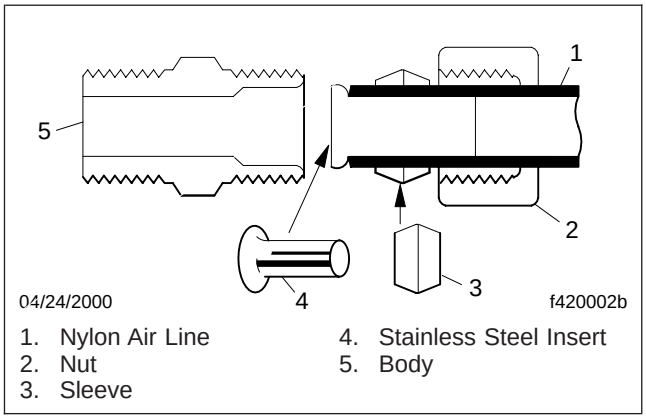
⚠ CAUTION

If the air line is bent to a radius smaller than the specified minimum bend radius, it may kink and shut off normal airflow to the component.

NOTE: When installing a nylon or a wire braid air line, be careful not to bend it past its minimum bend radius. For minimum bend radius values, see **Specifications 400**.

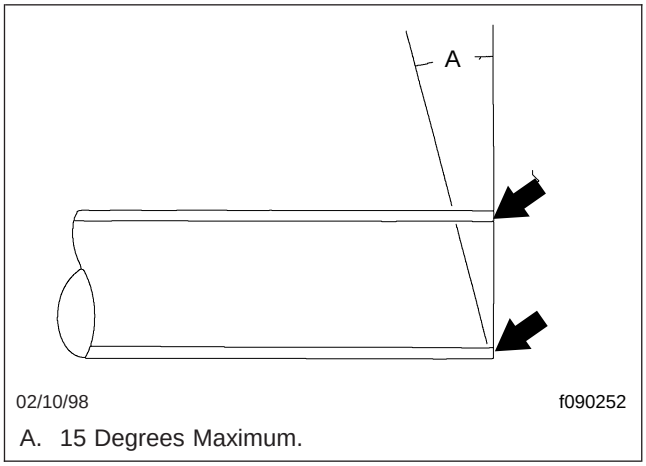
Nylon Air Lines and Compression Fittings

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the air line. See **Fig. 1**.
   - 3.1 Loosen the fitting nut.
   - 3.2 Pull the air line out of the fitting.
4. Use pliers to remove the stainless steel insert from the fitting. Discard the insert.
5. Clean all of the fitting components.
6. Place a new stainless steel insert into the fitting body. Use thumb pressure to press it into position.
7. Check the air line end for a square cut-off that does not exceed a 15-degree angle. Check that the air line is not distorted or damaged. See **Fig. 2**.



1. Nylon Air Line
2. Nut
3. Sleeve
4. Stainless Steel Insert
5. Body

Fig. 1, Nylon Air Line and Compression Fitting



A. 15 Degrees Maximum.

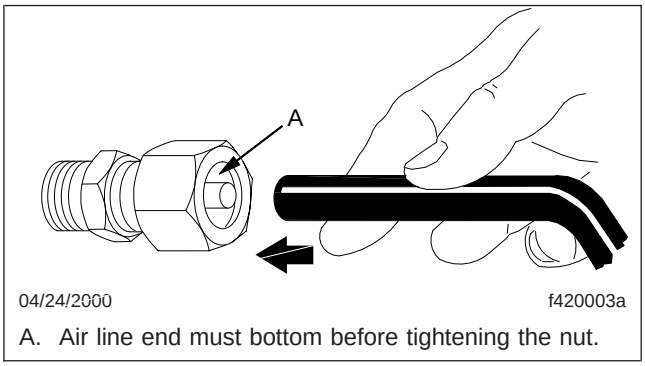
Fig. 2, Check Air Line End Angle

- 7.1 If the angle exceeds the specification, recut the air line.
- 7.2 Use a sharp blade to prevent collapsing the air line or leaving burrs.

8. Make sure the nylon air line ends and fittings are free of grease and debris. If the air line is crimped or otherwise damaged, replace it with a new air line.
9. Install a new sleeve in the nut. Start the threads of the nut on the fitting body.
10. Insert the squared end of the air line in the fitting until it bottoms in the body of the fitting. See **Fig. 3**.
11. Tighten the nut until one thread remains visible.

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Air Lines Replacement



A. Air line end must bottom before tightening the nut.

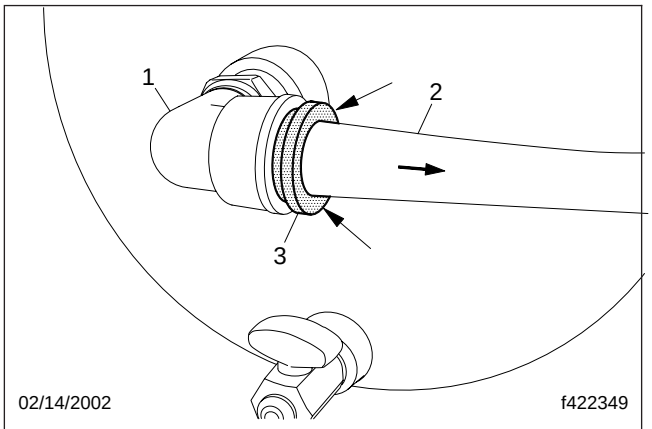
Fig. 3, Installing Nylon Air Line into Compression Fitting

12. Pull back on the air line to make sure it is fully seated.
13. Pressurize the air system. Check the air system for leaks.
14. Remove the chocks from the tires.

Nylon Air Lines and KV2 One-Touch Fittings

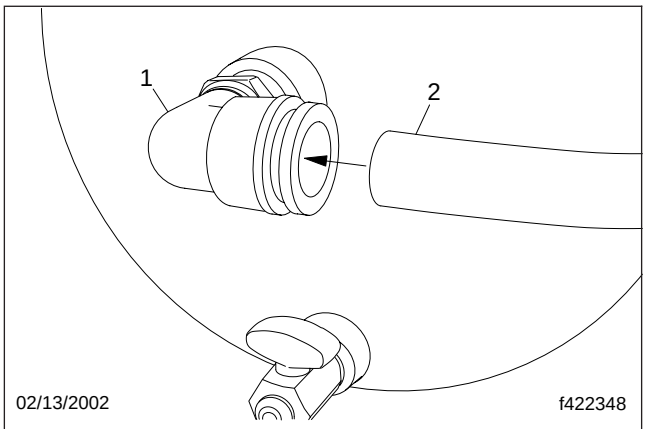
IMPORTANT: The use of a sharp air line cutter is highly recommended. This tool will insure a clean, perpendicular cut of the air line.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Push the air line into the fitting.
4. Press and hold the release button against the body of the fitting and remove the air line. See **Fig. 4**.
5. Remove the air line.
6. Clean any dirt or contamination from the leading edge of the air line.
7. Lubricate the leading end of the air line with light oil, petroleum jelly or silicone lubricant.
8. Insert the end of the air line into the fitting until it bottoms. See **Fig. 5**.
9. Pull on the air line to verify it is properly retained.
10. Pressurize the air system. Check the air system for leaks.



1. Push-to-Connect Fitting
2. Air Line
3. Release Button

Fig. 4, Push on Release Button and Remove Air Line



1. Push-to-Connect Fitting
2. Air Line

Fig. 5, Insert Air Line

11. Remove the chocks from the tires.

Wire Braid Air Lines

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the air line.
   - 3.1 Unthread the swivel fitting nut.
   - 3.2 Remove the air line assembly from the mating fitting.

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4. Make sure the wire braid air line assembly is free of grease and dirt. Replace the assembly if the air line or fitting is crimped or otherwise damaged.
5. Install the air line and finger-tighten the nut.
6. Using two wrenches to prevent twisting of the air line, tighten the nut until it seats solidly. Tighten the nut one-sixth turn more.
7. Pressurize the air system. Check the air system for leaks.
8. Remove the chocks from the tires.

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⚠ WARNING

Make sure the air system has been reduced to 0 psi before attempting to remove an air line. Do not disconnect pressurized air lines as they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

Replacement

⚠ CAUTION

Before working on or around air brake systems and components, see Safety Precautions 100.

⚠ CAUTION

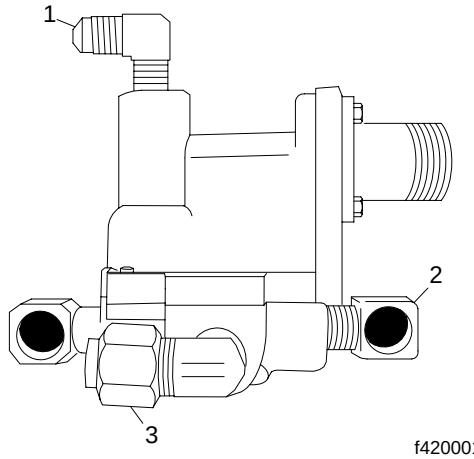
Never use diagonal pliers, a razor knife, saw or dull cutting tool to cut nylon air lines. The use of such tools leaves the air line with a sharp edge, burr or out-of-round condition which can damage the seal when the air line is inserted into the fitting. This reduces the sealing ability of the fitting. The use of a sharp air line cutter is highly recommended. This tool will insure a clean, perpendicular cut of the air line.

Brass or Steel Pipe Fittings

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the air line from the fitting. For instructions, see **Subject 110**.
4. Using an open-end wrench or similar tool, rotate the fitting counterclockwise until it is completely disengaged from the fitting port. See **Fig. 1**.
5. Make sure the fitting is free of grease, dirt, and old sealant. Apply liquid thread sealant (white) to the threads and finger-tighten securely.

NOTE: Always apply the sealant to the external thread, so that any excess will be scraped off externally rather than internally to the joint.

6. Install the fitting:
   - *For a fitting that must be positioned*, tighten one additional turn from finger-tight using a wrench. Continue to tighten the fitting clockwise until it is correctly positioned. Never turn the fitting counterclockwise to position it.
   - *For a fitting that does not require positioning*, tighten 1-1/2 additional turns from finger-tight.
7. Install the air line in the fitting. For instructions, see **Subject 110**.
8. Pressurize the air system. Check the air system for leaks.
9. Remove the chocks from the tires.



1. Wire Braid Hose Fitting
2. Brass or Steel Pipe Fitting
3. Nylon Tube Compression Fitting

Fig. 1, Screw-On Fittings

Brass or Steel Pipe Fittings on Plastic Components

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the air line from the fitting. For instructions, see **Subject 110**.
4. Remove the fitting.
5. Install the fitting. For tightening specifications, see the applicable table in **Specifications, 400**.
6. Install the air line in the fitting. For instructions, see **Subject 110**.

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Fittings Replacement

7. Pressurize the air system. Check the air system for leaks.
8. Remove the chocks from the tires.

Copper Fittings

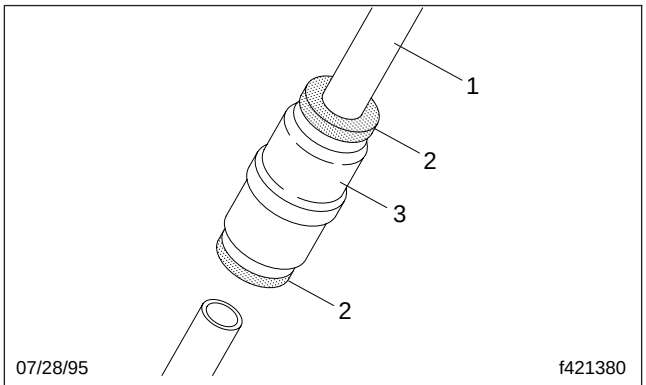
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the air line from the fitting. For instructions, see **Subject 110**.
4. Loosen the nut and remove the fitting.
5. Position the fitting.
6. Finger-tighten the nut.
7. Using two wrenches to prevent twisting of the air line, tighten the nut the number of turns shown in the applicable table in **Specifications 400**.
8. Install the air line in the fitting. For instructions, see **Subject 110**.
9. Pressurize the air system. Check the air system for leaks.
10. Remove the chocks from the tires.

Quick-Connect Fittings

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.

NOTE: If damaged, quick-connect fittings must be replaced as an assembly.

3. Push in on the fitting collar to release the air line.
4. Pull the air line out of the fitting. See **Fig. 2**.
5. Push the air line into the fitting.
6. Pull the collar away from the fitting to secure the air line.
7. Check and make sure that the air line is seated in the fitting.
8. Pressurize the air system. Check the air system for leaks.
9. Remove the chocks from the tires.



1. Air Line
2. Collar
3. Fitting

Fig. 2, Nylon Air Line and Quick-Connect Fitting

KV2 One-Touch Fittings

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the air line from the fitting. For instructions, see **Subject 110**.
4. Using an open-end wrench or similar tool, rotate the fitting's hexstud end counterclockwise until it is hand-loose.
5. Continue to rotate the fitting by hand until it is completely disengaged from the fitting port.
6. Clean any dirt or thread sealant from the fitting and fitting port.
7. If required, apply liquid thread sealant (white) to the threads.
8. Insert the fitting into the port and rotate it clockwise until it is hand-tight.
9. Using an open-end wrench or similar tool, tighten the fitting to the manufacturer's recommended torque. For torque specifications, see the applicable table in **Specifications 400**.
10. Rotate the fitting body by hand to the correct position.
11. Install the air line in the fitting. For instructions, see **Subject 110**.

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12. Pressurize the air system. Check the air system for leaks.
13. Remove the chocks from the tires.

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Specifications

Nylon Air Lines			
Number	Inside Diameter Inch	Outside Diameter Inch	Minimum Bend Radius inches (mm)
4	0.170	1/4	1.00 (25)
6	0.251	3/8	1.50 (38)
8	0.376	1/2	2.00 (51)
10	0.441	5/8	2.50 (64)
12	0.566	3/4	3.00 (76)

Table 1, Nylon Air Lines

211 Wire Braid (Medium Pressure) Air Lines *			
Number	Inside Diameter Inch	Outside Diameter Inch	Minimum Bend Radius inches (mm)
4	3/16	0.52	3.00 (76)
5	1/4	0.58	3.38 (86)
6	5/16	0.67	4.00 (102)
8	13/32	0.77	4.63 (118)
10	1/2	0.92	5.50 (140)
12	5/8	1.08	6.50 (165)
16	7/8	1.23	7.38 (187)
20	1-1/8	1.50	9.00 (229)

* 211 air lines are identified by part number and size (for example, part numbers 211-4, 211-5, and so on).

Table 2, 211 Wire Braid (Medium Pressure) Air Lines

213 Wire Braid Air Lines *			
Number	Inside Diameter Inch	Outside Diameter Inch	Minimum Bend Radius inches (mm)
4	3/16	0.49	0.75 (20)
5	1/4	0.55	1.00 (25)
6	5/16	0.62	1.25 (30)
8	13/32	0.74	1.75 (45)
10	1/2	0.83	2.25 (55)
12	5/8	0.96	2.75 (70)
16	7/8	1.21	3.50 (90)
20	1-1/8	1.49	4.50 (115)

* 213 air lines are identified by two green stripes 180 degrees apart, part numbers, and size (for example, part numbers 213-4, 213-5, and so on).

Table 3, 213 Wire Braid Air Lines

KV2 Stud End Torque into Metallic Ports *		
Thread, NPTF Inch	Torque †	
	lbf·in (N·cm)	lbf·ft (N·m)
1/16	62–80 (700–900)	—
1/8	62–80 (700–900)	—
1/4	106–124 (1200–1400)	—
3/8	—	16–18 (22–24)
1/2	—	21–22 (28–30)

* Aluminum, zinc, steel and brass ports.
† The component in which the KV2 One-Touch fitting is being installed may have torque values lower than those listed here. Please see the component supplier's recommended torque specifications.

Table 4, KV2 Stud End Torque into Metallic Ports

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Specifications

Brass or Steel Pipe Fittings on Plastic Components			
Description	Port Size Inch	Torque	
		lbf·in (N·cm)	lbf·ft (N·m)
Midland Quick Release Valve	3/8	60–90 (680–1020) *	—
	1/2	—	13–17 (18–23) *
Bendix MV-2/MV-3 Valve	1/4	—	10 (14)

* Tighten to the lower torque value. If needed, turn the fittings to allow for the proper routing of the air lines.

Table 5, Brass or Steel Pipe Fittings on Plastic Components

Copper Fittings			
Number	Outside Diameter Inch	Additional Turns from Hand-Tight	
		Compression	Threaded Sleeve
2	1/8	1-1/4	1-1/2
3	3/16		
4	1/4		
5	5/16	1-3/4	
6	3/8	2-1/4	
8	1/2		
10	5/8		
12	3/4		
16	1		
20	1-1/4		

Table 6, Copper Fittings

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For a tractor plumbing diagram, see **Fig. 1**.

For a truck plumbing diagram, see **Fig. 2**.

For a plumbing diagram of a truck equipped with a hand brake, see **Fig. 3**.

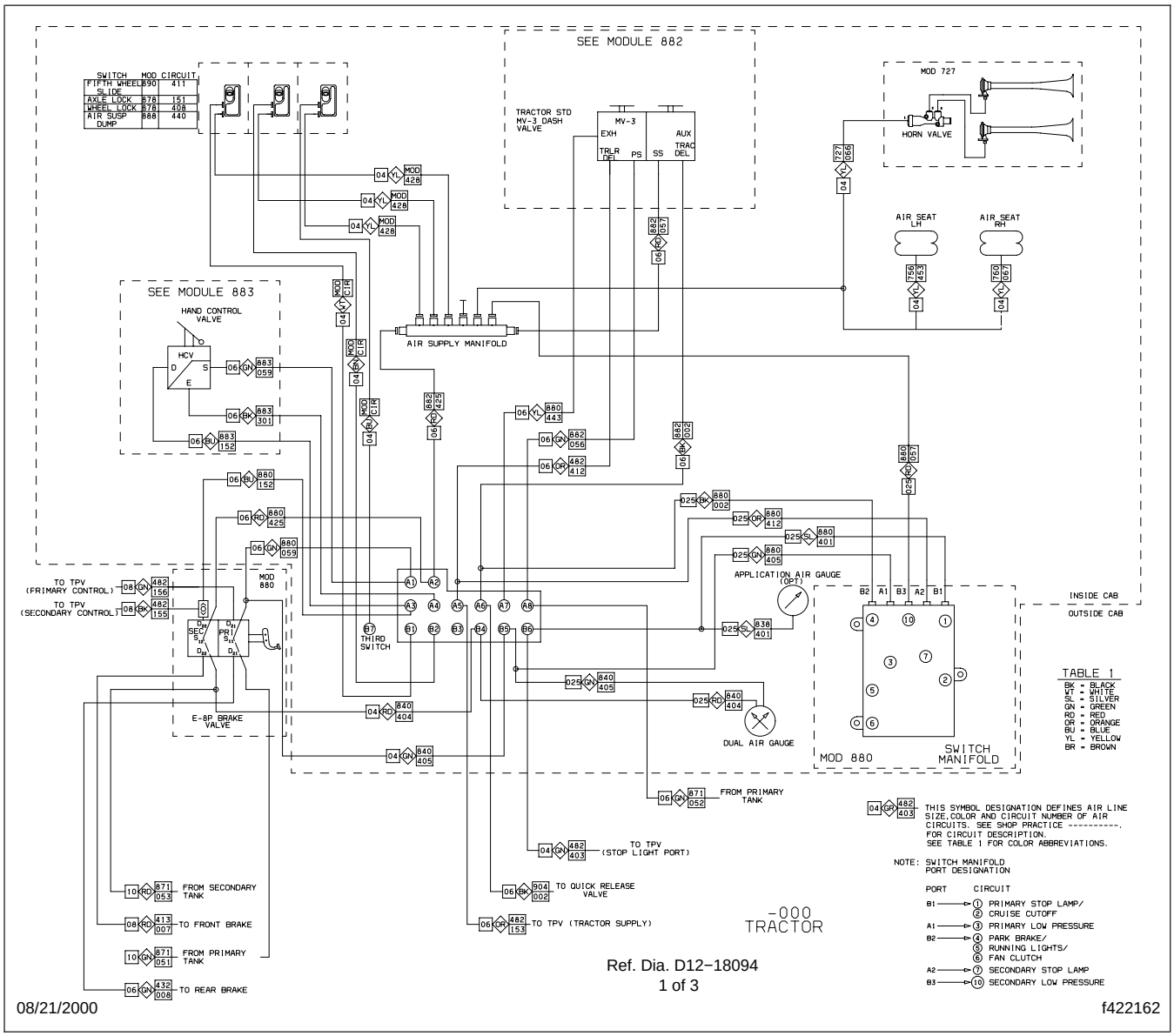


Fig. 1, Tractor Plumbing Diagram

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Cab Plumbing Diagrams

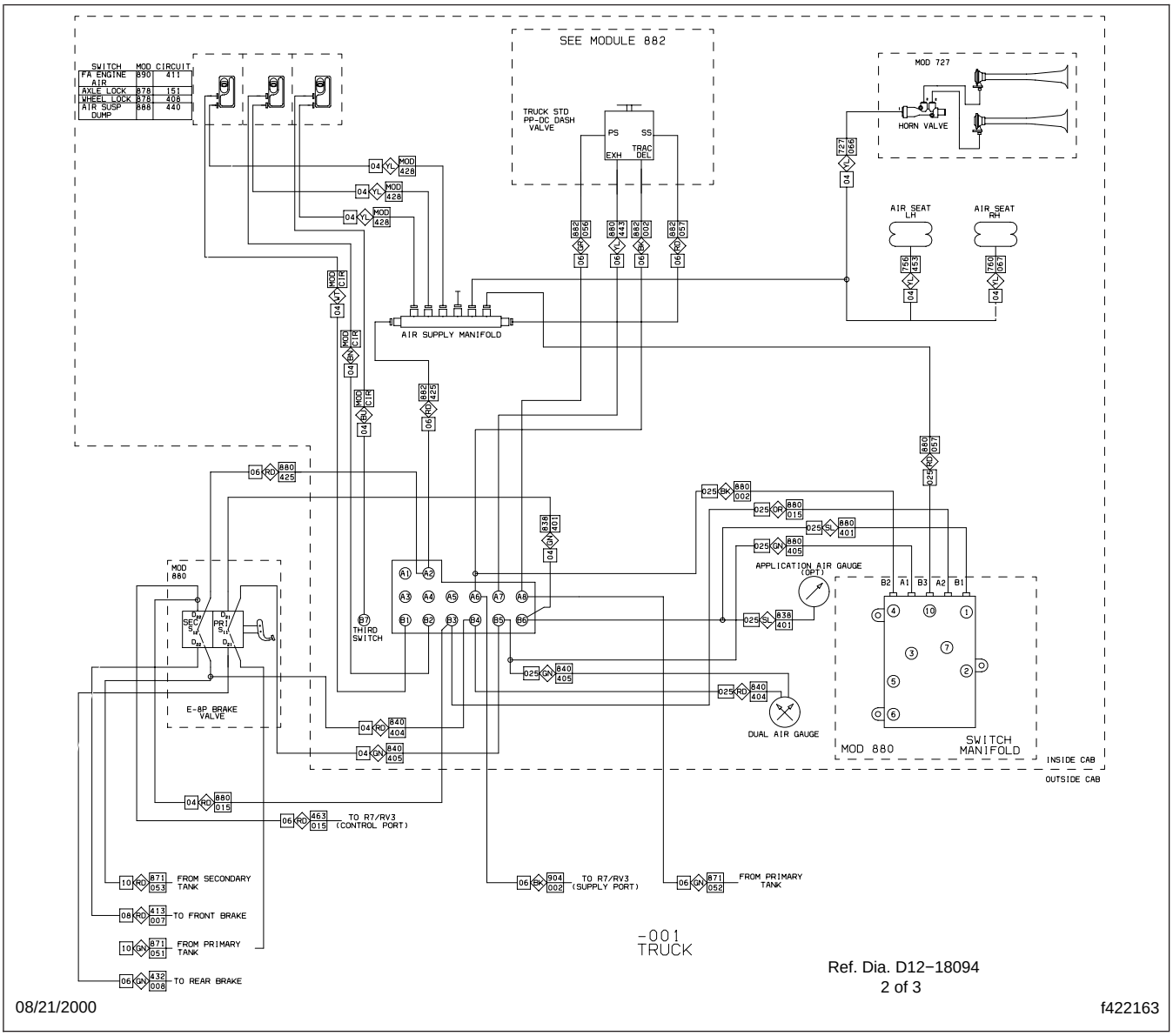


Fig. 2, Truck Plumbing Diagram

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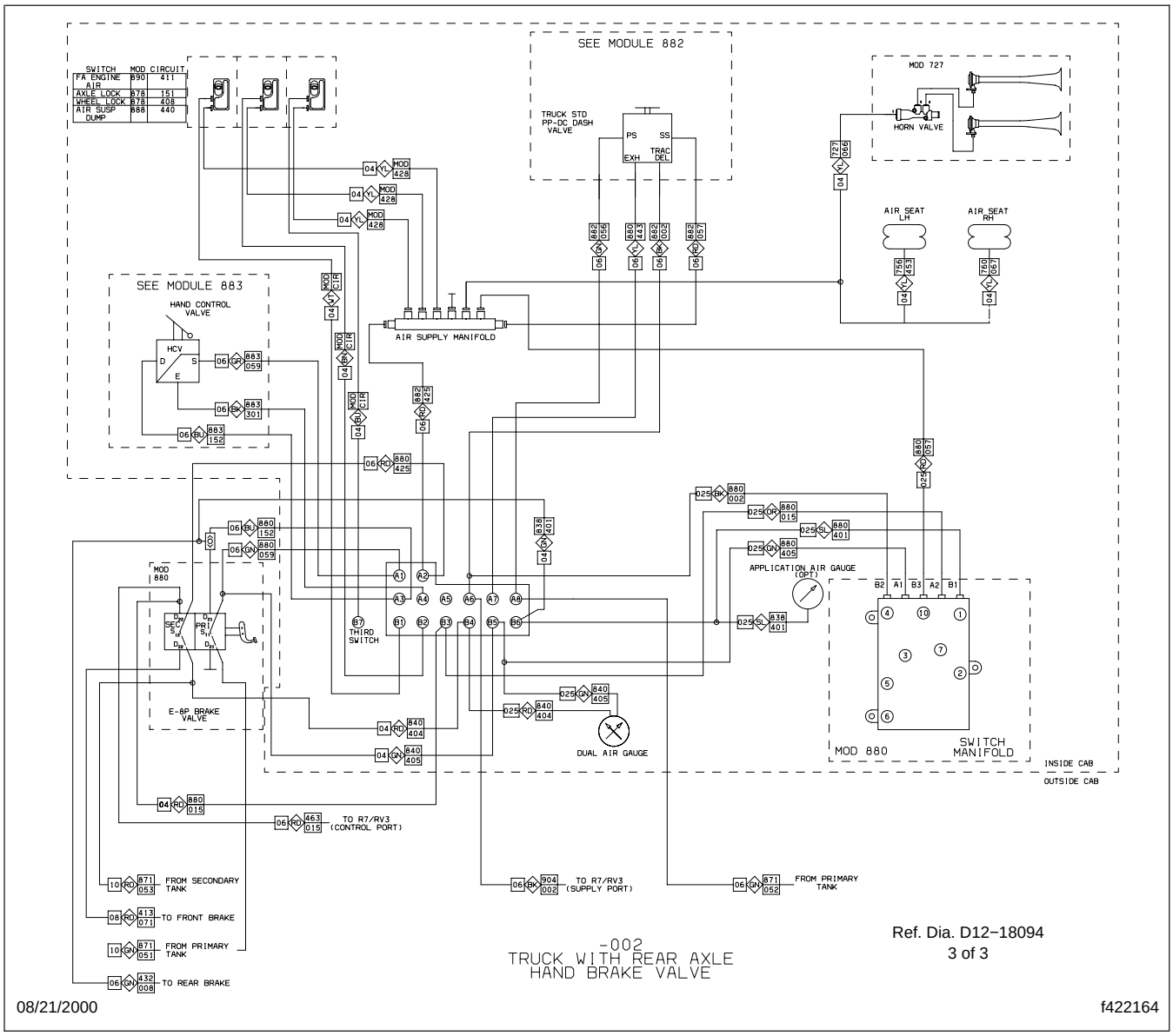


Fig. 3, Truck Equipped With Hand Brake Plumbing Diagram

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For a full view of the cab air lines schematic, see **Fig. 1**.

For partial (detailed) views of the cab air lines schematic, see **Fig. 2**, **Fig. 3**, and **Fig. 4**.

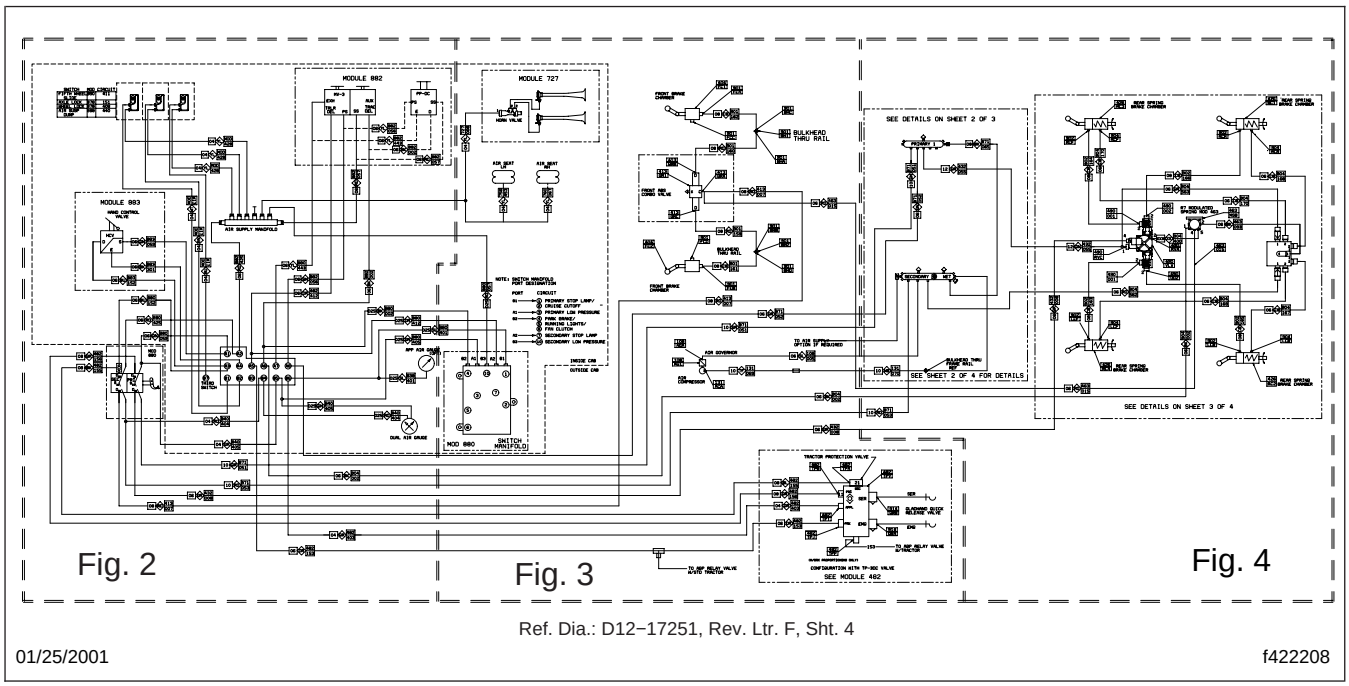
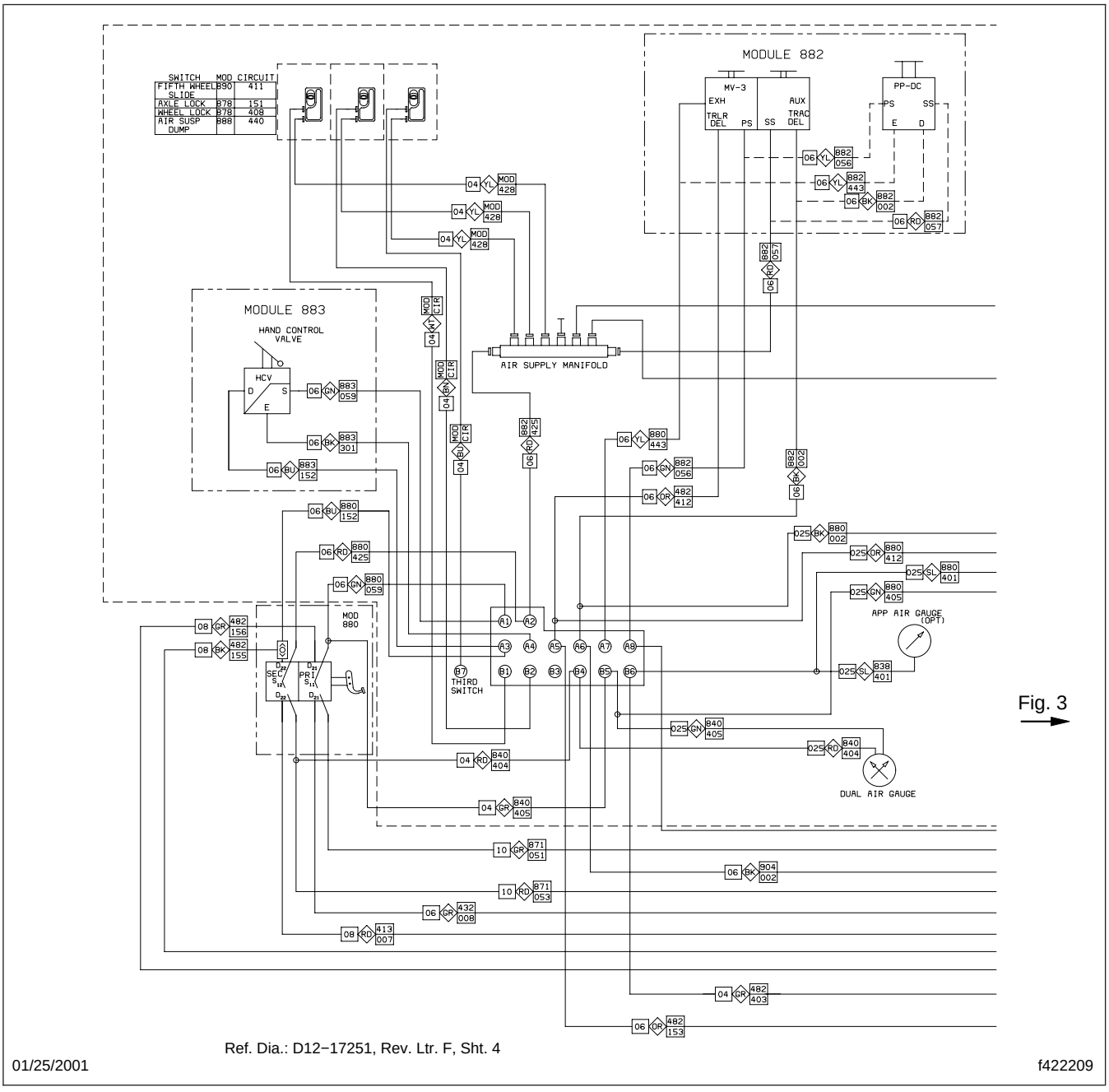


Fig. 1, Cab Air Lines Schematic (full view)

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Cab Air Lines Schematics

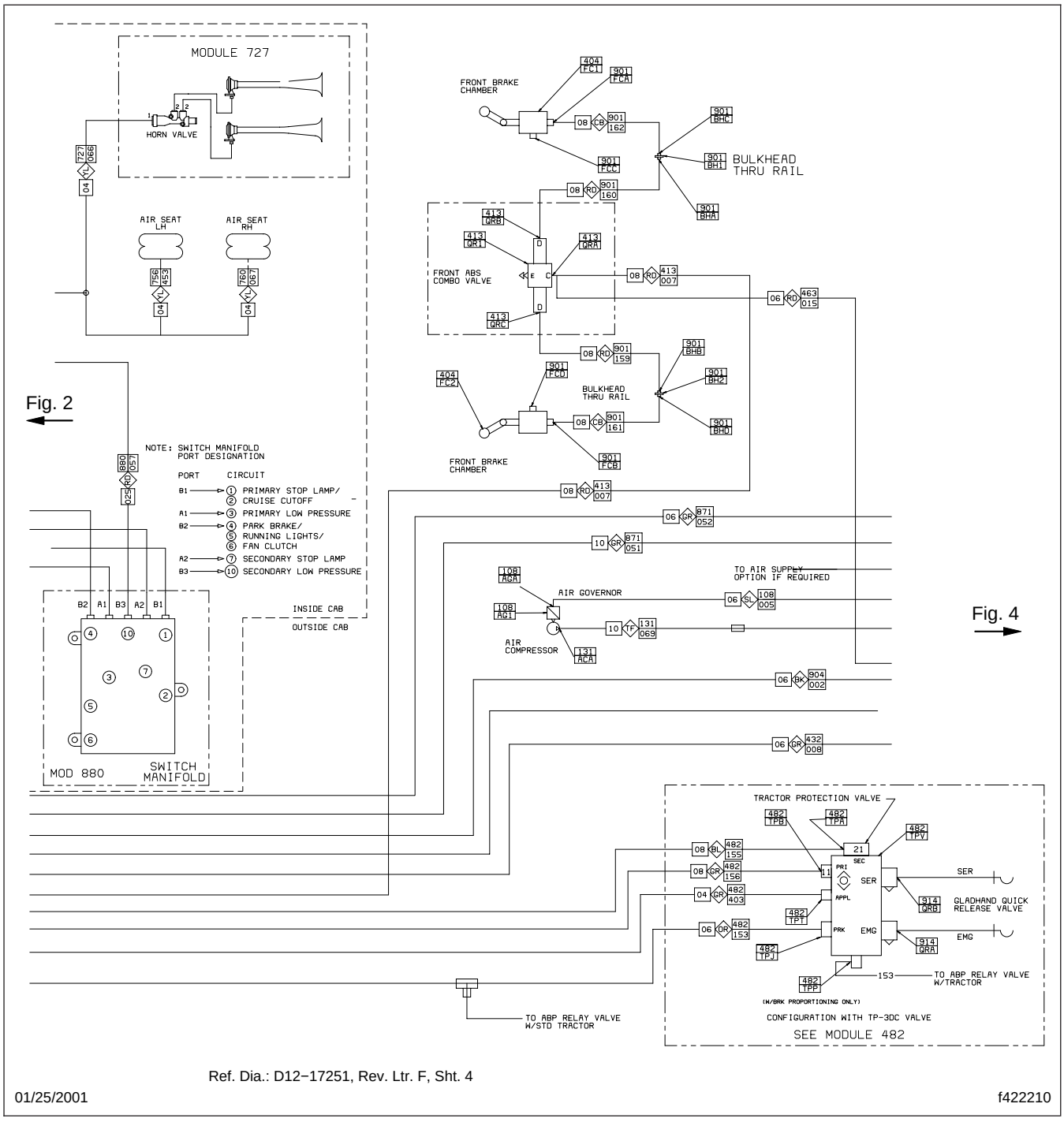


Ref. Dia.: D12−17251, Rev. Ltr. F, Sht. 4

01/25/2001 f422209

Fig. 2, Cab Air Lines Schematic (partial view)

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Ref. Dia.: D12−17251, Rev. Ltr. F, Sht. 4

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Fig. 3, Cab Air Lines Schematic (partial view)

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Cab Air Lines Schematics

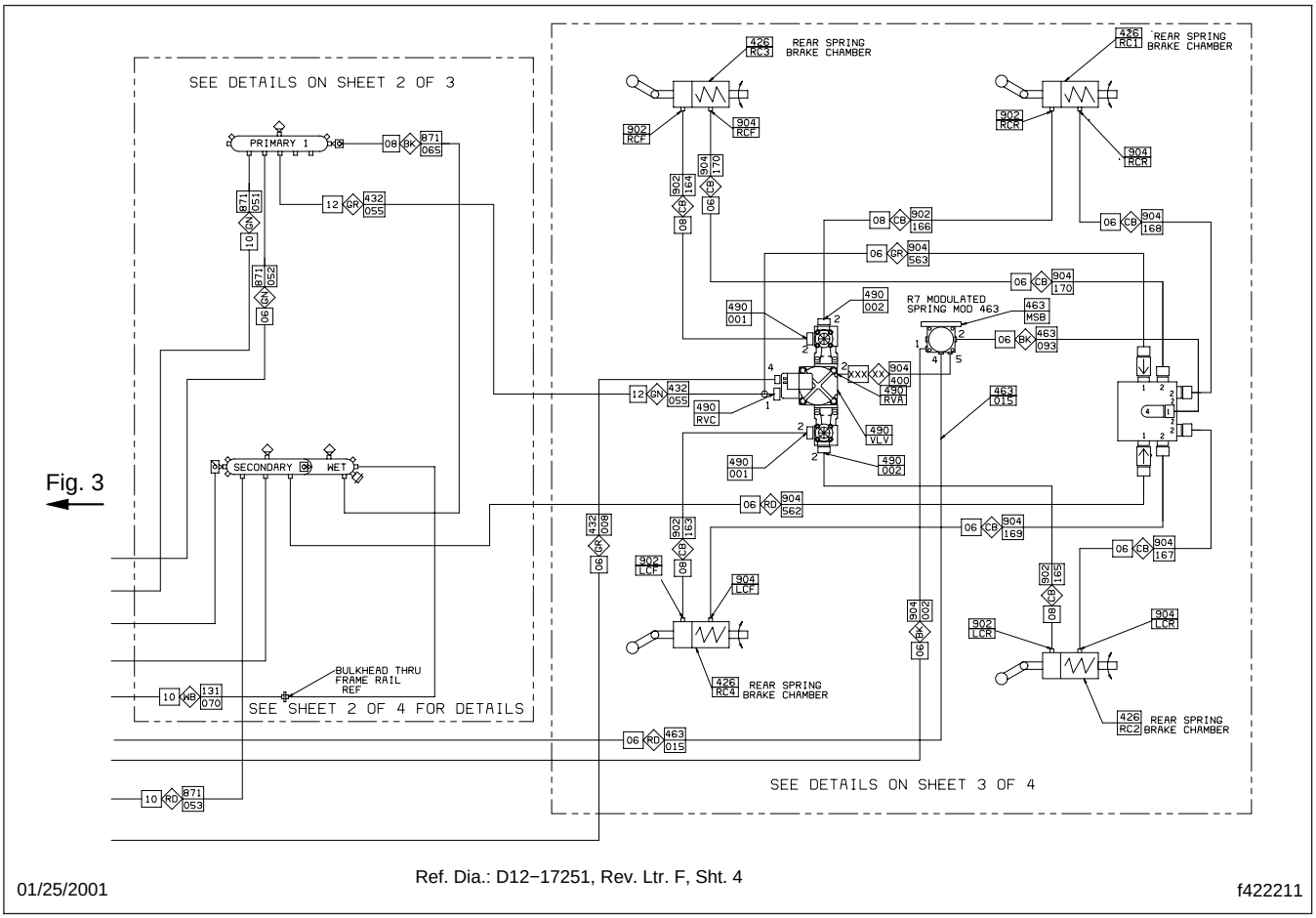


Fig. 4, Cab Air Lines Schematic (partial view)

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Front Axle and Air Tanks Air Lines Schematics

For a full view of the front axle and air tanks air lines schematic, see **Fig. 1**.

For partial (detailed) views of the front axle and air tanks air lines schematic, see **Fig. 2**, **Fig. 3**, **Fig. 4**, and **Fig. 5**.

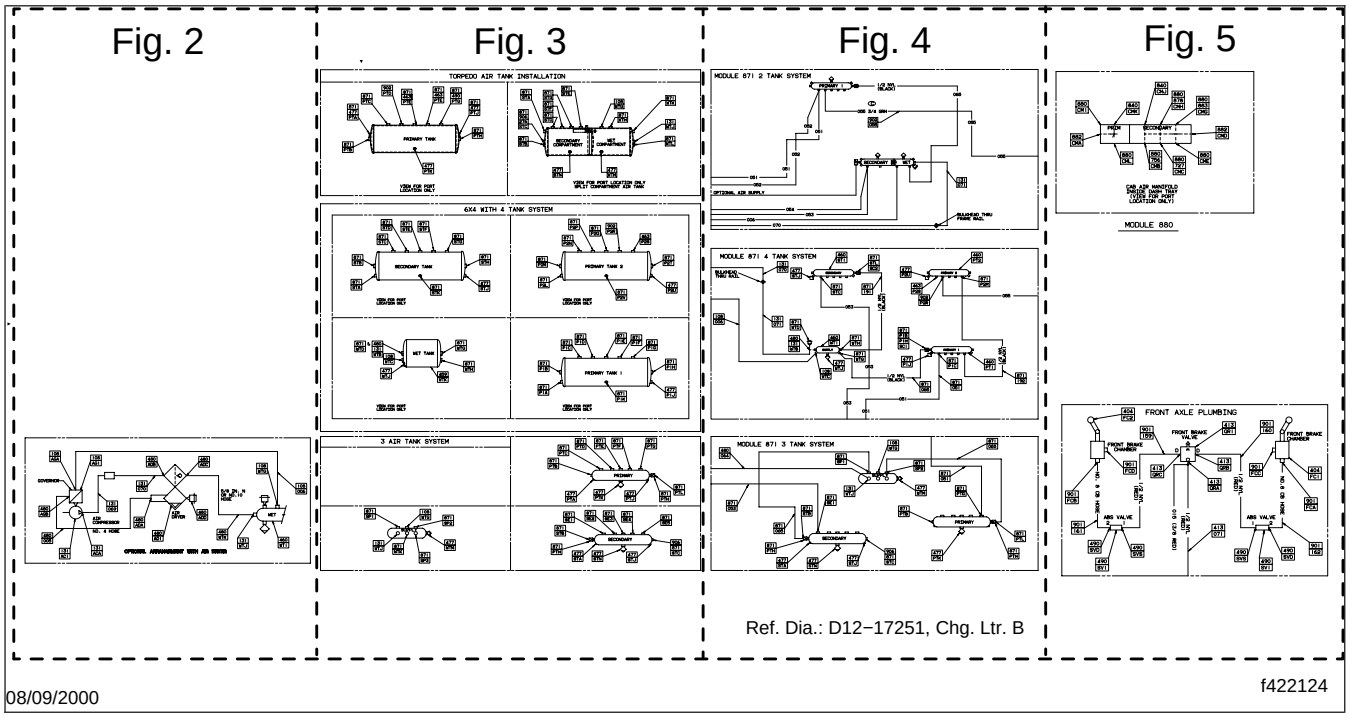


Fig. 1, Front Axle and Air Tanks Air Lines Schematic (full view)

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Front Axle and Air Tanks Air Lines Schematics

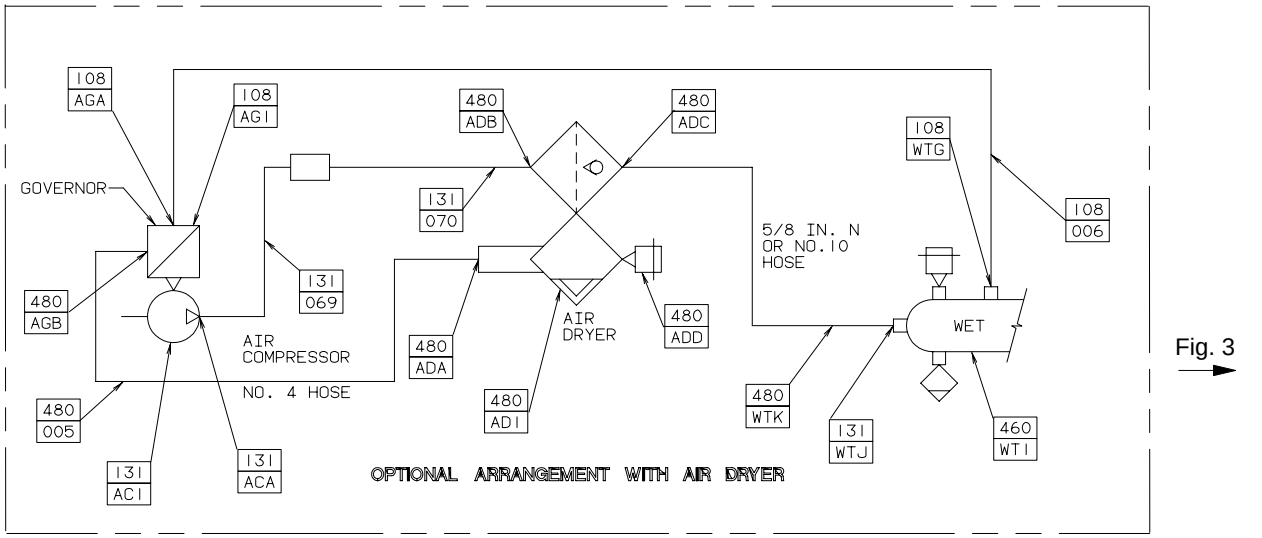


Fig. 3

Fig. 2, Front Axle and Air Tanks Air Lines Schematic (partial view)

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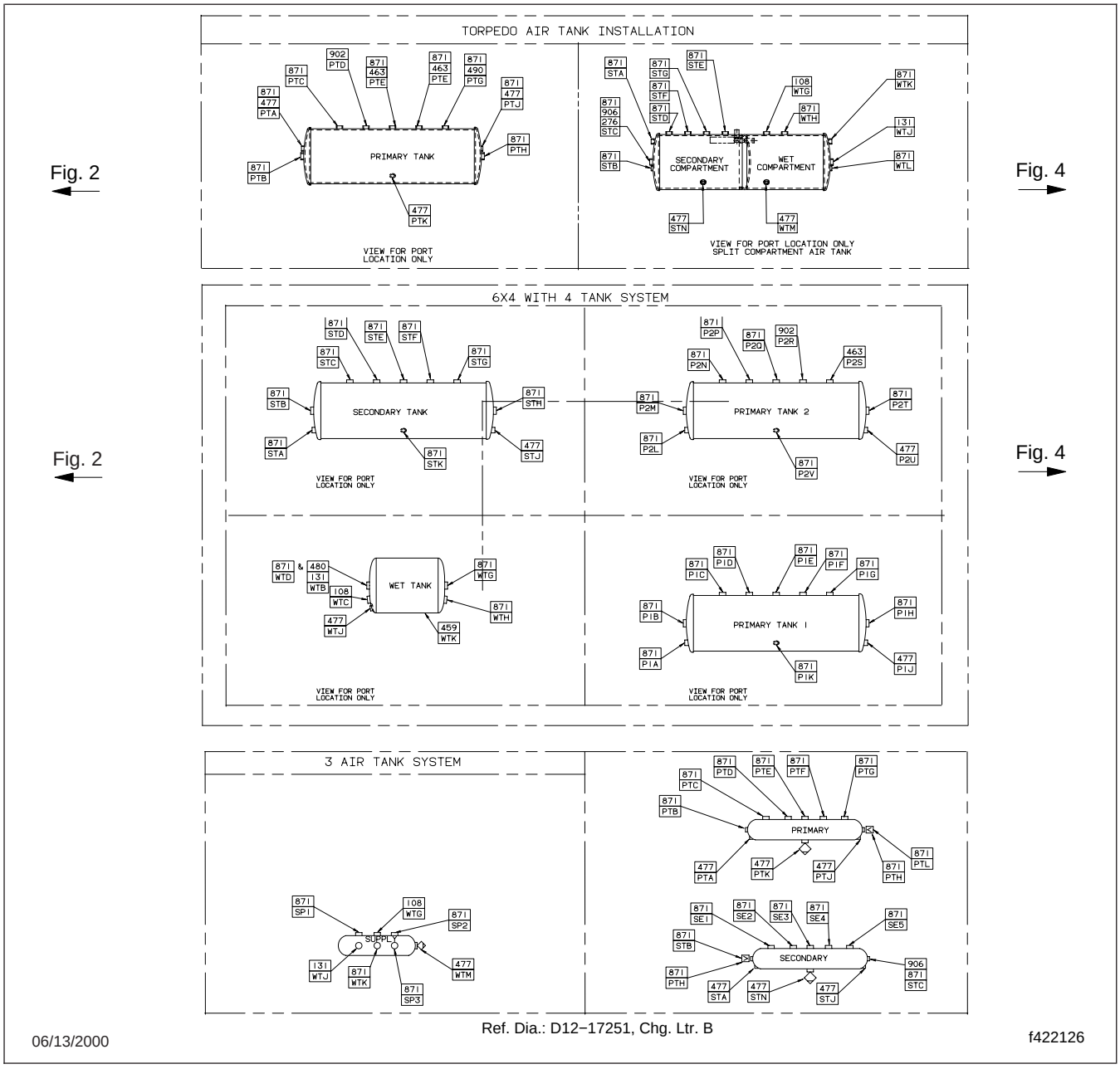


Fig. 3, Front Axle and Air Tanks Air Lines Schematic (partial view)

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Front Axle and Air Tanks Air Lines Schematics

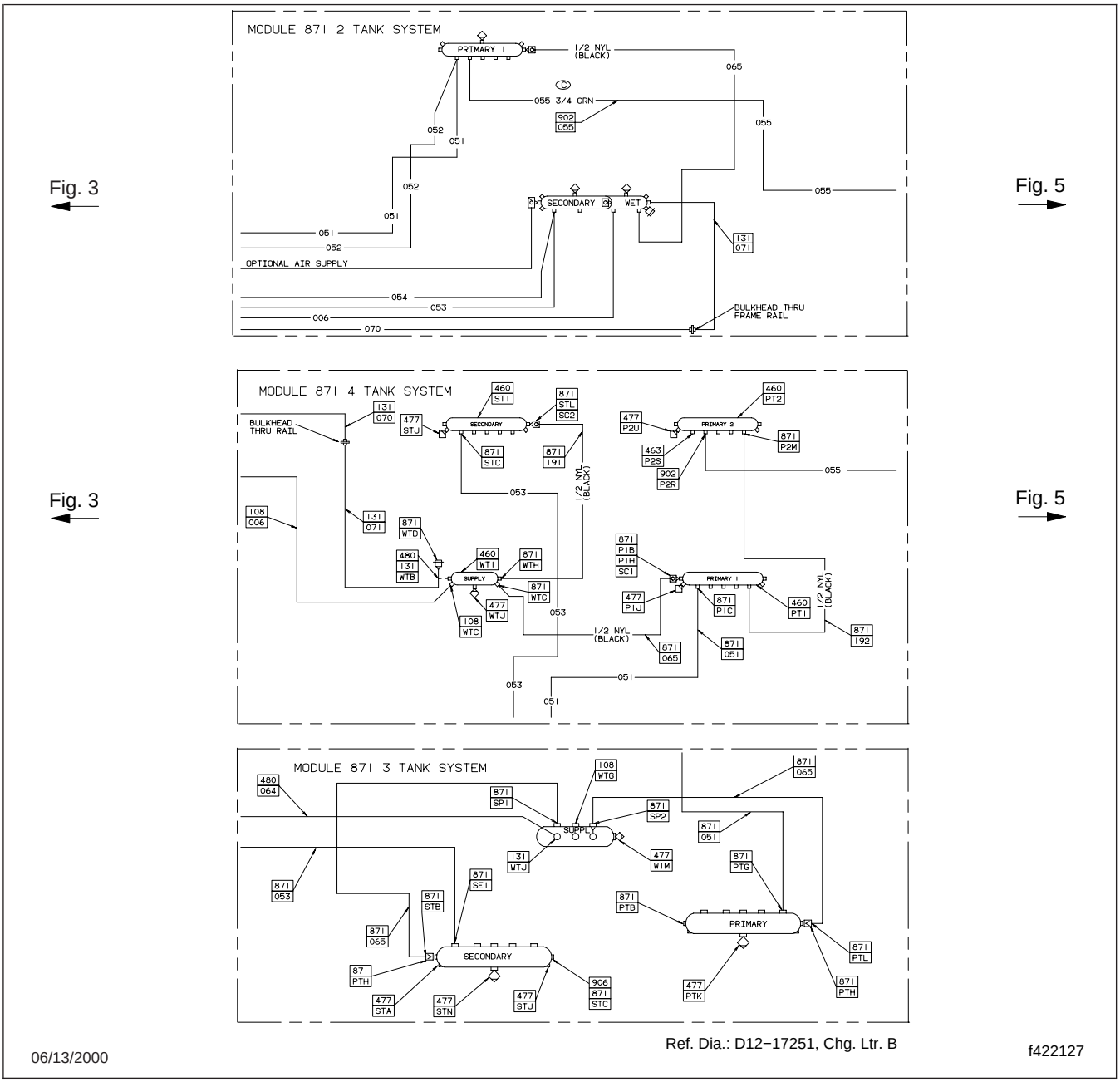


Fig. 4, Front Axle and Air Tanks Air Lines Schematic (partial view)

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Front Axle and Air Tanks Air Lines Schematics

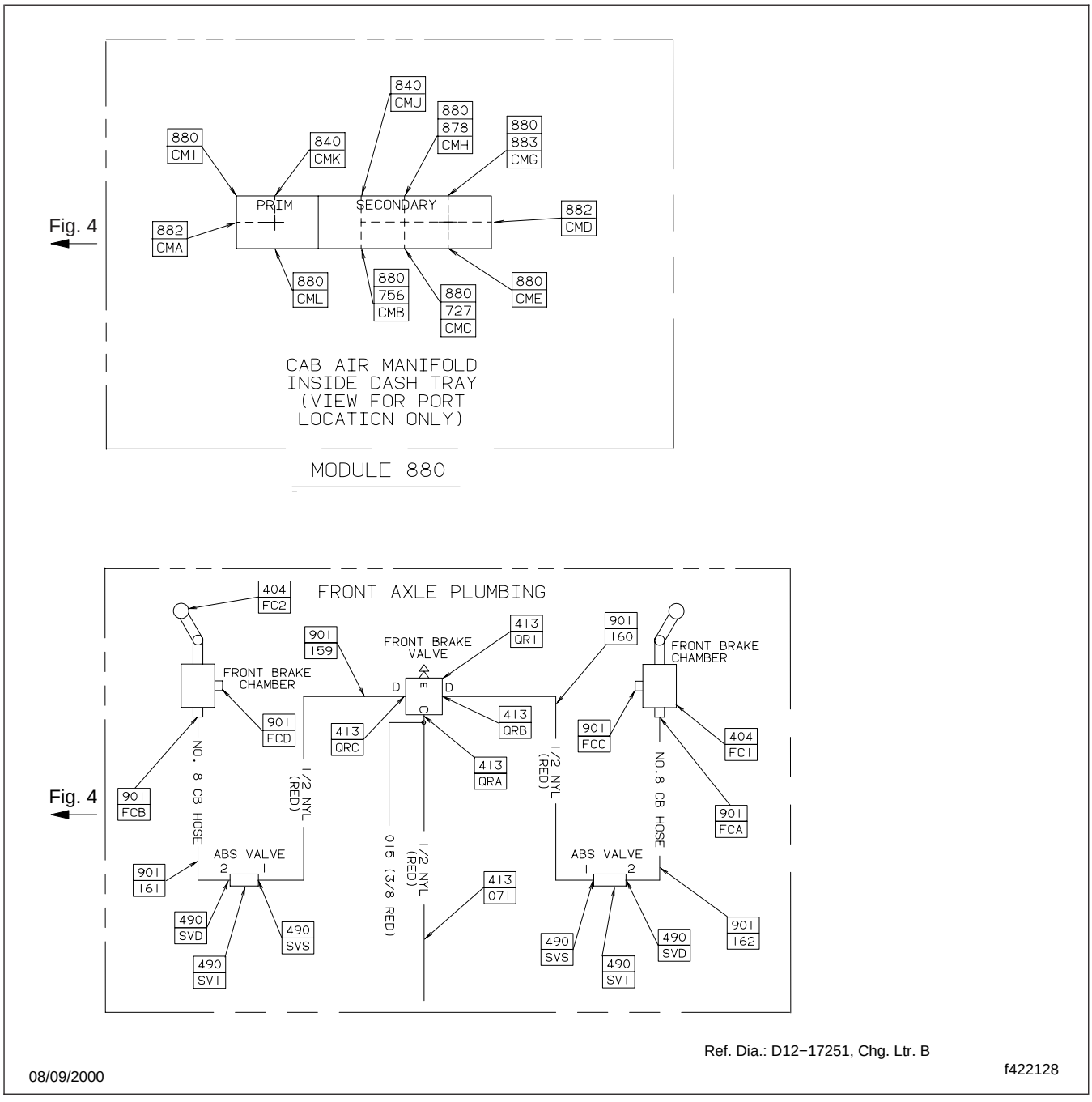


Fig. 5, Front Axle and Air Tanks Air Lines Schematic (partial view)

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For a full view of the rear axle air lines schematic, see **Fig. 1**.

For partial (detailed) views of the rear axle air lines schematic, see **Fig. 2**, **Fig. 3**, **Fig. 4**, and **Fig. 5**.

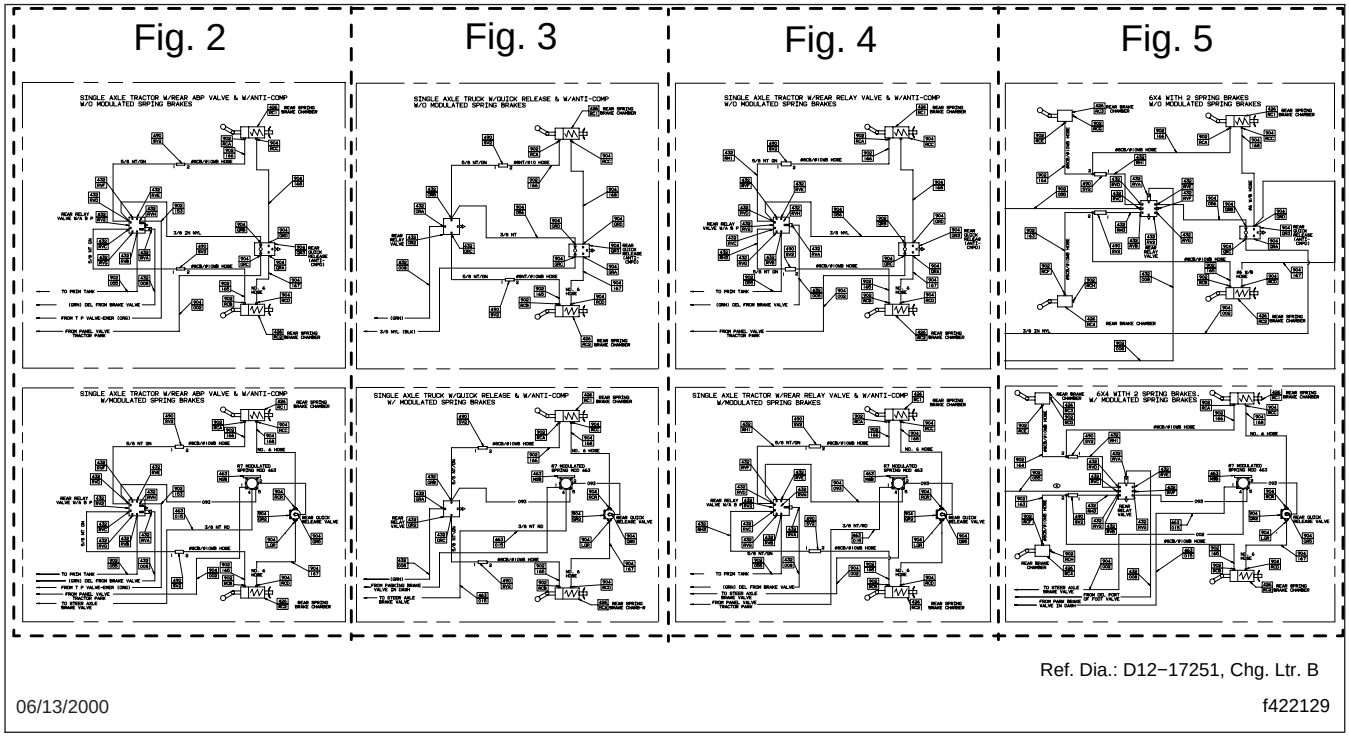


Fig. 1, Rear Axle Air Lines Schematic (full view)

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Rear Axle Air Lines Schematics

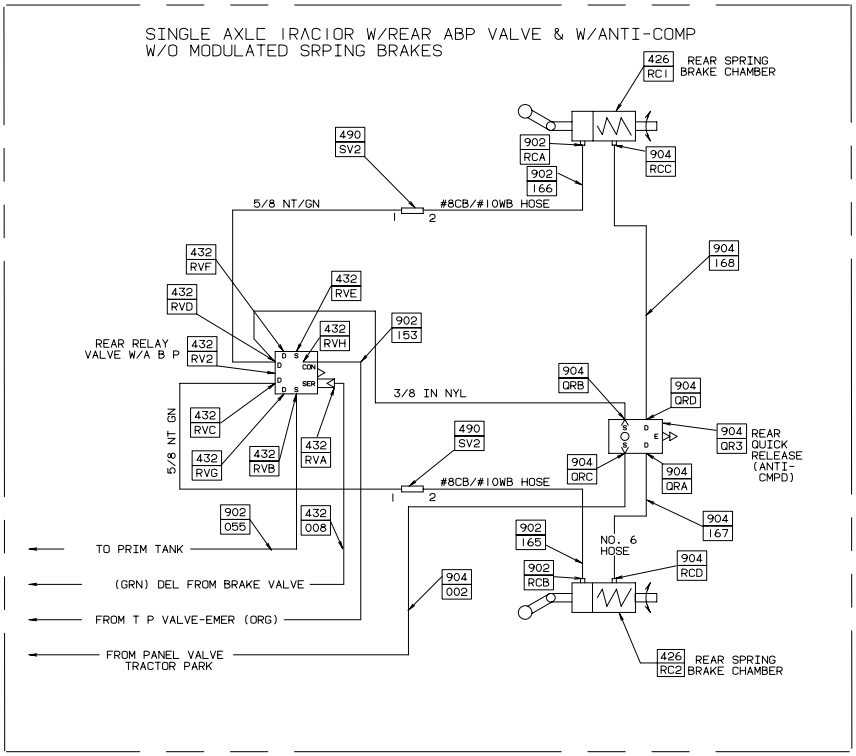


Fig. 3

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Fig. 2, Rear Axle Air Lines Schematic (partial view)

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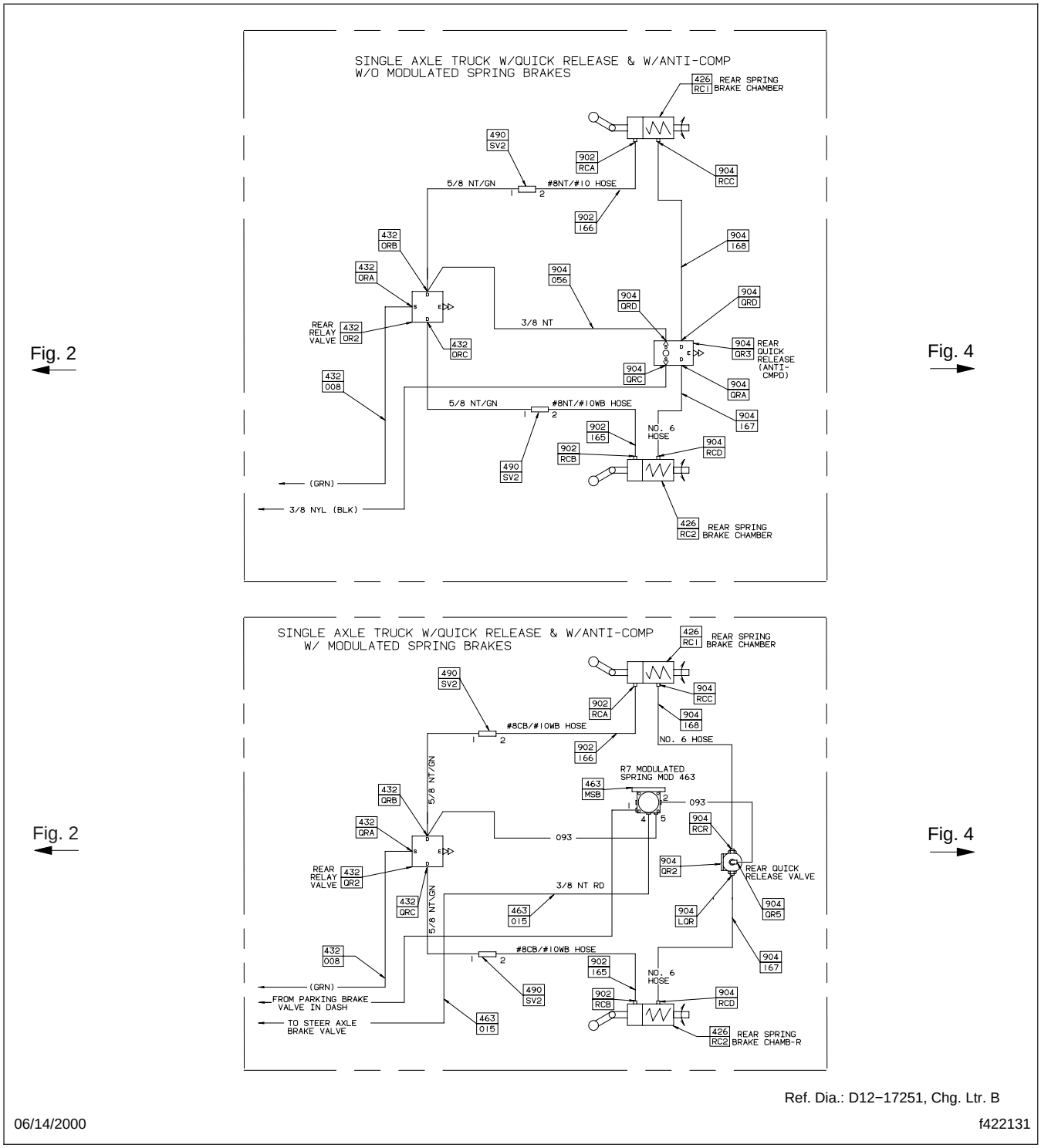


Fig. 3, Rear Axle Air Lines Schematic (partial view)

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Rear Axle Air Lines Schematics

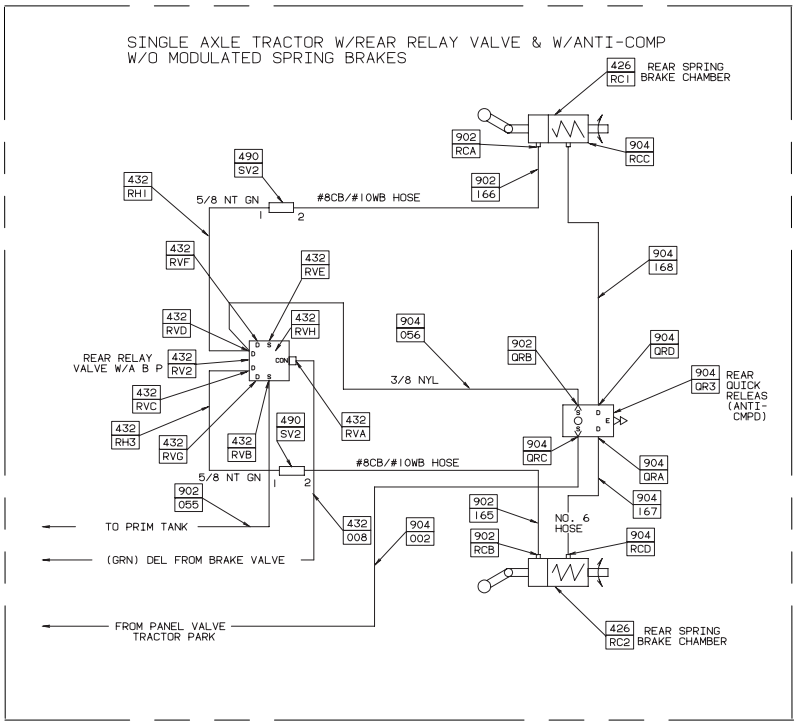


Fig. 3 ← Fig. 5 →

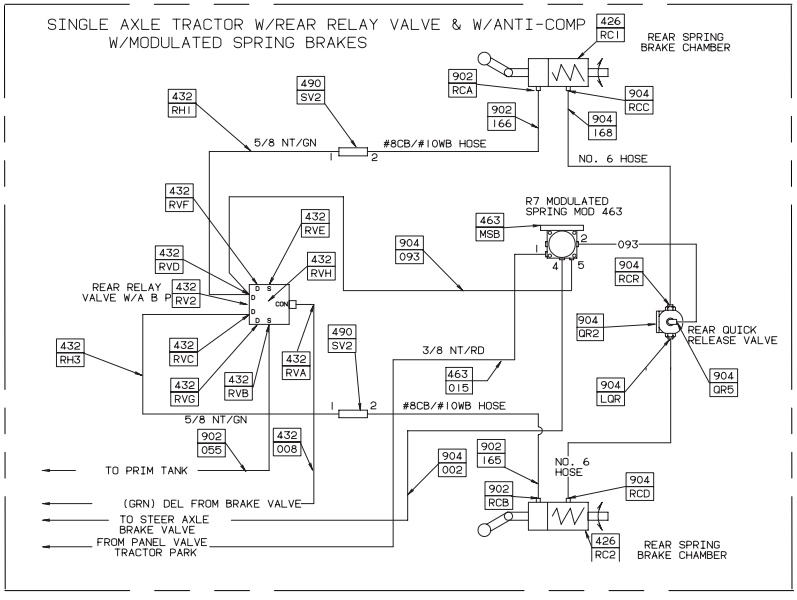


Fig. 3 ← Fig. 5 →

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Fig. 4, Rear Axle Air Lines Schematic (partial view)

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Fig. 4

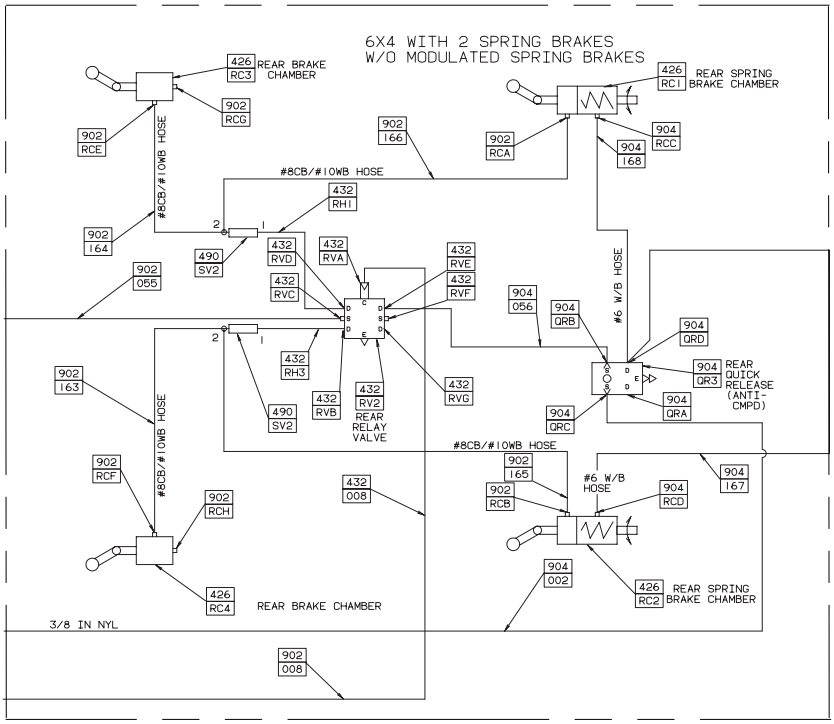
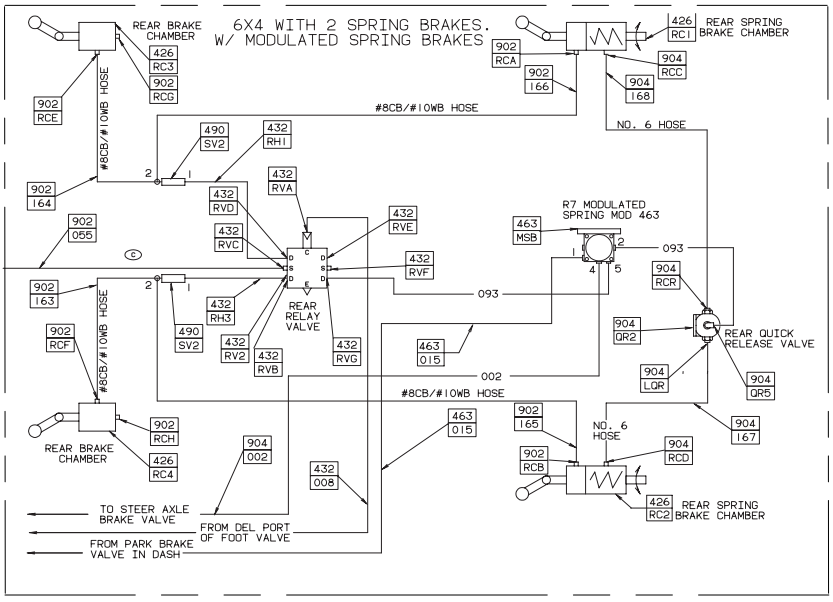


Fig. 4



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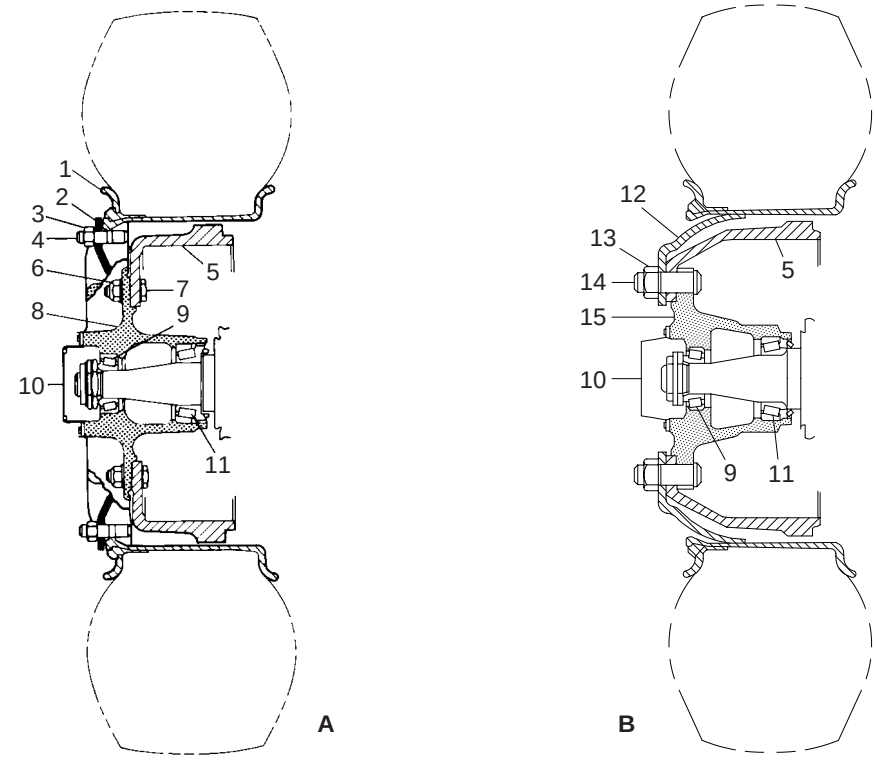
Fig. 5, Rear Axle Air Lines Schematic (partial view)

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General Information

The front and rear axle full-floating wheel hub assembly is made up of four major components: tapered wheel bearings, the wheel hub, wheel studs, and the brake drum. See **Fig. 1** and **Fig. 2**.

The brake drum and lining work together as a mated friction pair, with the drum responsible for both heat absorption and dissipation. Lining performance and life largely depend on the condition of the drum and whether it can adequately absorb and dissipate heat generated by braking action.



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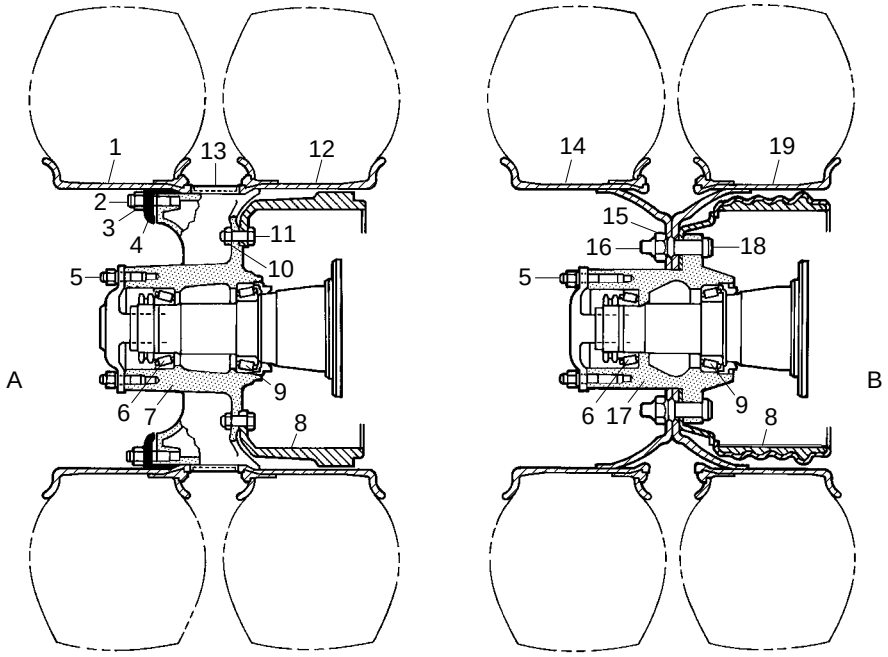
A. Spoke Wheel Assembly
B. Disc Wheel Assembly

1. Rim
2. Rim Clamp
3. Rim Stud Nut
4. Rim Stud
5. Brake Drum
6. Brake Drum Nut
7. Brake Drum Bolt
8. Spoke Wheel
9. Outer Wheel Bearing
10. Hub Cap
11. Inner Wheel Bearing
12. Disc Wheel
13. Wheel Nut
14. Wheel Stud
15. Hub

Fig. 1, Sectional View of Spoke and Disc Wheel Assemblies, Front Axle

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General Information



11/02/94 f350067a

A. Spoke Wheel and Brake Drum Assembly
B. Disc Wheel, Wheel Hub, and Brake Drum Assembly

1. Outer Rim
2. Rim Stud
3. Rim Stud Nut
4. Rim Clamp
5. Drive Axle Stud
6. Outer Wheel Bearing
7. Spoke Wheel
8. Brake Drum
9. Inner Wheel Bearing
10. Brake Drum Nut
11. Brake Drum Bolt
12. Inner Rim
13. Rim Spacer
14. Outer Wheel
15. Outer Wheel Nut
16. Inner Wheel Nut
17. Wheel Hub
18. Wheel Stub
19. Inner Wheel

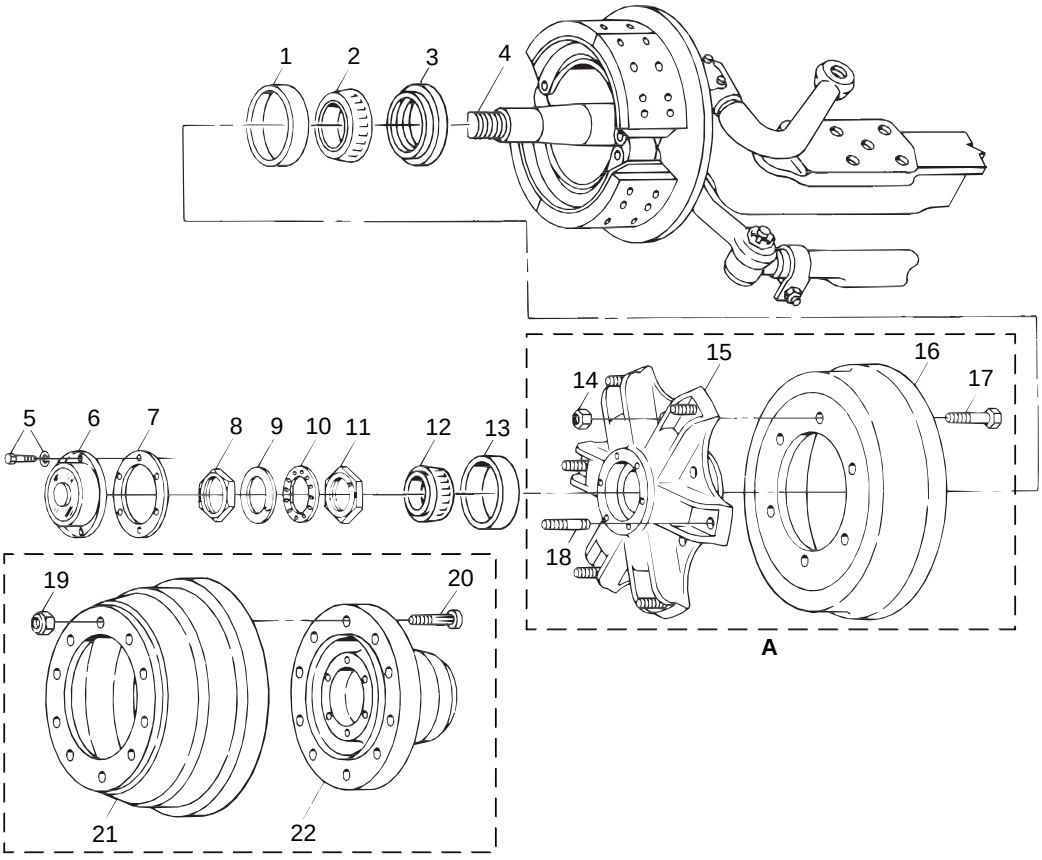
Fig. 2, Sectional View of Spoke and Disc Wheel Assemblies, Drive Axle

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Outboard-Mounted Drum Removal and Installation

Removal

When completing the following procedure, refer to **Fig. 1** and **Fig. 2**.



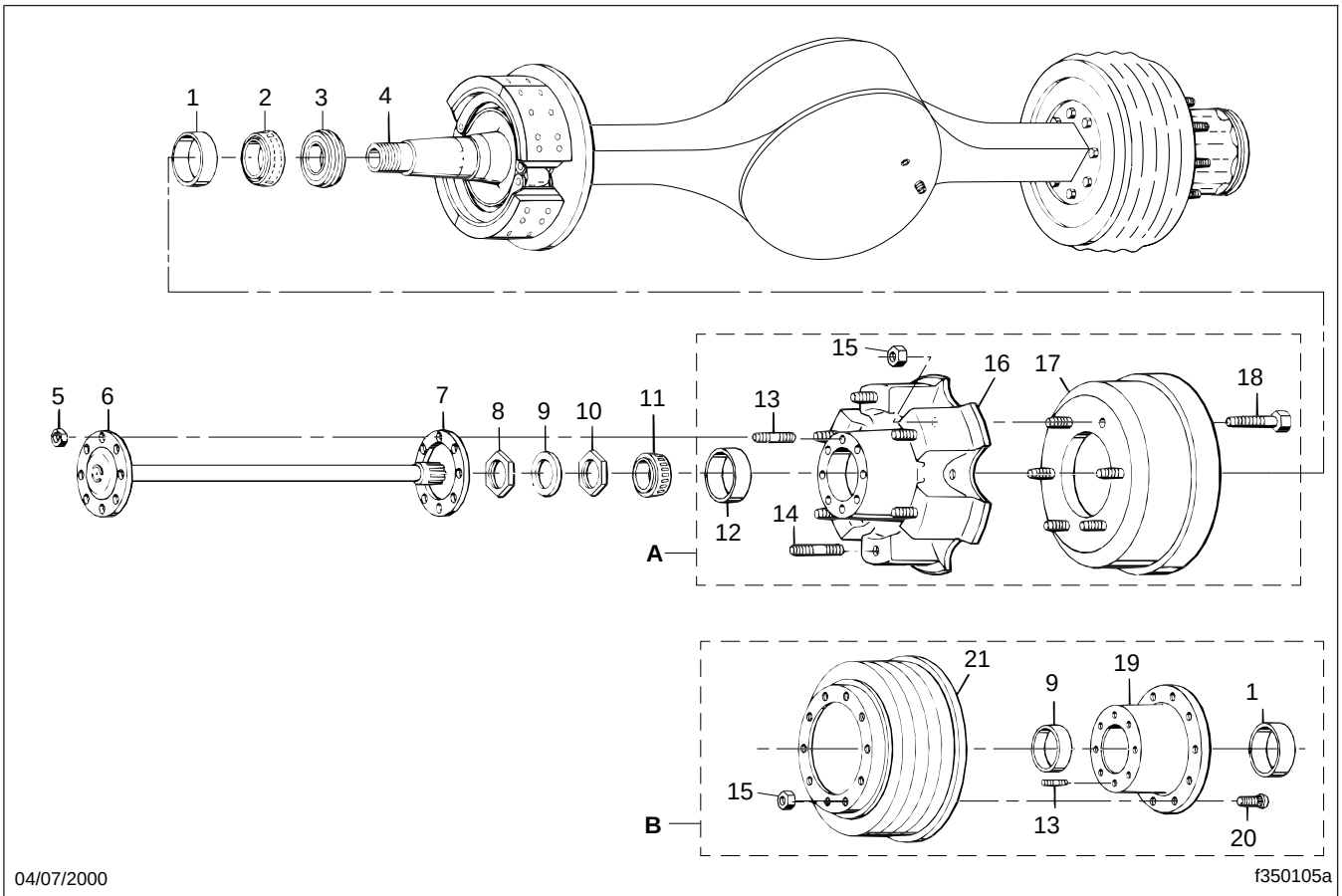
A. Spoke Wheel and Inboard-Mounted Drum Assembly
B. Disc Wheel, Hub, and Outboard-Mounted Drum Assembly

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle (Steering Knuckle)
5. Hub Cap Capscrew and Washer
6. Hub Cap
7. Hub Cap Gasket
8. Jam Nut
9. Lockwasher
10. Lockring
11. Wheel Bearing Adjusting Nut
12. Outer Wheel Bearing
13. Outer Wheel Bearing Cup
14. Brake Drum Nut
15. Spoke Wheel
16. Brake Drum, Inboard-Mounted
17. Brake Drum Bolt
18. Rim Stud
19. Wheel Nut
20. Wheel Stud
21. Brake Drum, Outboard-Mounted
22. Wheel Hub

Fig. 1, Front Axle, Typical

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Outboard-Mounted Drum Removal and Installation



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A. Spoke Wheel and Drum Assembly

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Lockring
10. Wheel Bearing Inner Adjusting Nut
11. Outer Wheel Bearing

B. Disc Wheel, Hub, and Drum Assembly

12. Outer Wheel Bearing Cup
13. Drive Axle Stud
14. Rim Stud
15. Brake Drum Nut
16. Spoke Wheel
17. Brake Drum, Inboard-Mounted
18. Brake Drum Bolt
19. Wheel Hub
20. Wheel Stud
21. Brake Drum, Outboard-Mounted

Fig. 2, Drive Axle, Typical

⚠ WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single

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Outboard-Mounted Drum Removal and Installation

axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

1. Park the vehicle on a level surface. Shut down the engine. If working on the front axle, set the parking brakes and chock the rear tires. If working on the rear axle, release the parking brakes and chock the front tires.
2. Raise the vehicle until the tires clear the ground. Place safety stands under the axle.
3. Back off the slack adjuster to release the brake shoes. For instructions, see **Section 42.11**.

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. Unless exposure can be reduced below legal limits, wear an air purifying respirator approved by MSHA or NIOSH at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

To reduce asbestos exposure below legal limits, apply either:

- **An enclosed-cylinder vacuum system equipped with a High Efficiency Particulate Air (HEPA) filter, or;**
- **A solvent spray system that keeps the asbestos-contaminated parts wet until they can be placed in a sealed and labelled plastic bag.**

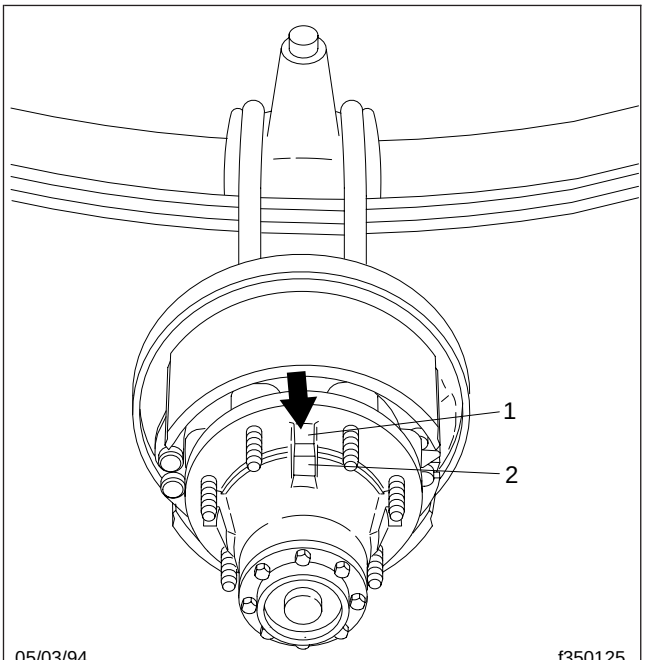
4. Remove wheel and tire assemblies. See **Group 40** for instructions.
5. Remove the brake drum.

   To minimize the possibility of creating airborne brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Using a rag soaked in water and wrung until nearly dry, remove any remaining dust. Do not use compressed air or dry brushing to clean the brake assembly.
6. Inspect the drum. See **Subject 120** for instructions.

Installation

1. Install the brake drum on the wheel hub.

   1.1 On hub-piloted drums, position the brake drum on the top step of the pilot pad. One of the hub's pilot pads should be at the 12 o'clock (top center) position. See **Fig. 3**.



NOTE: Pilot pad at 12 o'clock position
1. Drum Pilot 2. Wheel Pilot

Fig. 3, Front Axle Drum and Wheel Pilots (rear axle similar)

IMPORTANT: If the drum is not positioned correctly, the pilot pad could be damaged when the wheel nuts are torqued.

1.2 Make sure that the pilot pads securely center the drum (space between drum and hub is equal all around the hub).

IMPORTANT: If damage to the pads prevents the drum from centering, replace the

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Outboard-Mounted Drum Removal and Installation

hub. If necessary, to hold the drum in position, adjust the brakes before installing the wheels.

2. Install the wheel and tire assemblies. See **Group 40** for instructions.

⚠ WARNING

If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking ability, and the hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when the conditions described above exist could result in the loss of a wheel or loss of vehicle control, and possible personal injury.

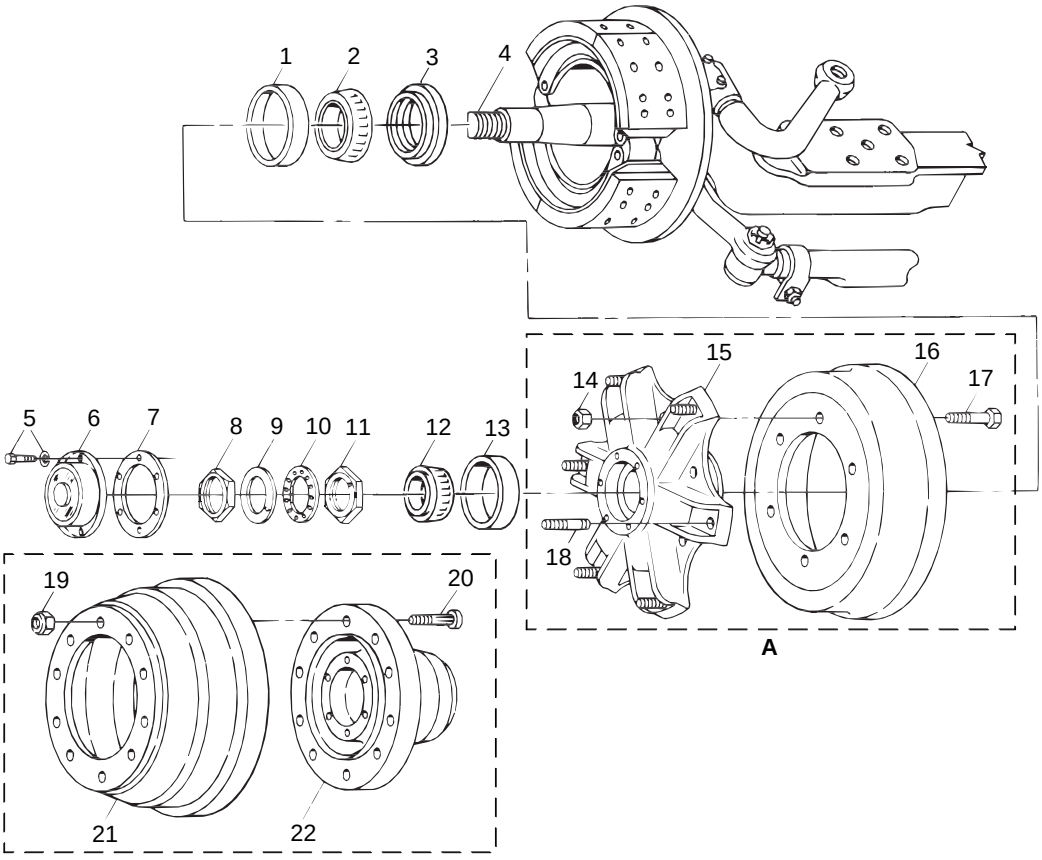
3. Adjust the brakes at the slack adjusters. For instructions, see **Group 42** of the *Acterra Maintenance Manual*.
4. Remove the safety stands from under the axle and lower the vehicle.
5. Apply the parking brakes (if not already applied). Remove the chocks from the tires.

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Inboard-Mounted Drum Removal and Installation

Removal

When completing the following procedure, refer to **Fig. 1** and **Fig. 2**.



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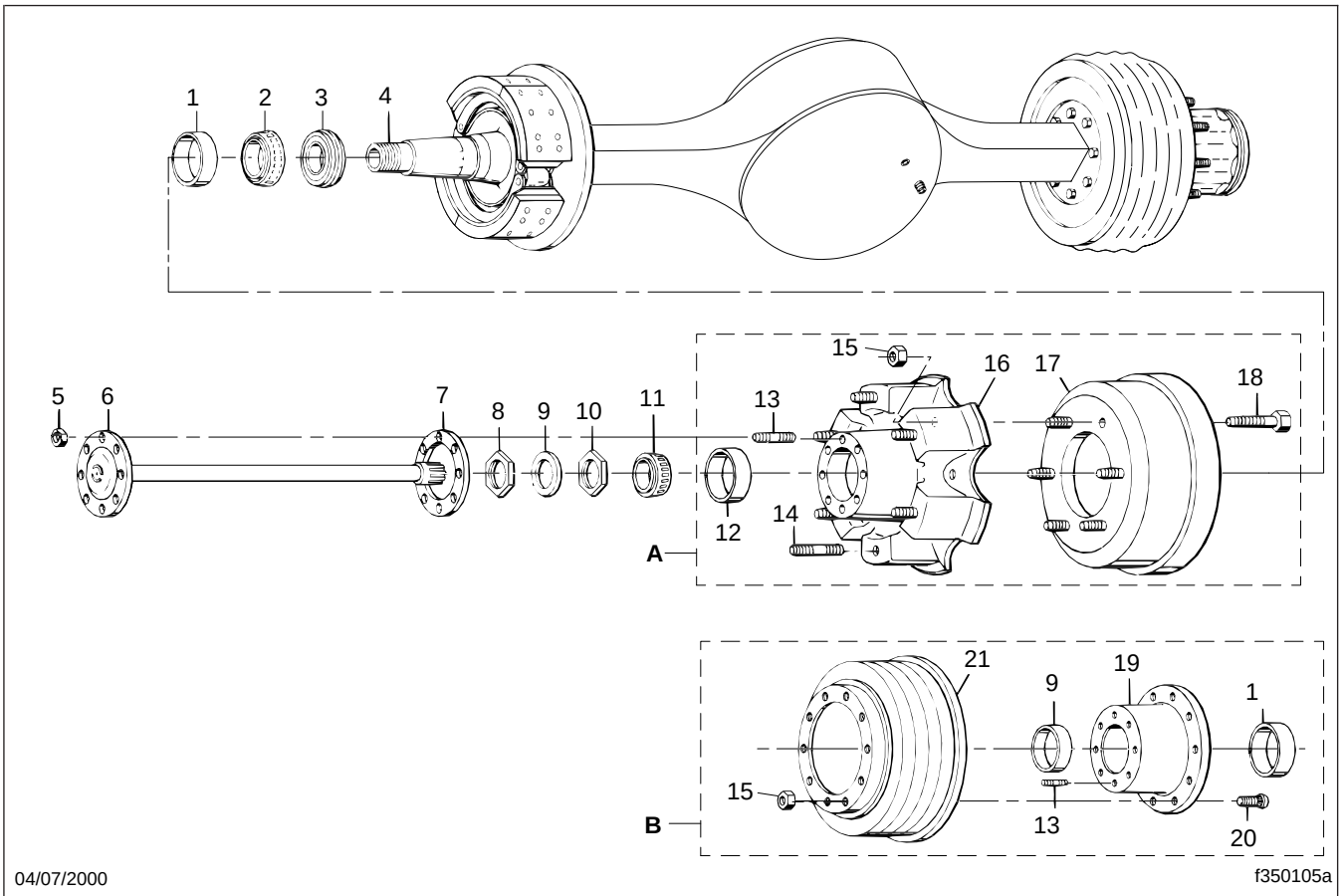
A. Spoke Wheel and Drum Assembly
B. Outboard-Mounted Hub and Drum Assembly

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle (Steering Knuckle)
5. Hub Cap Capscrew and Washer
6. Hub Cap
7. Hub Cap Gasket
8. Jam Nut
9. Lockwasher
10. Lockring
11. Wheel Bearing Adjusting Nut
12. Outer Wheel Bearing
13. Outer Wheel Bearing Cup
14. Brake Drum Nut
15. Spoke Wheel
16. Brake Drum, Inboard-Mounted
17. Brake Drum Bolt
18. Rim Stud
19. Wheel Nut
20. Wheel Stud
21. Brake Drum, Outboard-Mounted
22. Wheel Hub

Fig. 1, Front Axle, Typical

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Inboard-Mounted Drum Removal and Installation



04/07/2000 f350105a

A. Spoke Wheel and Drum Assembly

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Lockring
10. Wheel Bearing Inner Adjusting Nut

B. Disc Wheel Hub and Drum Assembly

11. Outer Wheel Bearing
12. Outer Wheel Bearing Cup
13. Drive Axle Stud
14. Rim Stud
15. Brake Drum Nut
16. Spoke Wheel
17. Brake Drum
18. Brake Drum Bolt
19. Wheel Hub
20. Wheel Stud

Fig. 2, Drive Axle, Typical

⚠ WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

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Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

1. Park the vehicle on a level surface. Shut down the engine. If working on the front axle, set the parking brakes and chock the rear tires. If working on the rear axle, release the parking brakes and chock the front tires.
2. Raise the vehicle until the tires clear the ground. Place safety stands under the axle to be serviced. Position a jack or wheel-and-tire dolly under the tires.
3. Back off the slack adjuster to release the brake shoes. For instructions, see **Section 42.11**.
4. Remove rim and tire assemblies. For instructions, see **Section 40.00**.
5. Remove the wheel hub. For instructions, see **Group 33** or **Group 35**.
6. Remove the brake drum nuts and detach the brake drum from the wheel.

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

7. To minimize the possibility of creating brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Using a rag soaked in water and wrung until nearly dry, remove any remaining dust. Do not use compressed air or dry brushing to clean the brake assembly.

Installation

1. Attach the brake drum to the wheel. Install the brake drum bolts and nuts. Tighten the nuts 240 lbf·ft (325 N·m).
2. Install the hub and wheel bearings. For instructions, see **Group 33** or **Group 35**.
3. Install the wheel and tire assembly. For instructions, see **Section 40.00**.
4. Adjust the brakes at the slack adjusters. For instructions, see **Group 42** in the *Acterra Maintenance Manual*.
5. Remove the safety stands from under the axle and lower the vehicle.
6. Remove the chocks from the tires.

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Inspection

New brake drums are purposely undersized to allow for turning, which may be needed if the drum is non-concentric when mounted on the hub. If a new drum is installed, the protective coating on the inner friction surface must first be removed with a solvent, and then rinsed with a hot water wash. Use a clean rag to remove any oily residue or metal chips from the friction surface.

If a drum must be turned or replaced, the other same-axle drum must be similarly turned or replaced to provide the same braking power on both wheels. Turned drums should not exceed the maximum allowable diameter, which is stamped on the outside surface of the drum. See **Fig. 1** for a typical location of this stamp.

NOTE: Drums that have been turned should then be cleaned by using fine emery cloth followed with a hot water wash. Drums that have been renewed using emery cloth should also be cleaned with a hot water wash.

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

Failure to replace drums when worn or turned to limits exceeding the maximum allowable diameter will cause drum weakness and reduced braking capacity, which can lead to distortion, higher drum temperatures, and ultimate drum breakage.

To minimize the possibility of creating airborne brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Using a rag soaked in water and wrung until nearly dry, remove any remaining dust. Do not use compressed air or dry brushing to clean the brake assembly.

If the drums are turned or replaced, replace the brake linings. For instructions, see **Section 42.03**.

1. Inspect the inner friction surface. If a veneered (highly glossed) or glazed surface exists, renew the drum by using 80-grit emery cloth or by turning the drums. See **Fig. 2**.

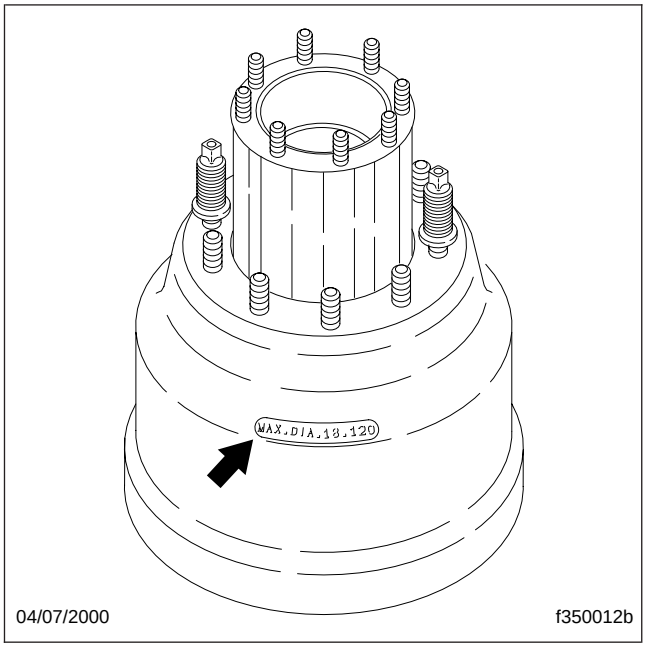


Fig. 1, Maximum Diameter Stamp

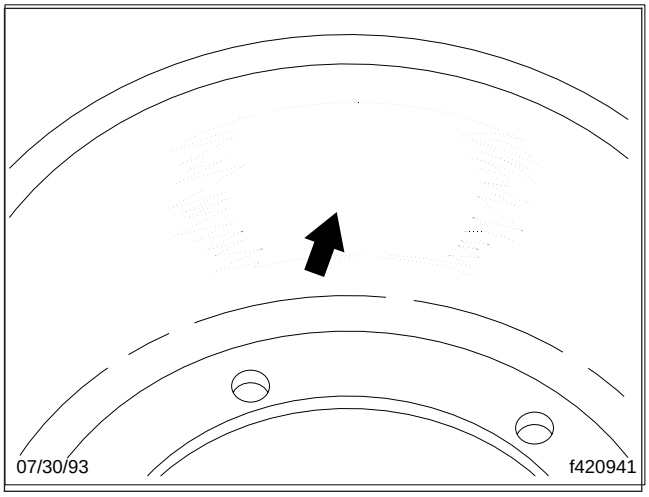


Fig. 2, Polished Drums

2. Inspect for heat checking, which is a form of buckling (cracking) resulting from a temperature differential in the drum wall between a relatively cool exterior and a hot friction surface. Heat checking is normal on all drums and may not

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Inspection

reduce performance and lining life if the network of fine hairline cracks remains small. See **Fig. 3**. Examine heat checks of drums often to be sure the checks have not widened into drum weakening cracks (substantial cracks extending to the open edge of the drum). See **Fig. 4**.

Replace the same-axle drums if substantial cracks are present, or if widening of the fine hairline cracks occurs.

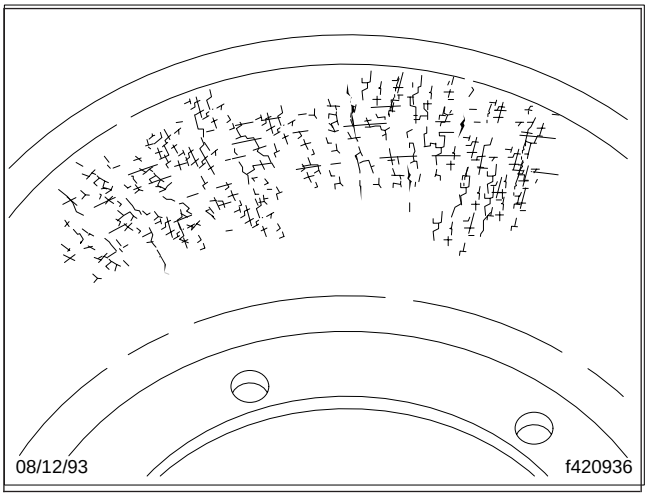


Fig. 3, Heat Checking

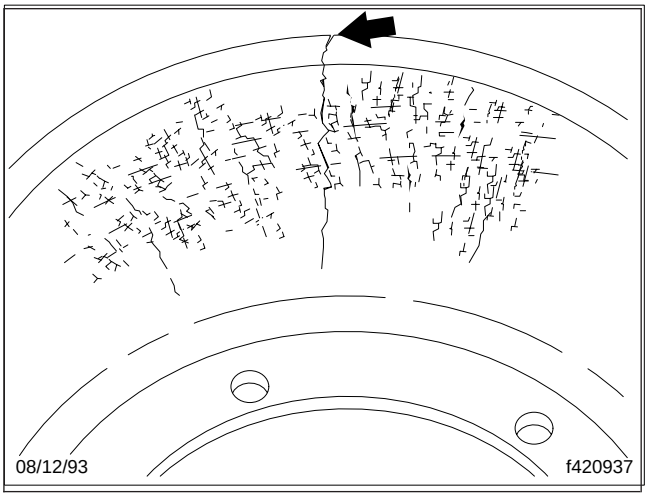


Fig. 4, Cracked Drums

NOTE: If there is normal heat checking as described above, inspect the drums at least every 12,000 miles (19 300 km) thereafter. If the vehicle is not equipped with brake dust shields, inspect the drums (using a flashlight from the inboard side of the wheels) every 6,000 miles (9700 km). Inspect more often under adverse operating conditions.

3. Check for a contaminated inner friction surface. If fluids are present, such as oil or grease, remove them. Locate and correct the source of the contamination. If the brake drums are contaminated with fluids, the brake linings will also be affected. Since oil- or grease-saturated linings cannot be salvaged, they must be replaced. For instructions, see **Section 42.03**.

⚠ WARNING

Failure to replace fluid-contaminated brake linings could result in a partial loss of braking capacity.

4. Measure the inside diameter of the drum. If this measurement is greater than the maximum allowable diameter, replace the same-axle drums and linings. See **Fig. 5**.
5. Check for a variation in gauge readings at different points on the radius of the drum's working surface. If the variation is more than 0.010 inch (0.25 mm) at any point, the drum is out-of-round to unacceptable limits. Remachine or replace the same-axle drums. See **Fig. 5**.
6. Inspect the outside surface of the drum. Remove any accumulation of mud, dirt, or rust; foreign matter acts as an insulator, trapping heat within the drum.
7. Check for hard, slightly raised, dark-colored spots on the inner friction surface (see **Fig. 6**) or for a bluish cast on the brake parts (see **Fig. 7**), both of which are caused by high temperatures. If the drums' maximum allowable diameters have not been exceeded, remachine both same-axle drums. If spots or discoloration cannot be removed, or if remachining is not possible, replace the drums. Also replace the brake shoe return springs. For instructions, see **Section 42.03**.

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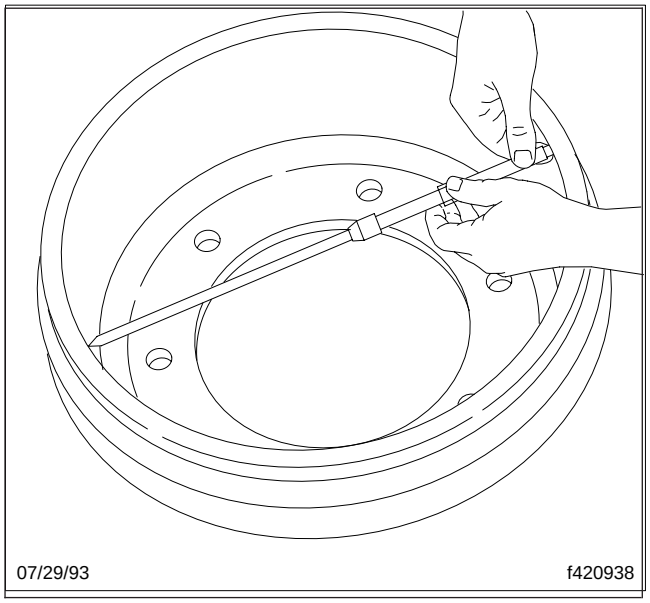


Fig. 5, Oversized Drums

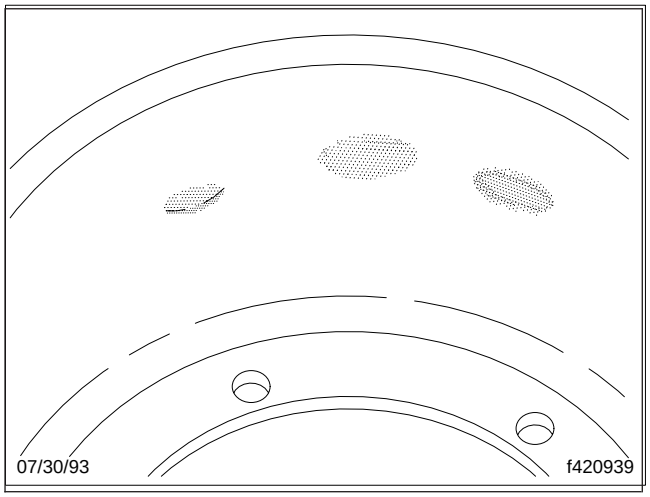


Fig. 6, Heat Spotted Drums

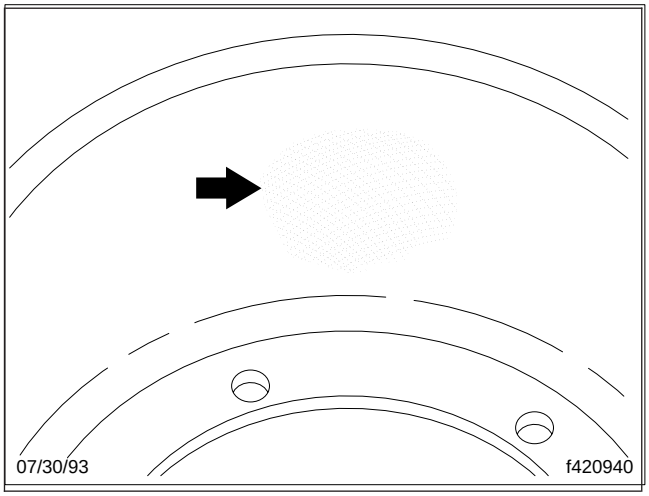


Fig. 7, Blue Drums

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Specifications

Fastener Torque			
Description	**Grade**	**Size**	**Torque lbf·ft (N·m)**
Brake Drum Bolt	8	3/4-10	240 (325)

Table 1, Fastener Torque

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General Information

Air reservoirs serve two main purposes:

1. They store compressed air used to apply the brakes and operate other air-powered devices, such as window lifts, windshield wipers, and seats.
2. They provide a place where air heated during compression can cool, and water vapor can condense into a liquid. Also, air reservoirs collect small amounts of oil passed by the compressor.

Vehicles with a stand-alone air dryer, or no air dryer, and not equipped with a dryer reservoir module (DRM), are equipped with three air reservoirs. Each reservoir is identified as one of three types: supply, primary, and secondary.

The supply reservoir (or wet tank) receives compressed air directly from the compressor. It collects most of the water and oil condensate from the air, and feeds air to the other reservoirs. At the outlet port of the supply reservoir (the port leading to the primary reservoir) is a safety valve that protects the air system against excessive air pressure build-up.

The primary reservoir is the air source for the brakes on the rear axle. At the inlet port of the primary reservoir is an inline check valve. The check valve allows air flow in one direction only, and prevents air flow in the reverse direction in case there is a drop in upstream air pressure.

The secondary reservoir is the air source for the front axle brakes. It is equipped with an internal check valve. The secondary reservoir supplies air to a pressure protection valve. This valve prevents complete loss of secondary air pressure if there is an air leak in any non-brake accessory.

All air reservoirs are equipped with drain valves to eject the water and oil emulsion from the tanks.

On vehicles equipped with an air dryer, the supply reservoir and the secondary reservoir are in a common tank. If there is no air dryer, the supply reservoir is a separate tank, mounted vertically in front of the secondary reservoir.

Some vehicles are equipped with a three-chamber air tank that is not part of a DRM. In the three-chamber air tank, there are two internal single check valves located in the supply air chamber (wet tank). The valves are installed in elbows welded into the belled partitions between the chambers. One valve controls air movement from the supply air chamber to the secondary air chamber. The other valve controls air movement from the supply air chamber to the primary air chamber. To see the check valves, remove a fitting from the top of the supply chamber and look through the port. The check valves are not serviceable. If they are not functioning correctly, replace them.

Trucks equipped with a DRM (Dryer-Reservoir Module) have primary and secondary air tanks as described above, but instead of a supply or wet tank they have a purge tank which is used to purge the moisture collected in the air dryer desiccant bed during compressor unloading. See **Section 42.22** for more information.

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Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

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Tests

WARNING

Before working on or around air brake systems and components, review "Safety Precautions" in Subject 100.

Be sure the air system is fully charged. Using a soap solution or leak detector, check for leaks on the outside surfaces of the reservoirs and drain valves. No leakage is permitted.

If leaks exist at the drain valve, note if they occur at the joint of the valve and coupler, or through the valve body. See **Subject 120**.

If leaks occur on the surfaces of the air reservoir, replace the tank; see **Subject 130**.

Internal Check Valves Test, Three-Chamber Air Reservoir

The three-chamber air reservoir has two internal check valves located in the supply chamber of the reservoir. To test the check valves for proper operation, perform the following test.

NOTE: Depending on vehicle configuration, this procedure may require two people.

1. Start the engine and fully pressurize the brake system. Shut down the engine.
2. Discharge the air from the supply chamber of the reservoir.
3. Watch the dash air-pressure gauges for the primary and secondary air systems. If either system looses pressure along with the supply chamber, the check valve is bad. Replace it. See **Subject 140**.

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Replacement and Leak Elimination

⚠ WARNING

Before working on or around air brake systems and components, review "Safety Precautions" in Subject 100.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Using two wrenches (hold the coupler in place with one of them), unscrew the drain valve from the coupler. Clean off the threads inside the coupler on the reservoir, removing all sludge and sealant build-up.

   Obtain a new drain valve if leaks occurred through the body of the valve.

   If leaks occurred at the joint of the drain valve and coupler, clean off the sludge and sealant from the threads of the valve. Check for damaged threads on the valve and inside the coupler. Replace damaged parts. If no damage exists, leakage was probably due to inadequate tightening of the drain valve in the coupler.
4. Apply Loctite®, or an equivalent sealant, to the end threads of the drain valve or coupler, as applicable, and install finger-tight. Tighten one and one-half additional turns (use two wrenches if installing the drain valve).
5. Perform a leak test after completing the installation. If leaks occur at the joint of the drain valve and coupler, tighten the valve up to one additional turn to stop the leaks.
6. Remove the chocks from the tires.

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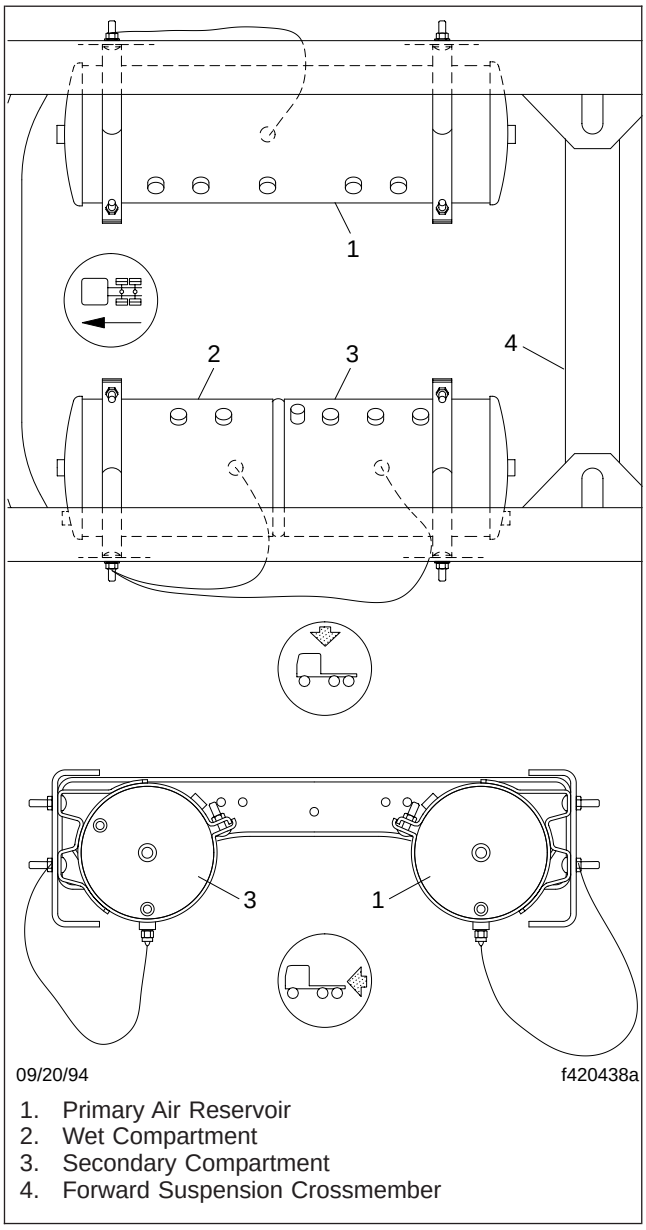
Replacement

IMPORTANT: For vehicles equipped with a dryer reservoir module (DRM), see **Section 42.22, Subject 160** for air reservoir replacement.

⚠ WARNING

Before working on or around air brake systems and components, review Safety Precautions 100.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Mark all reservoir air lines, couplers, and valves for reassembly. Carefully disconnect the parts. Cap the exposed ports tightly to keep contaminants out. If access is limited, remove the parts after removing the reservoir from its mount.
4. Remove the reservoir strap fasteners. Remove the reservoir.
5. If access is limited, do the next step first. If not, place a new reservoir in the mount, and install the strap fasteners. On two-piece straps (**Fig. 1**), tighten the nuts 20 to 25 lbf·ft (27 to 34 N·m). On one-piece straps (**Fig. 2**), tighten the nut 20 lbf·ft (27 N·m).
6. As referenced earlier, connect all air lines, couplers, and valves to the new reservoir, removing the caps as each part is installed.
7. Remove the chocks from the tires.

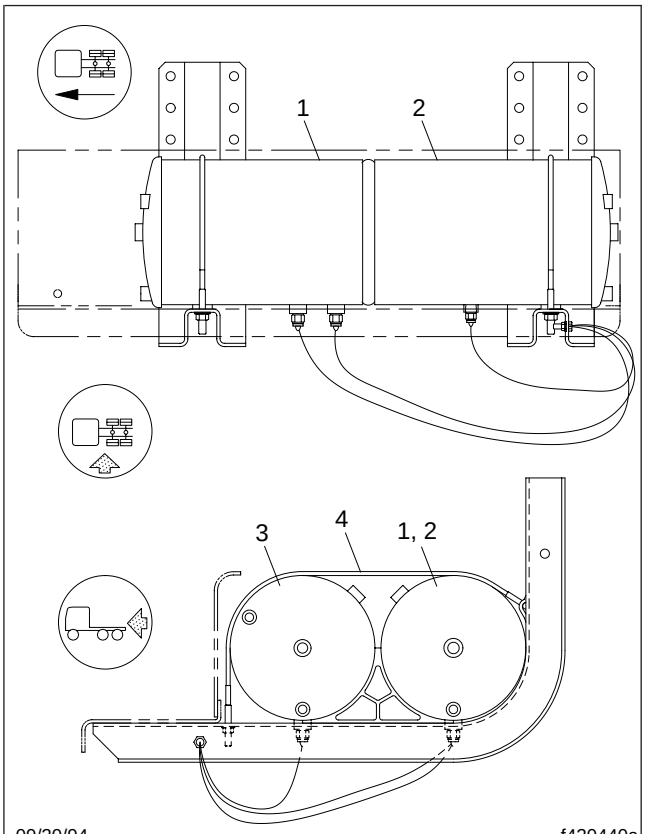


1. Primary Air Reservoir
2. Wet Compartment
3. Secondary Compartment
4. Forward Suspension Crossmember

Fig. 1, Chassis Mounted Air Reservoirs (vehicle with air dryer)

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Air Reservoir Replacement



1. Secondary Compartment
2. Wet Compartment
3. Primary Air Reservoir
4. One-Piece Strap

Fig. 2, Air Reservoirs Mounted on Left Step (vehicle with air dryer)

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⚠ WARNING

Before working on or around air brake systems and components, review "Safety Precautions" in Subject 100. Failure to do so could result in serious personal injury.

Internal Check Valve Replacement, Two-Chamber Air Reservoir

Contamination in the two-chamber, wet/secondary, reservoir may cause the inline check valve to become clogged or stuck closed. This can result in insufficient air buildup. Sterling vehicles were built with an internal check valve that is not serviceable. If insufficient air buildup is noted, install an external bypass line. Contact the PDC for the appropriate bypass kit for your vehicle.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Drain the secondary air reservoir.
3. At the top ports of the reservoir, remove the pressure-protection valve and the 90-degree elbow from the wet reservoir side, and the existing fittings from the secondary side.
4. Install a T-fitting on each side of the reservoir. See **Fig. 1**.
5. On the secondary reservoir side, install the existing plumbing on the top port of the T-fitting. On the side port of the T-fitting, install a check valve, then a 45-degree elbow.
6. On the wet reservoir side, install the existing plumbing onto the top port of the T-fitting. Install a brass fitting on the side port of the T-fitting.
7. Install a 1/2-inch air line between the 45-degree elbow on the secondary side, and the brass fitting on the wet side.
8. Charge the air system and inspect for leaks. Repair as needed.
9. Remove the chocks from the tires.

Internal Check Valve Replacement, Three-Chamber Air Reservoir

Before changing the internal check valve(s), test the system to determine which valve is bad. See **Subject 110** for the procedure.

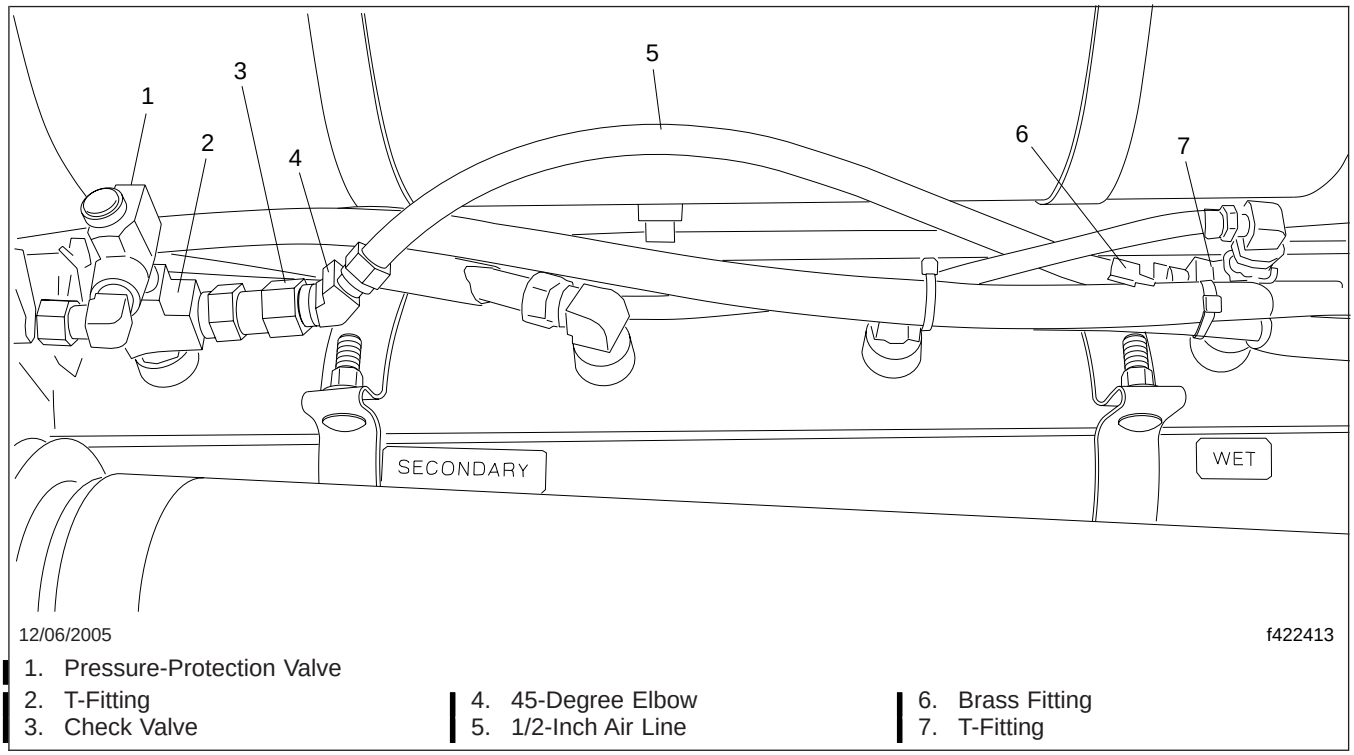
1. Park the vehicle on a level surface, shut down the engine, and chock the tires.
2. Drain the brake air system completely.
3. Remove the appropriate fittings from the top of the supply-air chamber to access the valve(s) to be replaced. See **Fig. 2**.

NOTE: Use appropriate measures to ensure that the socket is securely attached to the extension, and that the valve is secured in the socket, so that they do not drop into the reservoir during this procedure.

4. Using a six-point, 1/2-inch, deep socket on a 10-inch extension, unscrew the valve from the fitting in the bell of the chamber partition and remove it from the reservoir.
5. Install the new valve in the fitting in the bell of the chamber partition. Tighten the valve to 27 lbf·ft (40 N·m).
6. Install the air reservoir fittings that were removed.
7. Pressurize the air system and check for leaks around any fittings that were removed, then perform the "Internal Check Valves Test, Three-Chamber Air Reservoir" to determine that the problem has been fixed. See **Subject 110**.
8. Before returning the vehicle to service, test the brakes for proper operation.

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Internal Check Valve Replacement

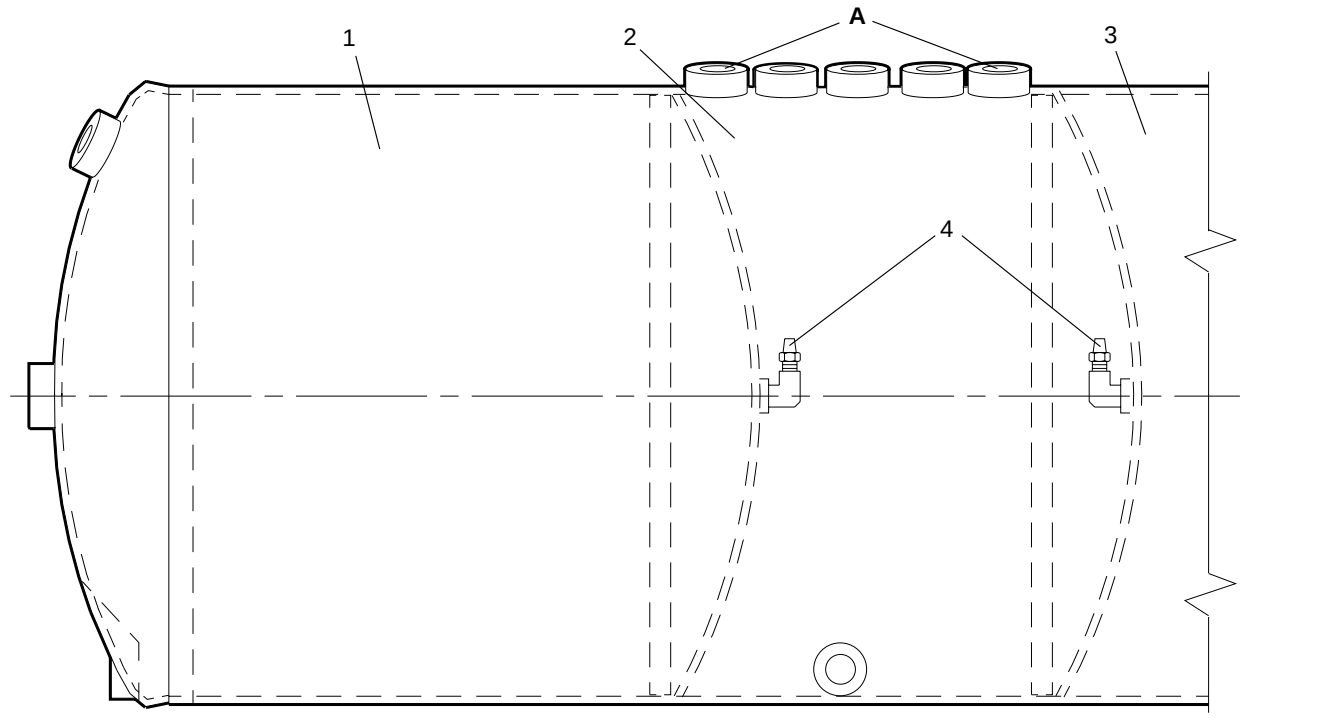


1. Pressure-Protection Valve
2. T-Fitting
3. Check Valve
4. 45-Degree Elbow
5. 1/2-Inch Air Line
6. Brass Fitting
7. T-Fitting

Fig. 1, Check Valve Bypass

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Internal Check Valve Replacement



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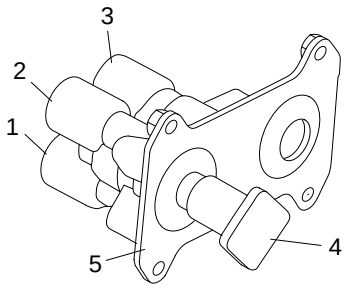
A. Access valves through these fittings.
1. Secondary Air Chamber
2. Supply Air Chamber
3. Primary Air Chamber
4. Check Valves (2)

Fig. 2, Internal Check Valves, Three-Chamber Air Reservoir

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General Information

The Bendix PP–DC parking brake hand valve is a push-pull, manually operable on/off valve. See **Fig. 1**. It is dash-mounted and provides in-cab control of the parking brakes.



1. Exhaust
2. Supply
3. Delivery
4. Valve Button
5. Cover

Fig. 1, Bendix PP–DC Parking Brake Hand Valve

The valve is pressure sensitive; it automatically moves from the applied to the exhaust position if total system pressure drops below 20 to 30 psi (138 to 207 kPa). Manually pulling the valve button will also apply the parking brakes.

The PP–DC body is made of molded black acetal copolymer. The valve is designed to accept 1/4 inch P.T. or push-to-connect fittings that use SAE J844D nonmetallic air brake tubing.

The PP–DC valve ports are embossed as shown in **Table 1**. The valve's maximum operating pressure is 150 psi (1034 kPa). The valve's operating temperature is –40 to 200°F (–40 to 93°C) and its basic weight is approximately 0.8 lb (0.36 kg).

PP–DC Ports and I.D.'s	
Port	**Embossed I.D.**
Primary Reservoir Supply	Supply 11
Secondary Reservoir Supply	Supply 12
Delivery	Delivery 21
Exhaust	Exhaust 3

Table 1, PP–DC Ports and I.D.'s

The PP–DC receives its supply of air from the primary service reservoir or the secondary service reservoir, whichever is at the higher pressure. When the button is pushed in, the valve delivers air to the spring brake chambers (usually through a spring brake valve and a relay or quick release valve). The air releases the spring brakes for normal vehicle operation. See **Fig. 2**.

To apply the parking brakes, the button is pulled out. This exhausts the PP–DC delivery and releases air from the spring brake chambers.

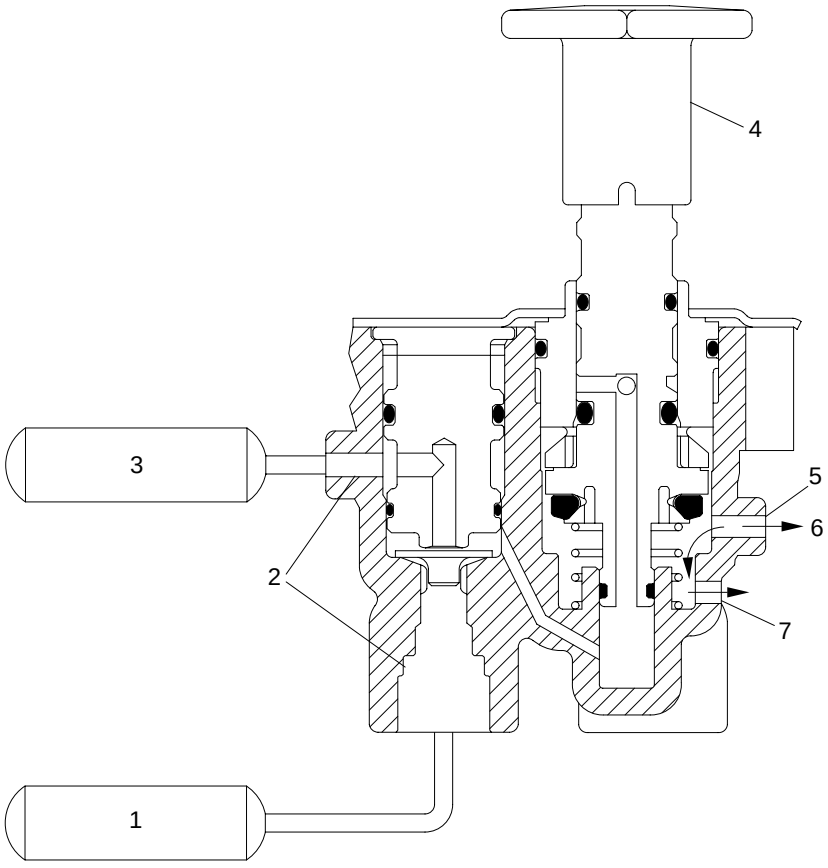
If total system pressure drops below 20 to 30 psi (138 to 207 kPa), the valve will automatically pop out, which removes the hold-off air in the chambers and applies the spring brakes. When the button pops out, the exhaust seal moves to open the exhaust port to atmosphere, allowing delivery line pressure to exhaust. The plunger O-ring moves to seal off supply pressure. Spring brake hold-off air is exhausted through the spring brake relay valve.

To release the parking brakes, the push-pull button is pushed in. The PP–DC plunger moves, closing the exhaust port with the exhaust seal and allowing the plunger O-ring to move past the guide spool. Supply air then travels out the delivery port to release the brakes. The double check valve diaphragm seals the secondary reservoir supply port and allows air to pass from the primary reservoir into the PP–DC.

If primary service reservoir pressure drops below secondary service reservoir pressure, the double check valve will react. It seals the primary service reservoir supply port and supplies the PP–DC with air from the secondary service reservoir. The push-pull button remains in and the spring brakes remain released.

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General Information



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1. Primary Service Reservoir
2. Supply Port
3. Secondary Service Reservoir
4. Valve Button
5. Delivery Port
6. To R7 Valve
7. Exhaust Port

Fig. 2, PP–DC Parking Brake Hand Valve (sectional view)

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Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

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IMPORTANT: To do the following tests, connect two separate 120 psi (827 kPa) air sources to the PP–DC supply ports. See **Fig. 1**. Tee an accurate test gauge into the supply lines, and provide for a means to control supply line pressure. Connect a small volume air source with a gauge to the delivery port.

Operating Test

1. Park the vehicle on a level surface. Shut down the engine. Chock the tires.
2. Start the engine and build up the air pressure to the normal operating level.
3. With the parking brake hand valve button pulled out, supply either supply port with 120 psi (827 kPa) of pressure. Push the button in. Air pressure should rise in the delivery line and equal supply line pressure.

   Pull the button out. Delivery pressure should exhaust to zero.
4. Build air pressure to each supply source to 120 psi (827 kPa). Decrease supply pressure at the secondary service reservoir supply port at a rate of 10 psi (69 kPa) per second.

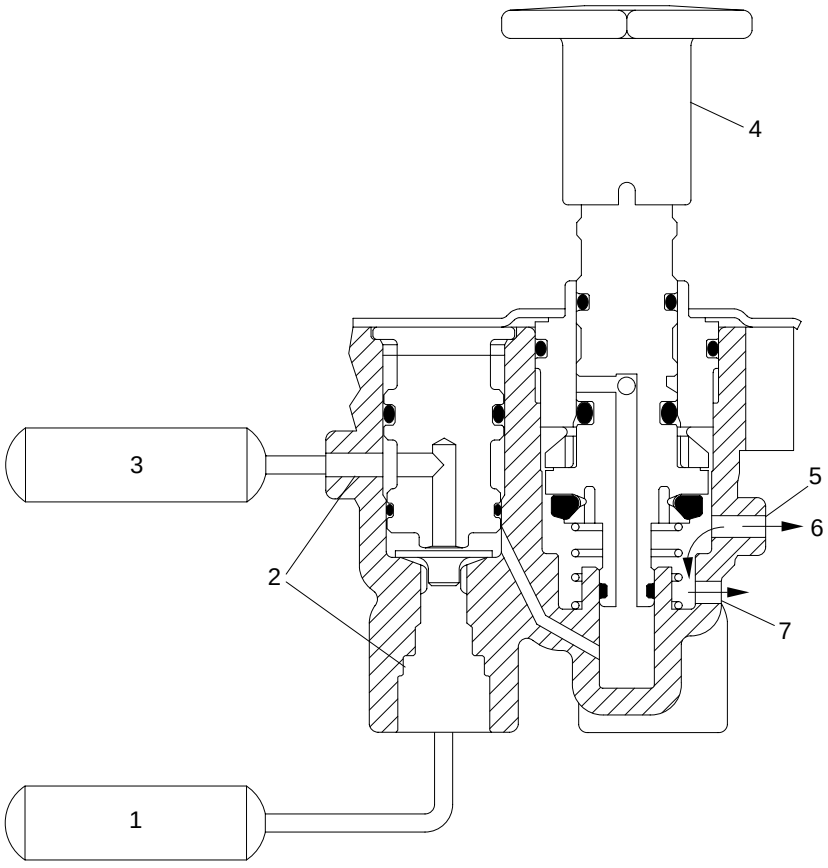
   Primary supply pressure and delivery pressure should not drop below 100 psi (689 kPa). Repeat this step for decreasing primary service reservoir pressure.
5. Build air pressure to each supply source to 120 psi (827 kPa). Decrease both supply pressures to below 20 to 30 psi (138 to 207 kPa). The button should automatically pop out when the pressure is within that range.
6. If the valve does not work as described, repair or replace the valve following the instructions in **Subject 120**.
7. Remove the chocks from the tires.

Leakage Test

1. Park the vehicle on a level surface and shut down the engine. Chock the tires.
2. Supply the valve with 120 psi (827 kPa) from the primary reservoir supply port.
3. With the button pulled out, coat the exhaust port and the plunger stem with a soap solution. Leakage at either fitting should not exceed a 1-inch (2.5-cm) bubble in 5 seconds. No leakage should be detected from the secondary reservoir supply port.
4. Supply the valve with 120 psi (827 kPa) from the secondary reservoir supply port. No leakage should be detected from the primary reservoir supply port.
5. With the button pushed in, coat the exhaust port and the plunger stem with a soap solution. Leakage at the fittings should not exceed a 1-inch (2.5-cm) bubble in 3 seconds.
6. If leakage is excessive, repair or replace the valve following the instructions in **Subject 120**.
7. Remove the chocks from the tires.

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Operating and Leakage Tests



1. Primary Service Reservoir
2. Supply Port
3. Secondary Service Reservoir
4. Button
5. Delivery Port
6. To R7 Valve
7. Exhaust Port

Fig. 1, Parking Brake Hand Valve (sectional view)

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Removal

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air tanks.
3. Turn the valve button counterclockwise and remove it from the valve stem.
4. Remove the eight screws holding the auxiliary finish panel. See **Fig. 1**. Remove the auxiliary finish panel. For instructions, see **Section 60.07**.

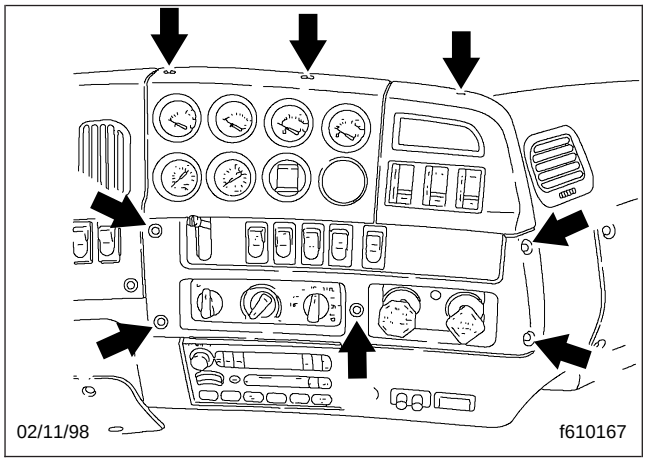


Fig. 1, Auxiliary Finish Panel Screws

5. Mark the air lines for later reference. Disconnect the lines from the valve assembly. See **Fig. 2**.

NOTE: The primary supply line is green. The secondary supply line is red. The exhaust line is black and 1/2-inch (13-mm) in diameter. The delivery line is black and 3/8-inch (9.6-mm) in diameter.

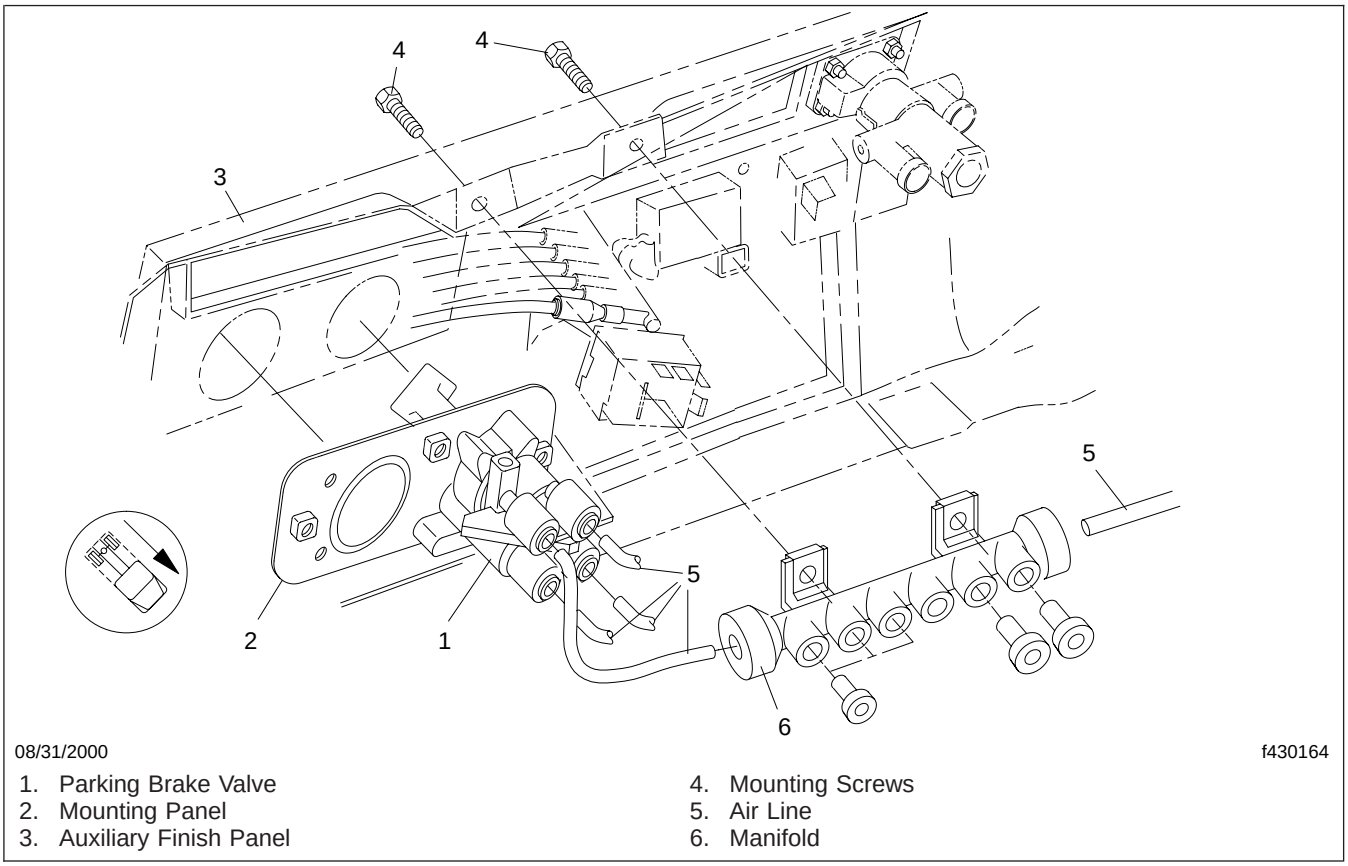
6. Remove the four screws that attach the valve to the mounting panel. Remove the valve.

Installation

1. Position the valve assembly on the mounting panel. Install the four mounting screws.
2. Connect the air lines to the applicable fittings.
   - 2.1 Hand-tighten the fittings.
   - 2.2 Using a wrench, tighten the fittings until the connections feel firm.
   - 2.3 Tighten the fittings an additional one-sixth turn.
3. Install the auxiliary finish panel. For instructions, see **Section 60.07**.
4. Screw the valve button onto the valve stem.
5. Leak test the fittings following the instructions in **Subject 110**.
6. Refill the air tanks.
7. Remove the chocks from the tires.

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Removal and Installation



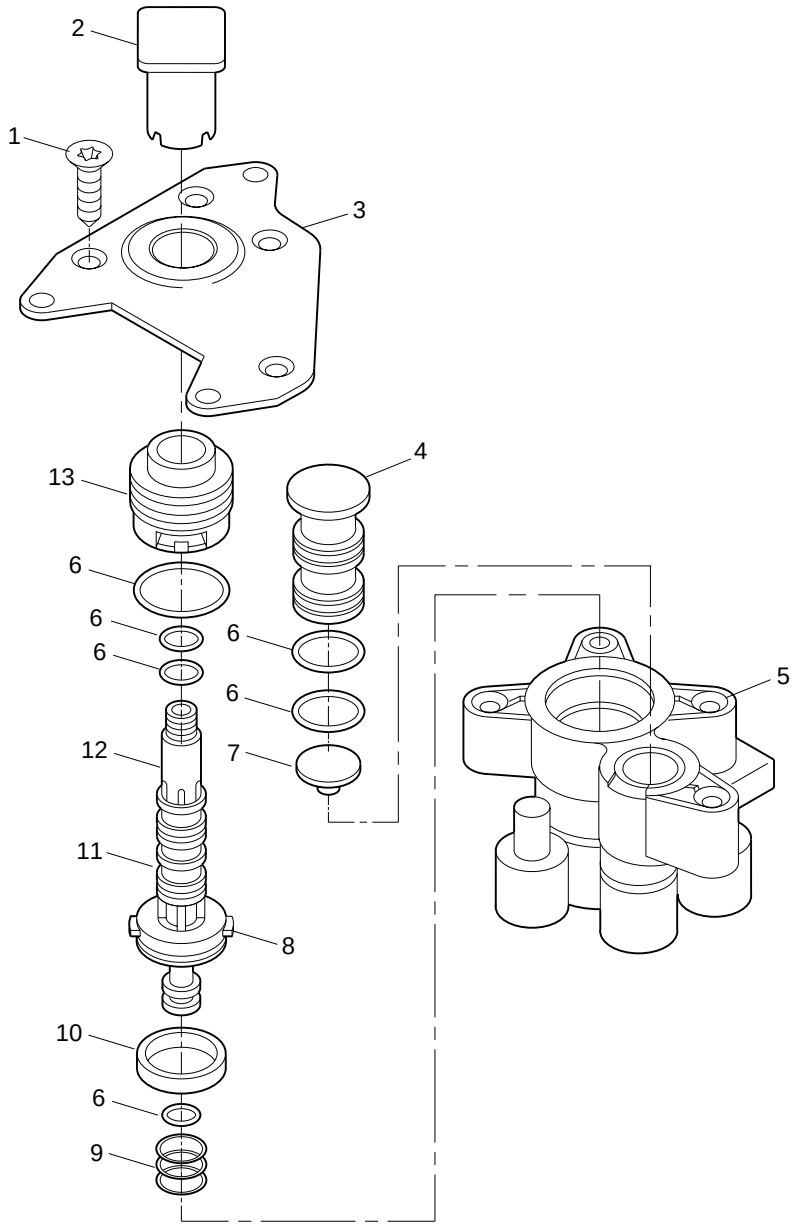
1. Parking Brake Valve
2. Mounting Panel
3. Auxiliary Finish Panel
4. Mounting Screws
5. Air Line
6. Manifold

Fig. 2, Parking Brake Hand Valve Mounting

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Disassembly, Cleaning and Inspection, and Assembly

Disassembly (See Fig. 1)



1. Screw
2. Valve Button
3. Cover
4. Check Valve Seat
5. Valve Body
6. O-Ring
7. Check Valve
8. Index Tab
9. Plunger Spring
10. Exhaust Seal
11. Plunger
12. Plunger Stem
13. Guide Spool

Fig. 1, Parking Brake Hand Valve (exploded view)

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Disassembly, Cleaning and Inspection, and Assembly

WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

1. Park the vehicle on a level surface. Shut down the engine. Chock the tires.
2. Remove the valve assembly from the dash.
3. Put the valve assembly in a soft-jawed or padded vise.
4. Remove the screws that attach the cover to the body. Remove the cover.
5. Pull the plunger stem and remove the plunger and guide spool from the body.
6. Remove and discard the plunger spring.
7. Using a screwdriver (if needed), carefully remove the check valve seat from the body. Use care not to damage either the check valve seat or the valve body.
8. Remove and discard the check valve seat O-rings.
9. Turn the body upside down and gently tap it on a flat surface to remove the check valve. Discard the check valve.
10. Remove the guide spool from the plunger. Remove and discard the O-ring from the guide spool.
11. Remove and discard the O-rings from the plunger. Also remove and discard the exhaust seal.

Cleaning and Inspection

1. Wash all metal parts in mineral spirits and thoroughly dry them.
2. Inspect all re-usable parts for excessive wear or damage.
3. Inspect the body for gouges or deep scuffing.
4. Replace any parts not determined usable with genuine Bendix replacements.

Assembly (See Fig. 1)

WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

1. Prior to assembly, be sure to follow the "Cleaning and Inspection" instructions above.
2. Lubricate all O-rings, O-ring grooves, rubbing surfaces and bores with Bendix silicone lubricant No. 291126 or equivalent.
3. Position the check valve in its seat in the body with the flat surface of the valve facing up. If needed, reach into the body to make sure that the valve is seated evenly in the bore.
4. Install the O-rings on the check valve seat and install the assembly into the body. Make sure that the check valve seat is even with the valve body surface.

NOTE: Upon installation, the plunger spring should surround the protrusion or "lip" at the bottom of the body bore.

5. Install the plunger spring into the body. Make sure that the spring is upright and seated properly in the body bore.
6. Install the O-rings and exhaust seal onto the plunger. Install the plunger into the body.

   For ease of installation, line up the plunger's index tabs with the spaces in the body bore.
7. Install the O-ring on the guide spool. Install the spool over the plunger and into the body. Firmly press the guide spool into position.
8. Place the cover onto the body. Install the screws that attach the cover to the body. Tighten the screws 35 lbf·in (400 N·cm).
9. Install the valve in the dash.
10. Test the valve following the instructions in **Subject 110**.
11. Remove the chocks from the tires.

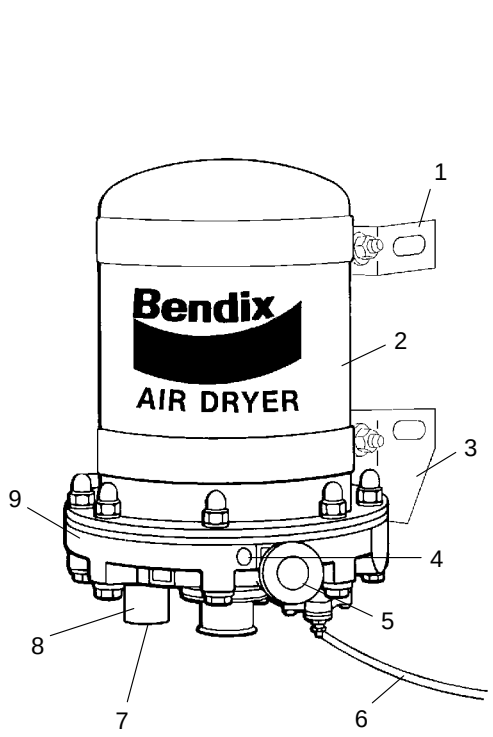
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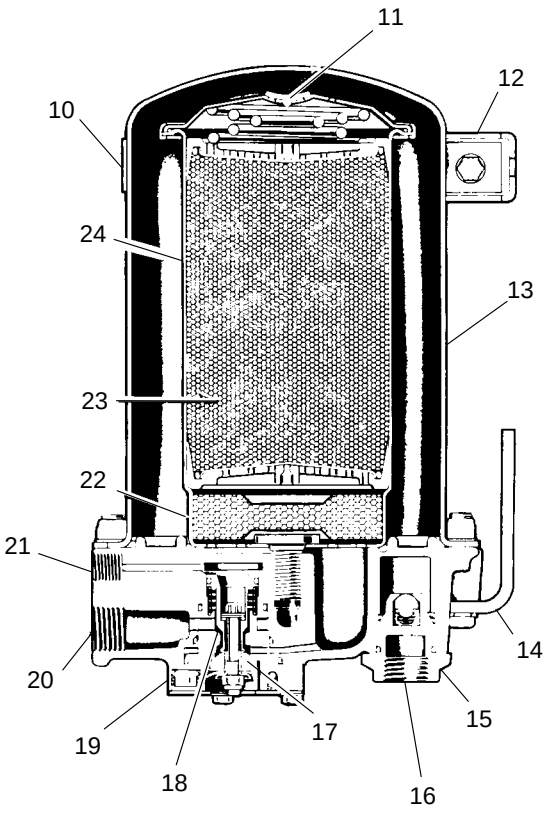
General Information

The function of the Bendix AD–9 air dryer is to collect and remove air system contaminants in solid, liquid, and vapor form before they enter the brake system. See **Fig. 1**.

able purge valve housing assembly features a purge valve mechanism and a turbocharger cutoff that are designed to prevent loss of engine turbo boost pressure during the purge cycle of the air dryer.

To ease servicing, the desiccant cartridge and dis-





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1. Upper Bracket
2. Outer Shell
3. Lower Bracket
4. Control Port
5. Supply Port
6. Wiring Harness
7. Delivery Port
8. Check Valve Assembly
9. End Cover
10. Upper Bracket Strap
11. Check Valve
12. Upper Bracket
13. Housing
14. Lower Bracket
15. Check Valve Assembly
16. Delivery Port
17. Purge Valve
18. Turbo Cutoff Piston
19. Purge Valve Housing Assembly
20. Supply Port
21. Control Port
22. Oil Separator
23. Desiccant Bed
24. Desiccant Cartridge

Fig. 1, Bendix AD–9 Air Dryer and Cutaway View

The AD–9 air dryer consists of a desiccant cartridge and a die-cast aluminum end cover secured to a cylindrical steel outer shell with eight capscrews and nuts. The end cover contains a check valve assembly, a safety valve, three threaded air connections and the purge valve housing assembly. The removcharge check valve assembly are screw-in types. The purge valve housing assembly, which includes the heater and thermostat assembly, and the discharge check valve assembly, can be serviced without removing the air dryer from the vehicle. The

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General Information

screw-in desiccant cartridge requires removal of the air dryer assembly from the vehicle.

The AD–9 has three female pipe thread air connections; each is identified in **Table 1**.

The AD–9 air dryer alternates between two operational modes or cycles during operation: the charge cycle and the purge cycle.

AD–9 Pipe Thread Connections	
Port I. D.	**Function/Connection**
4–CON	Control Port (purge valve control and turbo cutoff)
11–SUP	Supply Port (air in)
2–DEL	Delivery Port (air out)

Table 1, AD–9 Pipe Thread Connections

CHARGE CYCLE **(See Fig. 2)**

When the compressor is loaded (compressing air), pressurized air, along with oil, oil vapor, water, and water vapor flow through the compressor discharge line to the supply port of the air dryer end cover. As air travels through the end-cover assembly, its direction of flow changes several times, reducing the temperature, causing contaminants to condense and drop to the bottom or sump of the air dryer end cover.

After exiting the end cover, air flows into the desiccant cartridge. Once in the cartridge, air first flows through an oil separator, which removes water, oil, oil vapor, and solid contaminants.

Air exits the oil separator and enters the desiccant drying bed. Air flowing through the column of desiccant becomes progressively drier as water vapor sticks to the desiccant material in a process known as adsorption. The desiccant cartridge using the adsorption process typically removes 95 percent of the water vapor from the pressurized air.

Most of the dry air exits the desiccant cartridge through its integral single check valve to fill the purge volume between the desiccant cartridge and outer shell. Some air also exits the desiccant cartridge through the purge orifice adjacent to the check valve.

Dry air flows out of the purge volume through the single check valve assembly and out the delivery port to the first (supply) reservoir of the air system.

The air dryer remains in the charge cycle until air brake system pressure builds to the governor cutout setting.

PURGE CYCLE **(See Fig. 3)**

When the brake system pressure reaches the governor cutout setting, the compressor unloads (air compression stopped), and the purge cycle of the air dryer begins. When the governor unloads the compressor, it pressurizes the unloader mechanism and line connecting the governor unloader port to the AD–9 end cover control port. The purge piston moves in response to air pressure causing the purge valve to open to atmosphere and partially close off the supply of air from the compressor. This is further discussed under "Turbo Cutoff Feature."

Contaminants in the end cover sump are expelled immediately when the purge valve opens. Also, air that was flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected by the oil separator are removed by air flowing from the desiccant drying bed to the open purge valve.

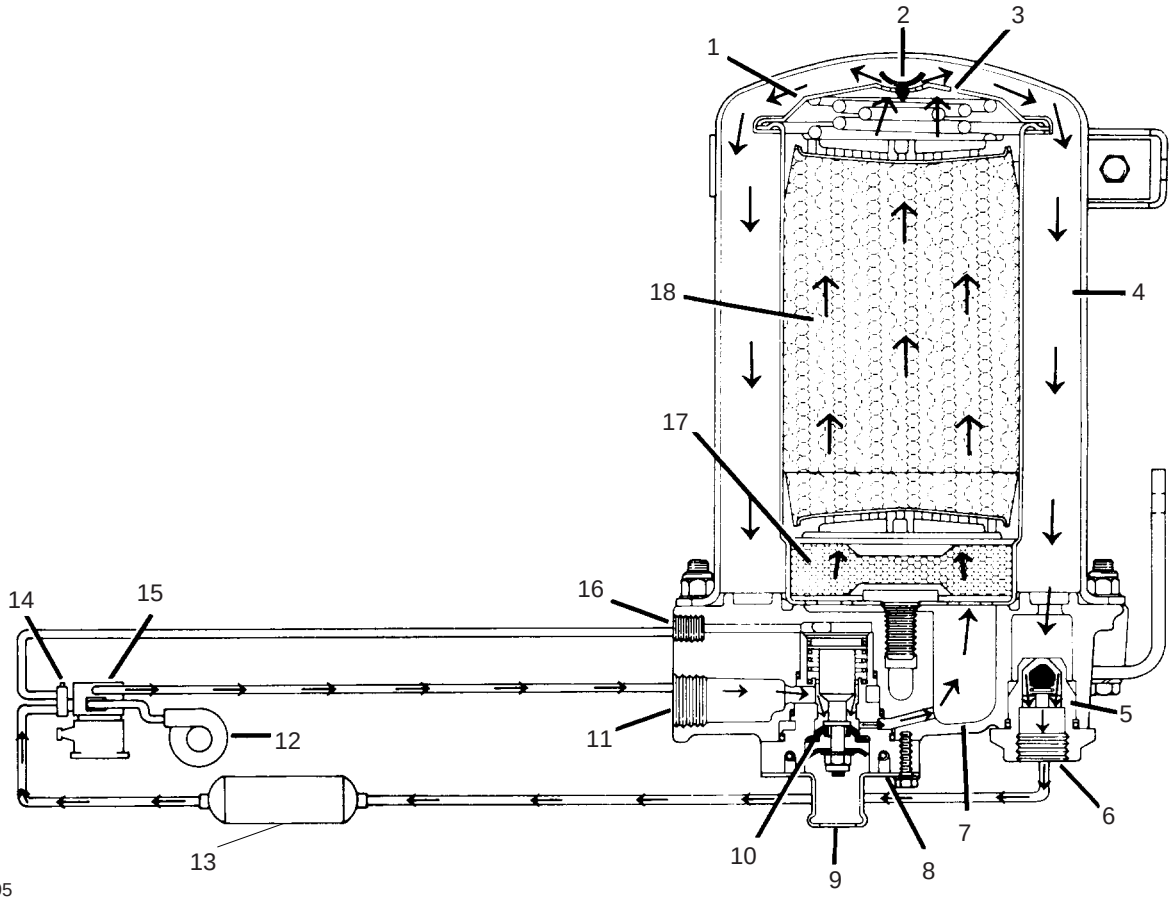
The initial purge and desiccant cartridge decompression last only a few seconds and are signaled by an audible burst of air at the AD–9 exhaust. The actual reactivation of the desiccant drying bed begins as dry air flows from the purge volume through the desiccant cartridge purge orifice and into the desiccant drying bed. Pressurized air from the purge volume expands after passing through the purge orifice; its pressure is lowered and its volume increased. Dry air flowing through the drying bed reactivates the desiccant material by removing the water vapor sticking to it. Generally, it takes 15 to 30 seconds for the entire purge volume of a standard AD–9 to flow through the desiccant drying bed.

The end cover single check valve assembly prevents compressed air in the brake system from returning to the air dryer during the purge cycle. After the 30 second purge cycle is complete, the air dryer is ready for the next charge cycle to begin.

The purge valve will remain open after the purge cycle is complete. It will not close until air brake system pressure is reduced and the governor signals the compressor to charge.

NOTE: The air dryer should be periodically checked for operation and tested for leaks. See

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1. Desiccant Cartridge
2. Check Valve
3. Orifice
4. Purge Volume
5. Check Valve Assembly
6. Delivery Port
7. Sump
8. Heater Element
9. Exhaust
10. Purge Valve
11. Supply Port
12. Engine Turbo
13. Reservoir
14. Governor
15. Compressor
16. Control Port
17. Oil Separator
18. Desiccant Bed

Fig. 2, AD–9 Charge Cycle

Group 42 of the *Acterra Maintenance Manual* for intervals and procedures.

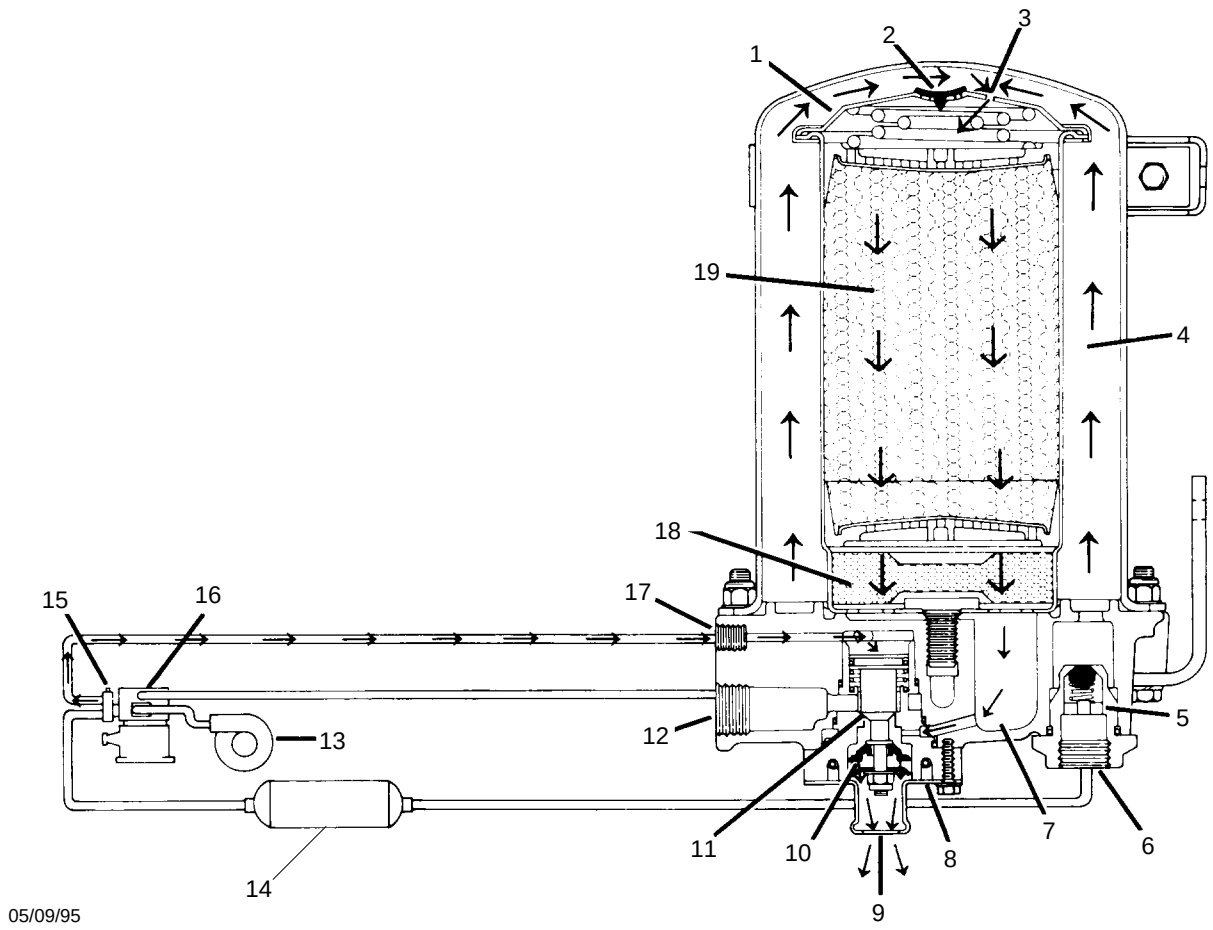
TURBO CUTOFF FEATURE **(See Fig. 4)**

The primary function of the turbo cutoff valve is to prevent loss of engine turbocharger air pressure through the AD–9 in systems where the compressor intake is connected to the engine turbocharger. The turbo cutoff valve also reduces the puffing of air out the open exhaust when a naturally aspirated, single cylinder compressor equipped with an inlet check valve is in use.

At the beginning of the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve (tapered portion of the purge piston) contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the discharge line and AD–9 supply port is restricted from entering the air dryer. While the turbo cutoff *effectively* prevents loss of turbocharger boost pressure to the engine, some seepage of air may be detected under certain conditions of compressor, engine, and turbocharger operation. Even so, there will be low pressure trapped in the discharge line.

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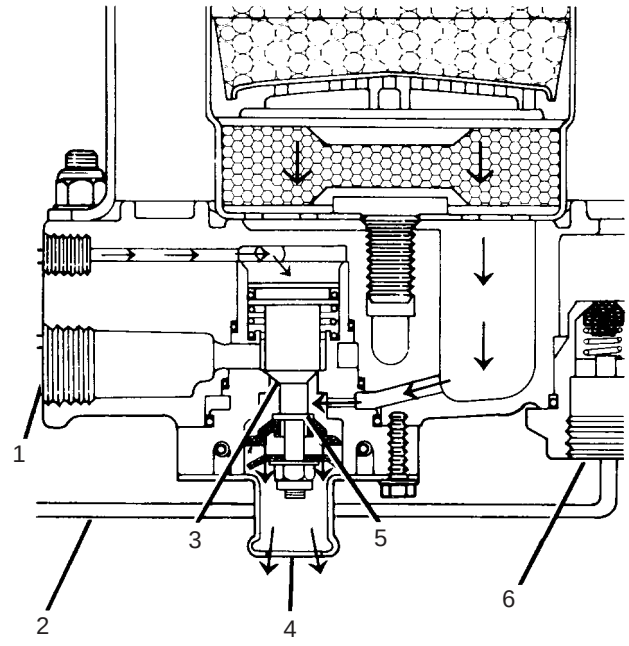
General Information



1. Desiccant Cartridge
2. Check Valve
3. Orifice
4. Purge Volume
5. Check Valve Assembly
6. Delivery Port
7. Sump
8. Heater Element
9. Exhaust
10. Purge Valve
11. Turbo Cutoff Piston
12. Supply Port
13. Engine Turbo
14. Reservoir
15. Governor
16. Compressor
17. Control Port
18. Oil Separator
19. Desiccant Bed

Fig. 3, AD–9 Purge Cycle

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1. Supply Port
2. Discharge Line
3. Turbo Cutoff Piston
4. Exhaust
5. Purge Valve
6. Check Valve Assembly

Fig. 4, AD–9 Turbo Cutoff

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Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

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Removal

WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain all reservoirs to zero pressure.

CAUTION

Compressor discharge line may still contain residual pressure.

3. Remove the air dryer.
   - 3.1 Identify and disconnect the three air lines from the end cover. Note the position of end cover ports relative to the vehicle.
   - 3.2 Unplug the vehicle wiring harness from the heater and thermostat assembly connector on the purge valve housing assembly.
   - 3.3 Loosen the hexbolt securing the upper mounting strap.
   - 3.4 Remove, save, and mark the two end cover capscrews, locknuts, and four special washers that retain the lower mounting bracket to the end cover. Also mark the two holes of the end cover. (These bolts are longer than the other six bolts.)
   - 3.5 Remove the air dryer from its mounting brackets.

Installation (See Fig. 1)

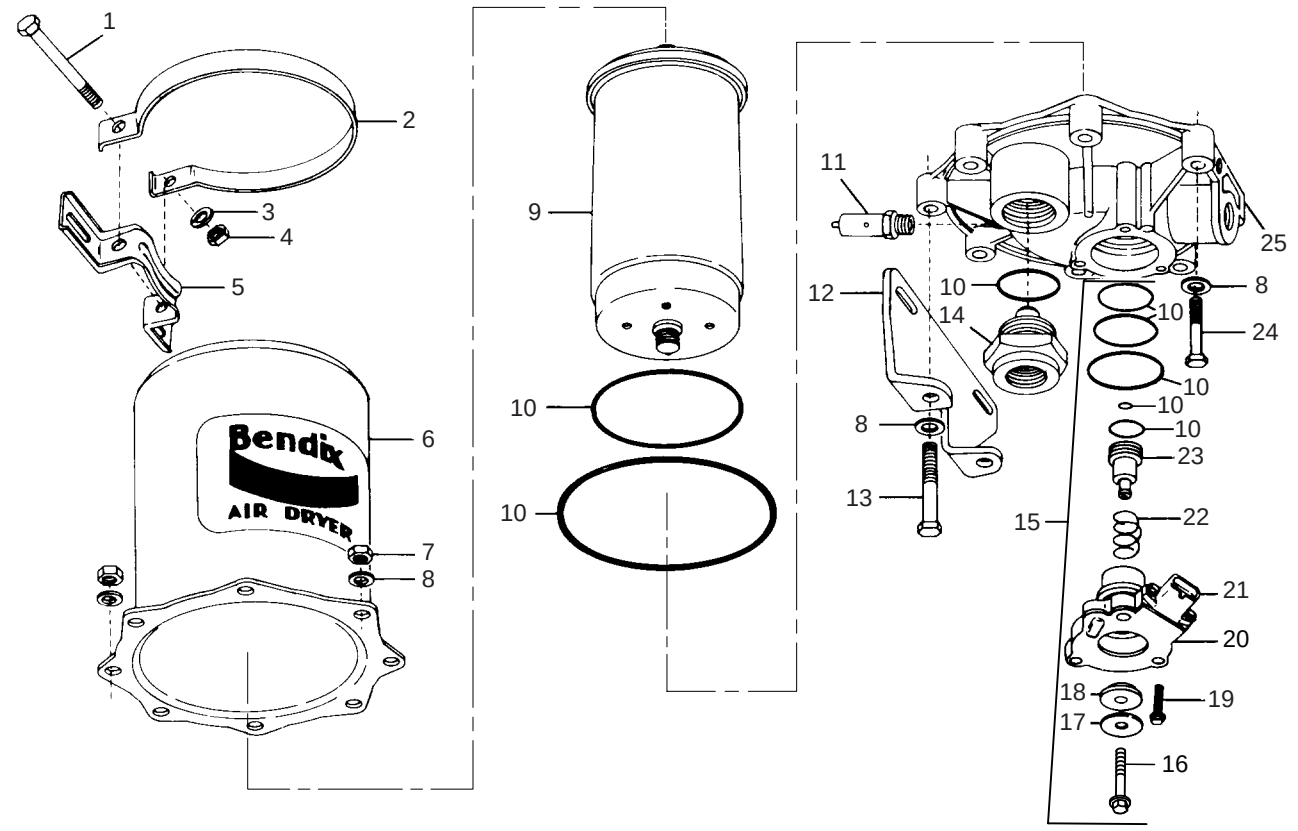
WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

1. Install the assembled air dryer on the vehicle.
   - 1.1 Position the air dryer into the upper mounting bracket and strap. Align the two unused holes in the end cover with the bottom mounting bracket so that the bottom bracket supports the air dryer. The end cover should rest on the bracket.
   - 1.2 Using the remaining two capscrews, four special washers, and two locknuts, secure the air dryer to the lower bracket. Tighten the two remaining capscrews 23 to 32 lbf·ft (31 to 43 N·m).
   - 1.3 Tighten the bolt and nut on the upper mounting bracket strap 80 to 120 lbf·in (900 to 1360 N·cm).
   - 1.4 Connect the three air lines to the correct ports on the end cover as identified in "Removal."
   - 1.5 Connect the vehicle wiring harness to the air dryer heater and thermostat assembly connector by plugging it into the air dryer connector until its lock tab snaps in place.
2. Test the air dryer following instructions in Group 42 of the *Acterra Maintenance Manual*.

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Removal and Installation



1. 5/16-Inch x 4-1/2-Inch Upper Bracket Capscrew
2. Upper Bracket Strap
3. 5/16-Inch Lockwasher
4. 5/16-Inch Locknut
5. Upper Mounting Bracket
6. Housing
7. Locknut
8. 3/8-Inch Special Washer
9. Desiccant Cartridge
10. O-Ring
11. Safety Valve
12. Lower Mounting Bracket
13. 3/8-Inch Capscrew (Long)
14. Check Valve Assembly
15. Purge Valve Assembly
16. Purge Valve Bolt
17. Exhaust Diaphragm
18. Purge Valve
19. 1/4-Inch Tapping Screw
20. Purge Valve Housing
21. Heater and Thermostat Assembly
22. Return Spring
23. Purge Piston
24. 3/8-Inch Capscrew
25. End Cover

Fig. 1, Bendix AD-9 Air Dryer

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Disassembly (See Fig. 1)

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

⚠ CAUTION

While servicing the air dryer, do not use a clamping device (vise, C-clamp, etc.) to hold any die cast aluminum part, as component damage may result. To hold the end cover, install a pipe nipple in the supply port, and clamp the nipple in a vise.

NOTE: As a convenience when rebuilding the air dryer, several replacement parts and maintenance kits are available that do not require full disassembly. Use the instructions provided with these parts or kits.

1. Remove the air dryer from the vehicle. See Subject 110.
2. Remove the check valve assembly and O-ring. Remove the O-ring from the check valve assembly.
3. Remove the purge valve housing assembly.
   - 3.1 Remove the three self-tapping screws that secure the purge valve housing assembly to the end cover assembly.
   - 3.2 Pull the purge valve housing assembly out of the end cover assembly.
   - 3.3 Remove and discard the three O-rings from the exterior of the purge valve housing assembly.

   NOTE: These O-rings may lodge in and have to be removed from the end cover bores.
4. Remove the heater and thermostat assembly.
   - 4.1 Remove and discard the two screws that attach the heater and thermostat assembly to the purge valve housing.
   - 4.2 Gently rotate the electrical connector to the left until the thermostat clears the purge valve housing. Slide the heater element out to the right and up. Discard the assembly.
5. Disassemble the purge valve housing assembly.
   - 5.1 If a flat non-extended exhaust cover is used, leave it intact while servicing the purge valve housing assembly.

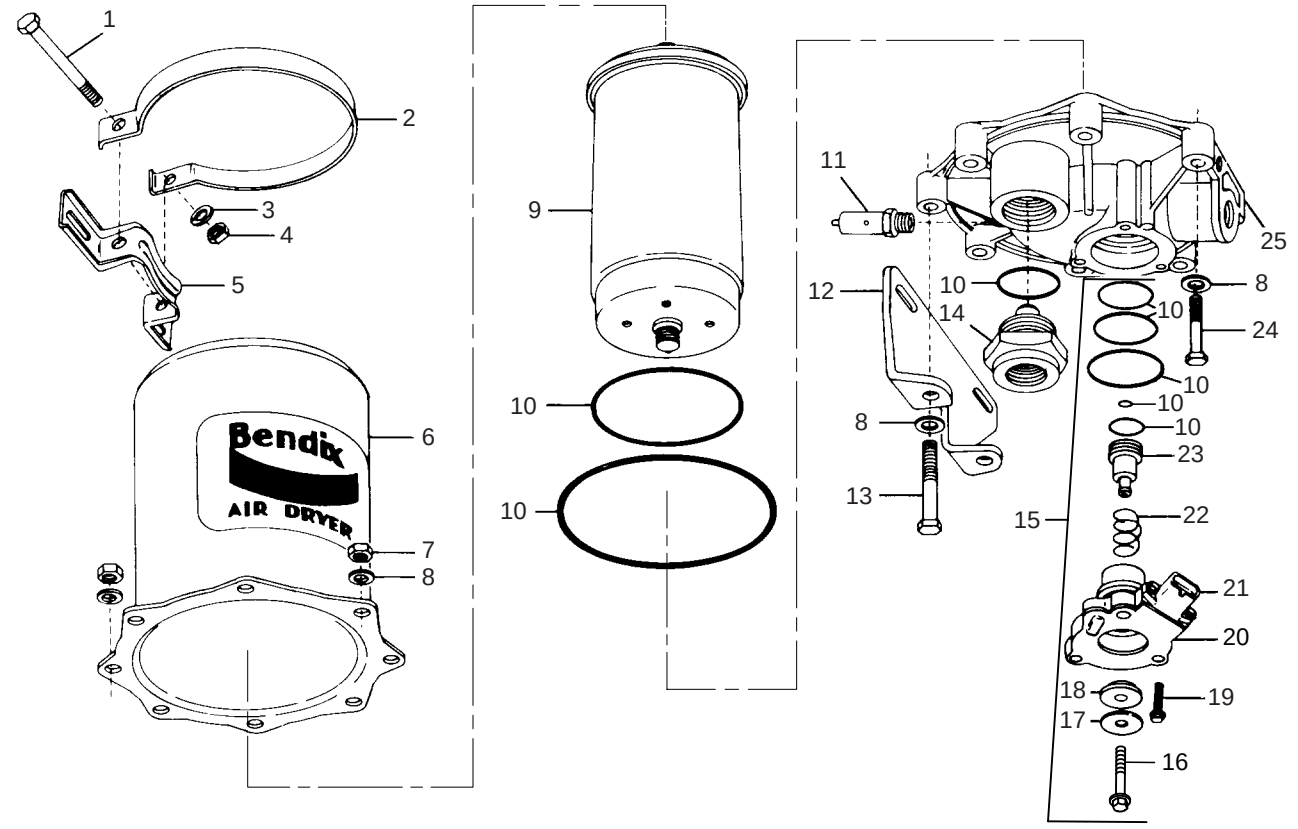
     If an extended type exhaust cover is used for the attachment of an exhaust hose, *carefully* separate the exhaust cover from the purge valve housing. *Use a thin flat blade to pry the exhaust cover off, taking care not to damage the potting material (RTV sealant) under the cover.*
   - 5.2 Remove the bolt from the bottom of the purge valve housing assembly. Remove the diaphragm and the purge valve from the purge valve housing.
   - 5.3 Remove the purge piston, the return spring and two O-rings (one on the outside and the other on the inside of the purge piston).
6. Remove the remaining 6 capscrews, locknuts, and 12 special washers that secure the end cover to the housing. Separate the end cover and desiccant cartridge from the housing.
7. Remove the end cover-to-outer housing O-ring.
8. Do not remove the safety valve from the end cover unless it is known to be inoperative. If replacement is needed, apply thread sealant or Teflon® tape on the threads of the replacement valve and tighten 10 to 33 lbf·ft (14 to 45 N·m). Make sure the drain hole (slot) is facing down.

NOTE: It may be necessary to apply up to 50 lbf·ft (68 N·m) of torque to separate the desiccant cartridge from the end cover.

9. Place a strap or chain wrench around the desiccant cartridge so that it is about 2 to 3 inches (5 to 8 cm) away from the end cover. Rotate the cartridge counterclockwise until it completely separates from the end cover.
10. Remove the desiccant cartridge O-ring from the end cover.

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Disassembly, Cleaning, Inspection, and Assembly



1. 5/16-Inch x 4-1/2-Inch Upper Bracket Capscrew
2. Upper Bracket Strap
3. 5/16-Inch Lockwasher
4. 5/16-Inch Locknut
5. Upper Mounting Bracket
6. Housing
7. Locknut
8. 3/8-Inch Special Washer
9. Desiccant Cartridge
10. O-Ring
11. Safety Valve
12. Lower Mounting Bracket
13. 3/8-Inch Capscrew (Long)
14. Check Valve Assembly
15. Purge Valve Assembly
16. Purge Valve Bolt
17. Exhaust Diaphragm
18. Purge Valve
19. 1/4-Inch Tapping Screw
20. Purge Valve Housing
21. Heater and Thermostat Assembly
22. Return Spring
23. Purge Piston
24. 3/8-Inch Capscrew
25. End Cover

Fig. 1, Bendix AD–9 Air Dryer

Cleaning and Inspection

1. Wash all metal parts thoroughly, using a quality commercial solvent, such as mineral spirits. Thoroughly dry all metal parts before assembly.
2. Check for severe corrosion, pitting, and cracks on the inside and outside of all metal parts that will be reused. Superficial corrosion and pitting on the outside of the upper and lower body halves is acceptable.

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3. Inspect the bores of both the end cover and the purge valve housing for deep scuffing or gouges.
4. Make sure that all purge valve housing and end cover passages are open and free of blockages.
5. Inspect the pipe threads in the end cover. Make sure they are clean and free of thread sealant.
6. Inspect the purge valve housing bore and seats for excessive wear and scuffing.
7. Inspect the purge valve piston seat for excessive wear.
8. Inspect all air line fittings for corrosion. Clean all old thread sealant from the pipe threads.
9. Replace all removed O-rings with new ones that are provided in the kits.
10. Replace parts that show any of the conditions described in the previous steps.

Assembly (See Fig. 1)

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

1. Before and during assembly, coat all O-rings, O-ring grooves, and bores with a generous amount of barium-based lubricant unless otherwise advised.

IMPORTANT: When installing the heater and thermostat assembly, make sure that the seal ring under the electrical connector is not twisted.

2. Install the heater and thermostat assembly.
   - 2.1 Insert the heater element into the slot in the purge valve housing until the connector contacts the housing.
   - 2.2 Gently push the connector and the thermostat to the left until the thermostat clears the cavity in the housing. Turn the connector to the right while pushing the thermostat all the way down into the cavity.

     Make sure that the connector is seated evenly against the housing.
   - 2.3 Install the two mounting screws. Tighten the screws 10 to 20 lbf·in (120 to 220 N·cm).
3. Assemble the purge valve housing.
   - 3.1 Install the O-ring on the purge piston. Place the return spring in the purge valve housing. Place the O-ring in the bore of the purge piston. Insert the purge piston into the spring. Push the piston into the purge valve housing until it bottoms.
   - 3.2 While holding the purge piston in, install the purge valve with its rubber side first, followed by the diaphragm and the bolt. Torque the purge valve bolt 60 to 80 lbf·in (680 to 900 N·cm).
   - 3.3 Install the three O-rings in their correct locations on the purge valve housing.
   - 3.4 If an extended type exhaust cover was removed, install it on the purge valve housing assembly, making sure the "bubble" portion is positioned over the thermostat.
   - 3.5 Install the assembled purge valve housing in the end cover; make sure you orient both parts so that the connector is about 10 degrees clockwise from the supply port. Also, make sure the purge valve housing is fully seated against the end cover.
   - 3.6 Secure the purge valve housing to the end cover using the three self-tapping screws. Start all three screws by hand, then torque them 50 to 80 lbf·in (560 to 900 N·cm).
4. Install an O-ring on the check-valve assembly. Install the assembly in the end cover using a socket. Tighten it 17 to 21 lbf·ft (23 to 28 N·m).
5. Install the desiccant cartridge in the end cover.
   - 5.1 Install the smaller desiccant cartridge O-ring in its groove in the end cover. Using a light coat of barium grease, lubricate the bottom of the desiccant cartridge in the area that will contact the O-ring and end cover.
   - 5.2 Screw the desiccant cartridge into the end cover until the cartridge contacts the

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Disassembly, Cleaning, Inspection, and Assembly

O-ring. Using a strap or chain wrench positioned 2 to 3 inches (5 to 8 cm) from the bottom of the cartridge, turn the desiccant cartridge clockwise 180 to 225 degrees beyond the position where initial contact was made with the O-ring. Torque should not exceed 50 lbf·ft (68 N·m).

6. Install the housing over the desiccant cartridge.
   - 6.1 Install the large O-ring on the shoulder in the end cover. Place the housing over the desiccant cartridge and align the holes.
   - 6.2 Install the 6 capscrews, locknuts, and the 12 special washers, making sure they are positioned as referenced earlier. The two longer capscrews will be used to secure the air dryer to its mounting bracket.
   - 6.3 Tighten the six capscrews and nuts in a star pattern (depending on lower bracket location) 23 to 32 lbf·ft (31 to 43 N·m). See **Fig. 2**.

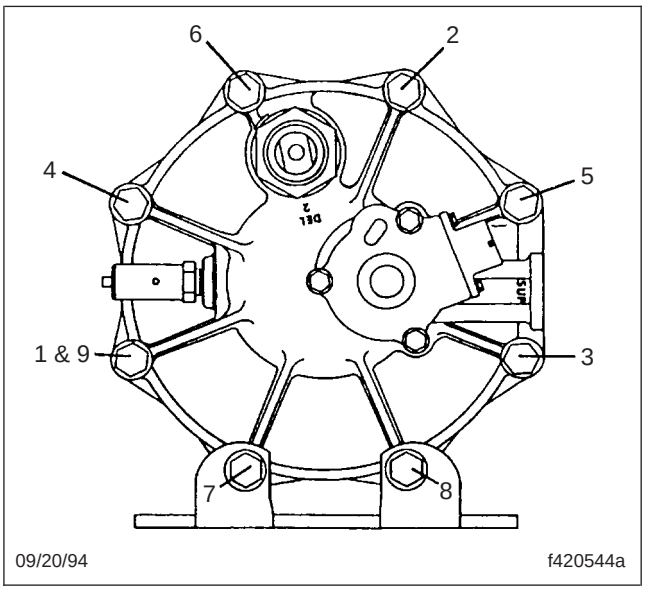


Fig. 2, End Cover-to-Housing Torque Pattern

NOTE: The two remaining bolt holes in the end cover and two 3/8-inch capscrews must be the ones marked during removal to ensure correct orientation of the ports and adequate length of the capscrews.

7. Connect the electrical connector to the heater and thermostat assembly.

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Testing

During cold-weather operation, check the operation of the end cover heater and thermostat assembly.

1. With the ignition on, check for voltage to the heater and thermostat assembly. Unplug the electrical connector at the air dryer, and place the test leads on each of the pins of the male connector. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check that a good ground path exists.
2. Check the thermostat and heater operation. Turn off the ignition switch and cool the end cover assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the female connector. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly, and 6.8 to 9.0 ohms for the 24-volt heater assembly.

NOTE: Some early models of the AD–9 will have resistance readings of 1.0 to 2.5 ohms for the 12-volt heater assembly, and 4.8 to 7.2 ohms for the 24-volt heater assembly. If the resistance is higher than this, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

3. Warm the end cover assembly to over 90°F (32°C) and again check the resistance. It should exceed 1000 ohms. If it does, the thermostat and heater assembly is operating properly. If it doesn't, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

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Troubleshooting Tables

Problem—Air Dryer is Constantly Cycling or Purging

Problem—Air Dryer is Constantly Cycling or Purging	
Possible Cause	**Remedy**
Excessive system leakage	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
Excessive leakage in fittings, hoses, and tubing connected to compressor, air dryer, and wet tank	Using a soap solution, test for leakage at the fittings, drain valve, and safety valve in the wet tank. Repair or replace as needed.
Inoperative check valve assembly in air dryer end cover	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at the opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5 cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Inoperative governor	Test the governor for proper cutin or cutout pressures and excessive leakage in both positions.
Leaking purge valve housing assembly or O-rings in air dryer end cover	With the supply port open to atmosphere, apply 120 psi (830 kPa) at the control port. Apply a soap solution to the supply port and exhaust port (purge valve seat area). Permissible leakage is a 1-inch (2.5 cm) bubble in 5 seconds. Repair or replace as needed.
Excessively leaking compressor unloader mechanism	Remove the air strainer or fitting from the compressor inlet cavity. With the compressor unloaded, check for unloader piston leakage. Slight leakage is allowed.
Holset "E" type compressor	Test the air dryer system. For instructions, refer to Bendix Product Bulletin PRO-08-19 entitled *"Troubleshooting the Holset "E" Compressor System with Bendix Air Dryer."*
Lack of air at the governor RES port (rapid cycling of governor)	Test the governor for proper pressure at the RES port. Pressure should not drop below cutin pressure when the compressor begins the unloaded cycle. If the pressure does drop, check for kinks or restrictions in the line connected to the RES port. The line connected to the RES port on the governor must be the same diameter, or larger than the lines connected to the UNL ports on the governor.

Problem—Water in the Vehicle Reservoirs

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Excessive contaminants in desiccant cartridge assembly	Replace the desiccant cartridge.
Discharge line of improper length or material	Discharge line must consist of at least 6 ft (1.8 m) of wire braid Teflon® core hose, copper tubing, or a combination of both, or 4.5 ft (1.4 m) of wire braid Teflon core hose and 4.5 ft (1.4 m) of wire braid rubber core hose between the discharge port of the compressor and the air dryer supply port. Discharge line lengths and inside diameter requirements are dependent on the vehicle application. Contact your local Bendix representative for further information.

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Troubleshooting

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Air system charged from outside air source not passed through an air dryer	If the system must have an outside air fill provision, the outside air should pass through an air dryer. This practice should be minimized.
Air dryer not purging	Refer to "Problem—Air Dryer Does Not Purge or Exhaust Air."
Purge (air exhaust) is insufficient due to excessive system leakage	Refer to "Problem—Air Dryer is Constantly Cycling or Purging."
Air bypasses desiccant cartridge assembly	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed.
Purge (air exhaust) time significantly less than minimum allowable	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed. Replace the desiccant cartridge assembly.
Excessive air usage; air dryer not compatible with vehicle air system	Install an accessory bypass system. Consult your Bendix representative for additional information.

Problem—Safety Valve on Air Dryer is Popping Off or Exhausting Air

Problem—Safety Valve on Air Dryer is Popping Off or Exhausting Air	
Possible Cause	**Remedy**
Plugged or saturated desiccant cartridge	Check the compressor for excessive oil passing, or incorrect installation. Repair or replace as needed.
Inoperative check valve in air dryer end cover	Test to determine if air is passing through the check valve. Repair or replace as needed.
Problem in fittings, hose, or tubing between air dryer and wet tank	See if air is reaching the first reservoir. Inspect for kinked tubing or hose. Check for undrilled or restricted hose or tubing fittings.
Safety valve setting lower than maximum system pressure	Reduce the system pressure, or install a safety valve with a higher pressure setting.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Excessively leaking air dryer purge valve	With the compressor loaded, apply a soap solution on the purge valve exhaust to test for excessive leakage. Repair the purge valve as needed.
Inoperative governor	Check the governor for proper cutin and cutout pressures, and excessive leakage in both positions. Repair or replace as needed.
Purge control line connected to reservoir or exhaust port of governor	Connect the purge control line to the unloader port of the governor.
Frozen open purge valve due to inoperative heater or thermostat, bad wiring, or blown fuse	Test the heater and thermostat, following instructions in this manual.
Reversed inlet and outlet air connections; unable to build system pressure	Reconnect the lines properly.
Kinked or blocked discharge line	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.

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Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Excessive bends in discharge line; water collecting and freezing	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
Excessively leaking system	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
Purge valve stays open; supply air leaks to control side	Replace the purge valve assembly O-rings.

Problem—Air Dryer Does Not Purge or Exhaust Air

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
Broken, kinked, frozen, plugged, or disconnected purge control line	See if air flows through the purge control line when the compressor is unloaded. The purge control line must be connected to the unloader port of the governor.
Inoperative air dryer purge valve	See if air reaches the purge valve. If it does, repair the purge valve.
Inoperative governor	Check the governor for proper cutin and cutout pressures, and excessive leakage in both positions. Repair or replace as needed.
Reversed inlet and outlet air connections; unable to build system pressure	Reconnect the lines properly.
Kinked or blocked discharge line	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
Excessive bends in discharge line; water collecting and freezing	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.

Problem—Desiccant is Being Expelled from the Air Dryer Purge Valve Exhaust (May Look Like Whitish Liquid, Paste, or Small Beads); or, Unsatisfactory Desiccant Life

Problem—Desiccant is Being Expelled from the Air Dryer Purge Valve Exhaust (May Look Like Whitish Liquid, Paste, or Small Beads); or, Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
Problem usually occurs with one or more previous problems	Refer to the appropriate corrections listed previously.
Air dryer not securely mounted; excessive vibration	Vibration should be held to a minimum. Tighten the mounting fasteners.
Damaged cloth-covered perforated plate in air dryer desiccant cartridge, or incorrectly rebuilt cartridge	Replace the plate or cartridge as needed. High operating temperatures may cause deterioration of filter cloth. Check the installation.
Compressor passing excessive oil	Check for proper compressor installation; if symptoms persist, replace the compressor.
Faulty heater and thermostat, wiring, or fuse; not allowing air dryer to purge during cold weather	Test the heater and thermostat, following instructions in this manual.

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Troubleshooting

Problem—Desiccant is Being Expelled from the Air Dryer Purge Valve Exhaust (May Look Like Whitish Liquid, Paste, or Small Beads); or, Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
Improperly attached desiccant cartridge to the end cover	Check the torque and tighten if necessary. See **Specifications, 400**.

Problem—Pinging Noise is Excessive During Compressor Loaded Cycle

Problem—Pinging Noise is Excessive During Compressor Loaded Cycle	
Possible Cause	**Remedy**
Pinging noise due to a single cylinder compressor with high pulse cycles	A slight pinging sound may be heard during system build-up when a single cylinder compressor is used. If this sound is deemed objectionable, it can be reduced substantially by increasing the discharge line volume. This is done by adding a 90 in ^{3} (1475 cm ^{3}) reservoir between the compressor and the air dryer.

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)	
Possible Cause	**Remedy**
Air compressor inlet pressurized by engine turbocharger	Some pressure leakage past the metal seat of the turbocharger cutoff feature of the AD–9 air dryer is normal, and may be heard. This slight loss of air will not affect the engine or turbocharger performance.
Inoperative check valve assembly in air dryer end cover	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at the opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode	
Possible Cause	**Remedy**
Compressor does not "unload"	Check the governor installation. If there is no air line from the governor to the compressor, or the line is restricted, repair or replace as needed.

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See **Fig. 1** for a full view of the air dryer wiring.

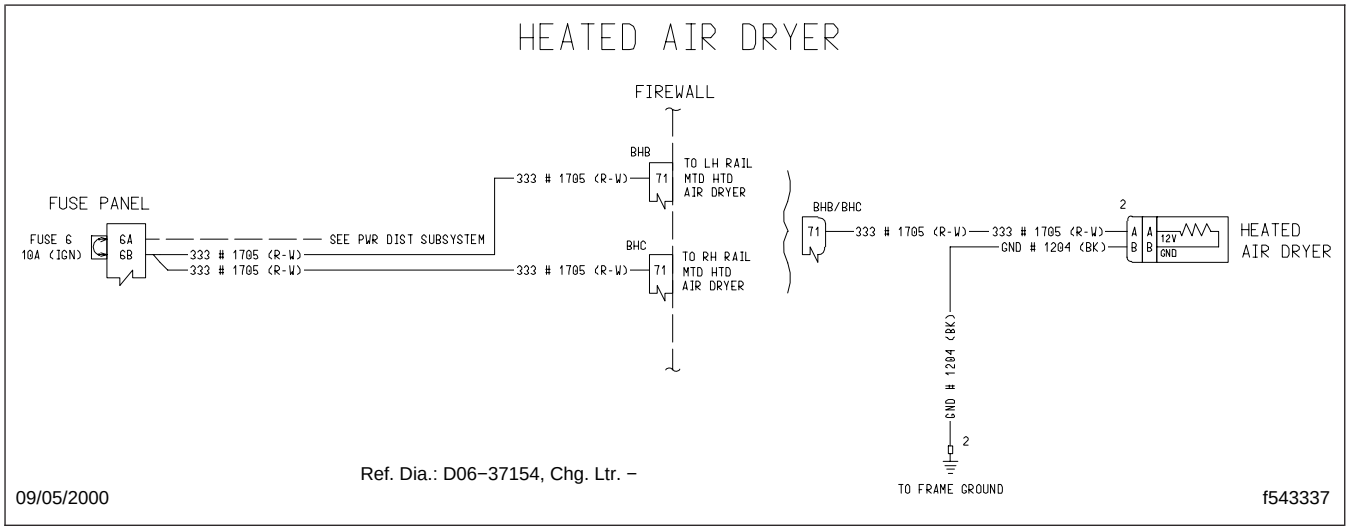


Fig. 1, Air Dryer Wiring

Torque Specifications		
Description	**Torque lbf·in (N·cm)**	**Torque lbf·ft (N·m)**
Purge Valve Nut and Bolt	60–80 (680–900)	—
Purge Valve Housing Screws	50–80 (560–900)	—
Desiccant Cartridge *	—	50 (68)
End Cover Nuts and Capscrews	—	23–32 (31–43)
Air Dryer Lower Mounting Bracket Capscrews	—	23–32 (31–43)
Air Dryer Upper Mounting Bracket Bolt and Nut	80–120 (900–1360)	—
Safety Valve	—	10–33 (14–45)
Heater and Thermostat Assembly Mounting Screws	10–20 (120–220)	—
Check Valve Assembly	—	17–21 (23–28)

* Tighten 180 to 225 degrees after the cartridge end cover makes contact with the cartridge O-ring (not to exceed 50 lbf·ft [68 N·m]).

Table 1, Torque Specifications

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General Information

The Meritor automatic slack adjuster (**Fig. 1**) has two main functions:

- As a lever, it converts the straight-line force of the brake chamber pushrod to torque on the brake camshaft. Rotation of the camshaft forces the brake shoes against the brake drum.
- As an automatic adjuster, it automatically maintains brake chamber pushrod stroke, which controls lining-to-drum clearance during operation.

Meritor's automatic slack adjuster automatically adjusts the clearance between the brake lining and the brake drum (rotor). When linings wear, this clearance increases and causes the chamber pushrod to move a greater distance to apply the brakes.

During operation, if the chamber stroke exceeds the design limit, the automatic slack adjuster will automatically adjust the pushrod's return stroke to control clearance between the lining and the drum (rotor) and reset the stroke to the correct length.

A pressed-in, sealed actuator boot is standard equipment on Meritor slack adjusters. The boot features a metal retaining ring with additional material that extends beyond the base of the retainer. The boot forms a seal once it is pressed into the slack adjuster body.

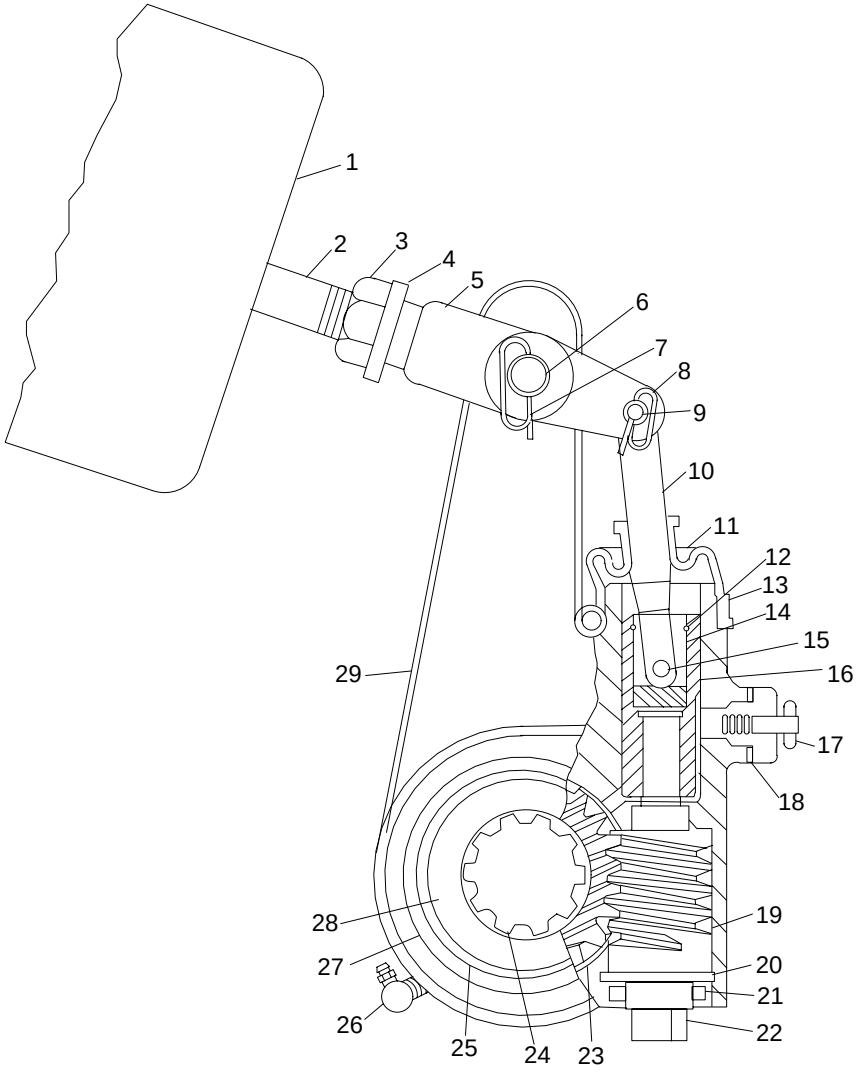
Meritor's automatic slack adjusters, including the factory-installed slack adjusters on the Q Plus cam brakes, have a one-piece threaded clevis. See **Fig. 2**.

The one-piece threaded clevis:

- Has a threaded hole for the pushrod;
- Can be straight or offset;
- Is used on all service replacement automatic slack adjusters.

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General Information

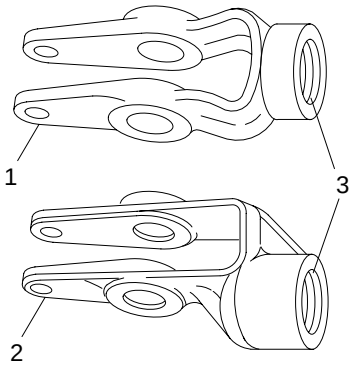


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1. Brake Air Chamber
2. Brake Chamber Pushrod
3. Clevis Jam Nut
4. Collar
5. Clevis
6. Large Clevis Pin
7. Large Clevis Pin Retainer Clip
8. Small Clevis Pin Retainer Clip
9. Small Clevis Pin
10. Actuator Rod
11. Boot
12. Piston Retaining Ring
13. Boot Retaining Clamp
14. Actuator Piston
15. Roller (Pin)
16. Actuator (Adjusting Screw)
17. Pull-Pawl Assembly
18. Gasket
19. Worm
20. Worm Retaining Snap Ring
21. Worm Grease
22. Manual (Worm) Adjusting Nut End
23. Gear-to-Body Seal
24. Camshaft Splines
25. Gear Retainer/Seal
26. Grease Fitting (if equipped)
27. Gear Thrustwasher
28. Gear
29. Slack Adjuster Arm

Fig. 1, Automatic Slack Adjuster (sectional view)

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1. Straight Clevis
2. Offset Clevis
3. Threads

Fig. 2, One-Piece Threaded Clevis Configurations

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Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

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Slack Adjuster Removal and Installation

Removal

1. With the vehicle parked on a level surface, set the parking brakes, and shut down the engine. Chock the tires.

⚠ WARNING

Manually cage each parking brake chamber power spring in the release (no application) position before continuing. Loss of brake chamber air pressure will cause sudden application of the parking brakes, which could result in personal injury.

2. If the rear slack adjusters will be removed, release the parking brakes, then cage the power spring of the parking brake chamber.
3. Remove the retainer clips from the large and small clevis pins. Remove the clevis pins. See **Fig. 1**.

⚠ CAUTION

Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

4. Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm). See **Fig. 2**.

   Wedge the tool in place. Pull-pawls are spring-loaded; when the tool is removed, the pull-pawl will engage the teeth automatically.
5. Using a wrench, manually turn the square adjusting nut clockwise to move the slack adjuster away from the clevis. See **Fig. 3**.
6. Remove the snap ring, washer(s), and seal (if equipped) that secure the slack adjuster in place on the brake camshaft; save them for later installation.
7. Remove the slack adjuster from the camshaft.
8. Note the location and number of any remaining spacing washers on the camshaft. Remove the spacers and seal (LX500 and MX500 series only), and save them for later installation.

Installation

NOTE: For brake chambers that have pushrods with threaded clevises, measure the pushrod length before installing the new slack adjuster. With the brakes fully released, and no air pressure to the chamber, check the dimension between the chamber face and the centerline of the 1/2 inch clevis pin hole. It should be 2.25 inches (57 mm) for long stroke chambers, and 2.75 inches (70 mm) for standard stroke chambers.

1. Inspect the parts and prepare the slack adjuster for installation.
2. Check the brake camshaft splines for wear or corrosion.

IMPORTANT: The following lubricants provide corrosion protection. Do not mix them with other types of lubricants.

3. Coat the camshaft splines and the splines of the slack adjuster gear with Meritor 0-637, Meritor 0-695 (LX500 and MX500 only), Southwest SA 8249496, or an equivalent.
4. Apply the service brake several times. Make sure the return spring retracts the pushrod quickly and completely. Replace the return spring or brake chamber, if needed.
5. Slide the spacing washer(s) on the camshaft.

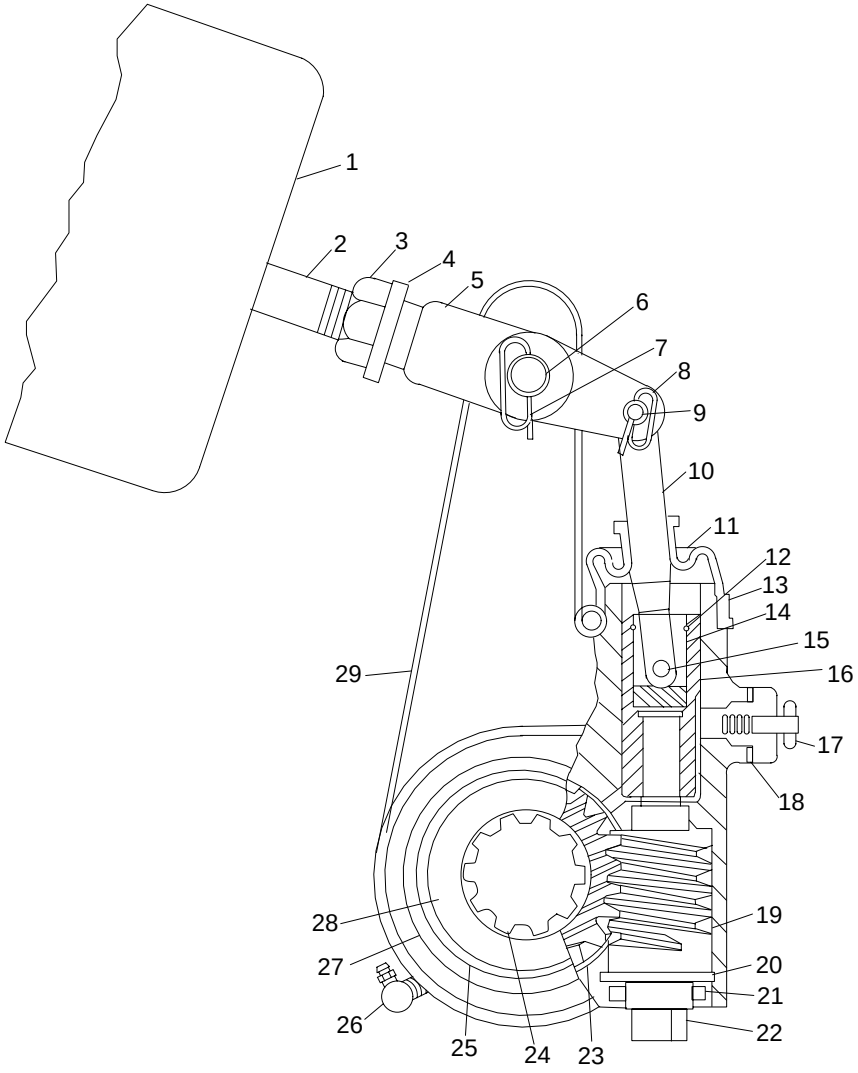
   On LX500 and MX500, install the slack adjuster seal with the lip facing the brake spider.
6. If reinstalling the same slack adjuster:
   - 6.1 Slide the slack adjuster on the camshaft, with the actuator rod on the side opposite the brake chamber.
   - 6.2 On LX500 and MX500, install the orange slack adjuster seal on the camshaft. The lip on the seal must face the snap ring.
   - 6.3 Install the outer washer(s) and snap ring on the camshaft.

⚠ CAUTION

Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could

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Slack Adjuster Removal and Installation

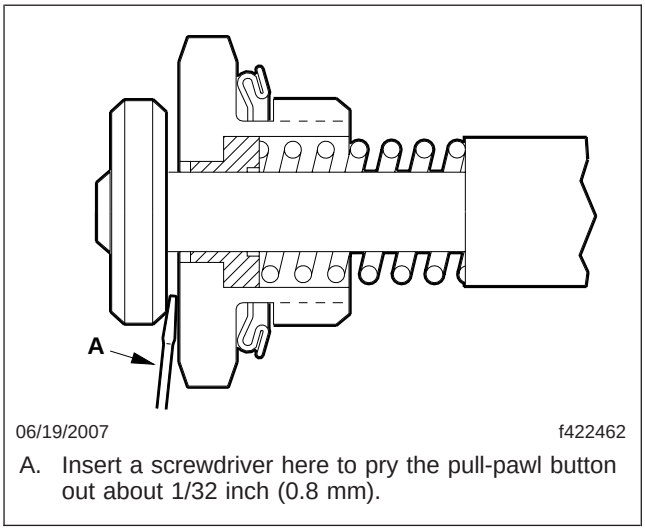


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1. Brake Air Chamber
2. Brake Chamber Pushrod
3. Clevis Jam Nut
4. Quick-Connect Collar (if equipped)
5. Clevis
6. Clevis Pin (large)
7. Retainer Clip (large)
8. Retainer Clip (small)
9. Clevis Pin (small)
10. Actuator Rod
11. Boot
12. Piston Retaining Ring
13. Boot Retaining Clamp
14. Actuator Piston
15. Roller (Pin)
16. Actuator (Adjusting Sleeve)
17. Pull-Pawl Assembly (shown 90 degrees out of position)
18. Gasket
19. Worm
20. Worm Retaining Snap Ring
21. Worm Seal
22. Manual Adjusting Nut
23. Gear-to-Body Seal
24. Camshaft Splines
25. Gear Retaining Ring
26. Grease Fitting (if equipped)
27. Gear Thrustwasher
28. Gear
29. Slack Adjuster Housing

Fig. 1, Meritor Automatic Slack Adjuster

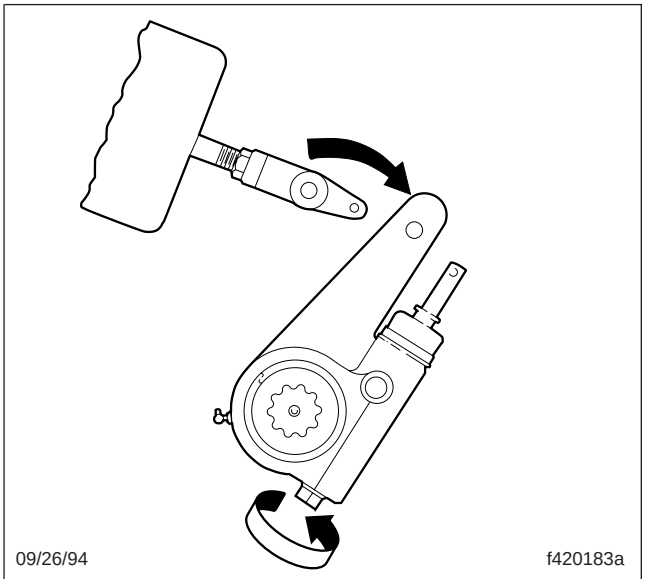
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A. Insert a screwdriver here to pry the pull-pawl button out about 1/32 inch (0.8 mm).

Fig. 2, Pull-Pawl Assembly



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Turn the manual adjusting nut clockwise.

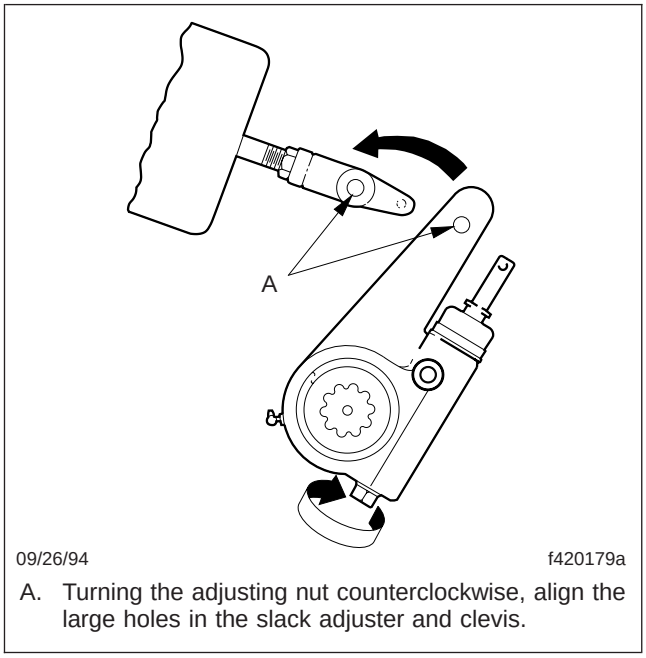
Fig. 3, Slack Adjuster Removal

damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

6.4 Using a screwdriver or an equivalent tool, pry the pawl button out at least 1/32 inch (0.8 mm). See **Fig. 2**. Wedge the tool in place.

IMPORTANT: Never pull the pushrod out to meet the slack adjuster or push the slack adjuster into position. Always turn the adjusting nut for positioning.

6.5 Using a wrench, turn the manual adjusting nut counterclockwise to align the hole in the slack adjuster housing with the large hole in the clevis. See **Fig. 4**.



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A. Turning the adjusting nut counterclockwise, align the large holes in the slack adjuster and clevis.

Fig. 4, Slack Adjuster Installation

7. If installing a new slack adjuster:

7.1 Using an installation template, measure the old and new slack adjusters. Measure from the center of the large clevis-pin hole to the center of the camshaft opening. See **Fig. 5**.

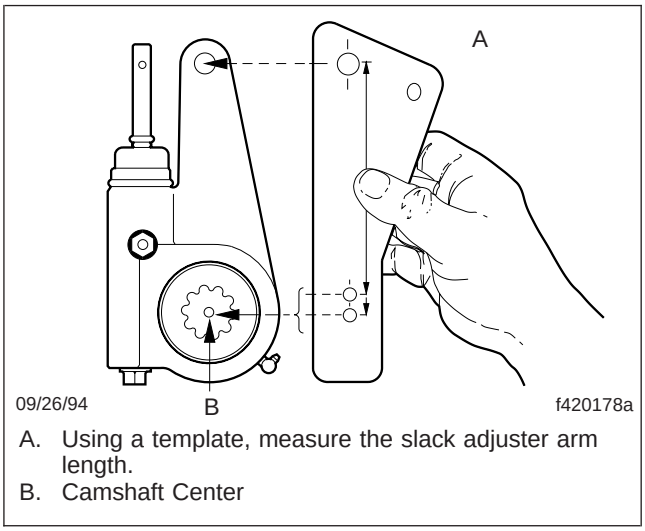
Make sure the old and new slack adjusters are the same length.

7.2 Slide the slack adjuster on the camshaft, with the actuator rod on the side opposite the brake chamber.

7.3 On LX500 and MX500 series, install the orange slack adjuster seal on the camshaft. The lip on the seal must face the snap ring.

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Slack Adjuster Removal and Installation



A. Using a template, measure the slack adjuster arm length.
B. Camshaft Center

Fig. 5, Slack Adjuster Measurement

7.4 Install the outer washer(s) and snap ring on the camshaft.

7.5 Using a dial indicator, measure the in-and-out (axial) end play of the camshaft. If necessary, add the appropriate number of spacing washers to achieve the correct axial end play.

- For all Cam-Master brakes, except LX500 and MX500 series, there should be no more than 0.060 inch (1.52 mm) movement.
- For LX500 and MX500, the axial end play should be no more than 0.020 inch (0.51 mm).

⚠ CAUTION

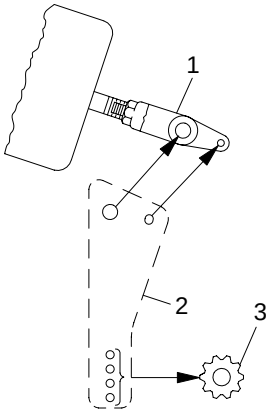
Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

7.6 Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm). See **Fig. 2**. Wedge the tool in place.

IMPORTANT: Never pull the pushrod out to meet the slack adjuster or push the slack adjuster into position. Always turn the adjusting nut for positioning.

7.7 Using a wrench, turn the manual adjusting nut counterclockwise to align the hole in the slack adjuster housing with the large hole in the clevis. See **Fig. 4**.

7.8 With the brakes fully released, place the installation template over the clevis and camshaft end. See **Fig. 6**.



Place the template over the clevis and camshaft end.
1. Clevis
2. Template
3. Camshaft End

Fig. 6, Template Placement

7.9 Temporarily insert the large clevis pin through the large holes in the template and the clevis.

7.10 Select the hole in the lower part of the template that matches the length of the slack adjuster. Hold the template in place on the center of the camshaft with a pencil.

7.11 Make sure the small hole in the clevis is completely visible through the 1/8-inch hole at the top of the template.

If it is not, loosen the clevis jam nut, and turn the clevis adjusting nut to adjust the position of the clevis on the pushrod until the small clevis hole is completely visible.

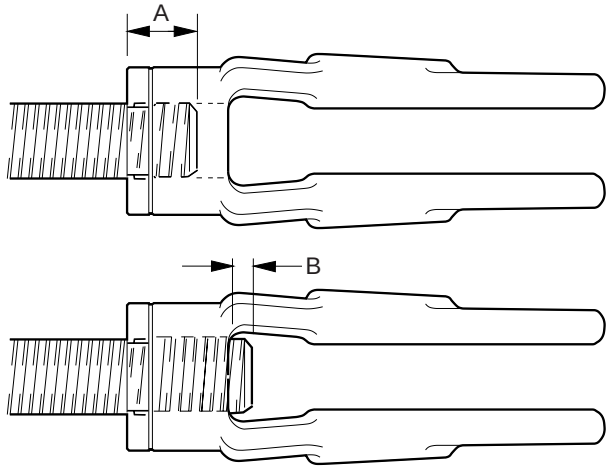
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IMPORTANT: The pushrod must be installed in the clevis at least 1/2 inch (13 mm) and not extend beyond it more than 1/8 inch (3 mm).

7.12 Make sure there is at least 1/2 inch (13 mm) of thread engagement between the clevis and the pushrod. Also, check that the pushrod does not extend through the clevis more than 1/8 inch (3 mm). See **Fig. 7**.

If necessary, cut the pushrod, install a new pushrod, or install a new brake chamber.

7.13 Temporarily insert the small clevis pin through the template, clevis, and actuator rod to make sure the alignment is correct. Repeat the adjustment, if necessary. When the alignment is correct, remove both clevis pins and the template.



A. Minimum 1/2 inch (13 mm).
B. Maximum 1/8 inch (3 mm).

Fig. 7, Checking Pushrod Engagement

8. Apply antiseize compound to the two clevis pins.
9. Insert both clevis pins with their pinheads on the inboard side of the slack adjuster. Be sure the small clevis pin is inserted through the hole in the actuator rod. Install new retaining clips to secure the clevis pins.
10. If it was loosened, tighten the clevis jam nut to the following values.
    - For 1/2–20 threads, tighten the clevis jam nut 20 to 30 lbf·ft (27 to 41 N·m).
    - For 5/8–18 threads, tighten the jam nut 25 to 50 lbf·ft (34 to 68 N·m).
11. Lube the slack adjuster through the grease fitting until the lubricant is forced out through the pawl slot or through the gear splines around the inboard snap ring.
12. Adjust the brakes. See "Brake Adjustment" below.

Brake Adjustment

NOTE: A properly working self-adjusting slack adjuster does not require manual adjustment while in service.

⚠ WARNING

Manually adjusting an automatic slack adjuster to bring the pushrod stroke within legal limits is likely masking a mechanical problem. Adjustment is not repairing. Before adjusting an automatic slack adjuster, troubleshoot the foundation brake system and inspect it for worn or damaged components. Improperly maintaining the vehicle braking system may lead to brake failure, resulting in property damage, personal injury, or death.

1. If a rear axle slack adjuster was installed, manually uncage the parking brake.
2. Fully release the brakes (the air chamber pushrod must be fully retracted).

⚠ CAUTION

Before turning the manual adjusting nut on the slack adjuster, disengage the pull-pawl. Failure to do so could damage the pull-pawl teeth. A damaged pull-pawl will not allow the slack adjuster to automatically adjust the brake clearance.

3. Using a screwdriver, pry the pull-pawl button out at least 1/32 inch (0.8 mm) to disengage the pull-pawl teeth from the slack adjuster actuator. See **Fig. 2**. Wedge the screwdriver in place. The pull-pawl will need to be disengaged until the brake adjustment is complete.

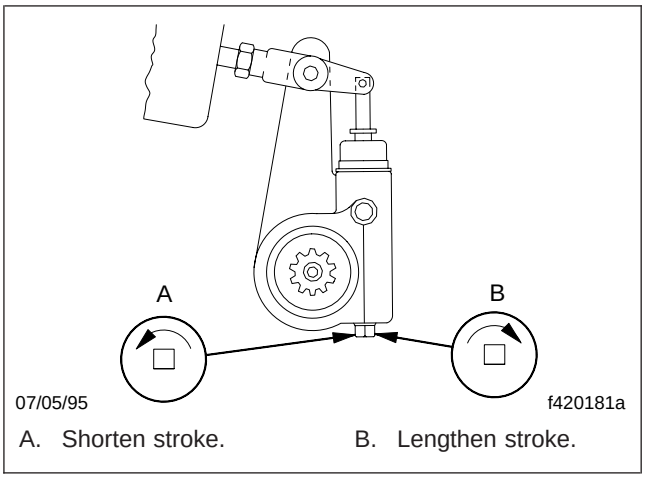
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Slack Adjuster Removal and Installation

NOTE: When the screwdriver is removed, the pull-pawl will engage automatically.

4. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment), as follows. See **Fig. 8**.

   4.1 Turn the adjusting nut counterclockwise until the brake linings touch the brake drum.



A. Shorten stroke. B. Lengthen stroke.

Fig. 8, Adjusting the Stroke

   4.2 Then, turn the adjusting nut clockwise 1/2 turn.

5. Measure and adjust the free-stroke, as follows.

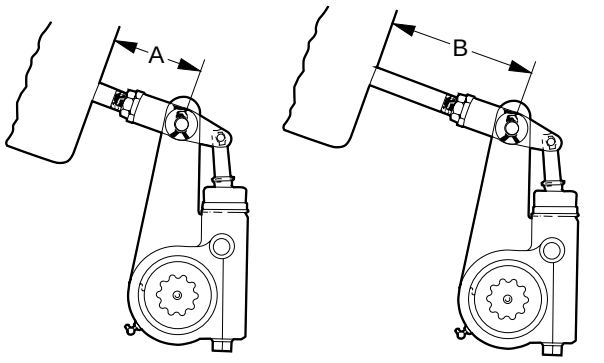
   5.1 With the brakes released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension A. See **Fig. 9**.

   5.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum.

   Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension B. See **Fig. 9**.

   5.3 Subtract dimension A from dimension B. The difference between these measurements is the free-stroke.

   5.4 The free-stroke for a new brake installation should be 5/8 to 3/4 inch (16 to 19 mm). For a brake that is in service, the free-stroke should be 1/2 to 5/8 inch (13 to 16 mm). If it is not, turn the adjusting nut 1/8 turn, as shown in **Fig. 8**. Then, measure the free-stroke again; readjust it until it is correct.



NOTE: For either free-stroke or applied chamber stroke, subtract measurement A from B.

A. Measurement with the brakes released.
B. Measurement with the brakes applied by manual lever (free-stroke) or pressurized brake application (applied chamber stroke).

Fig. 9, Measuring the Stroke

6. Measure and adjust the applied chamber stroke (fine adjustment), as follows.

   6.1 If system pressure is not already at 100 psi (689 kPa), start the engine and build air pressure, then shut down the engine.

   6.2 With the brakes released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension A. See **Fig. 9**.

   6.3 Fully apply the brakes. Then, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 9**, Ref. B. Record this measurement as dimension B.

   6.4 Subtract dimension A from dimension B. The difference between these measurements is the true applied chamber stroke.

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⚠ CAUTION

The adjusted applied chamber stroke should be as short as possible but not so short that the free-stroke is too short and the linings drag. If the linings drag, the brakes could be damaged.

6.5 The applied chamber stroke must not exceed the maximum value specified in **Table 1**.

If the applied chamber stroke is incorrect, turn the adjusting nut 1/8-turn counterclockwise to shorten the stroke, or 1/8-turn clockwise to lengthen it. See **Fig. 8**. Measure the applied stroke again and readjust it until it is correct.

6.6 If the slack adjuster is not maintaining the correct applied chamber stroke, check the condition of the foundation brakes. See **Section 42.03, Subject 150**.

7. Remove the screwdriver from the pull-pawl assembly. This will engage the pull-pawl with the actuator.

⚠ WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

8. In a safe area, check for proper brake operation before you put the vehicle in service, as follows.

8.1 Apply and release the brakes several times to check for air leaks and proper operation of the slack adjusters.

8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.

8.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than others show a lack of braking effort on those wheels.

Brake Chamber Stroke Specifications			
Chamber Type (Size)	Maximum Applied Stroke*: inch (mm)	Free-Stroke: inch (mm)	
		New Brake Installation	In-Service Brake
Long Stroke†			
16 and 20	2-1/2 (64)	5/8–3/4 (16–19)	1/2–5/8 (13–16)
24 and 30	3 (76)		

* Specifications are relative to a brake application with 80–90 psi (550–620 kPa) air pressure in the brake chambers.

† Long stroke design is indicated by a tag, or embossing, on the brake chamber.

Table 1, Brake Chamber Stroke Specifications

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Specifications

Lubricant Specifications	
Lubricant Type	**Temperature**
Amoco Super Permalube No. 2	–40°F (–40°C) or Above
Aralub 3837	
Citco Premium Lithium EP No. 2	
Exxon Ronex MP No. 2	
Kendall L–427 Super Blu No. 2	
Mobilith AW No. 1	
Meritor 0–616–A	
Meritor 0–692	
Shell Darina No. 1	
Sohio Factran EP No. 2	
Texaco Hytherm EP No. 1	
Texaco Thermotex EP No. 1	
Tribolube 12, Grade 1	
Mobil 28	Below –40°F (–40°C)
Meritor 0–645	

Table 1, Lubricant Specifications

Slack Adjuster Arm Lengths	
Slack Adjuster Arm Length inches (mm)	**Chamber Size**
5 (127)	9, 12, 16, 20, 24, 30
5-1/2 (140)	9, 12, 16, 20, 24, 30
6 (152)	24, 30
6-1/2 (165)	30

Table 2, Slack Adjuster Arm Lengths

Maximum Adjusted Brake Chamber Strokes	
Chamber Size	**Maximum Chamber Stroke for Cam Brake in inches (mm)**
9	Less than 1-1/2 (38)
12	Less than 1-1/2 (38)
16	Less than 1-3/4 (44)
20	Less than 1-3/4 (44)
24	Less than 1-7/8 (48)
24 *	Less than 2 (51)

Maximum Adjusted Brake Chamber Strokes	
Chamber Size	**Maximum Chamber Stroke for Cam Brake in inches (mm)**
30	Less than 2 (51)

* Long stroke.

Table 3, Maximum Adjusted Brake Chamber Strokes

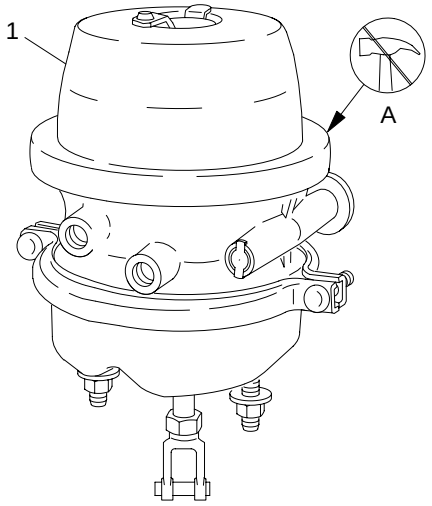
Thread Sizes	
Chambers	**Thread Sizes inch**
9, 12,16	1/2–20
20, 24, 30, 36	5/8–18

Table 4, Thread Sizes

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DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



02/22/2000 f421352

A. Do not remove the factory-sealed clamp ring.
1. Model TR-T (TR Series) Brake Chamber

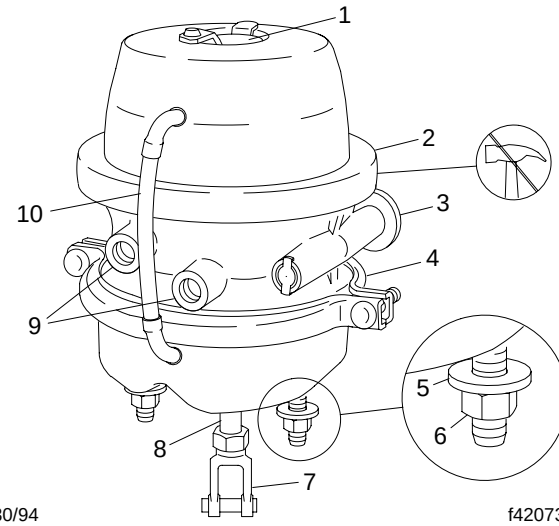
Fig. 1, Brake Chamber

IMPORTANT: On MGM TR series chambers, the parking/emergency brake section is factory sealed (no clamp ring) and is a *non-serviceable* unit.

General Information

MGM TR series tandem cam brake chambers consist of a service brake section and a parking/emergency spring brake section. See **Fig. 2**. The service brake section is the smaller section near the clevis assembly.

In the service brake section, the flange case and non-pressure chamber contain a service return spring, piston rod assembly, and service brake diaphragm.



08/30/94 f420730c

Do not remove the factory-sealed clamp ring.
1. End Cover Cap
2. Factory Sealed Parking Brake Clamp Ring
3. Release Bolt Storage Pocket
4. Service Brake Clamp Ring
5. Hardened Flatwasher
6. Prevailing Torque Locknut
7. Clevis Assembly
8. Piston Rod
9. Air Inlet Ports
10. External Breather Tube

Fig. 2, Model TR-T (TR Series) Brake Chamber

In the parking/emergency brake section, the flange case and the head contain a return spring, a pushrod assembly, a parking (spring) brake diaphragm, a piston, a power spring, and a detachable release bolt.

All MGM brake chambers are mounted to the frame using prevailing torque locknuts and hardened flatwashers.

MGM TR series chambers may be equipped with an external breather tube that protects the parking brake chamber from contaminants. These chambers are called Model TR-T chambers. See **Fig. 2**.

Periodic maintenance of the brake chambers is required. Also, whenever the service brake chamber is disassembled (*do not attempt to disassemble the parking brake chamber*), the parts should be inspected for damage. For maintenance schedules and procedures, and for inspection of brake chamber parts, see the *Acterra Maintenance Manual*.

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General Information

SERVICE BRAKES

As the brake pedal is depressed, compressed air enters the service brake chamber through a port. Air pressure acts upon a diaphragm, which forces the piston rod toward the non-pressure chamber, applying a straight-line force to the slack adjuster, which converts it to a rotational force. This, in turn, rotates the camshaft and applies the brakes.

When the brake pedal is released, air is exhausted from the service brake chamber, and the return spring allows the diaphragm, piston rod, and slack adjuster to return to their normal positions, releasing the brakes.

PARKING/EMERGENCY BRAKES

During parking brake release, compressed air enters the parking brake chamber and acts upon the diaphragm and piston, fully compressing the power spring. When the power spring is compressed, the parking brakes are released; the service brakes can then be operated at the brake pedal.

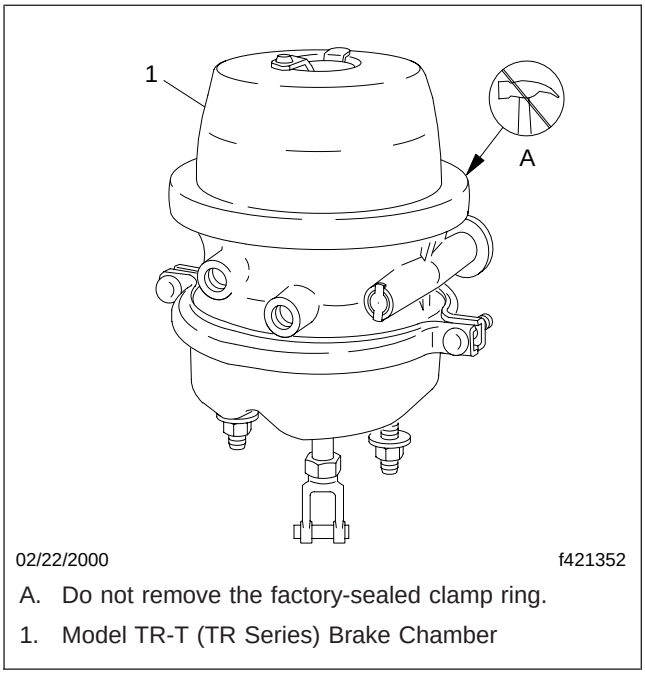
During parking brake application, air is exhausted from the parking brake chamber. The power spring releases, forcing the piston and parking brake diaphragm toward the flange case. The resulting motion on the pushrod forces the service brake diaphragm and piston rod outward, applying the brakes.

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Power Spring Manual Compression and Reset

⚠ DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



A. Do not remove the factory-sealed clamp ring.

1. Model TR-T (TR Series) Brake Chamber

Fig. 1, Brake Chamber

Manual Compression (Parking Brake Release)

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Remove the end cover cap from the center hole in the head of the chamber. See **Fig. 2**.

⚠ DANGER

Do not attempt to cage the power spring if the parking brake chamber is damaged severely enough to lose its structural integrity. If the power spring were to break loose, it could result in death, severe personal injury, or property damage.

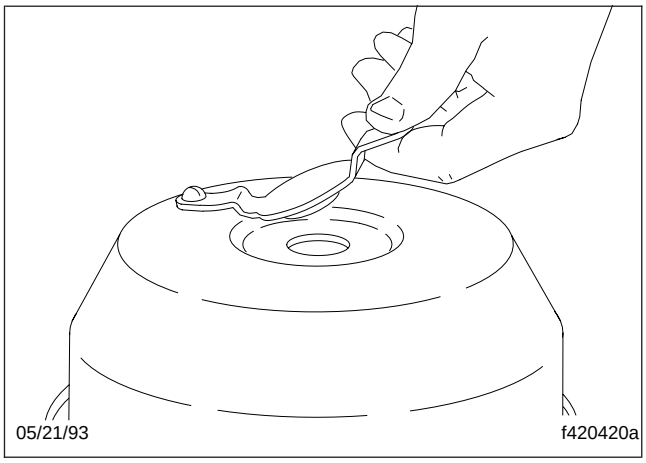


Fig. 2, Remove the End Cover Cap

A DAMAGED PARKING BRAKE CHAMBER IS EXTREMELY DANGEROUS! Only qualified service personnel should attempt to remove and disarm a damaged chamber. Using a torch, burn off the piston rod in the space between the clevis and the base of the service chamber.

Remove the chamber carefully from its bracket, and disarm it inside a suitable container. For disarming procedures, consult the MGM service manual.

3. Manually release the parking brake (cage the power spring).

   3.1 Using a hand wrench (*do not use an impact wrench*), unscrew the release nut, and remove the nut, flatwasher, and release bolt from the storage pocket on the side of the chamber. See **Fig. 3**.

   IMPORTANT: If these parts are not stored on the chamber, they must be otherwise obtained or purchased; the parking brake cannot be manually released without them.

   3.2 Apply at least 90 psi (620 kPa) air pressure to the parking brake inlet port (set the parking brake in the "release" position).

   3.3 Insert the release bolt into the center hole in the chamber head. See **Fig. 4**. Insert

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Power Spring Manual Compression and Reset

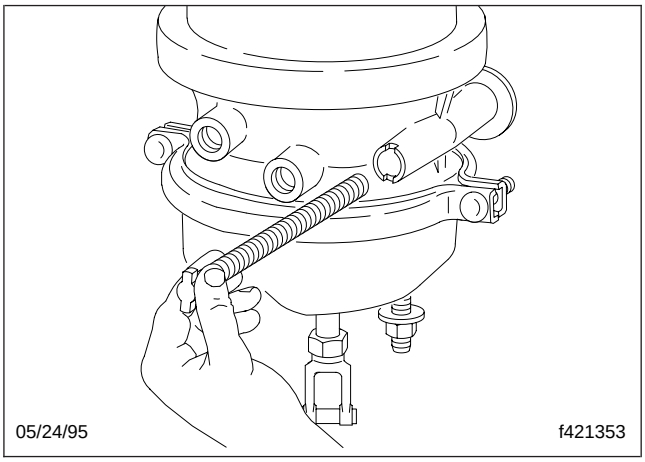


Fig. 3, Remove the Release Bolt

the bolt until it bottoms out into the hole in the piston inside the chamber.

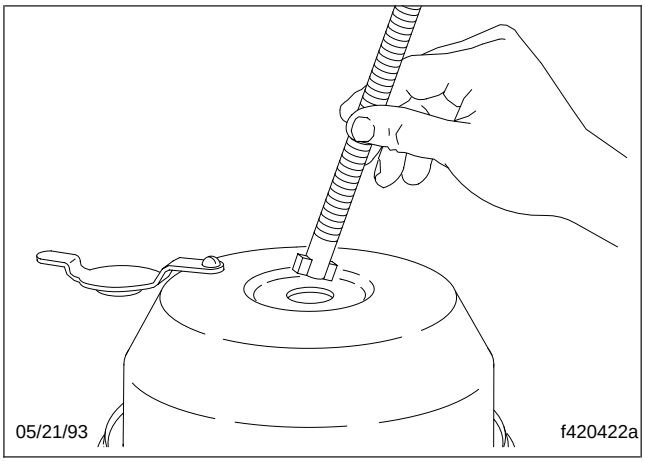


Fig. 4, Insert the Release Bolt

IMPORTANT: If you are not absolutely sure that the formed end of the bolt has engaged the piston correctly, repeat this step. Repeat it until you are absolutely sure.

3.4 Turn the release bolt one-quarter turn clockwise, and pull the bolt out to lock its formed end into the piston.

IMPORTANT: If the bolt does not lock into the piston in less than a 1/2 inch (13 mm) outward movement, repeat these steps until you are sure it does lock.

3.5 Holding the bolt locked into the piston, install the flatwasher and release nut on the end of the release bolt, and turn down the nut against the flatwasher until it is finger-tight. See **Fig. 5**.

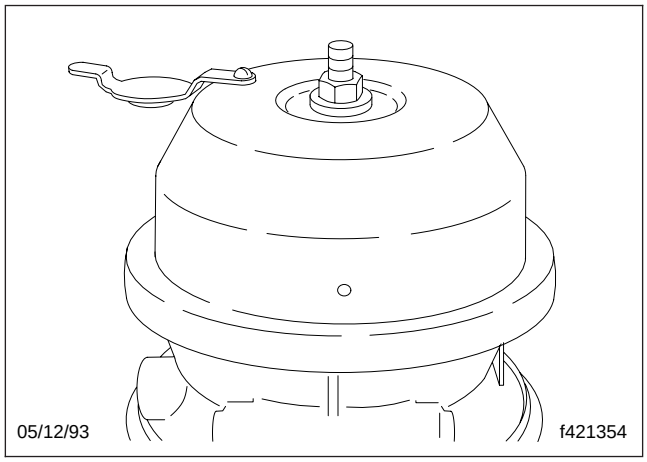


Fig. 5, Flatwasher and Release Nut Installed

⚠ CAUTION

Do not exceed 50 lbf·ft (68 N·m) torque on the release nut; and do not use an impact wrench on this nut. Too much torque could distort the head of the chamber and prevent manual release of the parking brake.

3.6 Using a hand wrench (*do not use an impact wrench*), turn the release nut clockwise until the bolt extends 3 inches (76 mm) above the nut. See **Fig. 6**.

IMPORTANT: Do not exceed the 3-inch (76-mm) length.

4. Once the power spring has been caged, exhaust the compressed air from the parking brake.

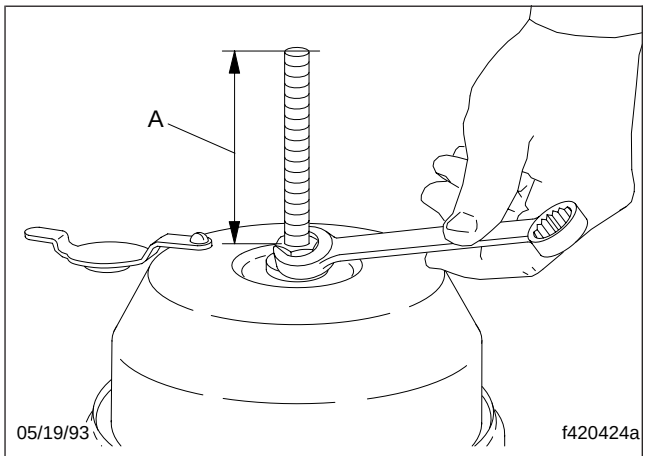
Manual Reset (Parking Brake Reset)

1. Uncage the power spring.

1.1 Apply at least 90 psi (620 kPa) air pressure to the parking brake inlet port (set parking brake in the "release" position).

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Power Spring Manual Compression and Reset



Do not exceed the 3-inch (76-mm) length.
A. Measure this distance.

Fig. 6, Turn the Release Nut

CAUTION

Do not exceed 50 lbf·ft (68 N·m) torque on the release nut; and do not use an impact wrench on this nut. Too much torque could distort the head of the chamber and prevent manual release of the parking brake.

1.2 With air applied to the parking brake section (the parking brake control valve is in the "release" position), use a hand wrench to turn the release nut *counterclockwise* until the bolt bottoms out in the unit.

1.3 Remove the nut and flatwasher.

1.4 Push the release bolt into the piston and turn the release bolt one-quarter turn counterclockwise to unlock its formed end from the piston. Remove the release bolt from the center hole of the chamber.

2. Using a hand wrench (*do not use an impact wrench*), install the release bolt, flatwasher, and release nut in the storage pocket. MGM recommends 10 lbf·ft (14 N·m) torque on the nut against the flatwasher. See **Fig. 7**.

3. Snap the end cover cap in place over the center hole in the chamber head. See **Fig. 8**.

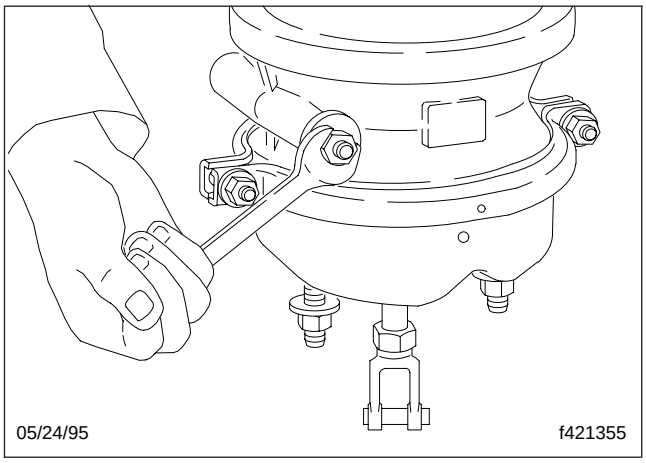


Fig. 7, Tighten the Release Nut

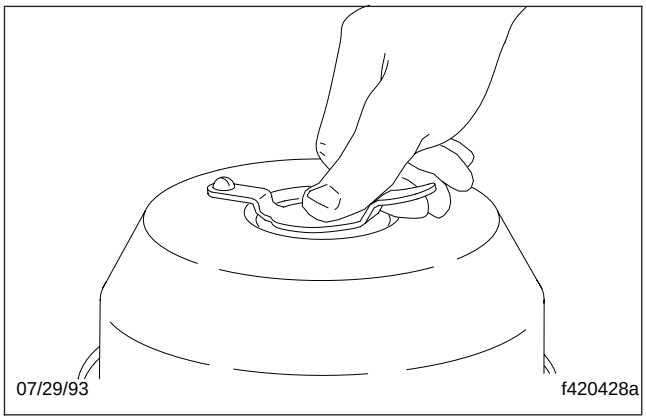


Fig. 8, Snap the End Cover Cap in Place

CAUTION

If the external breather tube or end cover cap is missing or incorrectly installed, road dirt and debris can adversely affect the operation of the brake chamber. Once inside the chamber, dirt and debris cause the internal parts to deteriorate and shorten their lives. Operating the unit without the external breather tube or end cover cap in place voids the MGM warranty.

4. Check the plastic end cover cap periodically. If it is damaged or missing, replace it with a new one at once. For intervals, see the *Acterra Maintenance Manual*.

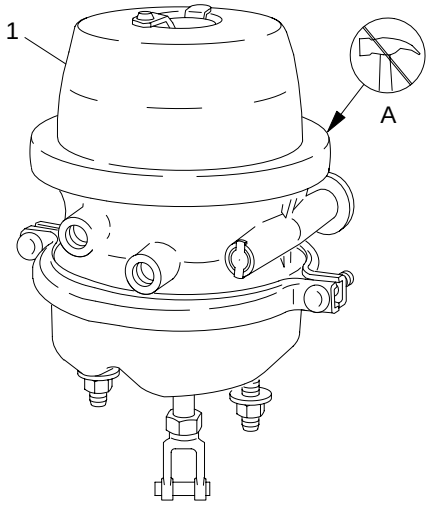
5. Remove the chocks from the tires.

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Service Brake Diaphragm Removal and Installation

DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



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A. Do not remove the factory-sealed clamp ring.

1. Model TR-T (TR Series) Brake Chamber

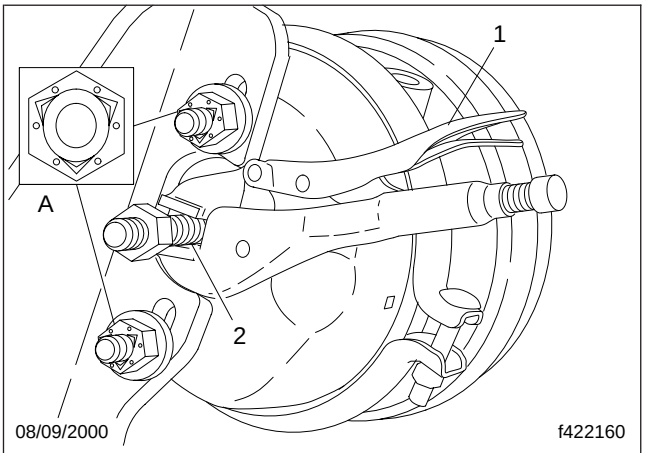
Fig. 1, Brake Chamber

Removal

1. To make removal and installation of the parking brake section easier (without removing the service brake chamber), lock off the service chamber piston rod.

   1.1 Apply the service brakes by actuating the driver's foot brake treadle valve.

   1.2 With the brakes applied, clamp a pair of locking-jaw pliers on the piston rod to lock the rod in place when the air pressure is released. See Fig. 2.



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A. Prevailing Torque Locknut

1. Locking-Jaw Pliers
2. Piston Rod

Fig. 2, Lock the Piston Rod in Place

WARNING

Before caging (compressing) the power spring, chock the vehicle tires and read the warnings and instructions in Subject 100. When the power spring is caged, the vehicle may be without brakes, allowing it to roll out of control, possibly resulting in personal injury or property damage.

2. Manually release the parking brake (cage the power spring). For instructions, see Subject 100.

3. Mark the air lines for later reference. Carefully disconnect them from the brake chamber.

   On chambers equipped with an external breather tube, disconnect the tube and elbow from the service brake chamber.

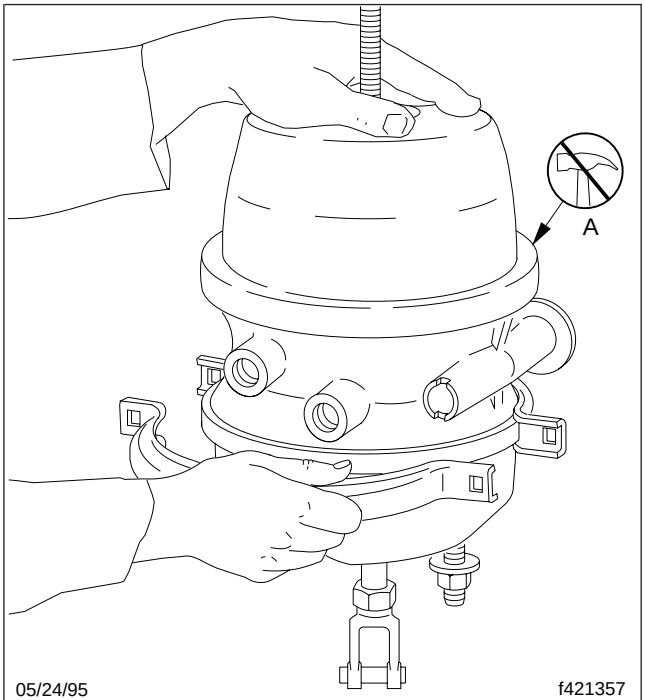
4. Remove the parking brake section from the service brake section.

   4.1 Using a hand wrench (*do not use an impact wrench*), remove the clamp nuts on the *service* clamp ring (*do not disassemble the parking brake section*).

   4.2 While holding the parking brake section securely in place, remove the service clamp ring. Remove the parking brake section from the service brake non-pressure chamber. See Fig. 3.

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Service Brake Diaphragm Removal and Installation



A. Do not remove the factory-sealed clamp ring.

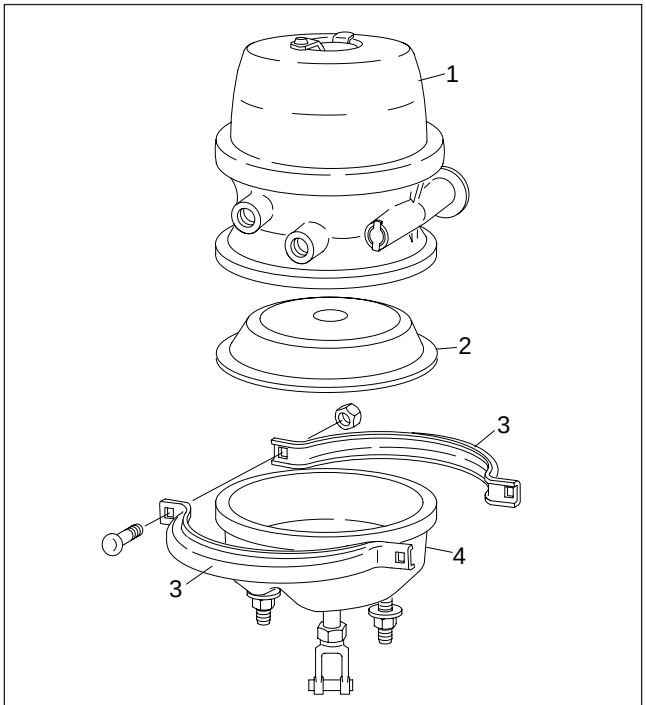
Fig. 3, Remove the Service Clamp Ring

5. Remove the service brake diaphragm from the bottom of the parking brake section.

Installation

IMPORTANT: At this time, take the opportunity to inspect the parking/emergency brake section, and replace it if it shows signs of damage, corrosion, or rust. Follow the detailed inspection instructions in the *Acterra Maintenance Manual*.

1. Inspect all parts in the service (non-pressure) chamber. Replace any damaged or worn parts with genuine MGM-engineered replacement parts.
2. Place the new service brake diaphragm in the bottom recess of the parking brake section. See **Fig. 4**.
3. Install the (new, if needed) parking/emergency brake section.



1. Parking/Emergency Brake Section
2. Service Brake Diaphragm
3. Service Brake Clamp Ring
4. Service Brake (Non-Pressure) Chamber

Fig. 4, Brake Chamber Parts

3.1 If installing a new parking brake section, be sure it is the same size and make as the old one.

3.2 Check that the release bolt is fully extended outward. For instructions, see **Subject 100**.

3.3 Install the parking brake section on the service chamber so that all mating parts are aligned straight and the air lines are positioned to mate with the vehicle air supply lines.

4. Install the service brake clamp ring.

4.1 With the service brake clamp ring in place, install the clamp bolts and nuts.

4.2 Using a hand wrench (*do not use an impact wrench*), alternately tighten each clamp nut in increments of 60 to 120 lbf·in

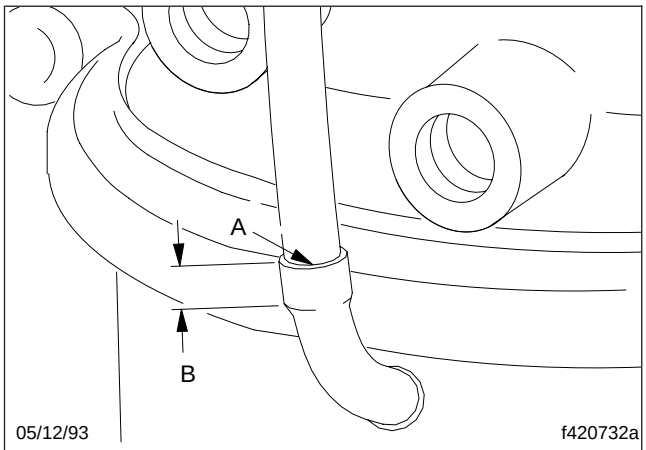
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(680 to 1360 N·cm) while constantly rechecking the alignment of mating parts.

If realignment is needed, loosen the nuts again, and repeat this substep.

4.3 Firmly tap around the circumference of the service clamp ring with a rubber mallet to ensure full seating of the clamp. Tighten the nuts to a final torque of 25 to 30 lbf·ft (34 to 41 N·m).

5. Make sure the air hose fittings are free of grease, dirt, and other debris. Apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*do not use an impact wrench*), tighten the fittings 25 lbf·ft (34 N·m).
6. Using the vehicle system air, charge the parking brake with full line pressure—at least 100 psi (690 kPa). Using only soapy water (*never any type of oil,* which could deteriorate rubber parts), check for air leaks at the air lines and fittings. If bubbles or leaks appear, tighten the fittings slightly, but not over 25 lbf·ft (34 N·m).
7. With the parking brake still charged with full line pressure, apply and hold the foot brake treadle valve down to charge the service brake chamber. Remove the locking-jaw pliers from the service piston rod so that the piston returns to a normal position in the chamber.
8. Test for air leaks around the circumference of the *service* brake clamp ring. If bubbles or leaks appear, firmly tap the circumference of the clamp ring with a rubber mallet, and retighten the clamp nuts until leaks cease (*do not touch the parking brake section*). MGM recommends 25 to 30 lbf·ft (34 to 41 N·m) torque on the clamp hexnuts.
9. On chambers equipped with an external breather tube, make sure that the open end of the tube is free of grease, dirt, and other debris. Apply a high-quality rubber cement to the tube and insert it into the elbow at least a 1/2 inch (13 mm). See **Fig. 5**. Insert the tube into the service brake chamber.
10. With air pressure now exhausted from the service brake chamber, but held on the parking brake, reset the parking brakes by uncaging the power spring, and snap the end cover cap in place. For instructions, see **Subject 100**.
11. Adjust the brakes at the slack adjuster.



A. Apply adhesive here.
B. Check for 1/2 inch (13 mm) minimum engagement.

Fig. 5, Install the External Breather Tube

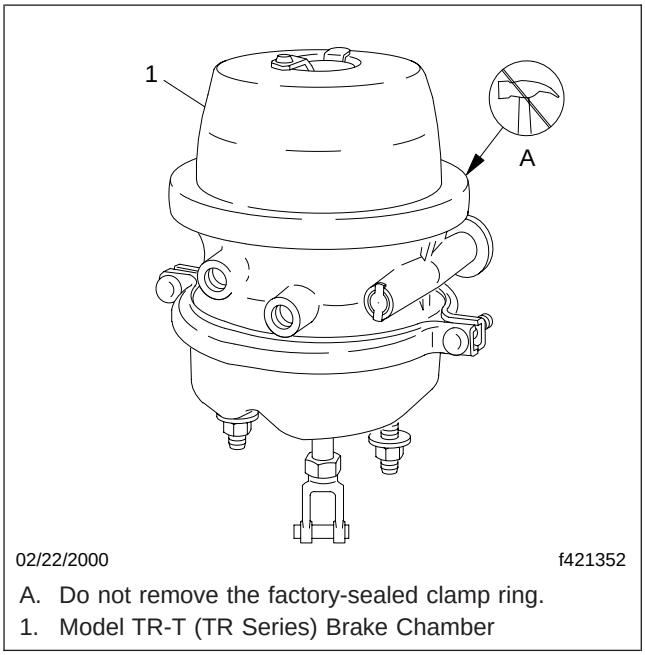
IMPORTANT: After replacing any brake chamber components, check the piston rod stroke and actuating alignment to ensure correct installation and foundation brake adjustment. No foundation brake adjustments, parking brake or service brake, can be made at the chamber and all "stroke" adjustments must be made at the slack adjuster. For instructions, see **Section 42.11** "Automatic Slack Adjusters, Meritor".

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Replacement

⚠ DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



A. Do not remove the factory-sealed clamp ring.
1. Model TR-T (TR Series) Brake Chamber

Fig. 1, Brake Chamber

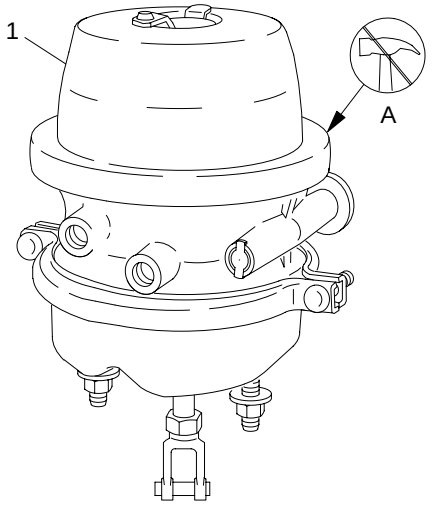
IMPORTANT: The parking/emergency brake section can be replaced as a unit. For instructions, see **Subject 110**.

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Combination Service and Parking Brake Chamber Removal and Installation

⚠ DANGER

Do not attempt to remove the factory-sealed parking brake clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



02/22/2000 f421352

A. Do not remove the factory-sealed clamp ring.

1. Model TR-T (TR Series) Brake Chamber

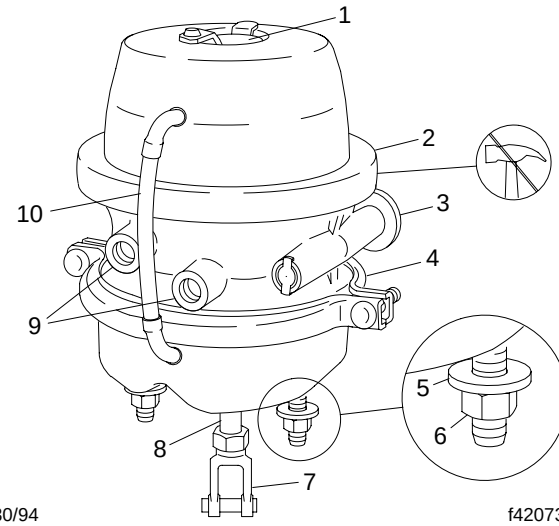
Fig. 1, Brake Chamber

Removal (See Fig. 2)

⚠ WARNING

Before caging (compressing) the power spring, chock the vehicle tires and read the warnings and instructions in Subject 100. When the power spring is caged, the vehicle may be without brakes, allowing it to roll out of control, possibly resulting in personal injury or property damage.

1. Manually release the parking brake (cage the power spring). For instructions, see **Subject 100**.
2. Mark the air lines for later reference. Carefully disconnect the air lines from the brake chambers.
3. Remove the brake chamber from the vehicle.



08/30/94 f420730c

Do not remove the factory-sealed clamp ring.

1. End Cover Cap
2. Factory Sealed Parking Brake Clamp Ring
3. Release Bolt Storage Pocket
4. Service Brake Clamp Ring
5. Hardened Flatwasher
6. Prevailing Torque Locknut
7. Clevis Assembly
8. Piston Rod
9. Air Inlet Ports
10. External Breather Tube

Fig. 2, Model TR-T (TR Series) Brake Chamber

3.1 Remove the cotter pin(s) from the clevis pin(s). Remove the clevis pin(s) from the clevis. Disconnect the clevis from the slack adjuster.

NOTE: Meritor automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

3.2 Make sure the parking brake has been released manually (the power spring has been caged). For instructions, see **Subject 100**. Also, make sure that the service brake piston is fully retracted (in the brakes "OFF" position). Record both of the following dimensions in either inches or mm, measuring outward from the base of the service brake chamber (**Fig. 3**):

- X dimension: to end of threaded piston rod

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Combination Service and Parking Brake Chamber Removal and Installation

- Y dimension: to centerline of (large) clevis pin

IMPORTANT: If new chambers are to be attached to manual slack adjusters, the Y dimension is the most critical measurement. When installing the new assembly, its service piston rod must be cut to exactly duplicate this "rod-plus-clevis" length *after* the clevis assembly is installed on the piston rod. See **Fig. 4**.

If new chambers are to be attached to automatic slack adjusters, the X dimension is the most critical measurement. When installing the new assembly, its service piston rod must be cut to exactly duplicate the "rod only" length *before* the clevis assembly is installed on the piston rod. See **Fig. 4**.

3.3 From each mounting stud, remove any installed nuts and washers. Cautiously remove the brake chamber from the mounting bracket.

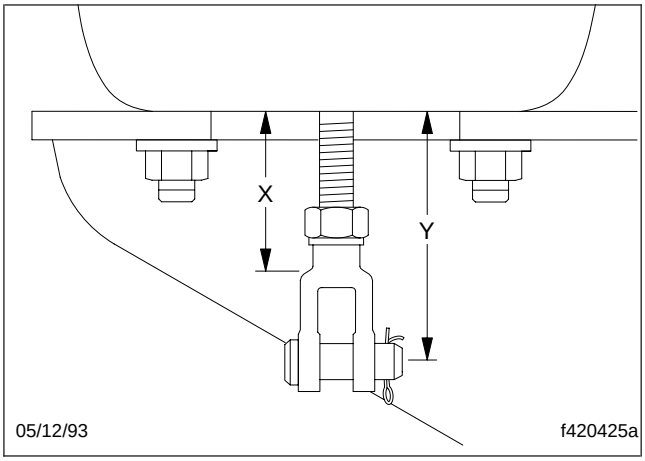


Fig. 3, Measure X and Y

Installation (See Fig. 2)

1. If installing a new brake chamber unit, perform the following steps:

   1.1 Make sure the power spring is caged (release bolt fully extended outward). If not, go to **Subject 100** and perform the applicable steps.

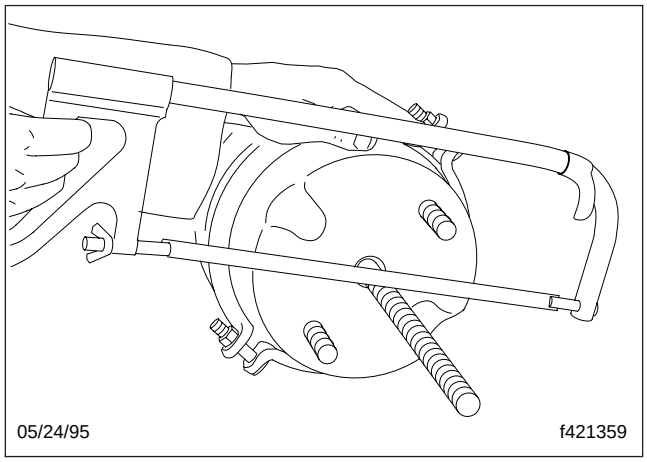


Fig. 4, Cut the Service Piston Rod

   1.2 Make sure that the piston rod is the same length as the rod on the old unit (measure the rods when *both* chambers are caged).

   1.3 Be sure the new chamber is the same size and make as the brake chamber installed on the other side of the axle.

   1.4 Remove the prevailing torque locknut and hardened flatwasher from each of the mounting studs on the chamber.

2. Clean the face of the mounting bracket, and install the chamber on the bracket, paying close attention to positioning the chamber air inlet ports for correct alignment to the vehicle air lines.

⚠ WARNING

Tighten the mounting nuts with a hand wrench, not an impact wrench. An impact wrench could damage the mounting fasteners, reducing the force of the brakes. This could result in personal injury or property damage.

3. Install one hardened flatwasher and prevailing torque locknut on each mounting stud. Using a hand wrench (*do not use an impact wrench*), tighten the nuts 100 to 115 lbf·ft (136 to 156 N·m). Make sure the flatwasher is installed between the locknut and the mounting bracket.

   On chambers equipped with an external breather tube, make sure that the tube is installed in the side of the chamber that faces away from the

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Combination Service and Parking Brake Chamber Removal and Installation

road surface. An improperly installed breather tube voids the MGM warranty.

4. Check mating and alignment with the vehicle air lines.

   4.1 Using a hand wrench (*do not use an impact wrench*), loosen the clamp nuts on the *service* clamp ring (*do not disassemble the parking brake section*).

   4.2 Reposition the air inlet ports, as needed, to mate with vehicle air supply lines.

   Alternately tighten each clamp nut in increments of 60 to 120 lbf·in (680 to 1360 N·cm) while constantly rechecking the alignment of mating parts.

   If realignment is needed, loosen the nuts again and repeat this substep.

   4.3 Firmly tap around the circumference of the service clamp ring with a rubber mallet to ensure full seating of the clamp. Tighten the nuts to a final torque of 25 to 30 lbf·ft (34 to 41 N·m).

5. Install the slack adjuster. For instructions, see **Section 42.11**.

6. Inspect the piston rod to be sure it is working free, not binding, and is square with the chamber bottom within ±3 degrees in any direction from zero to full stroke. If there is misalignment, make corrections by loosening the locknuts and repositioning the chamber on the mounting bracket, or by shimming the slack adjuster to the right or left on the camshaft.

7. Make sure the air hose fittings are free of grease, dirt, and other debris. Apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*do not use an impact wrench*), tighten the fittings 25 lbf·ft (34 N·m).

8. Using the vehicle system air, charge the parking brake with full line pressure, at least 100 psi (690 kPa). Using only soapy water (*never any type of oil,* which could deteriorate rubber parts), check for air leaks at the air lines and fittings. If bubbles or leaks appear, tighten the fittings slightly, but not over 25 lbf·ft (34 N·m).

IMPORTANT: If the service brake clamp ring was loosened to reposition the air inlet ports, apply air to the parking brake, and then apply and hold the foot brake treadle valve down to charge the service brake chamber. Now test for air leaks around the circumference of the *service* brake clamp ring. If bubbles or leaks appear, firmly tap the circumference of the clamp ring with a rubber mallet, and retighten the clamp nuts until leaks cease (*do not touch the parking brake section*). MGM recommends 25 to 30 lbf·ft (34 to 41 N·m) torque on the clamp hexnuts.

9. With air pressure now exhausted from the service brake chamber, but held on the parking brake, reset the parking brakes by uncaging the power spring and snap the end cover cap in place. For instructions, see **Subject 100**.

10. Adjust the brakes at the slack adjuster. For instructions, see **Section 42.11**.

IMPORTANT: After replacing any brake chamber, check the piston rod stroke and actuating alignment to ensure correct installation and foundation brake adjustment. No foundation brake adjustments, parking brake or service brake, can be made at the chamber and all "stroke" adjustments must be made at the slack adjuster. For instructions, see **Section 42.11**.

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Specifications

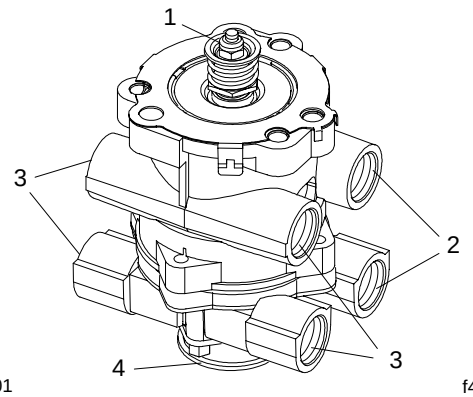
Torque Values	
Description	**Torque lbf·ft (N·m)**
Spring Brake Release Bolt Nut (in storage pocket)	10 (14)
Service Brake Clamp Ring Nut	25–30 (34–41)
Brake Chamber Mounting Stud Nut	100–115 (136–156)
Air Hose Fitting-to-Chamber	25 (34)

Table 1, Torque Values

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General Information

The E–8P dual brake valve (**Fig. 1**) is a frontwall-mounted, pedal-operated brake valve. It has two separate supply and delivery circuits for service (primary and secondary) braking. These provide the driver with a graduated control for applying and releasing the vehicle brakes.



NOTE: Auxilary Port is not shown.

1. Plunger
2. Delivery Ports (4 total)
3. Supply Ports (4 total)
4. Exhaust Port

Fig. 1, Bendix E-8P Valve

The E–8P dual brake valve circuits are identified as:

- The No. 1 or primary circuit, which is the portion of the valve between the spring seat which contacts the plunger and the relay piston;
- The No. 2 or secondary circuit, which is the portion between the relay piston and the exhaust cavity.

The primary circuit of the valve is similar in operation to a standard single circuit air brake valve and under normal operating conditions the secondary circuit is similar in operation to a relay valve. Both primary and secondary circuits of the brake valve use a common exhaust protected by an exhaust diaphragm.

Applying During Normal Operation

No. 1 or Primary Circuit

When the brake pedal is depressed, the plunger exerts force on the spring seat, graduating spring, and primary piston. The primary piston, which contains the exhaust valve seat, closes the primary exhaust valve. As the exhaust valve closes, the primary inlet valve is moved off its seat allowing primary air to flow out the No. 1 or primary delivery port.

No. 2 or Secondary Circuit

When the primary inlet valve is moved off its seat, air is permitted to pass through the bleed passage and enters the relay piston cavity. The air pressure moves the relay piston, which contains the exhaust seat, and closes the secondary exhaust valve. As the secondary exhaust valve closes, the inlet valve is moved off its seat allowing the secondary air to flow out the delivery of the same circuit. Because of the small volume of air required to move the relay piston, action of the secondary circuit of the valve is almost simultaneous with the primary circuit portion.

Applying with a Loss of Air

In the No.1 or Primary Circuit

Should air be lost in the primary circuit, the function will be as follows:

1. As the brake pedal is depressed and no air pressure is present in the primary circuit supply and delivery ports, the primary piston will mechanically move the relay piston.
2. As a result, the secondary exhaust valve will close.
3. The secondary inlet valve will open which will allow air to flow out the secondary delivery port.

In the No. 2 or Secondary Circuit

Should air be lost in the No. 2 or secondary circuit, the No. 1 or primary circuit will continue to function as described above under "Applying During Normal Operation", "No. 1 or Primary Circuit".

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General Information

Balanced

No. 1 or Primary Circuit

When the primary delivery pressure acting on the primary piston equals the mechanical force of the brake pedal application, the primary piston will move and the primary inlet valve will close. This, in turn, stops any further flow of air from the primary supply line through the valve. The exhaust valve remains closed preventing any escape of air through the exhaust port.

No. 2 or Secondary Circuit

When the air pressure on the delivery side of the relay piston approaches that being delivered on the primary side of the relay piston, the relay piston moves closing the secondary inlet valve. This, in turn, stops any further flow of air from the supply line through the valve. The exhaust remains closed as the secondary delivery pressure balances the primary delivery pressure.

When applications in the graduating range are made, a balanced position in the primary circuit is reached as the air pressure on the delivery side of the primary piston equals the effort exerted by the driver's foot on the pedal. A balanced position in the secondary side of the relay piston closely approaches the air pressure on the primary side of the relay piston.

When the brake pedal is fully depressed, both the primary and secondary inlet valves remain open and full reservoir pressure is delivered to the actuators.

Releasing

No. 1 or Primary Circuit

With the brake pedal released, mechanical force is removed from the spring seat, graduating spring, and primary piston. Air pressure and spring load moves the primary piston, opening the primary exhaust valve, allowing air pressure in the primary delivery line to exhaust out the exhaust port.

No. 2 or Secondary Circuit

With the brake pedal released, air is exhausted from the primary circuit side of the relay piston. Air pressure and spring load move the relay piston, opening the secondary exhaust valve, allowing air pressure in the secondary delivery line to exhaust out the exhaust port.

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Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

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Operating Test

IMPORTANT: If there is a change in the way a vehicle brakes, or if low pressure warnings occur, check the operation of the brake air system. Although the brake system may continue to work, do not operate the vehicle until the braking circuits, including the pneumatic and mechanical devices, have been repaired and are operating normally. Always check the brake system for correct operation after doing brake work, and before returning the vehicle to service.

Check for the correct brake valve operation as follows:

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires.

IMPORTANT: When checking the delivery pressure of the primary and secondary circuits, use test gauges that are accurate.

2. Connect test gauges to the primary and secondary delivery ports on the brake valve. Mark the air lines for installation.
3. Start the engine and build air pressure to 120 psi (827 kPa).
4. Depress the pedal to several different positions; check the pressure on the test gauges to ensure that it varies equally and proportionally with the movement of the brake pedal.
5. Fully depress the brake pedal, and release it. After a full application is released, the reading on the test gauges should promptly fall to zero.

NOTE: Pressure in the primary delivery circuit will be about 2 psi (14 kPa) greater than the pressure in the secondary delivery circuit (if both supply reservoirs are at the same pressure). This is normal for this valve.

6. Shut down the engine.
7. Remove the test gauges from the brake valve.
8. Connect the delivery air lines to the delivery ports on the brake valve, as marked during removal. Finger-tighten the nuts. Using a wrench, tighten the nuts until there is resistance. Tighten one-sixth additional turn.
9. Go to "Leakage Test."

Leakage Test

1. Apply and hold the brakes at a pressure of 80 psi (550 kPa).
2. Check the air line fittings for leaks. Tighten or replace fittings as needed.
3. Coat the exhaust port and body of the valve with a soap solution and check for leakage. The maximum leakage permitted is a 1-inch (25-mm) bubble in 3 seconds.
4. If the brake valve does not function as described above, or if leakage is excessive, replace it with a new or remanufactured unit.
5. Repeat the leakage test before placing the brake valve in service.
6. Remove the chocks from the tires.

⚠ WARNING

Do not operate the vehicle until the brakes have been checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

7. Test drive the vehicle in a safe area at low speed. Make several brake applications to be sure the vehicle comes to a safe stop.

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Dual Brake Valve Removal and Installation

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface. Shut down the engine. Chock the tires and hold the vehicle by means other than air brakes.

⚠ WARNING

When draining the air system, do not look into the air jets or direct them toward anyone, because dirt or sludge particles may be in the airstream. Do not disconnect pressurized hoses because they may whip as air escapes from the line. Failure to take all necessary precautions during service operations of the air brake system can result in personal injury.

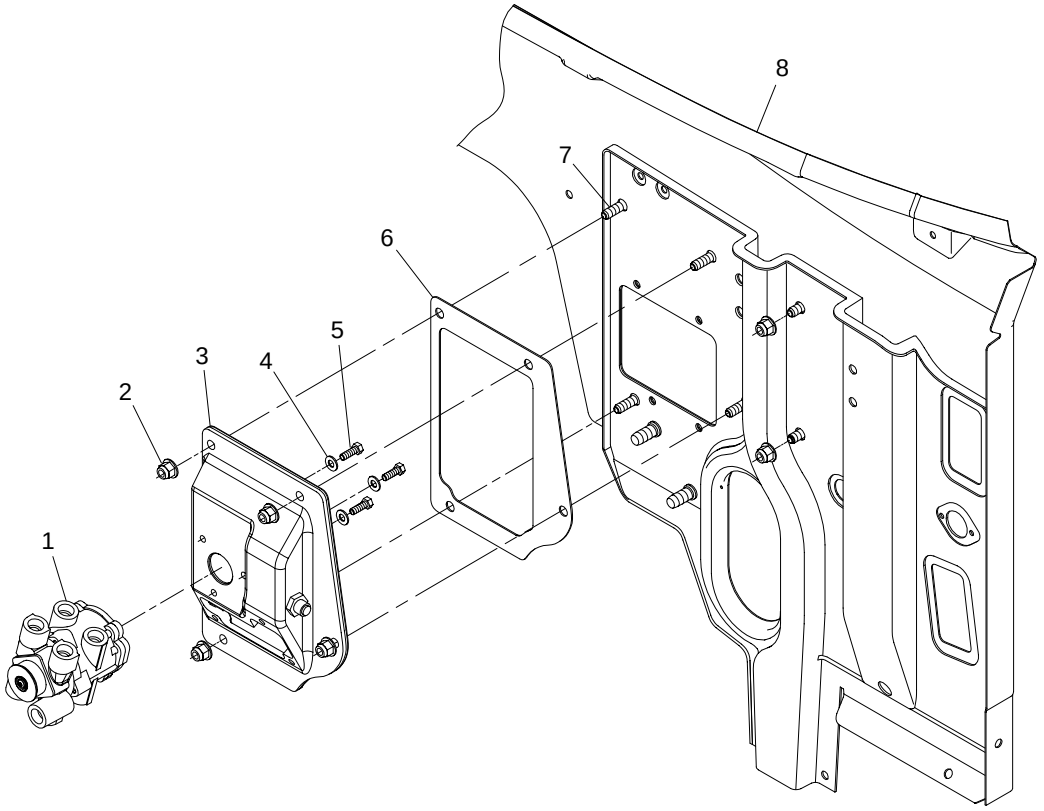
2. Drain the vehicle's air system.
3. Open the hood and locate the air brake valve (foot valve) mounted on the frontwall. See **Fig. 1**. Mark the brake valve and double check valve air lines for later assembly. A double check valve (Bendix DC-4) is mounted on the brake valve.
4. Disconnect the air lines from the brake valve and double check valve. Plug the lines to prevent contaminants from entering the pneumatic system.
5. Remove the under steering panel. See **Fig. 2**.
   - 5.1 Inside the cab, remove the five screws from the under steering panel.
   - 5.2 Remove the spacer.
   - 5.3 Remove the panel.
6. Remove the flanged hexnut, washer, and bolt securing the brake plunger to the air brake lever. See **Fig. 3**. Discard the hexnut.
7. Remove the bearing from the air brake lever. The bearing sits horizontally in a U-shaped cutout near the cab end of the brake plunger. See **Fig. 4**.
   - 7.1 Lift the brake pedal up and push the brake plunger in slightly.
   - 7.2 Reach behind the brake lever and remove the bearing from the plunger.

NOTE: It is not necessary to remove the 14 color-coded hoses from the manifold on the cab side of the mounting bracket. The air lines are long enough to allow the rest of the valve removal procedure to be done on the engine side of the frontwall.

8. In the engine compartment, remove the four flanged locknuts that attach the air valve and manifold bracket (mounting bracket) to the studs on the frontwall. See **Fig. 1**.
9. Remove the mounting bracket and valve from the studs.
10. On the inside of the mounting bracket, remove the three 5/16–18 capscrews and washers that secure the brake valve to the bracket. Remove the valve.
11. Remove the two 5/16–18 machine screws and washers securing the rubber seal assembly (rubber boot) to the mounting bracket. See **Fig. 5**. Remove the seal.
12. Slide the brake plunger out of the bore in the center of the mounting bracket. Wipe off the old grease from the plunger, rubber seal, and bracket.
13. Wipe out the old lubricant from the bore, and any bearing dust and using clean shop air.
14. Inspect the brake plunger bearing (in the center bore) and the sliding surface of the plunger. If there is any wear or damage (cracks or chips), replace the part.
15. Inspect the guide bearing and rubber seal assembly; replace the assembly if it is damaged.
16. Note the location and position of the air line fittings and double check valve on the brake valve, and remove them. Clean any dirt and old sealant from the threads on the fittings.

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Dual Brake Valve Removal and Installation



NOTE: For clarity, the frontwall is not shown between the dash panel in the cab (item 8) and the gasket in the engine compartment (item 6). The studs on the steering column bracket extend through the frontwall.

1. Brake Valve
2. M10 x 1.5 Flanged Locknut (4 qty.)
3. Mounting Bracket
4. Plated Washer (3 qty.)
5. 5/16–18 x 1-Inch Capscrew (3 qty.)
6. Gasket
7. Steering Column Bracket Stud
8. Frontwall

Fig. 1, Brake Valve Removal

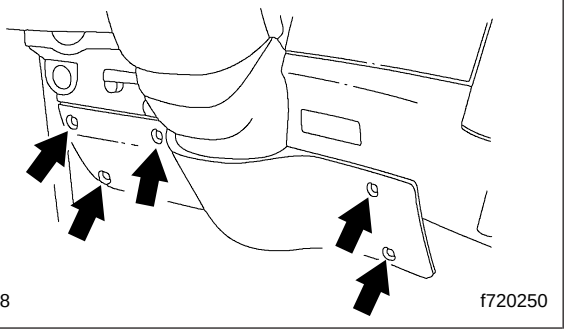


Fig. 2, Under Steering Panel Screw Location

Installation

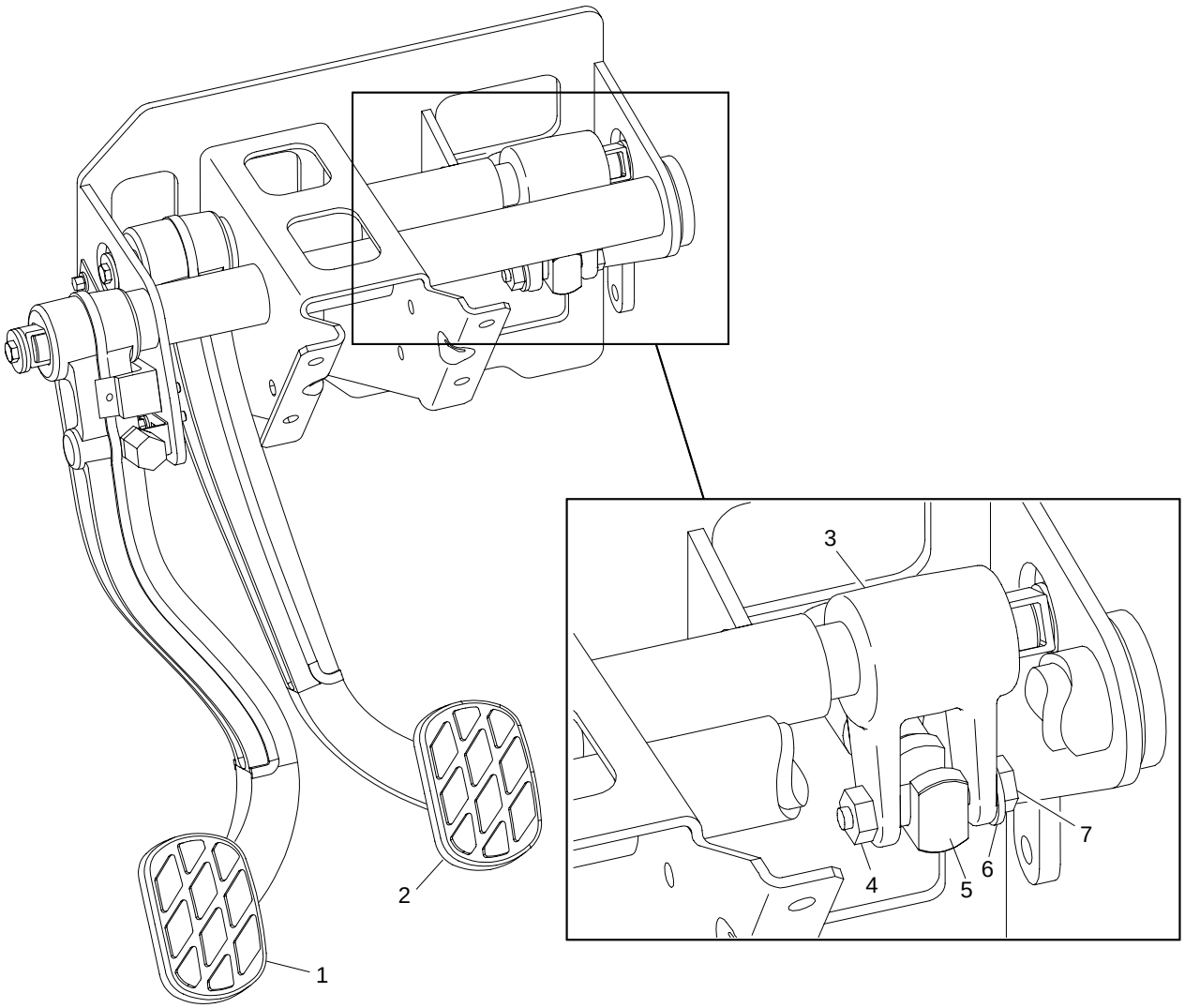
⚠ WARNING

When applying sealant, make sure excess sealant does not get inside the fittings. Loose foreign material inside the air plumbing may clog a valve, causing a loss of brake control that could result in personal injury and property damage.

1. Apply a small quantity of Loctite® pipe sealant with Teflon® 59241, or equivalent, to the male threads on each of the fittings for the brake valve.

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Dual Brake Valve Removal and Installation



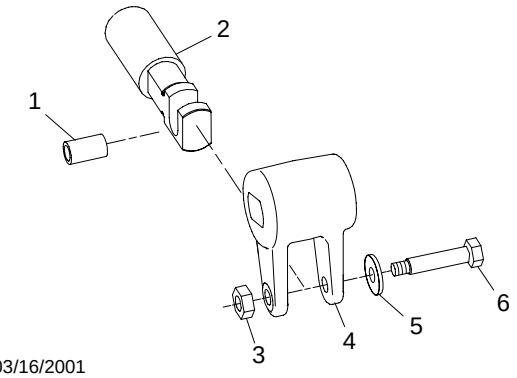
1. Clutch Pedal
2. Brake Pedal
3. Air Brake Lever
4. M8 Class 10 Flanged Hexnut
5. Brake Plunger
6. Hardened Washer
7. M8 x 1.25-50 Hexhead Socket Shoulder Bolt

Fig. 3, Brake- and Clutch-Pedal Assembly

2. Install the air line fittings and double check valve on the brake valve. Finger-tighten them, plus one additional turn with a wrench. If needed, continue tightening them slightly until they are positioned correctly.
3. Lightly Lubricate the sliding surface on the brake plunger and the bearing bore with a silicone-based grease such as Dow Corning 55 O-Ring Lubricant or Loctite V-755 O-Ring Lubricant.
4. Carefully slide the brake plunger into the bearing in the mounting bracket. Make sure the plunger is positioned correctly with the U-shaped cutout facing up. See **Fig. 3**.
5. Install the guide bearing and rubber seal assembly on the mounting bracket with the arrow point-

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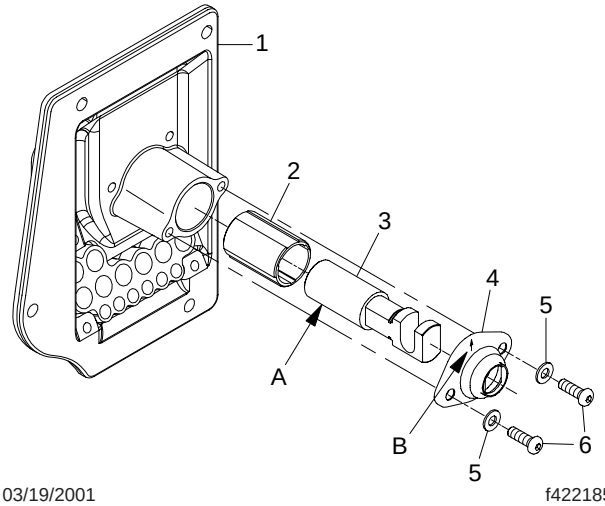
Dual Brake Valve Removal and Installation



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1. Bearing
2. Brake Plunger
3. M8 Class 10 Flanged Hexnut
4. Air Brake Lever
5. Hardened Washer
6. M8 x 1.25-50 Hexhead Socket Shoulder Bolt

Fig. 4, Air Brake Lever Assembly



03/19/2001 f422185

A. Apply a small amount of silicon grease on the contact surface between items 2 and 3.
B. Install the rubber seal assembly with the arrow pointing up.

1. Mounting Bracket
2. Brake Plunger Bearing
3. Brake Plunger
4. Guide Bearing and Rubber Seal Assembly
5. Plated Flatwasher
6. 5/16–18 x 1-Inch Machine Screw

Fig. 5, Brake Plunger Removal

ing up. Secure the seal with two washers and 5/16–18 machine screws. Tighten the screws 15 lbf·ft (20 N·m).

6. Place the brake valve on the outside of the mounting bracket and secure with three 5/16–18 capscrews and washers. Tighten the capscrews 15 lbf·ft (20 N·m).
7. Install the brake valve and mounting bracket as a unit on the studs on the frontwall. Secure in place with four M10 x 1.5 flanged locknuts. Tighten the locknuts 27 lbf·ft (37 N·m).
8. Inside the cab, place the lever bearing in the U-shaped cutout near the end of the brake plunger. See **Fig. 4**.
9. Align the lever bearing with the holes in the brake lever.

IMPORTANT: The shoulder bolt may be reused but the hexnut must be replaced after it is removed for any reason. When replacing the shoulder bolt or hexnut, use only the specified part numbers. **Do not substitute!**

10. Insert a washer and M8 x 1.25-50 shoulder bolt (23-12698-450) through the holes in the brake lever and bearing. Secure in place with a new M8, class 10 flanged hexnut (210100 008000). Tighten the nut 17 lbf·ft (23 N·m).
11. Install the under steering panel.
    - 11.1 Position the under steering panel.
    - 11.2 Install the spacer.
    - 11.3 Tighten the five screws. See **Fig. 2**.
12. Connect the air supply and delivery lines to the applicable ports on the brake valve, as marked during removal.
13. Perform the operating and leakage checks. For instructions, see **Subject 110**.
14. Close the hood.
15. Remove the chocks from the tires.

⚠ WARNING

Do not operate the vehicle until the brakes have been checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

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16. Test drive the vehicle in a safe area at low speed. Make several brake applications to be sure the vehicle comes to a stop.

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Dual Brake Valve Disassembly, Cleaning and Inspecting, and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Disassembly

Refer to **Fig. 1** during valve disassembly.

1. Park the vehicle on a level surface. Shut down the engine. Chock the tires.
2. Remove the valve from the vehicle following the instructions in **Subject 120**.
3. Remove the three capscrews that hold the treadle assembly to the basic brake valve.
4. Remove the screw securing the exhaust diaphragm and washer to the exhaust cover.
5. Remove the four screws that secure the exhaust cover to the lower body.
6. Remove the secondary inlet and exhaust valve assembly from the lower body.
7. Remove the four hexhead capscrews securing the lower body to the upper body. Separate the body halves.
8. Remove the rubber seal ring from the lower body.
9. While applying thumb pressure to the primary piston, lift up on the three lock tabs of the primary piston retainer.

⚠ CAUTION

The locknut and stem are used to contain the primary piston return spring, stem spring, and the relay piston spring. The combined force of these springs is approximately 50 lb (23 kg) and care must be taken when removing the locknut as the spring forces will be released. It is recommended that the primary piston and relay piston be manually or mechanically contained while the nut and stem are being removed.

10. Using a 3/8-inch wrench, hold the locknut on the threaded end of the stem. Insert a screwdriver to restrain the stem, remove the locknut, spring seat, and stem spring.

⚠ WARNING

Remove the relay piston, relay piston spring, primary piston and primary piston return spring from the upper body. Use care not to nick the seats.

11. A small washer will be found in the cavity of the lower side of the primary piston.
12. Disassemble the primary piston by rotating the spring seat nut counterclockwise. Separate the spring seat nut, spring seat, and rubber spring. Remove the piston O-ring.
13. Remove the large and small O-rings from the relay piston.
14. Remove the retaining ring securing the primary inlet and exhaust valve assembly in the upper body. Remove the valve assembly.

Cleaning and Inspecting

1. Clean all the metal parts in mineral spirits. Dry them with compressed air.
2. Check all the parts for excessive wear or deterioration. If any corrosion, wear, or damage is found, replace the part.
   - 2.1 Inspect the valve seats for nicks or burrs.
   - 2.2 Check the springs for cracks or corrosion.
   - 2.3 Replace the rubber parts and any part not found to be serviceable during inspection. Use only genuine Bendix replacement parts.
   - 2.4 Check all the air line fittings and clean any thread sealant from them.

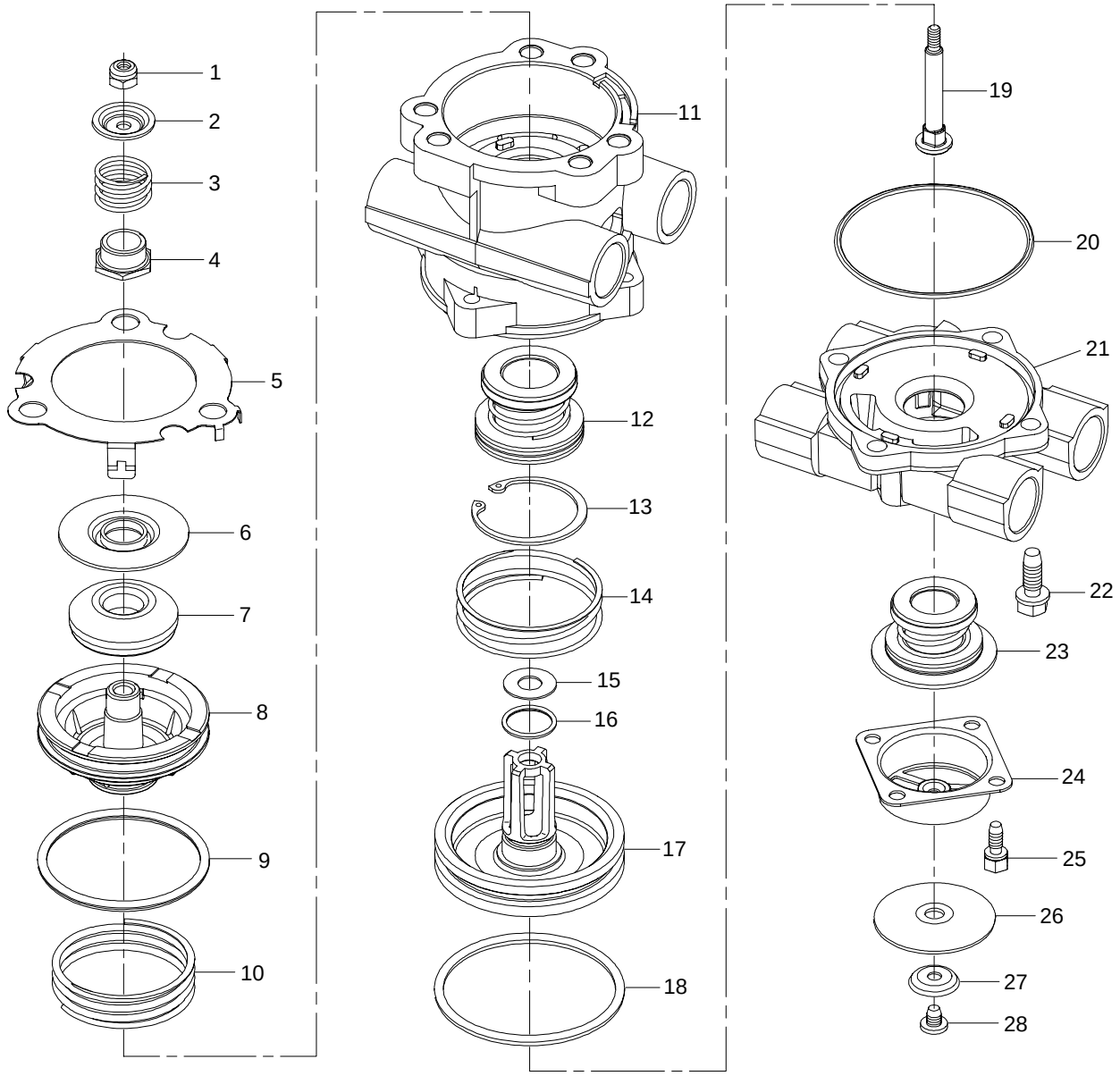
Assembly

Refer to **Fig. 1** during valve assembly.

IMPORTANT: Keep the brake valve parts clean during assembly.

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Dual Brake Valve Disassembly, Cleaning and Inspecting, and Assembly



1. Locknut
2. Spring Seat
3. Stem Spring
4. Primary Piston Spring Seat Nut
5. Primary Piston Retainer
6. Spring Seat
7. Rubber Spring
8. Primary Piston
9. Piston O-Ring
10. Primary Piston Return Spring
11. Upper Body
12. Primary Inlet/Exhaust Valve Assembly
13. Retaining Ring
14. Relay Piston Spring
15. Small Washer
16. Small O-Ring
17. Relay Piston
18. Large O-Ring
19. Stem
20. Rubber Seal Ring
21. Lower Body
22. Body Attaching Screws (Qty. 4)
23. Secondary Inlet/Exhaust Valve Assembly
24. Exhaust Cover
25. Exhaust Cover Attaching Screws (Qty. 4)
26. Exhaust Diaphragm
27. Diaphragm Washer
28. Screw

Fig. 1, Dual Brake Valve, Bendix E-8P

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Dual Brake Valve Disassembly, Cleaning and Inspecting, and Assembly

1. Using Dow Corning 55 O-ring lubricant or equivalent, lightly grease all the O-rings, O-ring grooves, piston bores, and all sliding surfaces.
2. Install the primary inlet and exhaust assembly in the upper body and replace the retaining ring to secure it. Be sure the retaining ring is seated completely in its groove.
3. Install the large and small O-rings on the relay piston.
4. Install the O-ring in the primary piston O-ring groove.
5. Install the rubber spring (do not lubricate), concave side down in the primary piston. Place the spring seat flat side up over the rubber spring.
6. Install the primary piston spring seat nut with its hex closest to the spring seat and rotate clockwise until the top surface of the spring seat is even with the top surface of the piston. Set it aside.
7. Place the relay piston spring in the concave portion of the relay piston. Install the relay piston through the primary inlet/exhaust assembly and into the under side of the upper body.
8. Place a screwdriver, blade up, in a vise. Insert the stem through the relay piston upper body sub assembly. Slide the assembly over the blade of the secured screwdriver. Engage the screwdriver blade in the slot in the head of the stem.
9. Place the washer over the stem and on top of the relay piston.
10. Install the primary return spring in the upper body piston bore.
11. Install the primary piston rubber spring subassembly over the stem, into the upper body piston bore.

⚠ CAUTION

The locknut and stem are used to contain the primary piston return spring, stem spring, and the relay piston spring. The combined force of these springs is approximately 50 lb (23 kg) and care must be taken when removing/installing the locknut as the spring forces will be released. It is recommended that the primary piston and relay piston be manually or mechanically contained while the nut and stem are being removed/installed.

12. Compress the relay piston and the retaining ring into the upper body from either side and hold compressed, either manually or mechanically.
13. Place the stem spring (over the spring seat nut), the spring seat (concave side up), and locknut on the stem. Torque 20 to 30 lbf·in (220 to 340 N·cm).
14. Install the primary piston retainer over the piston, making certain all three locktabs have engaged the outer lip of the body.
15. Replace the rubber seal ring on the lower body.
16. Install the four hexhead capscrews securing the lower body to the upper body. Torque 30 to 60 lbf·in (340 to 680 N·cm).
17. Install the secondary inlet/exhaust valve assembly on the lower body.
18. Install the screws that secure the exhaust cover to the lower body. Torque 20 to 40 lbf·in (220 to 460 N·cm).
19. Secure the screw holding the exhaust diaphragm and the diaphragm washer to the exhaust cover. Torque 5 to 10 lbf·in (60 to 120 N·cm).
20. Install all air line fittings and plugs making certain thread sealant material does not enter the valve.
21. Install the valve on the vehicle following the instructions in **Subject 120**.
22. Remove the chocks from the tires.

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Specifications

Torque Values		
Description	**Torque**	
	lbf·ft (N·m)	**lbf·in (N·cm)**
Outer Bolt Circle Capscrews	23 (31)	—
Stem Locknut	—	20–30 (220–340)
Lower Body-to-Upper Body Hexhead Capscrews	—	30–60 (340–680)
Exhaust Cover-to-Lower Body Screws	—	20–40 (220–460)
Exhaust Diaphragm and Washer-to-Exhaust Cover Screw	—	5–10 (60–120)
Guide Bearing and Rubber Seal Assembly Machine Screws	15 (20)	—
Brake Valve-to-Mounting Bracket Capscrews	15 (20)	—
Mounting Bracket-to-Steering Column Bracket Stud Flanged Locknuts	27 (37)	—
Brake Lever Flanged Hexnut	17 (23)	—

Table 1, Torque Values

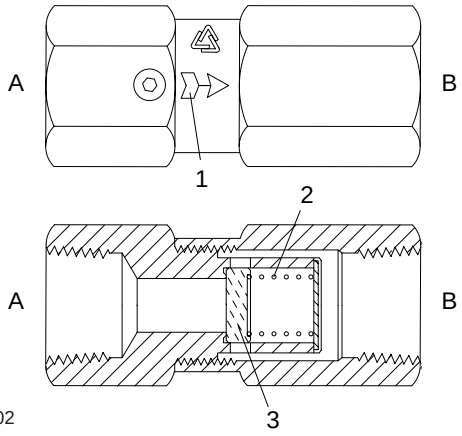
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General Information

The single check valve is installed in an air line to allow air flow in one direction and prevent air flow in the reverse direction. The check valve is installed in the upstream ends of the primary and secondary brake system air reservoirs to protect brake system air pressure in case the compressor, air pressure regulator or other air delivery component malfunctions.

The two types of SC-3 in-line single check valves are the wafer-style type (**Fig. 1**) and the ball type (**Fig. 2**).

NOTE: The SC-3 single check valve is NOT serviceable.



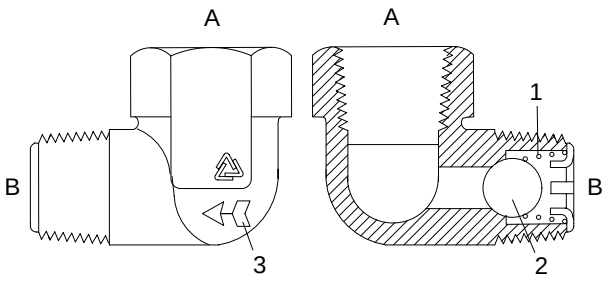
A. Supply Air
B. Delivery Air

1. Air-Flow Direction Arrow
2. Spring
3. Wafer-Type Check Valve

Fig. 1, Single Check Valve, Wafer-Type

Principle of Operation

Air flow in the normal direction moves the check valve from its seat, and the flow is unobstructed. Flow in the reverse direction is prevented by the seating of the ball or wafer-type disc, which is caused by a drop in up-stream air pressure and assisted by the spring.



A. Supply Air
B. Delivery Air

1. Spring
2. Ball-Type Check Valve
3. Air Flow Direction Arrow

Fig. 2, Single Check Valve, Ball-Type

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Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

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WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Leakage Test

After repairing or replacing the single check valve, do the following test:

1. With the brake air system fully pressurized, drain the air from the supply reservoir (wet tank).
2. Remove the air line from the supply side of the check valve.
3. Coat the open end of the check valve with soap suds. A 1-inch (2.5-cm) or smaller bubble in 5 seconds is acceptable.
4. If the check valve is leaking too much, replace it.

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⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air reservoirs.
3. Remove the supply line from the check valve.
4. Remove the check valve from the air reservoir.

Installation

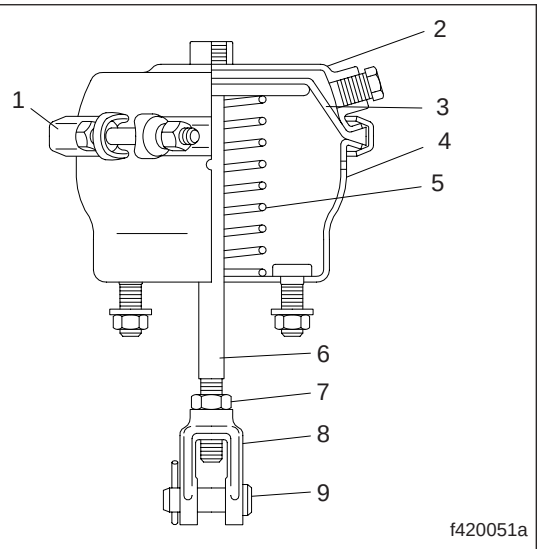
1. Screw the check valve into the supply end of the air reservoir. To ensure the valve is not reversed, the arrow marked on the valve body must point in the direction of air flow.
2. Leak test the check valve following the instructions under **Subject 110**.
3. Connect the supply line to the open end of the check valve.
4. Remove the chocks from the tires.

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General Information

Brake chambers convert the energy of compressed air into the mechanical force and motion needed to apply the brakes. Two chambers operate the brakes, one on each side of the axle.

Each brake chamber consists of two dished metal sections: the cover assembly and the body assembly, which are separated by a nylon-neoprene diaphragm. A metal two-segment clamp ring holds the assemblies together. See **Fig. 1**.



1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Midland Brake Air Chamber (sectional view)

In front of the diaphragm are the body, piston rod assembly, and a piston rod spring. The threaded piston rod assembly extends through the bottom of the body and connects to the clevis. See **Fig. 1**.

Different sized brake chambers are identified by numbers, which specify the effective area of the diaphragm. For example, a type 16 brake chamber has 16 square inches of effective area.

The greater the air pressure admitted to the brake chamber, the greater the force applied by the piston rod. Piston rod force is determined by multiplying the delivered air pressure by the effective diaphragm area. For example, if 60 psi (415 kPa) is admitted to a type 16 brake chamber, the force on the end of the piston rod is about 960 lb (436 kg).

When the brake pedal is depressed, air pressure from the brake valve passes through the port in the brake chamber cover to move the diaphragm and piston rod assembly forward. This compresses the spring, and applies a straight-line force to the slack adjuster, which converts it to a rotational force. This in turn rotates the camshaft and applies the brakes.

When the brake pedal is released, compressed air behind the diaphragm exhausts through the quick release valve. The spring then allows the piston rod assembly and diaphragm to return to their previous positions.

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Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

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NOTE: For both of these tests, the air system must be pressurized to at least 80 psi (550 kPa).

Leakage Test

1. Apply the brakes and hold them on full line pressure of at least 80 psi (550 kPa).
2. Using a soap solution, coat the clamp ring. Leakage is excessive if it produces a 1-inch (25-mm) bubble within 5 seconds.

⚠ CAUTION

Do not over-tighten the clamp ring. This can distort the flange sealing surface or the clamp ring itself.

3. If the leakage is excessive, tighten the clamp ring flange nuts evenly until the leakage is reduced. For acceptable torque ranges, see **Specifications, 400**.
4. Using a soap solution, coat the area around the piston-rod hole. No leakage is permitted. If there is leakage, replace the diaphragm. For instructions, see **Subject 120**.

Operating Test

1. Chock the tires.
2. Apply the brakes. Check that each piston rod moves out promptly, without binding.
3. Release the brakes. Check that each piston rod returns to the released position promptly, without binding.
4. Check the brake chamber stroke. It should be as short as possible without causing the brakes to drag. If needed, adjust the travel of the piston rod at the slack adjuster. See Group 42 in the *Acterra Maintenance Manual* for instructions.

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Diaphragm Replacement

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

NOTE: This procedure is for service of a leaking brake chamber *diaphragm only*. If there are any other problems, see the applicable subjects elsewhere in this section.

Replacement

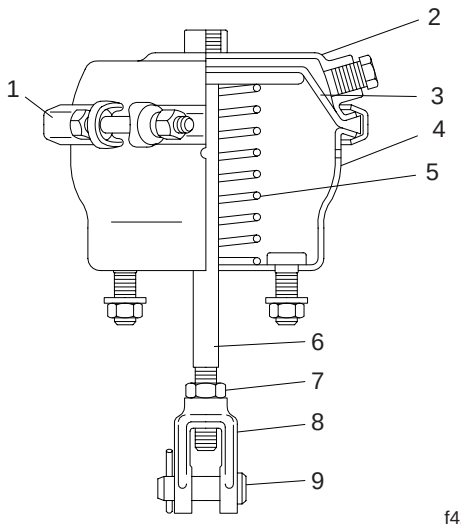
1. Park the vehicle on a level surface. Shut down the engine. Chock the tires.

⚠ WARNING

Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. Do not direct the airstreams at anyone. Do not disconnect pressurized hoses, since they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

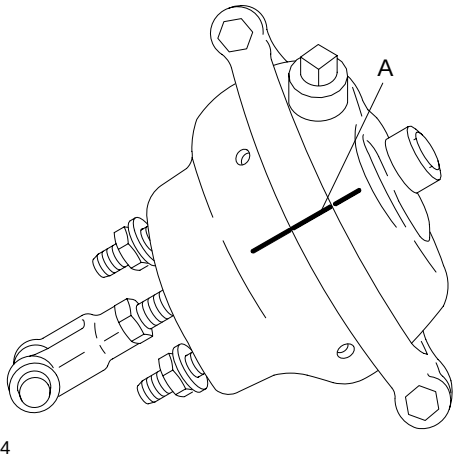
Follow the manufacturer's recommendations when working on any air device so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or compressed-air propulsion.

2. Drain the air reservoirs and lines.
3. Back off the slack adjuster. For instructions, see the applicable slack adjuster section in this manual. Pull out the piston rod. See **Fig. 1**. Clamp the rod at the chamber body to protect it from damage.
4. Before disassembly, mark a reference line along the chamber to allow the parts to be reassembled later in their old positions. See **Fig. 2**.
5. Replace the diaphragm.
   - 5.1 Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.
   - 5.2 Remove the cover assembly, and replace the diaphragm.



1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Midland Brake Air Chamber (sectional view)



A. Reference Line

Fig. 2, Chamber Reference Line

⚠ CAUTION

Do not overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

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Diaphragm Replacement

5.3 Position the cover assembly and clamp ring (aligning the reference marks), and install the clamp ring bolt and flange nut. Tighten the flange nuts evenly to eliminate leakage. For acceptable torque ranges, see **Specifications, 400**.

6. Release the clamp on the piston rod.
7. Do both of the tests in **Subject 110**.
8. Adjust the brakes at the slack adjuster. For instructions, see the applicable foundation brake section in this manual.
9. Remove the chocks from the tires.

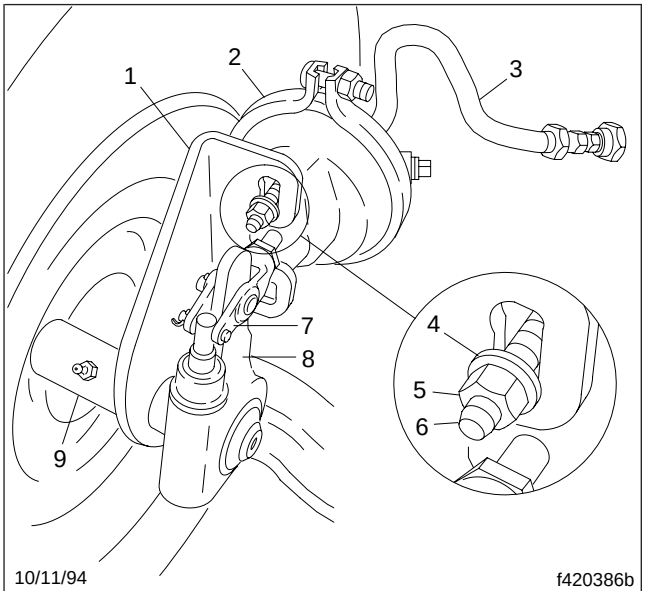
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Brake Chamber Removal and Installation

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Removal (See Fig. 1)



1. Chamber Mounting Bracket
2. Brake Chamber
3. Air Line
4. Hardened Flatwasher (2 qty.)
5. Prevailing Torque Locknut (2 qty.)
6. Chamber Mounting Stud (2 qty.)
7. Clevis Assembly
8. Slack Adjuster (Automatic Type)
9. Camshaft Tube

Fig. 1, Brake Chamber Assembly

1. Park the vehicle on a level surface. Shut down the engine. Chock the tires.

⚠ WARNING

Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. Do not direct the airstreams at other people. Do not disconnect pressurized hoses, since they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

Follow the manufacturer's recommendations when working on any air device so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or compressed-air propulsion.

2. Drain the air reservoirs and lines.
3. Carefully disconnect the air line from the brake chamber.
4. Remove the brake chamber.

   4.1 Remove the cotter pin(s) from the clevis pin(s).

   NOTE: Meritor automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

   4.2 Remove the clevis pin(s) from the slack adjuster.

   4.3 From each mounting stud, remove any installed nuts and washers. Remove the brake chamber from the vehicle.

Installation (See Fig. 1)

1. Before installing a new chamber, be sure the new chamber is the same size and make as the brake chamber on the other side of the axle.
2. Install the brake chamber.

   2.1 Attach the brake chamber to the mounting bracket using a hardened flatwasher and prevailing torque locknut. Install the flatwasher between the locknut and the mounting bracket.

   2.2 Tighten the locknuts. See **Table 1** for the correct torque value.

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Brake Chamber Removal and Installation

Mounting-Stud Locknut Torque Values		
Description	**Chamber Size (in ^{2})**	**Torque lbf·ft (N·m)**
Brake Chamber Mounting-Stud Locknuts	12	38–43 (52–58)
	16 (7/16–14 stud)	38–43 (52–58)
	16 (1/2–13 stud)	60–65 (81–88)
	16 (1/2–20 stud)	65–70 (88–95)
	20	120–130 (162–176)
	24	120–130 (162–176)

Table 1, Mounting-Stud Locknut Torque Values

2.3 Connect the clevis pin(s) to the slack adjuster.

NOTE: Meritor automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

2.4 Install and lock the cotter pin(s) to secure the clevis pin(s).

3. Adjust the brakes at the slack adjuster. For instructions, see the applicable foundation brake section in this manual.
4. Connect the air line to the brake chamber.

4.1 Check that the hoses are properly supported and, if needed, clamped to provide good clearance.

4.2 Before connecting the air line, make sure the fittings are clean and free of debris.

4.3 Connect the air line as follows:

- Finger-tighten the nut.
- Using a wrench, further tighten the nut until there is resistance.
- Tighten the nut one-sixth turn more.

5. Do both of the tests in **Subject 110**.
6. Remove the chocks from the tires.

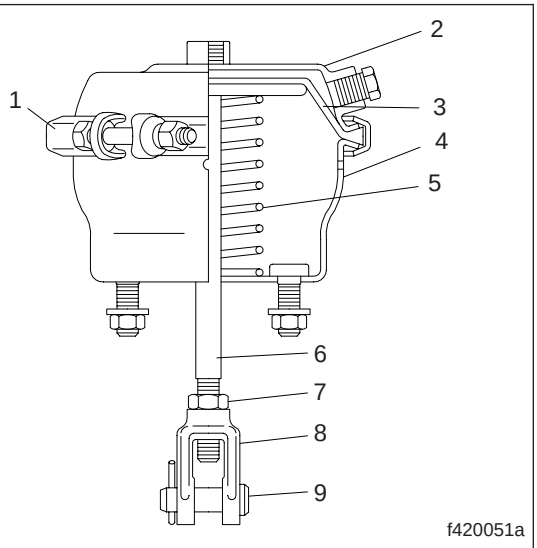
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Brake Chamber Disassembly, Cleaning and Inspection, and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Disassembly (See Fig. 1)

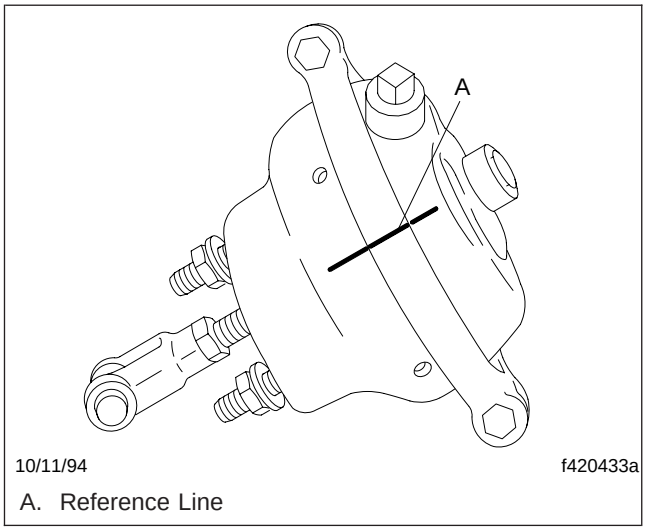


1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Midland Brake Air Chamber (sectional view)

NOTE: If the brake chamber is to be disassembled without removing the body assembly from the vehicle, first back off the slack adjuster. For instructions, see the applicable slack adjuster section in this manual.

1. Before disassembly, mark a reference line along the chamber to allow the parts to be reassembled later in their old positions. See Fig. 2.
2. Pull out the piston rod. Clamp the rod at the chamber body to protect it from damage.
3. Disassemble the brake chamber.
   - 3.1 Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.
   - 3.2 Remove the cover assembly and the diaphragm.
   - 3.3 Remove the clevis locknut and clevis from the piston rod, and release the clamp on the piston rod, being careful to contain the piston rod assembly and body until the return spring is relaxed.
   - 3.4 Remove the piston rod assembly and spring.



A. Reference Line

Fig. 2, Chamber Reference Line

Cleaning and Inspection

1. Clean all metal parts with cleaning solvent.
2. Inspect all parts for wear or damage; replace as needed.
   - 2.1 Check for dents on the cover and the body. If any dents are found, replace the part(s).
   - 2.2 Check the diaphragm for wear or deterioration and replace it if necessary. Midland recommends replacement of the diaphragm whenever the service brake chamber is opened for inspection.
   - 2.3 Inspect all other parts not considered serviceable. Replace if necessary.

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Brake Chamber Disassembly, Cleaning and Inspection, and Assembly

Assembly (See Fig. 1)

1. Stand the piston rod assembly upright on a flat surface (if the chamber was removed from the vehicle).
2. Assemble the brake chamber.
   - 2.1 Place the return spring on the piston rod.
   - 2.2 Place the body on the piston rod assembly, and press the body down, working against the tension of the spring, until the body bottoms out on the flat surface. Clamp the rod at the body, making sure to protect the rod from damage. Insert the piston rod assembly through the body and clamp the rod (if the body was not removed from the vehicle).
   - 2.3 Place the diaphragm in the body.

⚠ CAUTION

Do not overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

   - 2.4 Position the cover assembly and clamp ring (aligning the reference marks), and install the clamp ring bolt and flange nut. Tighten the flange nuts evenly to eliminate leakage. For acceptable torque ranges, see **Specifications, 400**.
3. Install the clevis locknut and clevis, and release the clamp on the piston rod.
4. If the brake chamber was removed from the vehicle, install it. For instructions, see **Subject 130**.
5. Do both of the tests found in **Subject 110**.

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Mounting-Stud Locknut Torque Values		
Description	**Chamber Size (in ^{2})**	**Torque lbf·ft (N·m)**
Brake Chamber Mounting-Stud Locknuts	12	38–43 (52–58)
	16 (7/16–14 stud)	38–43 (52–58)
	16 (1/2–13 stud)	60–65 (81–88)
	16 (1/2–20 stud)	65–70 (88–95)
	20	120–130 (162–176)
	24	120–130 (162–176)

Table 1, Mounting-Stud Locknut Torque Values

Clamp Ring Torque Values		
Description	**Chamber Size (in ^{2})**	**Torque lbf·in (N·cm)**
Clamp Ring Flange Nuts	12	200 to 250 (2260 to 2820)
	16	200 to 250 (2260 to 2820)
	20	110 to 225 (1240 to 2540)
	24	150 to 225 (1700 to 2540)

Table 2, Clamp Ring Torque Values

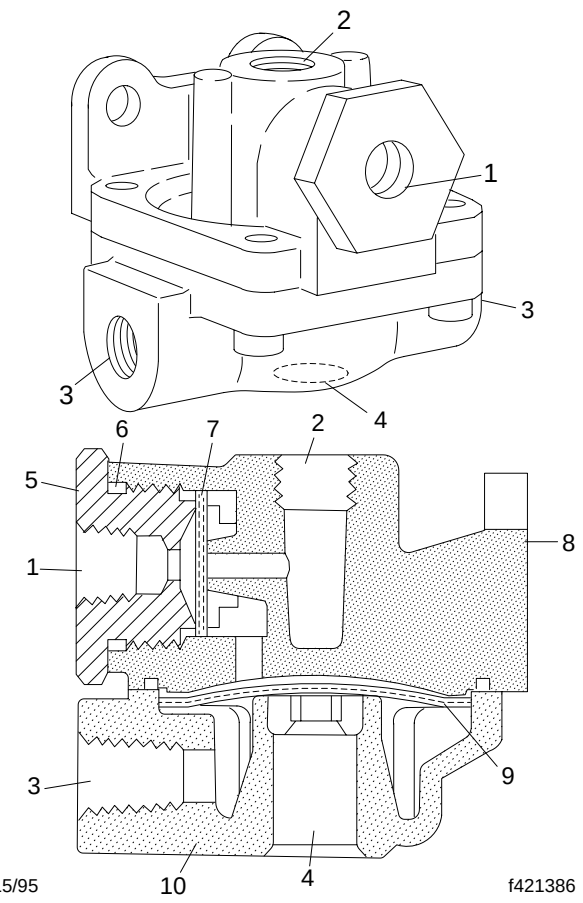
Piston Rod Nut Torque Values		
Description	**Chamber Size (in ^{2})**	**Torque lbf·ft (N·m)**
Piston Rod Nuts	12	20–30 (27–41)
	16 (7/16-inch Stud)	20–30 (27–41)
	16 (1/2-inch Stud)	20–30 (27–41)
	20	33–90 (45–122)
	24	33–90 (45–122)

Table 3, Piston Rod Nut Torque Values

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General Information

The QR–1C quick release valve is a dual function valve. See **Fig. 1**. Its primary function is to speed up the release of air pressure from the service brake chambers. Additionally, the valve works as an anti-compound device. The double check valve feature prevents a service and parking brake application from occurring at the same time.



1. Supply Port
2. Balance Port
3. Delivery Port
4. Exhaust
5. Cap Nut
6. Sealing Ring
7. Double Check Diaphragm
8. Body
9. Quick Release Diaphragm
10. Cover

Fig. 1, QR-1C Valve and Cross-Section

The QR–1C valve is generally mounted on the axle and serves two spring brake actuators. A balance line from the relay valve delivery port is connected to the balance port on top of the QR–1C quick release valve. The two side ports are for brake chamber connections. The supply port is connected to the delivery port of the parking brake control valve, and the exhaust port is located at the bottom of the valve. The air connections to the QR–1C are as follows:

1. The QR–1C delivery port is connected to the emergency port of the spring brake.
2. The QR–1C balance port is connected to the delivery of the brake valve or relay valve.

NOTE: If the relay valve is installed on the vehicle, it should be connected to the delivery side (not to the service or signal side).

3. The QR–1C supply port is connected to the delivery of the park control valve.

Parking Brakes Released

When the parking brakes are released, air from the parking brake control valve flows through the QR–1C valve. This forces the double check diaphragm and the quick release diaphragm to flex and seal the balance and exhaust ports. Air flows into the inlet ports of the parking brake chambers from the QR–1C valve delivery ports.

Parking Brakes Applied

When the parking brakes are applied, supply line air pressure to the QR–1C valve is exhausted through the parking brake control valve. As air pressure is exhausted from one side of the double check diaphragm and the quick release diaphragm, both diaphragms flex in the opposite direction to open the balance and exhaust ports. Parking brake pressure is released at the exhaust port of the QR–1C valve while a small amount of air trapped between the two diaphragms is released through a relay valve or the foot valve exhaust port.

Anti-Compounding

When a service brake application is made with the parking brakes applied, service air enters the balance port and flows through the QR–1C valve into the inlet ports of the parking brake chambers. This prevents application of the service and parking brakes at the same time. Service air passing through

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General Information

the QR–1C valve flexes the double check and quick release diaphragms, sealing the supply and exhaust ports. When the service brake application is released, air is exhausted from the parking brakes.

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Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

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Operating and Leakage Tests

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

The following tests should be performed after repairing or replacing the QR–1C valve to ensure that it is functioning properly.

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Release the parking brakes.
4. Remove the air line from the valve balance port. Build system air pressure to 120 psi (827 kPa). Coat the exhaust and balance ports with a soap solution; leakage of a 1-inch (2.5-cm) bubble in 5 seconds at either port is allowable. Install the air line at the balance port.
5. Apply the parking brakes. Step on the foot brake; the QR–1C valve should exhaust air at the exhaust port.
6. Drain the air system.
7. Remove the air line from the valve supply port. Build system air pressure to 120 psi (827 kPa). With the foot valve depressed, coat the supply port and the seam between the body and cover with a soap solution; leakage of a 1-inch (2.5-cm) bubble in 5 seconds at the supply port is allowable. No leakage between the body and cover is permitted. Install the air line at the supply port.
8. If the valve does not function properly, or if leakage is excessive, repair or replace it following the instructions in this section.
9. Remove the chocks from the tires.

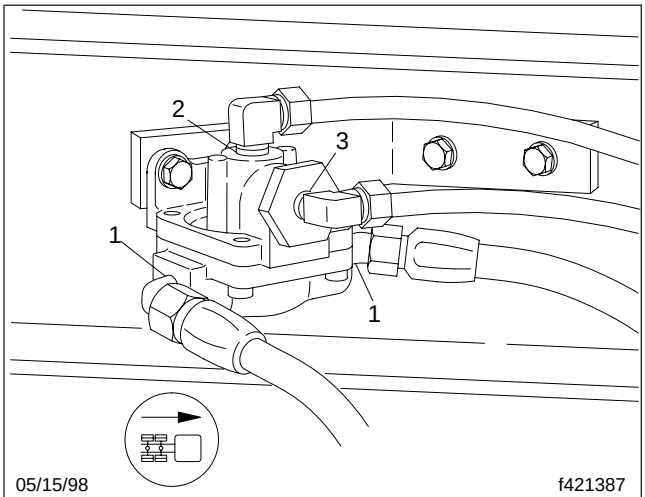
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Removal

WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so could result in personal injury.

1. Park the vehicle on a level surface and shut down the engine. Chock the tires or hold the vehicle by means other than air brakes.
2. Drain the air brake system.
3. Mark and disconnect the air lines from the quick release valve.
4. Remove the mounting bolts and the valve. See Fig. 1.



NOTE: Valve mounting inside the left frame rail shown.

1. Delivery Port
2. Balance Port
3. Supply Port

Fig. 1, QR-1C Valve Mounting (plumbing and location will vary depending on vehicle configuration)

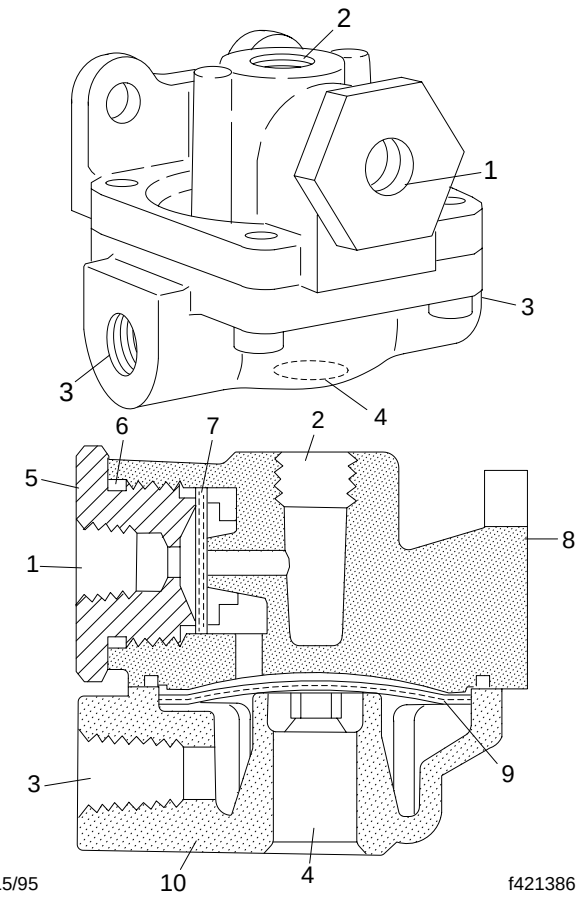
Installation

1. Install the quick release valve with the exhaust port facing down. Securely tighten the mounting bolts.
2. Connect the air lines to the quick release valve in the locations previously marked.
3. Remove the chocks from the tires.
4. Perform the operating and leakage tests in Subject 110.

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Disassembly, Cleaning and Inspection, and Assembly

Disassembly (See Fig. 1)



1. Supply Port
2. Balance Port
3. Delivery Port
4. Exhaust
5. Cap Nut
6. Sealing Ring
7. Double Check Diaphragm
8. Body
9. Quick Release Diaphragm
10. Cover

Fig. 1, QR-1C Valve and Cross-Section

1. Remove the quick release valve from the vehicle following the instructions in **Subject 120**.
2. Mark the valve body and cover for ease of installation.
3. Remove the cap nut at the supply port. Remove the sealing ring from the cap nut.
4. Remove the double check diaphragm.
5. Remove the four screws holding the valve cover on the valve body.
6. Separate the cover from the body and remove the sealing ring and the quick release diaphragm.

Cleaning and Inspection

1. Clean all metal parts in mineral spirits. Wipe all rubber parts clean.
2. It is recommended that all rubber parts and any other part showing signs of wear or deterioration be replaced with genuine Bendix parts.

Assembly

1. Install the sealing ring on the cap nut.
2. Install the double check diaphragm in the valve body.
3. Install the cap nut. Tighten the nut 150 to 400 lbf·in (1700 to 4520 N·cm).
4. Install the quick release diaphragm in the cover.
5. Install the valve cover on the body. Tighten the screws 30 to 60 lbf·in (340 to 680 N·cm) evenly and securely.
6. Install the quick release valve, following the instructions in **Subject 120**.
7. Do the operating and leakage test as instructed in **Subject 110**.

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General Information

The tractor protection valve system protects tractor air brakes during trailer breakaway and/or when severe air leakage develops in the tractor or trailer. This function is required by law.

In normal use, the tractor protection valve is used to shut off the trailer control line before disconnecting the tractor from the trailer. It is usually mounted at the rear of the tractor cab, and it is used in conjunction with a dash-mounted control valve.

The TP–3DC integrates tractor protection and double check valve functions. It also has an integral single check valve that prevents trapping of air in the trailer control line. This prevents service and spring brake compounding, and it avoids a trailer roll away situation if the trailer is parked with the air applied.

A stoplight switch port allows direct stoplight installation, and the auxiliary supply port, when connected to the BP–R1 control port, eliminates a tee in the tractor supply line. Also, a QR–L can be factory installed in the trailer control and/or supply port to meet timing requirements.

TP–3DC valve port designations and internal components are shown in **Fig. 1**.

Initial Charge **(See Fig. 2)**

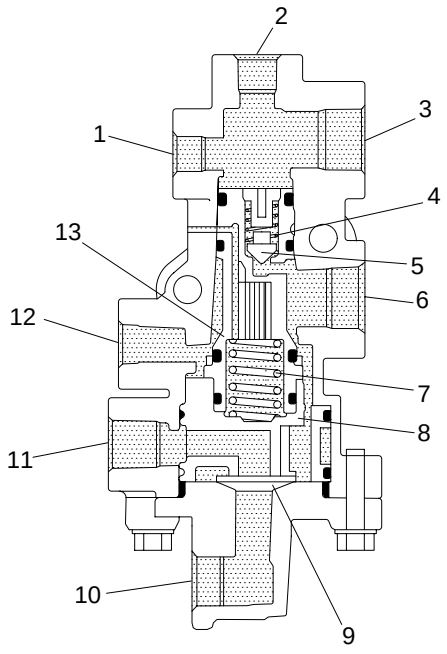
Pushing in the red trailer air supply knob on the instrument panel causes air to flow into the TP–3DC valve at the tractor supply port. Air flows through the valve housing, exiting via the auxiliary supply port (if used) and the trailer supply port, to pressurize the trailer brake system and release the trailer parking brakes.

As air pressure builds in the trailer supply circuit, the single check valve seats, and the valve plunger begins to move (against spring pressure) toward the guide. When pressure reaches about 45 psi (310 kPa), the plunger bottoms against the guide and the inlet valve is open.

The TP–3DC valve is in the "run" mode, and ready to receive and deliver a service brake application from either the foot valve or the hand valve.

Service Brake Application **(See Fig. 3)**

When the foot pedal is pressed, air flows to the TP–3DC valve tractor control primary and secondary ports. If the trailer control valve is also used, the external double check delivers the higher pressure (trailer control or foot valve secondary) to the TP–3DC tractor control secondary port.



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1. Tractor Supply
2. Auxiliary Supply
3. Trailer Supply
4. Tee Plug and Spring
5. Single Check Valve
6 Trailer Control
7. Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control (Primary)
11. Tractor Control (Secondary)
12. Stoplight Switch
13. Plunger

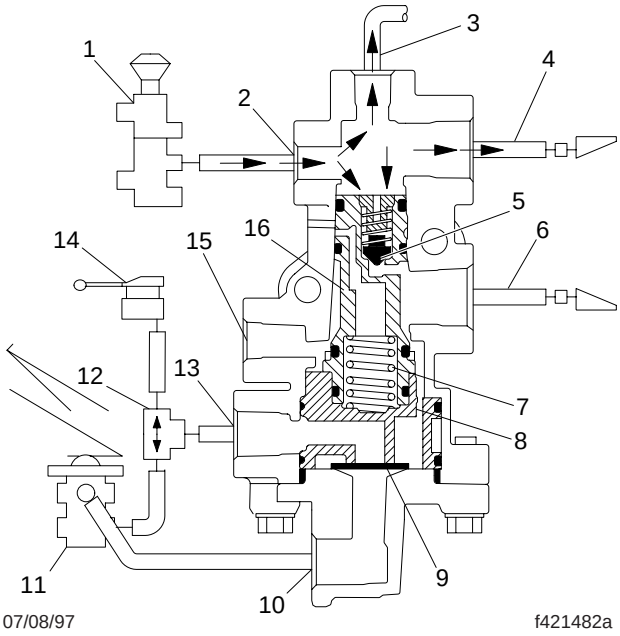
Fig. 1, TP-3DC Tractor Protection Valve (sectional view)

Inside the TP–3DC valve, the higher pressure (primary or secondary) moves the diaphragm to seal off the port at the lower pressure.

With the plunger bottomed against the guide and the inlet valve open (as described earlier), the higher pressure air flows through the valve to the trailer control port and the stoplight switch, applying the brakes and activating the stoplights.

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General Information



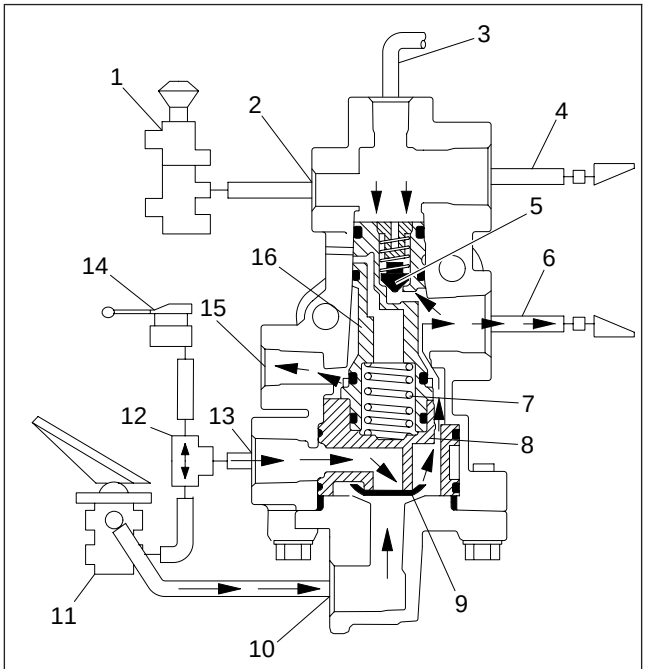
1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stoplight Switch Port
16. Plunger

Fig. 2, Initial Charge

NOTE: While air pressure also reaches the TP–3DC single check valve, the valve stays closed because supply pressure is acting on the other side.

Service Brake Release (See Fig. 4)

When the foot pedal is released, air stops flowing into the TP–3DC valve at the tractor control primary or secondary port. At the same time, air in the trailer control line returns to the valve, flowing back through the open inlet valve.



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stoplight Switch Port
16. Plunger

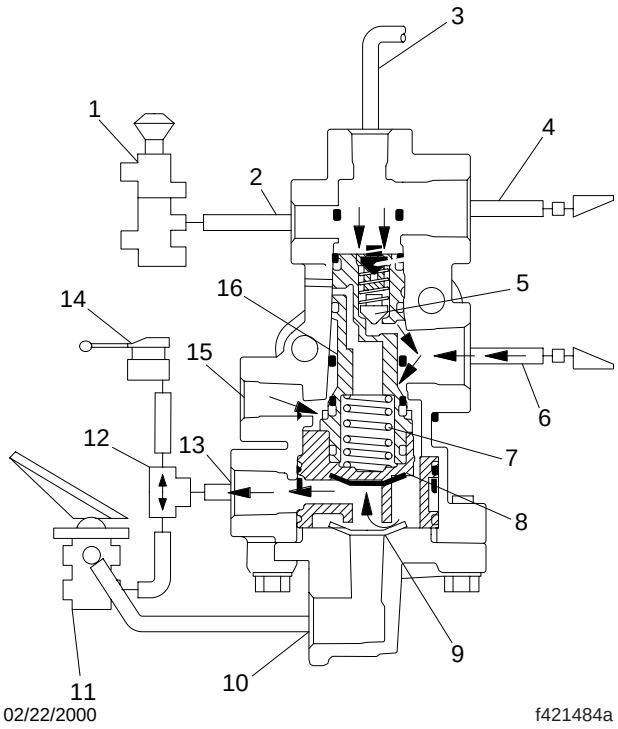
Fig. 3, Service Brake Application

The air forces the diaphragm to seat, sealing off the tractor control primary port. The air then exits the valve at the tractor control (secondary) port and flows to the foot valve or hand valve where it is exhausted.

Tractor Protection (See Fig. 5)

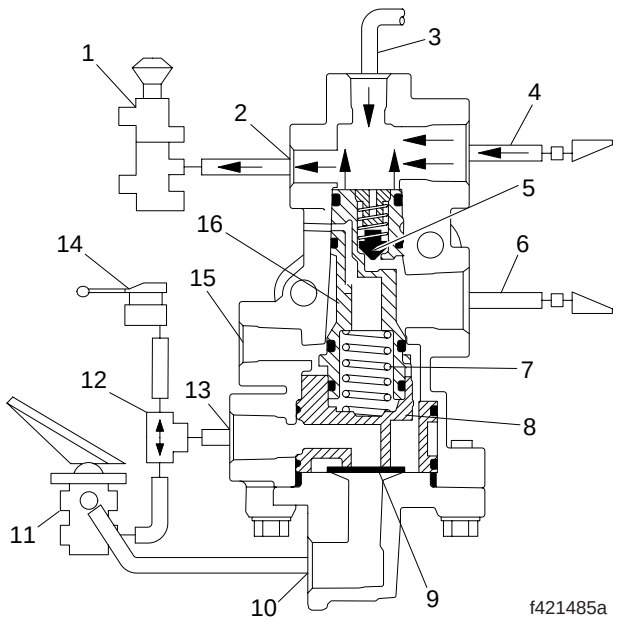
If the red trailer air supply knob on the instrument panel is pulled out (or if a large leak develops in the trailer supply circuit), pressure in the trailer supply circuit (and the auxiliary supply circuit, if used) is vented. When pressure drops to about 20 to 30 psi

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1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stoplight Switch Port
16. Plunger

Fig. 4, Service Brake Release



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stoplight Switch Port
16. Plunger

Fig. 5, Tractor Protection

(138 to 207 kPa), the pressure can no longer overcome the spring force inside the TP–3DC valve and the inlet valve closes.

With the inlet valve closed, air pressure from the foot brake or hand control valves will not reach the trailer control circuit when the brakes are applied.

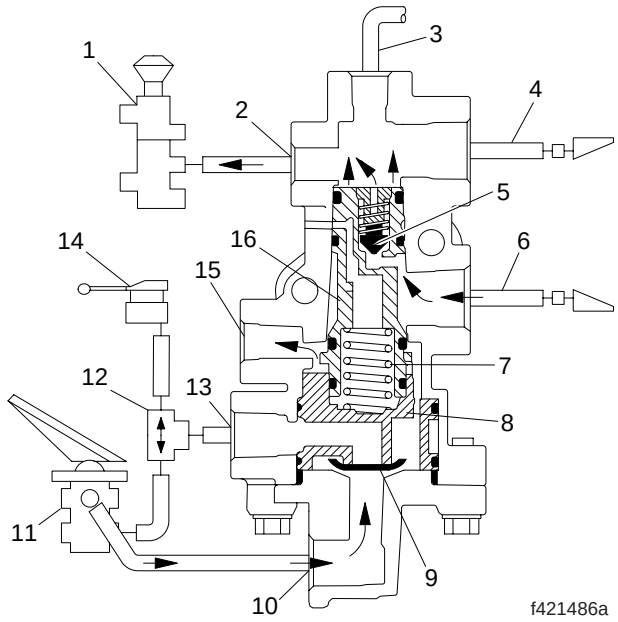
Anti-Compounding (See Fig. 6)

If the red trailer air supply knob on the instrument panel is pulled out while the service brakes are applied, the single check valve in the TP–3DC prevents simultaneous spring and service brake application. As pressure in the trailer supply circuit drops, the spring in the TP–3DC valve forces the inlet valve closed (as described above in "Tractor Protection." Any pressure in the trailer control circuit is relieved by passing first through the single check valve and then exhausting at the trailer supply valve.

If the service brakes (hand or foot) are released and applied again, the closed inlet valve prevents air pressure from reaching the trailer control circuit.

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General Information



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stoplight Switch Port
16. Plunger

Fig. 6, Anti-Compounding

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Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

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Leakage Test

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Start the engine. Run it until the air system is fully charged.
3. Shut down the engine and place the trailer air supply valve in the emergency position.
4. Disconnect the trailer control line hose coupling and apply a soap-water solution to the coupling.
5. With tractor reservoirs charged to at least 100 psi (689 kPa) make and hold a full service brake application using either the foot valve or the trailer control valve. Leakage at the hose coupling should not exceed a 1-inch (2.5-cm) bubble in 5 seconds.
6. Release the service brake application and place the trailer supply valve in the "run" position. Connect the trailer control valve to a test gauge.
7. Make a service brake application and note that service air pressure is present at the trailer control line hose coupling.
8. Disconnect the air line at the TP–3DC tractor control port (primary). Plug the line. Apply a soap-water solution to the valve.
9. Make a service brake application and check for leakage at the open tractor control port. Leakage should not exceed a 1-inch (2.5-cm) bubble in 5 seconds.
10. Reconnect the air line to the tractor control port (primary) and disconnect the air line at the tractor control port (secondary). Plug the disconnected line and apply a soap-water solution to the valve.
11. Make a service brake application and check for leakage at the open tractor control port. Leakage should not exceed a 1-inch (2.5-cm) bubble in 5 seconds.

IMPORTANT: If the valve does not function as described, or if leakage is excessive, repair or replace the valve.

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⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Removal

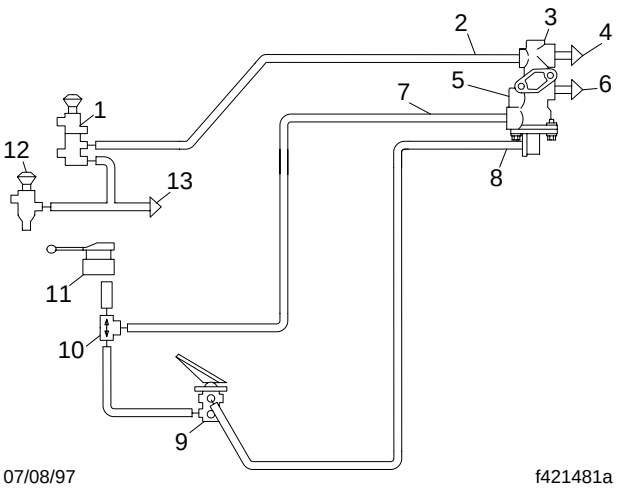
1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Open the air reservoir drain cocks to bleed the air from the system.
3. Remove the trailer hose assemblies from the TP–3DC valve. Disconnect the tractor service and supply lines. Mark the lines for later assembly reference. Cap the air lines tightly to keep out contaminants.
4. Remove the fasteners attaching the TP–3DC valve to the vehicle. Remove the valve.

Installation

1. Place the TP–3DC valve on the vehicle, and attach it with bolts, washers, and nuts. Tighten the nuts 11 to 15 lbf·ft (15 to 20 N·m).

NOTE: The delivery line from the trailer air supply valve is connected to the tractor emergency port of the TP–3DC valve. See Fig. 1. The delivery line from the brake valve (double check valve) is connected to the tractor service port of the TP–3DC valve. Trailer hose assemblies are installed in the trailer emergency and trailer service ports of the TP–3DC valve.

2. Remove the caps from the air lines. Connect the air hoses to the TP–3DC valve as follows:
   - If equipped with nylon tube air hoses, connect the hose fittings to the valve ports, and finger-tighten the nuts. Using a wrench, tighten the nuts at least two turns, or until no threads show on the fitting.
   - If equipped with wire braid hoses, connect the hose fittings to the valve ports, and hand-tighten the nuts. Using a wrench, tighten the nuts until there is resistance. Tighten one-sixth turn more. Do not overtighten.



1. Trailer Air Supply Valve
2. Tractor Supply
3. Auxiliary Supply Port
4. Trailer Supply
5. Stoplight Switch Port
6. Trailer Control
7. Tractor Control (Secondary)
8. Tractor Control (Primary)
9. Foot Brake Valve
10. Double Check Valve
11. Trailer Control Valve
12. Parking Brake Valve
13. To Tractor Spring Brakes

Fig. 1, Partial Plumbing Diagram

3. Close the drain cocks to the air reservoirs. Start the vehicle engine to pressurize the air system.
4. Leak test the TP–3DC valve following the instructions in Subject 110.
5. Remove the chocks from the tires.

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Disassembly, Cleaning and Inspection, and Assembly

Disassembly

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

1. Remove the valve from the vehicle, retaining the mounting hardware. For instructions, see **Subject 120**.
2. Scribe a line across the valve cover and valve body to ensure proper alignment during assembly.
3. Remove the two 1/4-inch screws which secure the valve cover to the valve body and allow the valve spring to expand until the valve cover can be removed. See **Fig. 1**.
4. Remove the cover O-ring and discard it.
5. Remove the diaphragm from the valve body and discard it.
6. Remove the guide from the valve body.
7. Remove the O-rings from the guide and discard them.
8. Remove the valve spring from the plunger. Remove the plunger from the valve body.
9. Remove the O-rings from the plunger and discard them.
10. Remove the collar and the O-ring from the plunger. Discard the O-ring, but keep the collar.

Cleaning and Inspection

⚠ WARNING

Wear goggles when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

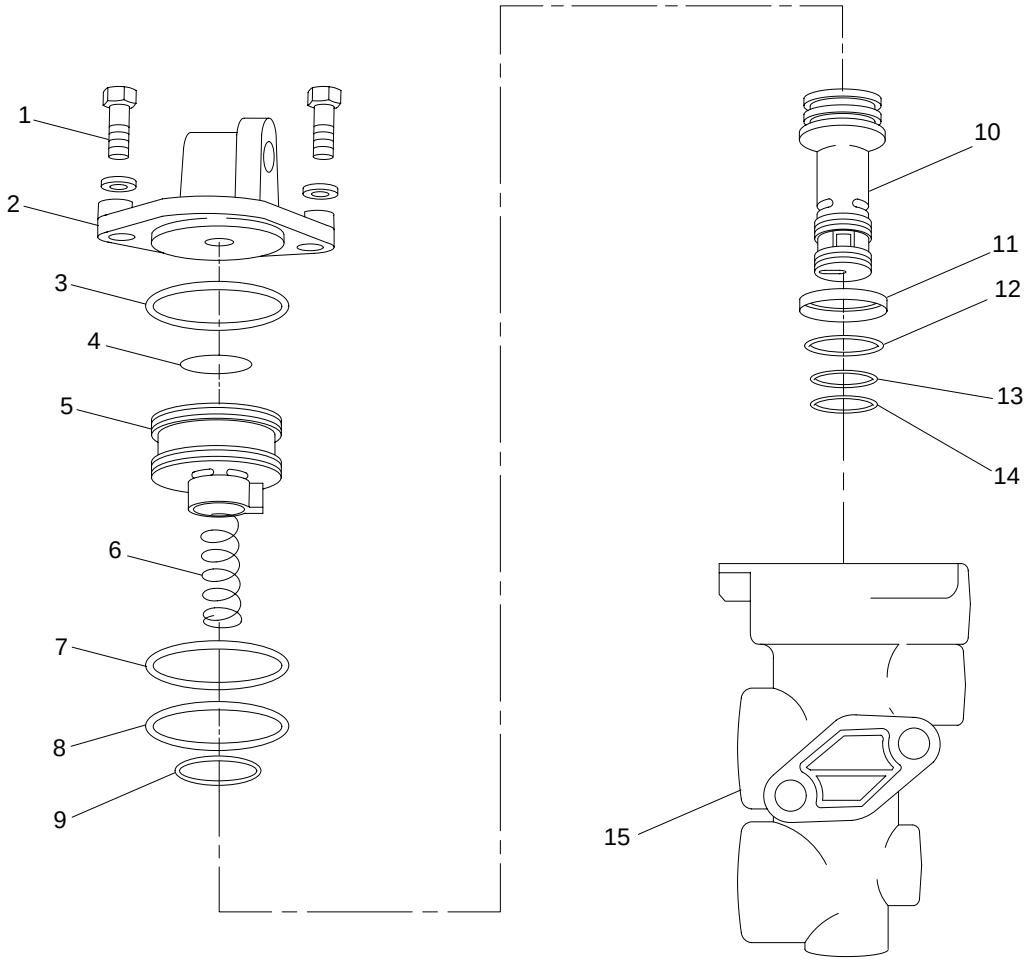
1. Wash all metal parts of the TP–3DC valve in cleaning solvent. Dry them using compressed air.
2. Examine the cover, body, guide, and plunger for corrosion, excessive wear, cracks, or other damage. If any of these conditions are found on a part, replace the part with a new one.
3. Check the spring for distortion and corrosion. If the spring is distorted or corroded, replace it.
4. Check the valve body bores for deep scratches or gouging.

Assembly

1. Lubricate the O-rings, O-ring grooves, body bores, and all sliding parts with the lubricant provided in the overhaul kit (Bendix silicone lubricant #291126 or equivalent).
2. Install the O-rings on the plunger.
3. Install the O-ring on the plunger and the collar over the O-ring. Make sure that the collar is fully seated and firmly in place over the O-ring.
4. Install the plunger into the valve body and the spring into the plunger.
5. Install the O-rings in their grooves on the guide.
6. Align the indexing tab on the guide with the notch in the valve body and install the guide in the valve body.
7. Place the diaphragm in its recess on the guide.
8. Place the O-ring on the cover.
9. Place the cover on the guide and press them down, against spring pressure, until the cover is seated against the valve body.
10. Install the two 1/4-inch screws and tighten them 30 to 60 lbf·in (340 to 675 N·cm).
11. Install the TP–3DC valve on the vehicle following the instructions in **Subject 120**.

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Disassembly, Cleaning and Inspection, and Assembly



1. 1/4-Inch Hex/Torx Screw
2. Valve Cover
3. Cover O-Ring
4. Diaphragm
5. Guide
6. Valve Spring
7. Guide O-Ring
8. Guide O-Ring
9. Plunger O-Ring
10. Plunger
11. Collar
12. O-Ring
13. Plunger O-Ring
14. Plunger O-Ring
15. Valve Body

Fig. 1, TP-3DC Valve (exploded view)

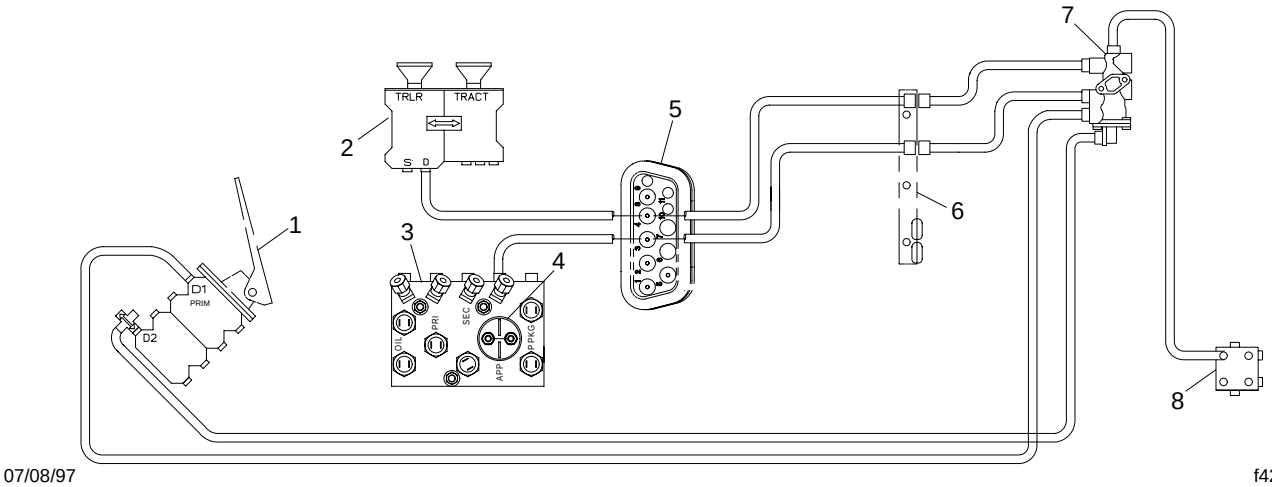
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Specifications

See **Fig. 1** for a TP–3DC plumbing diagram.

Torque Values		
Description	**Torque lbf·in (N·cm)**	**Torque lbf·ft (N·m)**
Valve Cover Capscrews	30–60 (340–675)	—
Valve Mounting Capscrews	—	11–15 (15–20)

Table 1, Torque Values



1. Foot Valve
2. Dash Valves
3. Air Manifold
4. Stoplight Switch
5. Pass-Thru Grommet
6. Junction Plate
7. TP–3DC Valve
8. Relay Valve

Fig. 1, TP-3DC Plumbing Diagram

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General Information

The TC–6 trailer brake control valve is normally used to operate the trailer brakes independently of the tractor brakes. It may be used, however, wherever a hand-controlled pressure graduation function is desired.

⚠ WARNING

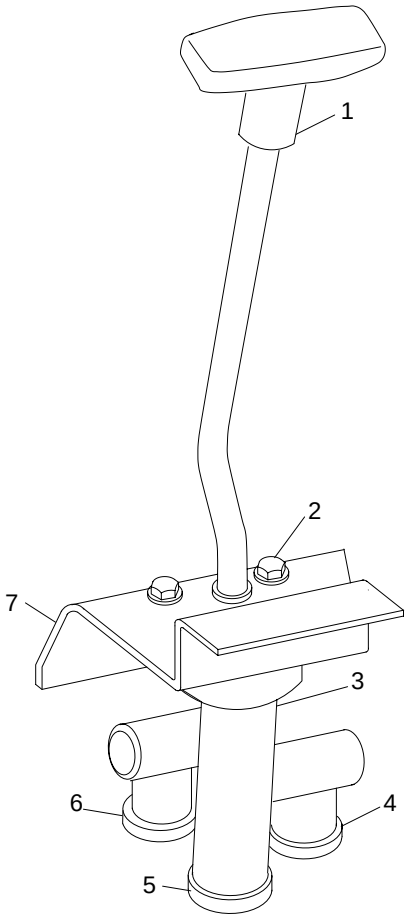
The TC–6 trailer brake control valve is not designed for use as a parking brake control and should never be used to hold the brakes applied when the operator leaves the vehicle. The air could bleed out of the trailer air tank allowing the vehicle to roll, which could cause personal injury or damage to the vehicle.

The TC–6 valve is handle-operated and is designed for panel or engine cover mounting. See **Fig. 1**.

When the TC–6 brake control valve handle is pulled through its 75-degree arc, the roller cam is rotated accordingly. The cam action forces the cam follower downward, compressing the graduating spring and creating a force on the plunger which depresses the inlet valve and delivers air under pressure to the delivery port. See **Fig. 2**.

As delivery pressure builds up in the delivery port, it is also effective under the plunger causing it to balance the force of the graduating spring until the inlet valve is seated against its seat in the body and against the plunger. This prevents the delivery air from exhausting through the center of the plunger, maintaining the desired pressure in the delivery line. See **Fig. 2**.

When the handle is released or moved to its release position, the cam follower is permitted to rise, opening the exhaust passage and allowing the air pressure in the delivery line to exhaust out the exhaust port.

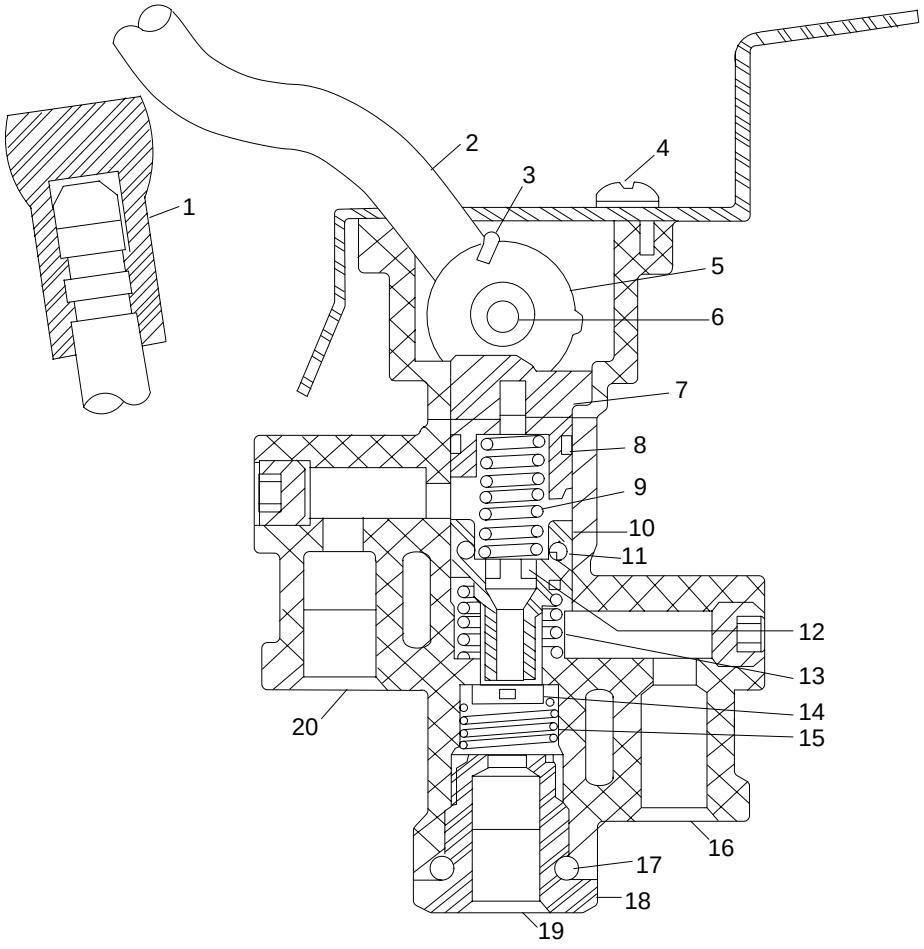


1. Handle
2. Slotted Head Capscrew (2 qty.)
3. Valve
4. Delivery
5. Supply
6. Exhaust
7. Bracket

Fig. 1, TC-6 Valve Assembly

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General Information



1. Knob
2. Handle
3. Torsion Spring
4. Slotted Head Capscrew (2 qty.)
5. Roller Cam
6. Pivot Pin
7. Cam Follower
8. O-Ring
9. Graduating Spring
10. Plunger
11. O-Ring
12. Washer
13. Plunger Return Spring
14. Inlet Valve
15. Inlet Valve Spring
16. Delivery
17. O-Ring
18. Capnut
19. Supply
20. Exhaust

Fig. 2, TC-6 Valve Components (Sectional View)

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Safety Precautions

⚠ WARNING

The TC–6 trailer control valve is not designed for use as a parking brake control and should never be used to hold the brakes applied when the operator leaves the vehicle. The air could bleed out of the trailer air tank allowing the vehicle to roll, which could cause personal injury or damage to the vehicle.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

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⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Test

NOTE: The TC–6 brake valve should be periodically checked for valve operation and tested for leaks. See Group 42 in the *Acterra Maintenance Manual* for intervals and procedures.

The following test should also be performed after repairing or replacing the TC–6 brake valve to insure that the valve is functioning properly:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Connect an accurate test gauge to the trailer service line hose. Leave the trailer emergency or supply hose connected to the trailer. If a trailer is not available, connect the trailer supply hose to an unvented dummy coupling or a plugged hose fitting. The trailer supply valve should be in the normal position.

NOTE: When the operating lever is moved to the fully applied position, the gauge should register full reservoir pressure. Intermediate positions should deliver proportional intermediate pressures. Upon release, the gauge should immediately register zero.

3. Locate the exhaust port or exhaust line (probably in the engine compartment) and apply a soap solution.
4. With the valve in the released position, no pressure should register on the test gauge. Leakage at the end of the exhaust line should not exceed a 1-inch bubble in 5 seconds.

   With the valve fully applied, leakage at the exhaust line should not exceed a 1-inch bubble in 3 seconds.
5. If the TC–6 valve does not function properly or if leakage is excessive, the TC–6 valve should be repaired or replaced following the instructions in this section.

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Control Valve Disassembly, Cleaning and Inspection, and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Disassembly

NOTE: The following assembly and disassembly instructions should be administered while using the Bendix Maintenance Kit, No. 289890.

1. Remove the TC–6 valve from the vehicle.
2. Place the lever in a vise. Pull firmly on the rubber handle and remove it.
3. Remove the two slotted head capscrews which hold the mounting bracket in place. Remove the mounting bracket. See **Fig. 1**.
4. Drive the pivot pin out of the body with a drift punch. Remove the handle, roller cam and torsion spring. Remove the roller cam from the handle. See **Fig. 2**.

NOTE: Note whether the friction washer is installed with ribs against or away from the sealing ring. It must be installed the same way during assembly.

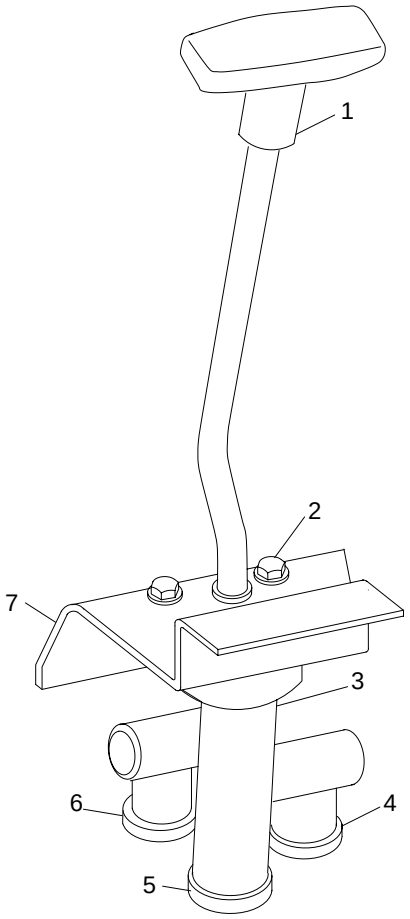
5. Remove the cam follower, graduating spring, plunger, and plunger return spring through the top of the valve. Care should be taken not to lose the washer.

NOTE: When using a vise, be sure it is not over-tightened because the valve body and internal parts could become distorted.

6. Place the valve body in a soft-jawed vise and remove the capnut. Remove the O-ring from the capnut.
7. Remove the inlet valve spring. Remove the inlet valve.

Cleaning and Inspection

1. Clean all metal and plastic parts with mineral spirits or equivalent.



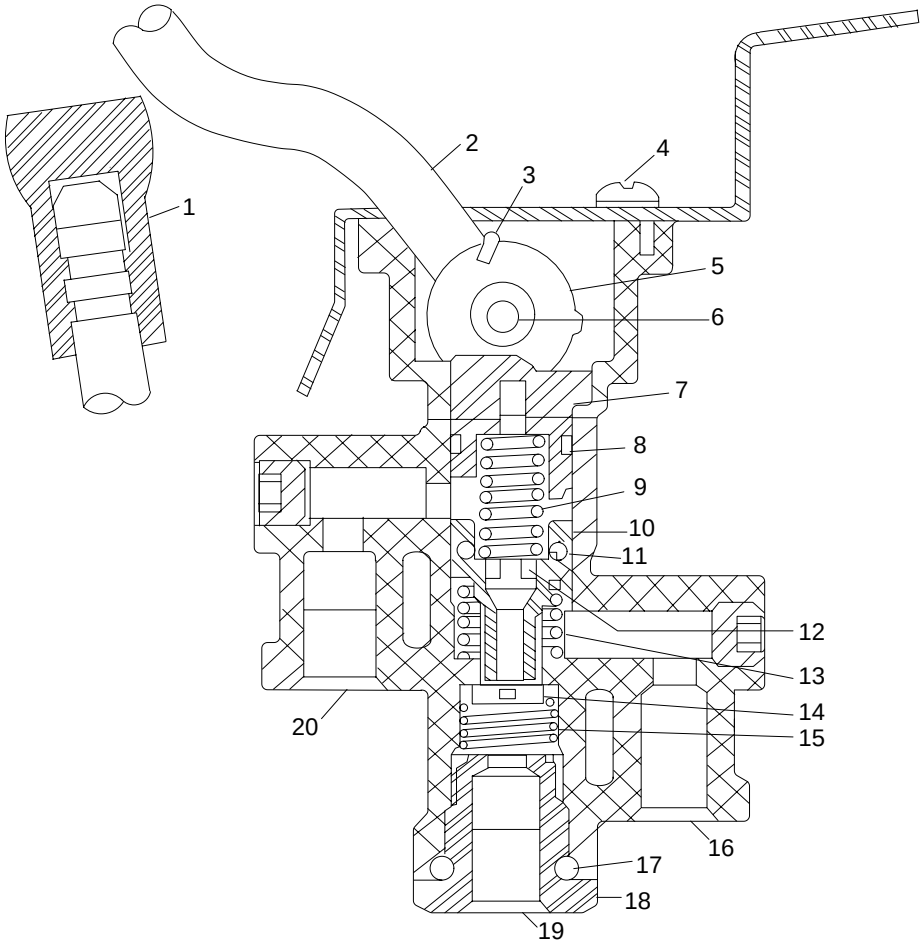
1. Handle
2. Slotted Head Capscrew (2 qty.)
3. Valve
4. Delivery
5. Supply
6. Exhaust
7. Bracket

Fig. 1, TC-6 Valve Assembly

2. Wipe all O-rings and rubber parts dry. Replace any which show signs of wear or deterioration.
3. Inspect the valve seats for nicks or burrs and remove any deposits.
4. Check all springs for distortion, cracks and corrosion.
5. Replace all parts not considered serviceable after inspection with genuine Bendix parts.

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Control Valve Disassembly, Cleaning and Inspection, and Assembly



1. Knob
2. Handle
3. Torsion Spring
4. Slotted Head Capscrew (2 qty.)
5. Roller Cam
6. Pivot Pin
7. Cam Follower
8. O-Ring
9. Graduating Spring
10. Plunger
11. O-Ring
12. Washer
13. Plunger Return Spring
14. Inlet Valve
15. Inlet Valve Spring
16. Delivery
17. O-Ring
18. Capnut
19. Supply
20. Exhaust

Fig. 2, TC-6 Valve Components (Sectional View)

Assembly

1. Prior to assembly, be sure to follow the "Cleaning and Inspection" instructions above.

NOTE: Do not lubricate the sealing ring, friction washer, or cam follower serrations.

2. Lubricate the valve bores, cam, pivot pin, plungers and all O-rings and O-ring grooves using Bendix lubricant No. 291126 or a silicone lubricant equivalent to Dow Corning 55–M.
3. Place the valve body in a soft-jawed vise with the ports pointing up. Place the inlet valve in the inlet cavity and install the inlet valve spring.

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Place the O-ring on the capnut and assemble the capnut in the body. Torque the capnut 50 to 150 lbf·in (565 to 1695 N·cm).

NOTE: The slightly larger O-ring goes on the cam follower.

4. Install the O-rings on the plunger and the cam follower.

NOTE: The cam follower must be positioned so that the projection on the side of the valve body matches the corresponding groove in the valve body.

5. Reverse the position of the valve body in the vise. Install the plunger return spring, the plunger, the washer, the graduating spring, and the cam follower. See **Fig. 2**.
6. Place the torsion spring in its approximate position in the valve body so that the end which engages the handle rests against the side of the body opposite the bracket retaining screw holes.
7. Place the roller cam in position and insert the pivot pin through the torsion spring and partially through the roller cam. Be sure to leave room to insert the wedge shaped end of the handle.
8. With a small screwdriver or similar tool, force the tang of the torsion spring towards the opposite wall of the body far enough so the handle may be inserted into the roller cam. Tap the pivot pin through until the ends of the pin are flush with either side of the body.
9. Place the mounting bracket in position. Secure it with the two slotted head capscrews. See **Fig. 1**.
10. Place the rubber knob back on the handle.
11. Install the TC–6 valve on the vehicle.
12. Test the valve following the instructions in **Subject 110**.

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Bendix TC–6 Trailer Brake Control Valve Removal and Installation

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Drain the air reservoirs.
3. Remove the red and yellow knobs from the brake control valve by unscrewing them from the valve stems. Mark the knobs in relation to the valve for later reference.
4. Remove the trailer brake handle. See Fig. 1.

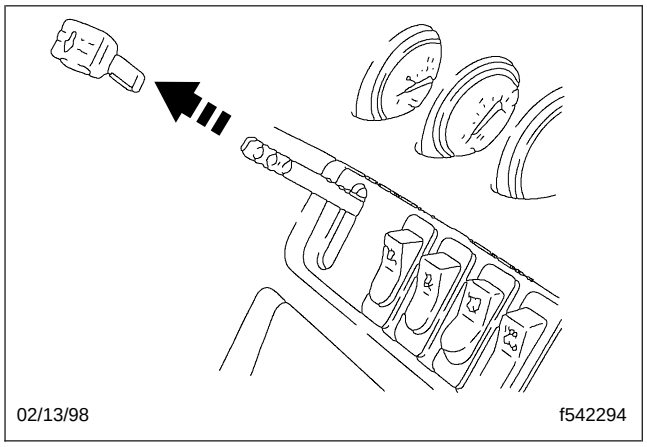


Fig. 1, Trailer Brake Handle

5. Remove the auxiliary dash panel screws. See Fig. 2.
6. Remove the brake mounting plate from the dash.
7. Remove the valve from the mounting plate.
8. Mark the air lines to the valve for later reference. Remove the air lines from the valve.

NOTE: The exhaust line is black, the supply line is green and the delivery line is blue.

9. Remove the valve.

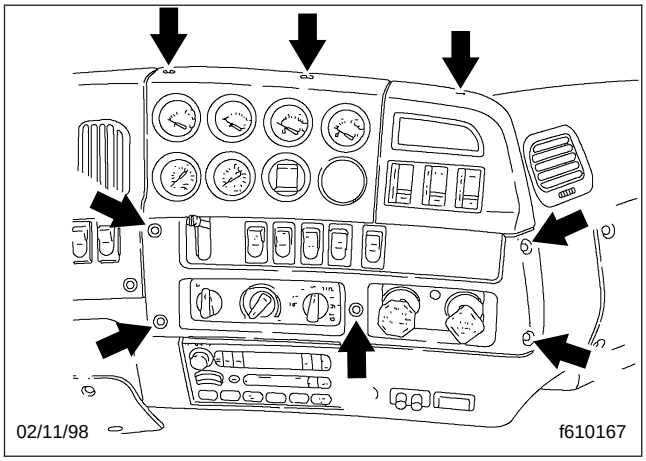


Fig. 2, Auxiliary Dash Panel Screws

Installation

1. Position the valve.
2. Connect the air lines to the valve.
3. Install the valve on the mounting plate.
4. Install the mounting plate on the dash.

IMPORTANT: Be careful not to pinch any wires or air lines.

5. Install the auxiliary dash panel screws.
6. Install the trailer brake handle.
7. Install the brake control valve knobs.
8. Remove the chocks from the tires.
9. Test the valve following the instructions in Subject 110.

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Specifications

Torque Values	
Description	**Torque lbf·in (N·cm)**
Capnut	50–150 (565–1695)

Table 1, Torque Values

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Brake Pedal Removal and Installation

Removal

See **Fig. 1** for a complete exploded view of the clutch- and brake-pedal assembly.

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the tires.
2. Remove the clutch pedal. For instructions on removal See **Section 25.03**, Subject 100.
3. Remove the clutch stop and neutral safety switch. See **Fig. 2**.
4. Remove the flanged hexnut, washer, and bolt securing the brake plunger to the air brake lever. See **Fig. 3**. Discard the hexnut.
5. Remove the bearing from the air brake lever. The bearing sits horizontally in a U-shaped cutout near the cab end of the brake plunger. See **Fig. 4**.
   - 5.1 Lift the brake pedal up and push the brake plunger in slightly.
   - 5.2 Reach behind the brake lever and remove the bearing from the plunger.
6. Remove the wedge, belleville washers, and capscrew from each end of the brake cross-shaft.
   - 6.1 Remove the capscrews and belleville washers from the wedge at each end of the brake cross-shaft.
   - 6.2 Pry the wedges out from end.
   - 6.3 Discard the wedges, washers, and capscrews. DO NOT REUSE!
7. Remove the two 5/16–18 machine screws and washers securing the rubber seal assembly (rubber boot) to the mounting bracket. See **Fig. 5**. Remove the seal.
8. Slide the brake plunger out of the bore in the center of the mounting bracket. Wipe off the old grease from the plunger, rubber seal, and bracket.
9. Wipe out the old lubricant from the bore, and any bearing dust and using clean shop air.
10. Inspect the brake plunger bearing (in the center bore) and the sliding surface of the plunger. If there is any wear or damage (cracks or chips), replace the part.
11. Inspect the guide bearing and rubber seal assembly; replace the assembly if it is damaged.

NOTE: Removing the brake lever allows the cross-shaft to move far enough to the right for the brake pedal to be removed.

12. Slide the cross-shaft to the left and remove the brake lever.
13. Slide the cross-shaft to the right and remove the brake pedal.

Installation

1. Slide the brake cross-shaft to the right and slide the brake pedal onto the shaft.
2. Slide the cross-shaft to the left and install the brake lever.
3. Lightly Lubricate the sliding surface on the brake plunger and the bearing bore with a silicone-based grease such as Dow Corning 55 O-Ring Lubricant or Loctite V-755 O-Ring Lubricant.
4. Carefully slide the brake plunger into the bearing in the mounting bracket. Make sure the plunger is positioned correctly with the U-shaped cutout facing up. See **Fig. 5**.
5. Install the guide bearing and rubber seal assembly on the mounting bracket with the arrow pointing up. Secure the seal with two washers and 5/16–18 machine screws. Tighten the screws 15 lbf·ft (20 N·m).
6. Inside the cab, place the lever bearing in the U-shaped cutout near the end of the brake plunger. See **Fig. 3**.
7. Align the lever bearing with the holes in the brake lever.

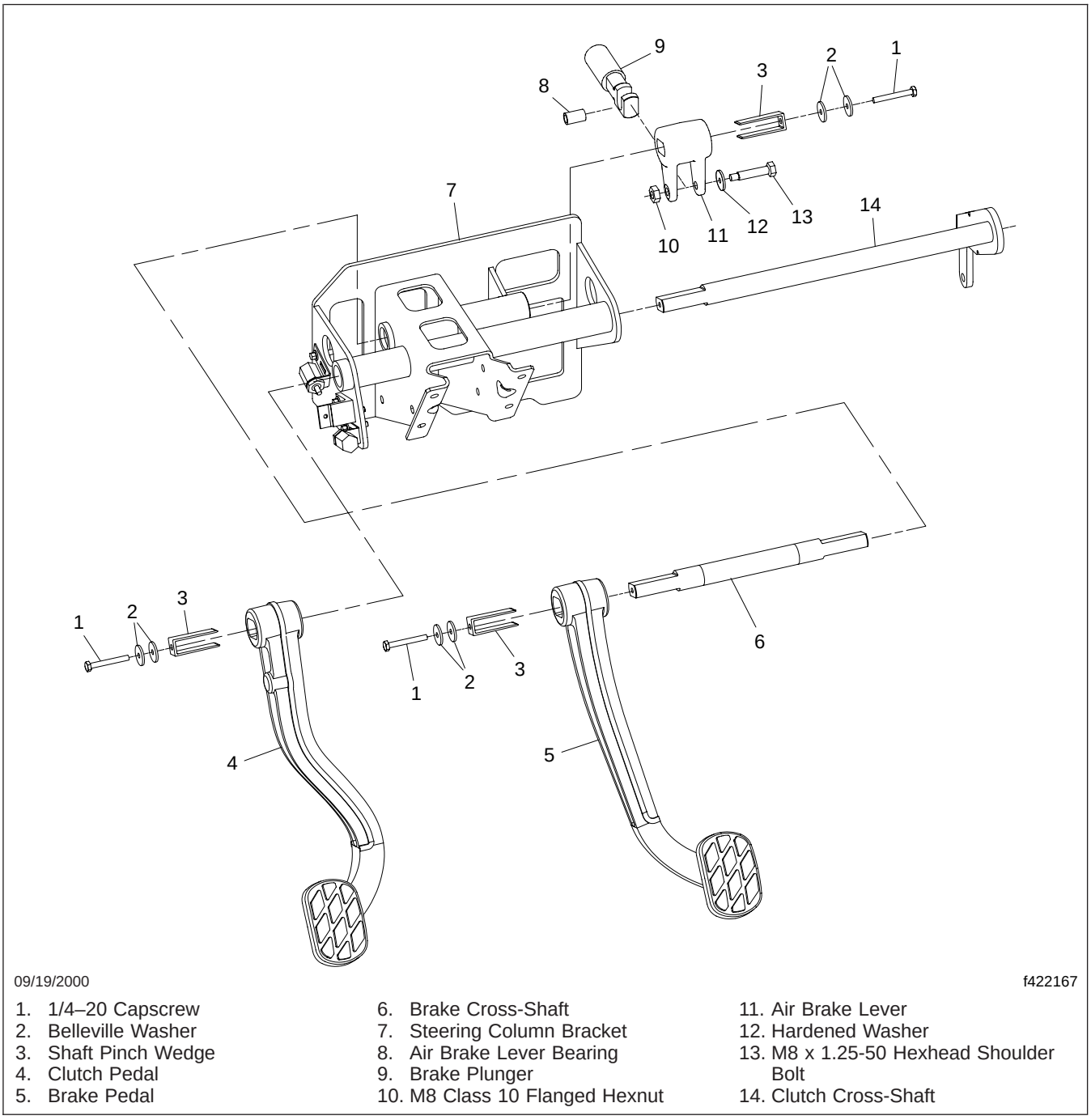
IMPORTANT: The shoulder bolt may be reused but the hexnut must be replaced after it is removed for any reason. For part numbers, see **Specifications 400**.

8. Insert a washer and M8 x 1.25-50 shoulder bolt through the holes in the brake lever and bearing. Secure in place with a new M8, class 10 flanged hexnut. Tighten the nut 17 lbf·ft (23 N·m).

IMPORTANT: The wedge, belleville washers and capscrews must be replaced after they are re-

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Brake Pedal Removal and Installation



1. 1/4–20 Capscrew
2. Belleville Washer
3. Shaft Pinch Wedge
4. Clutch Pedal
5. Brake Pedal
6. Brake Cross-Shaft
7. Steering Column Bracket
8. Air Brake Lever Bearing
9. Brake Plunger
10. M8 Class 10 Flanged Hexnut
11. Air Brake Lever
12. Hardened Washer
13. M8 x 1.25-50 Hexhead Shoulder Bolt
14. Clutch Cross-Shaft

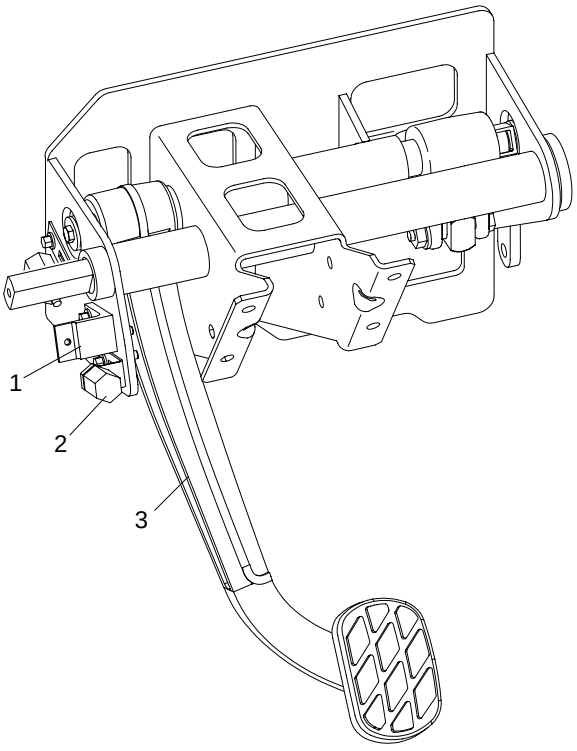
Fig. 1, Brake- and Clutch-Pedal Assembly

moved for any reason. For part numbers, see **Specifications 400**.

9. Install the wedge, belleville washers, and capscrew from each end of the brake cross-shaft.

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Brake Pedal Removal and Installation



1. Clutch Stop
2. Nuetral Safety Switch
3. Clutch Pedal

Fig. 2, Clutch Pedal Removed

IMPORTANT: The belleville washers are concave and must be installed facing each other as shown in **Fig. 6**.

9.1 Install the capscrews and belleville washers at each end of the brake cross-shaft. The belleville washers are concave and must be installed opening away from each other as shown in **Fig. 6**.

9.2 Tighten the capscrews 8 lbf·ft (10.8 N·m).

10. Install the clutch stop and neutral safety switch. See **Fig. 2**.
11. Install the Clutch Pedal. For instructions, see **Section 25.03**, Subject 100.
12. Remove the chocks from the tires.

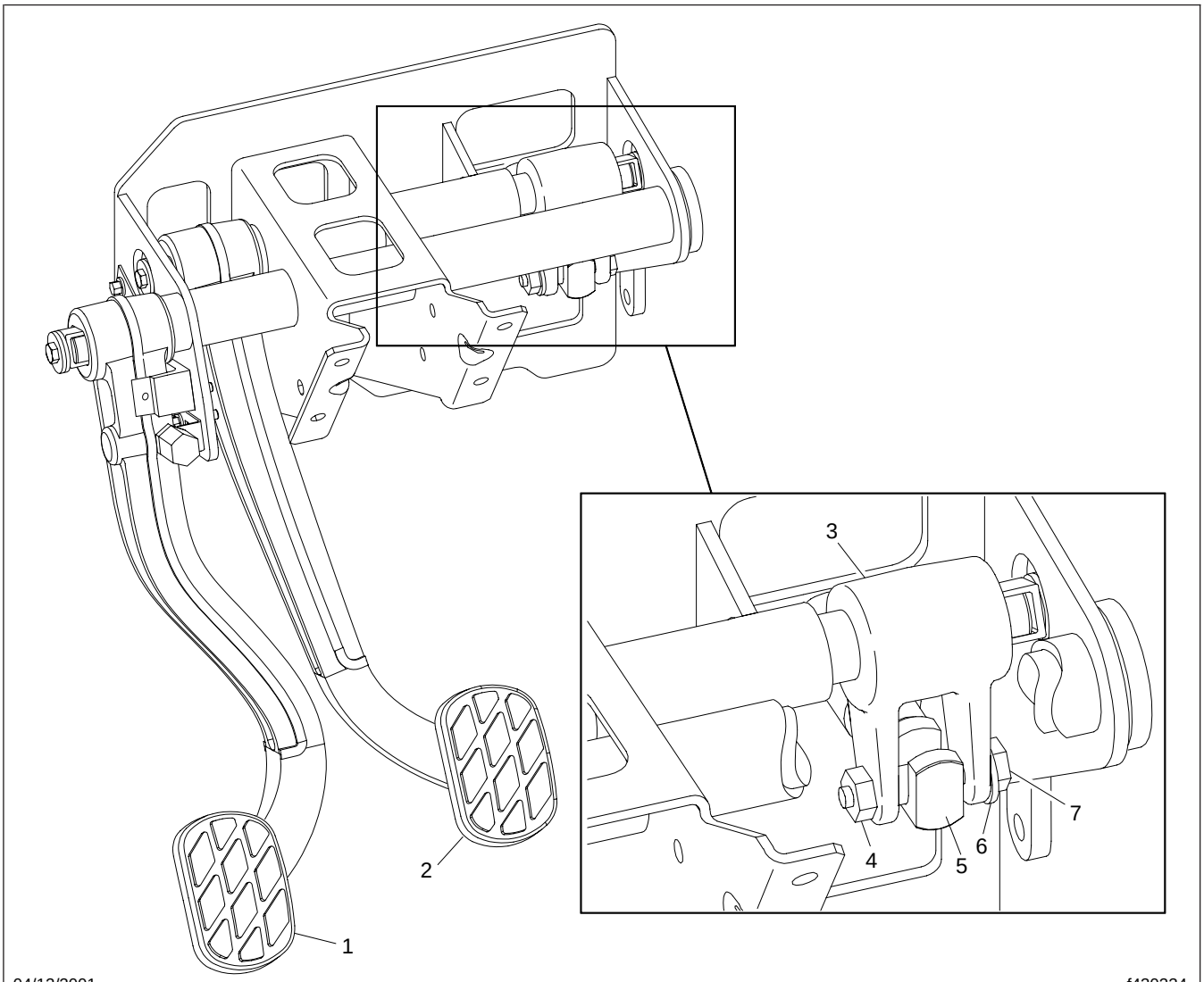
⚠ WARNING

Do not operate the vehicle until the brakes have been checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

13. Test drive the vehicle in a safe area at low speed. Make several brake applications to be sure the vehicle comes to a stop.

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Brake Pedal Removal and Installation

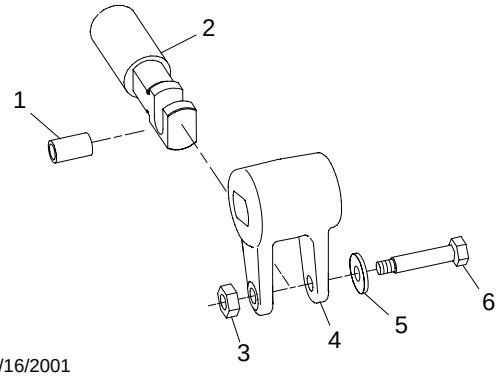


1. Clutch Pedal
2. Brake Pedal
3. Air Brake Lever
4. M8 Class 10 Flanged Hexnut
5. Brake Plunger
6. Hardened Washer
7. M8 x 1.25-50 Hexhead Shoulder Bolt

Fig. 3, Brake- and Clutch-Pedal Assembly

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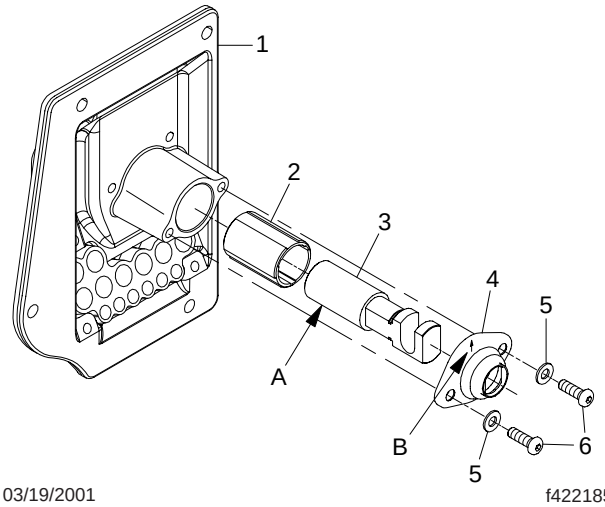
Brake Pedal Removal and Installation



03/16/2001 f430236

1. Bearing
2. Brake Plunger
3. M8 Class 10 Flanged Hexnut
4. Air Brake Lever
5. Hardened Washer
6. M8 x 1.25-50 Hexhead Socket Shoulder Bolt

Fig. 4, Air Brake Lever Assembly

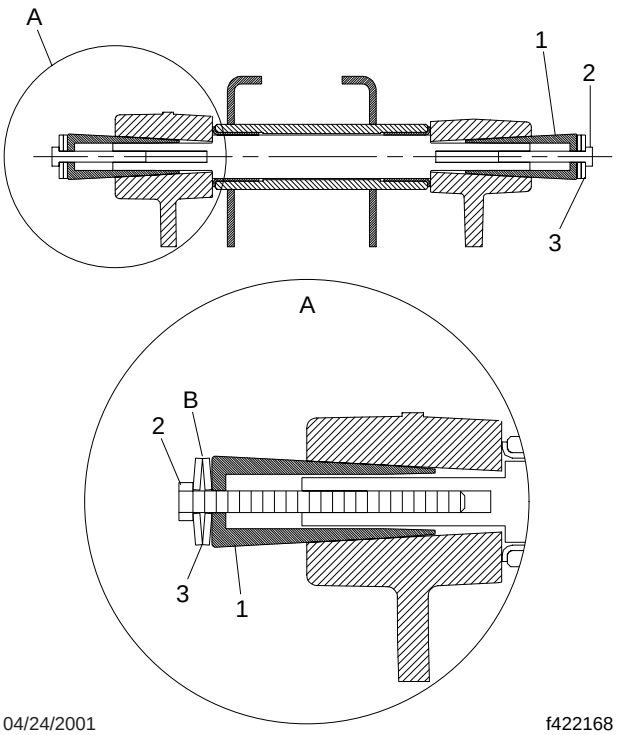


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A. Apply a small amount of silicon grease on the contact surface between items 2 and 3.
B. Install the rubber seal assembly with the arrow pointing up.

1. Mounting Bracket
2. Brake Plunger Bearing
3. Brake Plunger
4. Guide Bearing and Rubber Seal Assembly
5. Plated Flatwasher
6. 5/16–18 x 1-Inch Machine Screw

Fig. 5, Brake Plunger Removal



04/24/2001 f422168

A. Detailed Area
B. **IMPORTANT: Belleville washers must be installed facing each other.**

1. Wedge
2. 1/4–20 Capscrew
3. Belleville Washers

Fig. 6, Wedge Installation

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Specifications

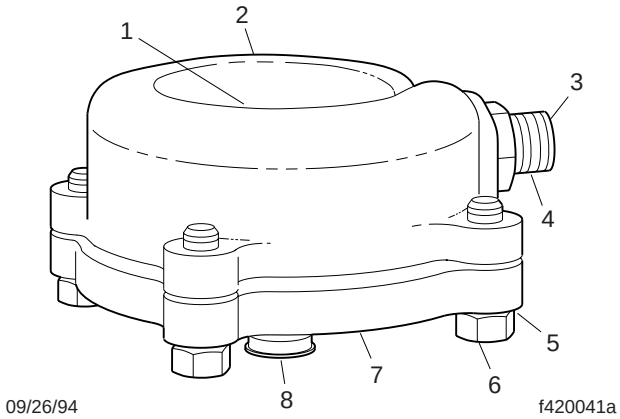
Brake Pedal Replacement Parts	
Description	**Part Number**
Shaft Pinch Wedge	12-17561-000
Belleville Washer	23-12105-000
1/4–20 Capscrew	23-12686-250
M8 Class 10 Flanged Hexnut	MBT N210100008000

Table 1, Brake Pedal Replacement Parts

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General Information

The DV–2 automatic reservoir drain valve automatically removes contaminants and water from the wet air tank each time the brakes are applied. See **Fig. 1**. The drain valve is attached to a drain cock located on the bottom of either end of the wet air tank. Since the brake application valve is protected by a check valve between the wet and dry air tanks, any leak or failure will not reduce the supply of air that is in the dry part of the system. If the leak is severe, it could prevent the continued resupply of air as it is used when applying the brakes. A failed drain valve will allow moisture to build up in the wet tank which in turn could reach the dry tank, and then travel into the air brake system where it could cause brake failure. A leaking drain valve allows wet tank leakdown which in turn can cause premature wear on the air compressor during vehicle operation as the air compressor continues to run to maintain wet tank air pressure.



1. Top Reservoir Port
2. Valve Body
3. Hexhead Nipple
4. Side Reservoir Port
5. Lockwasher (4 qty.)
6. Capscrew (4 qty.)
7. Valve Cover
8. Exhaust Port

Fig. 1, DV-2 Valve

With no pressure in the system, the drain valve's inlet and exhaust valves are closed. See **Fig. 2**. Upon charging the system, a slight pressure opens the inlet valve which permits air and contaminants to collect in the sump. See **Fig. 3**. The inlet valve remains open when pressure is rising in the system until the air compressor cuts off, allowing the spring action of the valve guide in the sump cavity to close the inlet valve. The inlet valve and the exhaust valve are now both closed. See **Fig. 4**. When the wet tank pressure drops approximately 2 psi (14 kPa), the air pressure in the sump cavity opens the exhaust valve and allows moisture and contaminants to be ejected from the sump cavity until pressure in the sump cavity drops sufficiently to close the exhaust valve. See **Fig. 5**.

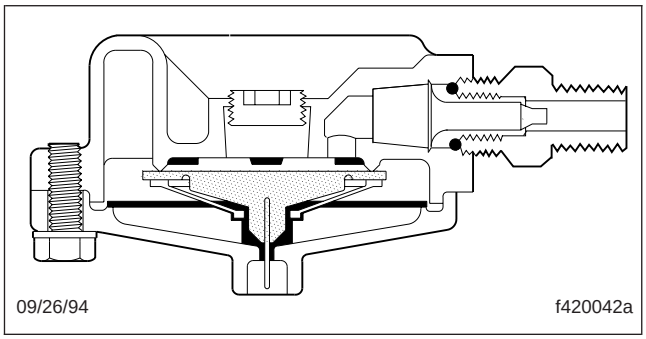


Fig. 2, No System Pressure

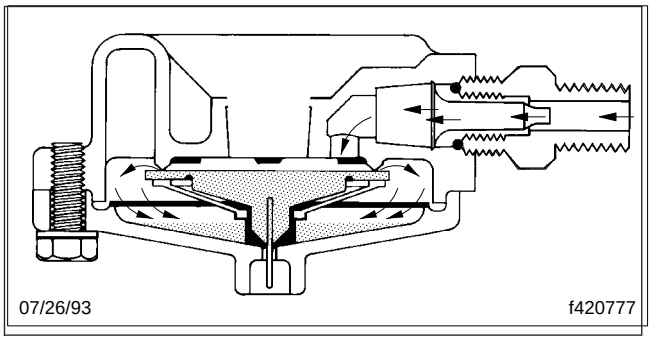


Fig. 3, Start of System Pressure Charging

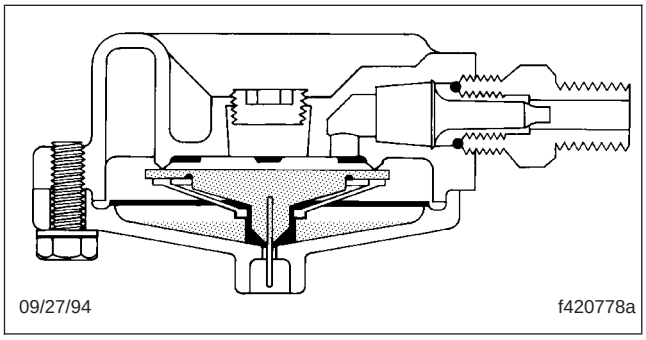


Fig. 4, System Pressure Rising

The length of time the exhaust valve remains open and the amount of moisture and contaminants ejected depends upon the sump pressure and the

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General Information

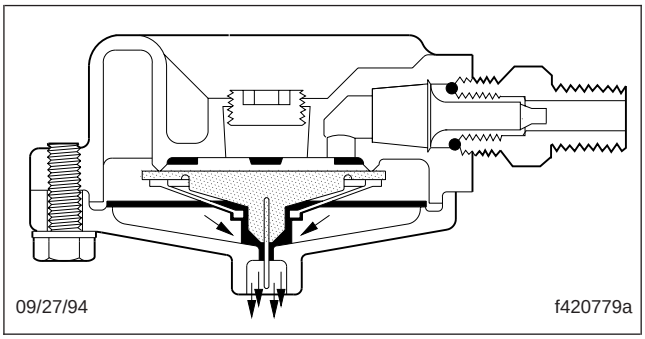


Fig. 5, Exhaust Cycle

wet tank pressure drop that occurs each time air is used from the system.

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Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

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⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Operating Test

Perform the following test after repairing or replacing the DV–2 valve to ensure that the valve is functioning properly.

With the system charged, apply the brakes several times. Each time the brakes are applied, an exhaust of air should occur from the exhaust port of the drain valve. If no air comes out, push the wire stem located inside the exhaust port. If no air comes out after pushing the wire stem, there may be a plugged filter in the adapter which should be replaced.

If the drain valve does not function properly, repair or replace it following the instructions in this section.

Leakage Test

Perform the following test after repairing or replacing the DV–2 valve to ensure that the valve is functioning properly.

With the system charged and pressure stabilized in the system, there should be no leaks at the drain valve exhaust port. A constant slight exhaust of air at the drain valve exhaust port could be caused by excessive leakage in the air brake system.

If the drain valve is leaking excessively, repair or replace it following the instructions in this section.

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⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the drain valve assembly from the end of the wet tank air reservoir.

Installation

1. Using a cleaning solvent, thoroughly flush and clean the wet tank reservoir to avoid early fouling at the drain valve. Aerate the wet tank thoroughly if solvents were used during cleaning.
2. Install the drain valve assembly on the wet tank by tightening the hexagonal nipple until the drain valve is positioned so that the valve body is parallel to the bottom of the wet tank with the exhaust port facing straight down. Make sure that the exhaust port is clear of any air, electric, or fuel lines. Make sure the drain valve is attached tight enough to prevent leakage.
3. Close the drain cocks to the wet and dry air reservoirs. Start the vehicle engine to pressurize the air system.
4. Leak test the drain valve following the instructions in **Subject 110**.
5. Remove the chocks from the tires.

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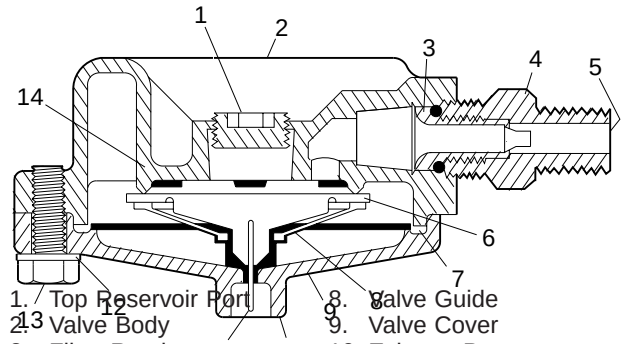
Disassembly, Cleaning and Inspection, and Assembly

WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

NOTE: For a cutaway view of the DV–2 valve, see **Fig. 1**.

Disassembly



1. Top Reservoir Port
2. Valve Body
3. Filter Retainer
4. Hexhead Nipple
5. Side Reservoir Port
6. Inlet and Exhaust Valve
7. Valve Sealing Ring
8. Valve Guide
9. Valve Cover
10. Exhaust Port
11. Wire Stem
12. Lockwasher (4 qty.)
13. Capscrew (4 qty.)
14. Inlet Valve Seat

Fig. 1, DV-2 Valve (cutaway view)

1. Remove the drain valve following the instructions in **Subject 120**.
2. Remove the four capscrews that hold the valve cover to the valve body.
3. Remove the valve cover and sealing ring.
4. Remove the valve guide, and the inlet and exhaust valve from the valve body.
5. Remove the hexhead nipple from the valve body.

Cleaning and Inspection

WARNING

Use eye protection when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

1. Wash all metal parts of the drain valve in an approved cleaning solvent. Dry the metal parts of the disassembled moisture ejection valve with compressed air.
2. Wipe all rubber parts with a clean cloth. Examine all rubber parts for wear, cracks, tears, or other deterioration. If any rubber parts are worn, cracked, torn or otherwise deteriorated, replace them with new parts.
3. Examine all metal parts for wear, cracks, or other damage. If any metal parts are worn, cracked, or otherwise damaged, replace them with new parts.
4. Clean and examine the filter. If it will not clean completely, or is torn or damaged, replace it with a new filter.

CAUTION

Do not reassemble the drain valve with a dirty filter; to do so could result in failure of the drain valve in service.

Assembly

Before assembling the drain valve, apply a light film of grease on the inlet valve seat.

CAUTION

Do not apply oil to the inlet and exhaust valve.

1. Install the valve sealing ring into its groove in the valve cover.
2. Install the valve guide over the inlet and exhaust valve.
3. Install the valve guide, and the inlet and exhaust valve as an assembly into the valve cover. The wire stem will project through the exhaust port.

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Disassembly, Cleaning and Inspection, and Assembly

4. Install the valve body on the valve cover and install the lockwashers and capscrews. Tighten the capscrews 72 to 96 lbf·in (820 to 1080 N·cm).
5. Install the hexhead nipple onto the valve body, and tighten it 48 to 72 lbf·in (540 to 820 N·cm).
6. Install the drain valve on the wet tank following the instructions in **Subject 120**.

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Specifications

Torque Values	
Description	**Torque lbf·in (N·cm)**
Valve Cover Capscrews	72–96 (820–1080)
Hexhead Nipple	48–72 (540–820)

Table 1, Torque Values

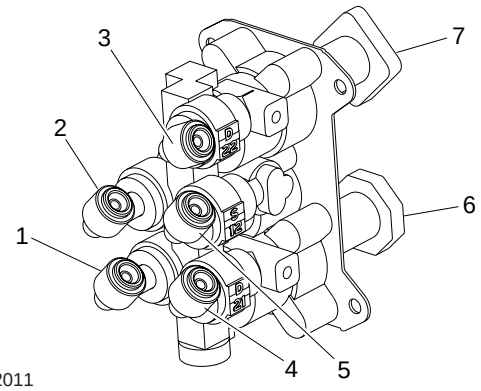
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General Description

The dash-mounted MV-3 control module is a two-button, push-pull control valve housed in a single body, which includes a dual circuit supply valve and a check valve.

The valve body, plungers, and spools are made out of a nonmetallic, noncorrosive material. All air connections are at the back of the valve. See **Fig. 1**.

The MV-3 module has several functions: tractor protection; trailer service air control; system park; trailer park only; trailer charge with tractor spring brakes applied (tractor park only); and supply reservoir selection.

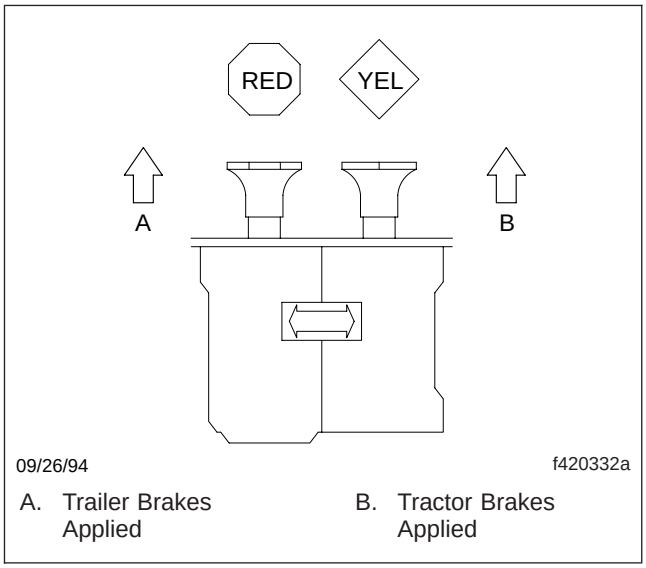


1. Exhaust
2. Primary Reservoir Supply
3. Delivery–Tractor Spring Brakes
4. Delivery–Trailer Supply
5. Secondary Reservoir Supply
6. Trailer Air Supply Knob
7. Parking Brake Control Valve Knob

Fig. 1, MV-3 Parking Brake Valve

The MV-3 includes a spring-loaded, dual-circuit supply valve, which selects the primary air reservoir as the air source for both control valves, unless the pressure in the primary air reservoir falls below that of the secondary air reservoir. Then, the dual-circuit supply valve will shuttle and establish the secondary air reservoir as the air source.

The trailer air supply valve, actuated by the red knob and the yellow knob, delivers air to the trailer supply line. See **Fig. 2**. The parking brake valve, actuated by a yellow knob, controls the spring parking brakes on the tractor, and when exhausted, simultaneously causes the trailer supply valve to trip and exhaust, thus applying both the tractor and the trailer parking brakes as required by federal regulations. See **Fig. 2**. The trailer parking brakes may be independently released by pushing only the trailer air supply valve (red) knob in.



A. Trailer Brakes Applied
B. Tractor Brakes Applied

Fig. 2, Trailer and Tractor Delivery Air Discharged (control knobs out)

Principles of Operation

Initial Charge

With both the primary and the secondary systems completely discharged, both knobs are out. See **Fig. 2**. When system pressure reaches 65 psi (448 kPa), the red knob (trailer air supply) may be pushed in, and should stay in, charging the trailer system and releasing the trailer parking brakes. See **Fig. 3**. The yellow knob (parking brake) may now be pushed in, which will supply air to the tractor parking brakes, releasing them.

Normal Operation Position

When both knobs are pushed in, air is supplied to the trailer and the tractor parking brakes; all parking brakes are released. See **Fig. 4**. This is the normal operating mode.

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General Information

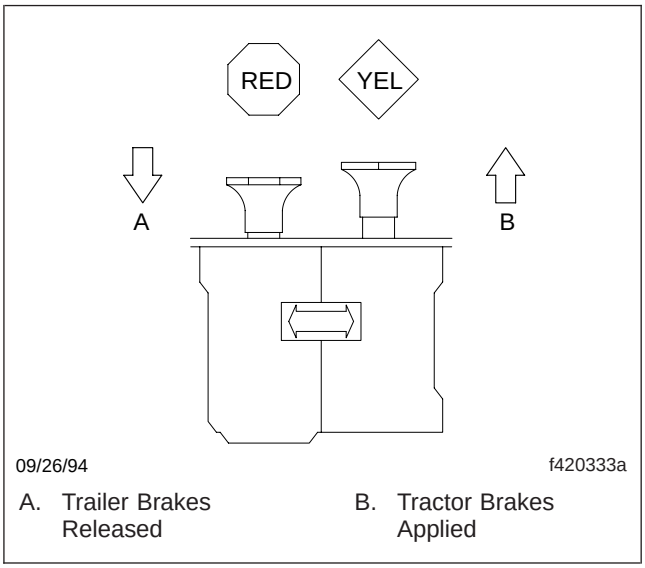


Fig. 3, Trailer Parking Brakes Released (red control knob pushed in)

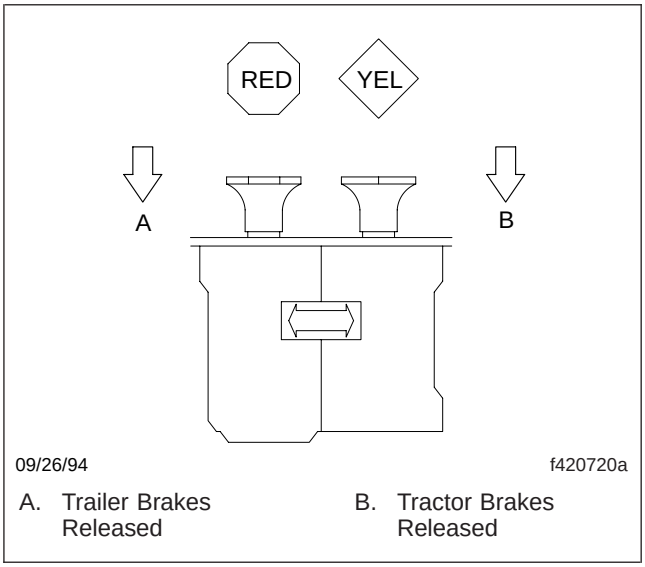


Fig. 4, Trailer and Tractor Brakes Released (both control knobs pushed in)

Actuation of Trailer Park or Emergency Brakes

To actuate the trailer parking brakes only, the red knob is pulled out, exhausting the trailer supply line. The trailer parking brakes are now applied, either by emergency air or parking brakes, depending on the type of trailer system. This mode would be used to uncouple from the trailer, and during bobtail operation. See **Fig. 5**.

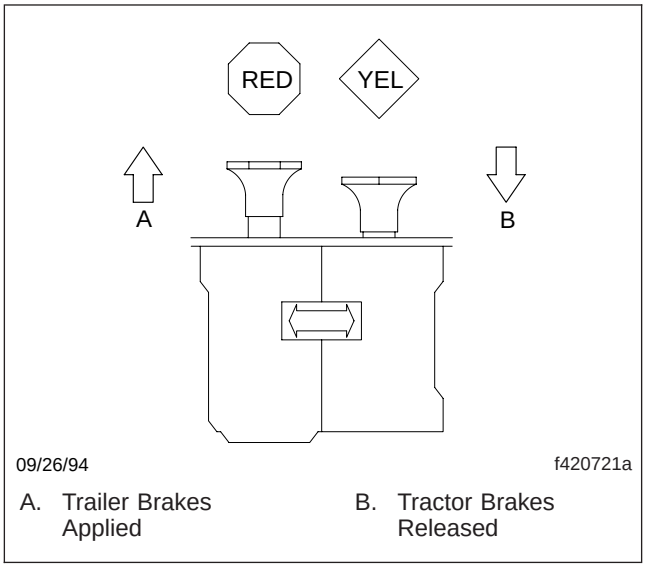


Fig. 5, Trailer Parking Brakes Applied (red control knob pulled out)

System Park

With both knobs pushed in, the parking brakes on both the tractor and the trailer may be actuated by pulling the yellow (parking brake) knob out. This exhausts the air from the tractor parking brakes and simultaneously causes the red (trailer air supply) knob to pop out, applying the trailer parking brakes (this complies with federal regulations that one control must apply all the parking brakes on the vehicle). See **Fig. 2**.

Trailer Charge

If both valves are out, parking the combination vehicle, and it is desired to recharge the trailer (leaving only the tractor parking brakes applied), the red knob may be pushed in, repressurizing the trailer supply line. This mode might also be used to park a combination vehicle with air-actuated emergency brakes on the trailer to provide demonstrated parking capability with the tractor spring brakes only. See **Fig. 3**.

Automatic Applications

If air pressure drops to 20 to 45 psi (138 to 310 kPa) in both the primary and the secondary systems, the

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red knob (trailer air supply valve) will automatically pop out, applying the emergency or parking brakes on the trailer. If the red knob is held in manually and the pressure decreases to 25 to 35 psi (172 to 241 kPa), a tripper piston within the MV-3 valve will move upward, exhausting the trailer supply, and applying the trailer parking brakes. If air pressure drops in both the primary and the secondary systems, the yellow (parking brake) knob will pop out at about 20 to 40 psi (138 to 276 kPa), applying the tractor parking brakes.

A warning buzzer and light are activated when pressure in either the primary or the secondary system drops below 64 to 76 psi (441 to 524 kPa).

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Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

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⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the eight screws from the auxiliary dash panel. See **Fig. 1**. Remove the auxiliary dash panel. For instructions, see **Section 60.07**.

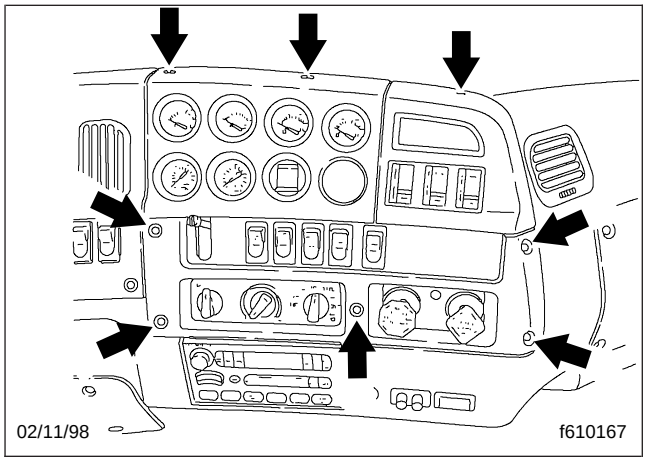


Fig. 1, Auxiliary Dash Panel Screws

4. Unscrew the red and yellow knobs from the stems of the spools on the MV–3 valve by turning them in a counterclockwise direction. Mark the knobs in relation to the valve for later reference.
5. Mark the air lines for later reference. Disconnect the lines from the valve assembly. See **Fig. 2**.

NOTE: The primary supply line is green. The exhaust line is yellow. The parking brake delivery line is black. The trailer charge delivery line is orange.

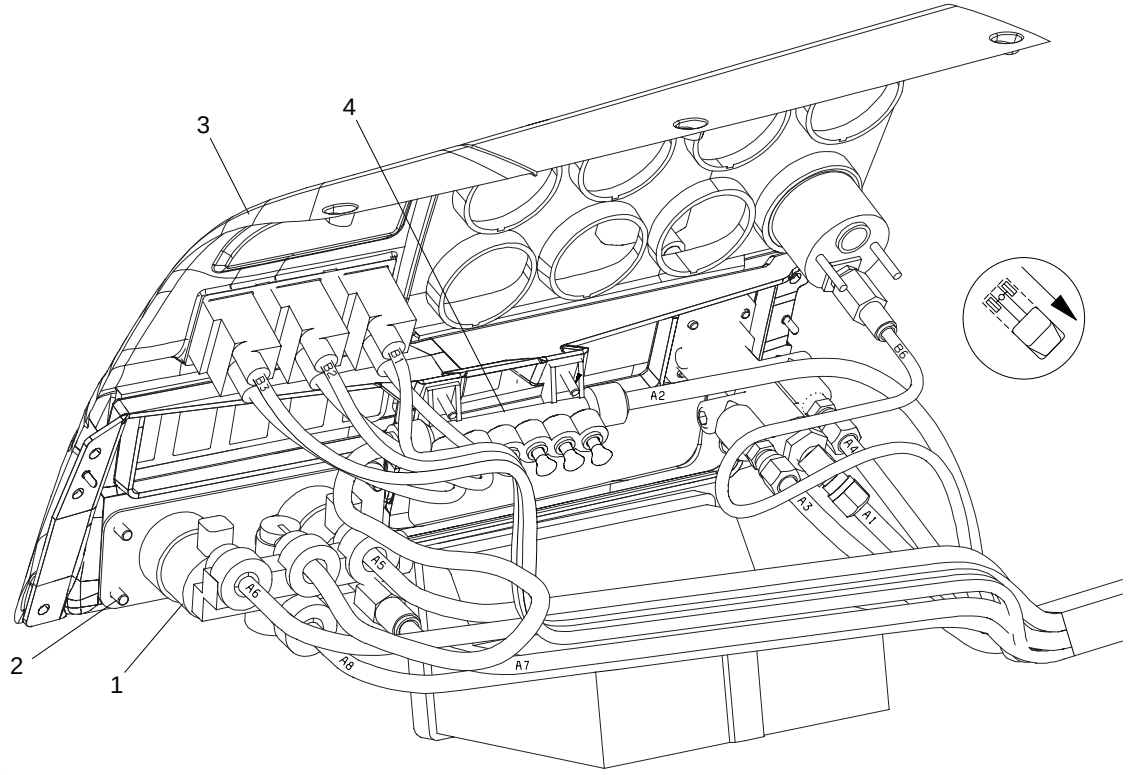
6. Remove the four screws that attach the valve to the mounting panel. Remove the valve.

Installation

1. Position the valve assembly on the mounting panel. Install the four mounting screws.
2. Connect the air lines to the applicable fittings.
3. Attach the red and yellow knobs onto the threaded stems of the valve spools, making sure they are correctly oriented as noted during removal.
4. Leak test the fittings following the instructions in **Subject 130**.
5. Install the auxiliary dash panel. For instructions, see **Section 60.07**.
6. Remove the chocks from the tires.

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Removal and Installation



1. Control Module
2. Mounting Plate
3. Auxiliary Dash Panel
4. Air Manifold

Fig. 2, Control Module Mounting

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Disassembly, Cleaning and Inspection, and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Disassembly

1. Remove the control module from the vehicle. For instructions, see **Subject 110**.
2. Remove the six screws from the cover plate and carefully remove the cover plate from the valve. See **Fig. 1**.
3. Remove the cap and O-ring from the bore of the tripper valve. Remove the tripper piston, large spring, small spring, and check valve. These parts will all fall out of the cavity of the MV–3 by tilting the body forward. Remove the O-ring from its groove on the piston.
4. Remove the two main spools from the body of the MV–3 valve by grasping the stem and pulling firmly. Remove the spring from the bottom of each spool cavity.
5. Pull the guide cap and guide spool over the threaded end of one of the plungers. Remove the O-ring from the guide cap and the O-ring from the guide spool. Remove the other O-rings and the exhaust seal from the plunger.
6. Repeat the previous step on the remaining spool assembly.
7. Remove the retaining ring from the cavity of the MV–3 body that contains the dual circuit supply valve.
8. Using a pair of needle-nose pliers, grasp the bar in the center of the cap and dual circuit supply valve and remove the dual circuit valve assembly. Remove the three O-rings from the valve or from the cavity of the body, if some have remained there. Other than the three external O-rings, do not disassemble the piston assembly further.

NOTE: If during the removal of this assembly from the body the cap dislodges from the rest of the valve, the remaining parts can be removed using bent wire. The spring, piston and O-ring that are internal to the dual circuit valve assembly are nonserviceable.

Cleaning and Inspection

The nonmetallic components making up most of the parts of the MV–3 *should not be immersed in any solvent type cleaner*. Old lubricant should be wiped out with a clean dry cloth.

If any visible damage to the body or the spools is found, replace the complete unit.

Assembly

Dual Circuit Supply Valve

1. Lubricate all O-rings, bores, and sliding surfaces with silicone lubricant Bendix 291126, Dow Corning 55-M, or equivalent.
2. Install O-rings onto the cap and dual circuit supply valve. Install the assembly, small diameter first, into its cavity in the body.
3. Install the retaining ring making sure it is fully seated in its groove.

Spools

1. Install the O-rings and the exhaust seal onto the stem of the plunger.

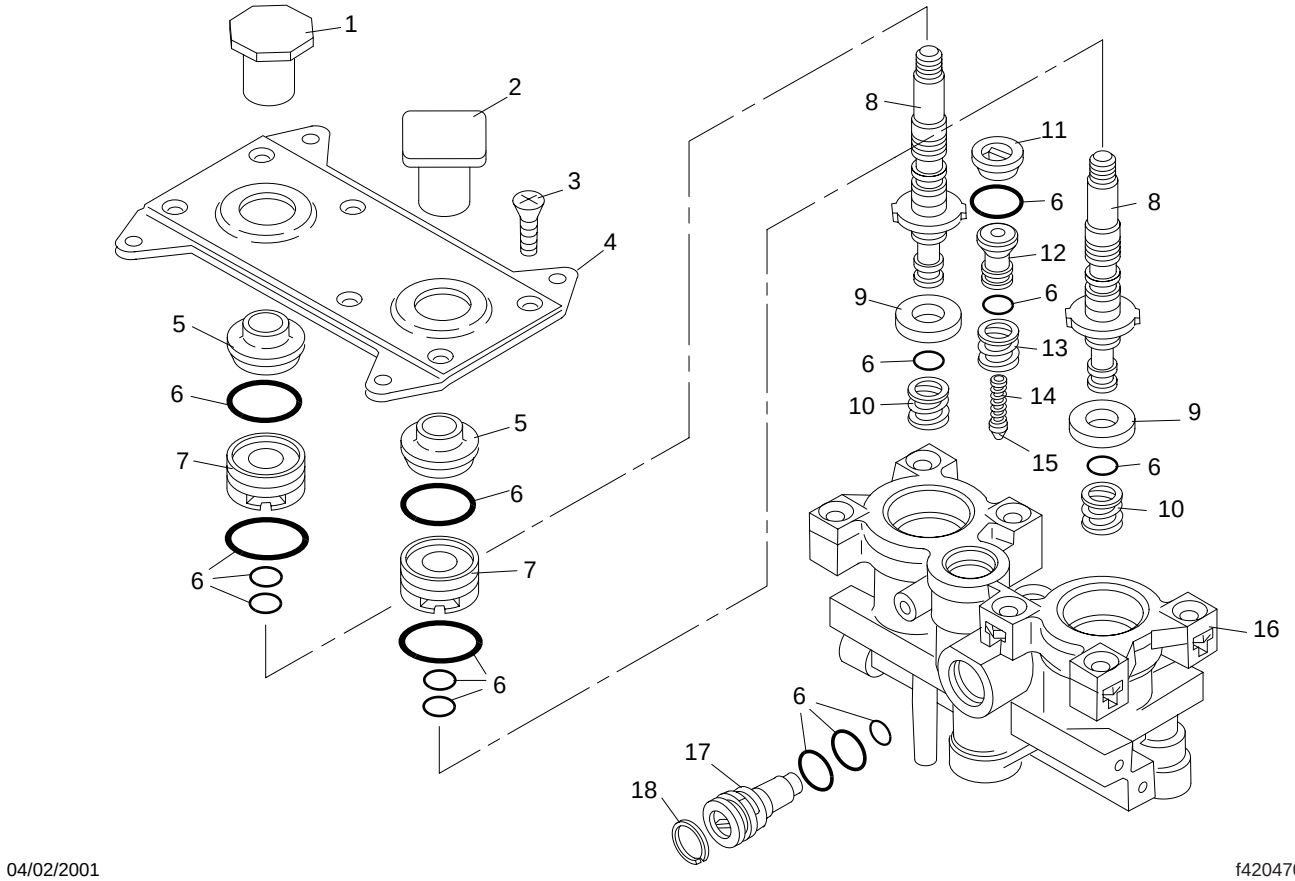
⚠ CAUTION

The exhaust seal must be installed so that its beveled surface mates with the beveled surface of the plunger. See Fig. 2.

2. Install the O-ring onto the guide spool and the O-ring onto the guide cap. Place the guide cap on top of the guide spool, and install the entire assembly over the threaded end of the plunger; press down firmly until it snaps into place.
3. Install the spring over the boss in the bottom of the spool cavity in the body of the MV–3 valve. Place the spool assembly into the body, keeping the spool square to the body. Press and turn the stem until the spool is fully seated in its cavity. Note the assembly is keyed and can be installed one way only.
4. Repeat the previous steps for the opposite spool.

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Disassembly, Cleaning and Inspection, and Assembly



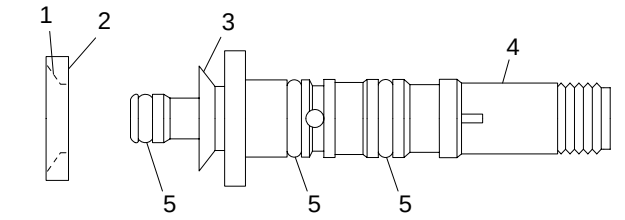
1. Red Trailer Air Supply Knob
2. Yellow Parking Brake Knob
3. Screw
4. Cover Plate
5. Guide Cap
6. O-Ring
7. Guide Spool
8. Plunger
9. Beveled Exhaust Seal
10. Spring
11. Cap
12. Tripper Piston
13. Large Diameter Spring
14. Small Diameter Spring
15. Check Valve
16. Valve Body
17. Cap and Dual Circuit Valve Assembly
18. Retaining Ring

Fig. 1, MV-3 Valve, (exploded view)

Shuttle and Check Valve

1. Install the O-ring into its groove on the tripper piston. Install the O-ring onto the cap.
2. Install the large spring on the piston and the small spring on the boss of the check valve.
3. Install the spring and check valve into their cavity in the body of the MV–3 valve (tapered end of the valve to enter cavity first). Make sure the spring is centered in the bore.
4. Install the piston assembly into the cavity, making sure the spring mates with the bore of the piston.
5. Install the cap and O-ring.
6. Attach the cover plate to the valve body using the six screws. Torque them 25 lbf·in (280 N·cm).
7. Install the control module in the vehicle. For instructions, see **Subject 110**.

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1. Inside Bevel
2. Exhaust Seal
3. Mating Exhaust Seal Bevel
4. Plunger
5. O-Ring

Fig. 2, Plunger Assembly

8. Check the operation of the valve using the instructions in **Subject 130**.

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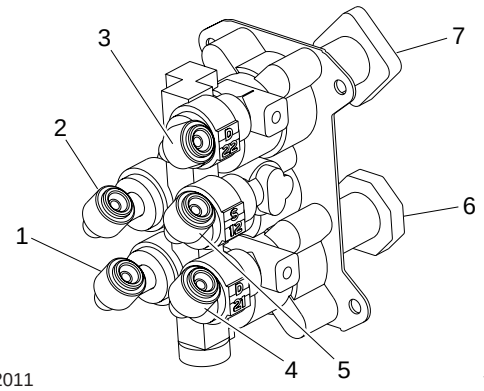
⚠ WARNING

Before working on or around air brake systems and components, see "Safety Precautions" in Subject 100. Failure to do so may result in personal injury.

Tests

With the air brake system charged to 120 psi (827 kPa), check for leaks, using the following instructions. Repair or replace components as needed.

1. Apply a soap solution and check for leakage between the body and cover plate. Leakage at the exhaust port should produce less than a 1-inch (25-mm) bubble in five seconds.
2. With the trailer supply line sealed, push in the red knob. The knob must stay in. Leakage at the exhaust port must not exceed a 1-inch (25-mm) bubble in 5 seconds. See **Fig. 1**.



1. Exhaust
2. Primary Reservoir Supply
3. Delivery–Tractor Spring Brakes
4. Delivery–Trailer Supply
5. Secondary Reservoir Supply
6. Trailer Air Supply Knob
7. Parking Brake Control Valve Knob

Fig. 1, MV–3 Parking Brake Valve

3. Slowly reduce pressure in both service reservoirs. The red knob must pop out at 20 to 35 psi (138 to 310 kPa).

NOTE: Trip-on pressure is the pressure at which the valve automatically changes position or "pops out." It is advised to use an accurate pressure gauge other than those in the truck when performing tests.

4. Hold the red knob in and continue to reduce pressure in all service reservoirs. Air must start to escape from the exhaust port when the trailer line pressure reaches 20 to 35 psi (138 to 241 kPa).
5. Release the red knob and rebuild the supply pressure to 120 psi (827 kPa). Push in the yellow knob; the yellow knob must remain in. Leakage at the exhaust port should not exceed a 1-inch (25-mm) bubble in 5 seconds.
6. Pull the red knob out. Slowly reduce pressure in all service reservoirs. There is not a federal trip pressure requirement for the yellow knob, but it will pop out at 20 to 30 psi (138 to 207 kPa).
7. Charge the system to 120 psi (827 kPa), and push both knobs in. Pull the red knob out. The yellow knob must remain in. Push the red knob in and pull the yellow knob out. The red knob must pop out at once.
8. Install a gauge to monitor tractor spring brake delivery pressure. Build 120 psi (827 kPa) pressure in the primary and secondary air reservoirs. Push in the yellow knob. Delivery pressure should equal the pressure in the primary air reservoir. Reduce the pressure in the primary air reservoir. The dual-circuit supply valve shuttle should switch to the secondary air reservoir. After the primary air reservoir pressure is reduced to zero, there should not be audible leakage at the primary air reservoir opening. Stop the leak that was created in the primary air reservoir.
9. Leaving the yellow knob in, recharge the secondary air reservoir to 120 psi (827 kPa). The delivery pressure should also read 120 psi (827 kPa). Recharge the primary air reservoir to 100 psi (690 kPa). Slowly vent the secondary air reservoir. As the secondary air reservoir pressure and the delivery line pressure descend, pressure should stabilize at about 100 psi (690 kPa).
10. Close all leakage points and charge both reservoirs to 120 psi (827 kPa). Position the red knob out and the yellow knob in. Develop a leak in the spring brake delivery line and hold the yellow knob in. See **Fig. 1**. The air reservoir pressures will go to zero. The dual-circuit supply valve shuttle should cycle during the leak-down period.

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Operating Tests

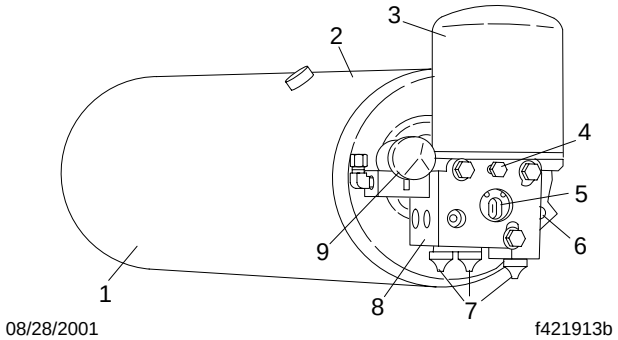
11. If the MV-3 fails to operate as described, or leakage exceeds the limits stated, replace or repair it using genuine Bendix parts.

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General Information

The function of the dryer reservoir module (DRM) (**Fig. 1**) is to provide the vehicle with an integrated air dryer, secondary reservoir, purge volume, and governor.

NOTE: Some DRM configurations also include an integrated primary reservoir.



NOTE: DRM shown without splash shield.

1. Integrated Reservoir (Secondary Volume)
2. Integrated Reservoir (Purge Volume)
3. Desiccant Cartridge
4. Safety Valve
5. Heater/Thermostat Assembly
6. Auxiliary Delivery Port
7. Pressure Protection Valves
8. AD-IS Air Dryer
9. Governor

Fig. 1, Dryer Reservoir Module

Principles of Operation

The air dryer collects and removes air system contaminants in solid, liquid, and vapor form before they enter the brake system. It provides clean, dry air to the components of the brake system, which also increases the life of the system.

Charge Cycle

When the compressor is loaded, compressed air, oil, oil vapor, water, and water vapor flow through the compressor discharge line to the supply port of the air dryer body.

As air travels through the air dryer assembly, its temperature falls, causing some of the contaminants to condense and drop to the bottom of the air dryer assembly, ready to be expelled at the next purge cycle. See **Fig. 2**.

The air then flows into the desiccant cartridge. Once in the desiccant cartridge, air flows through an oil separator that removes oil and solid contaminants.

Air then flows into the desiccant drying bed. Air flowing through the desiccant becomes progressively dryer as water vapor adheres to the desiccant material.

Dry air exits the bottom of the desiccant cartridge and flows through the center of the base assembly. The air then flows to the delivery check valve, to the safety valve and also through an orifice plug into the purge volume reservoir. Air traveling through the delivery check valve flows to the governor and three pressure protection valves.

As pressure builds during the initial charge, the purge volume fills. When the air pressure reaches 103 psi (710 kPa), the first pressure protection valve opens, filling the primary reservoir. When the primary reservoir pressure reaches 109 psi (752 kPa) the second pressure protection valve opens and air is supplied to the secondary reservoir and accessory pressure protection valve. When air pressure in the secondary reservoir reaches 85 psi (586 kPa), the remaining pressure protection valve opens and supplies air to the accessories.

NOTE: There is no external air line from the air dryer to the secondary reservoir. Air is supplied by a line passing through the purge reservoir.

The air dryer will remain in the charge cycle until the air brake system pressure builds to the governor cutout setting of approximately 130 psi (896 kPa).

Purge Cycle

When air brake system pressure reaches the cutout setting of the governor, the governor unloads the compressor and the purge cycle begins. When the governor unloads the compressor, it pressurizes the compressor unloader mechanism and the dryer control port. The purge piston moves in response to air pressure, causing the purge valve to open and the turbo cutoff valve to close. When the purge valve opens, water and contaminants are expelled. Air flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected in the oil separator are removed by air flowing from the purge

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General Information

volume, through the desiccant drying bed, and out through the open purge valve. See **Fig. 3**.

The purge cycle lasts only a few seconds and is detected by an audible burst of air at the air dryer exhaust.

The reactivation of the desiccant drying bed begins as dry air flows from the purge volume, through the purge orifice, and into the desiccant bed. Pressurized air from the purge volume expands after passing through the purge orifice; its pressure is lowered and its volume is increased. The flow of dry air through the drying bed reactivates the desiccant material by removing the water vapor adhering to it. Approximately 30 seconds is required for the entire purge volume of a standard air dryer to flow through the desiccant dryer bed.

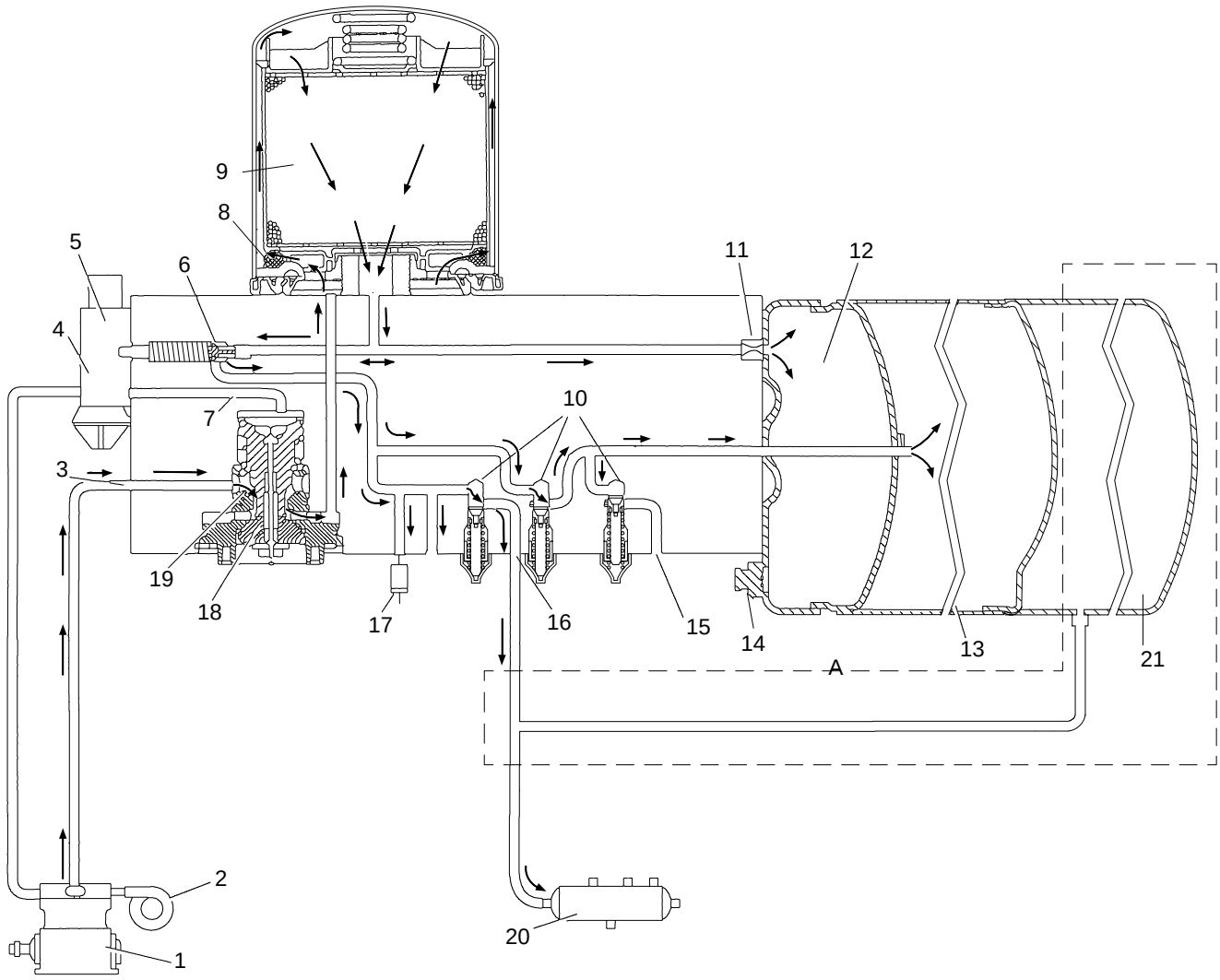
The delivery check valve assembly prevents air pressure in the brake system from returning to the air dryer during the purge cycle. After the purge cycle is complete, the air dryer is ready for the next charge cycle to begin.

Turbo Cutoff Feature

The primary function of the turbo cutoff valve is to prevent loss of turbocharger air pressure through the air dryer in systems where the compressor intake is connected to the engine turbocharger.

During the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the compressor discharge line and air dryer inlet port cannot enter the air dryer. This maintains turbocharger boost pressure to the engine.

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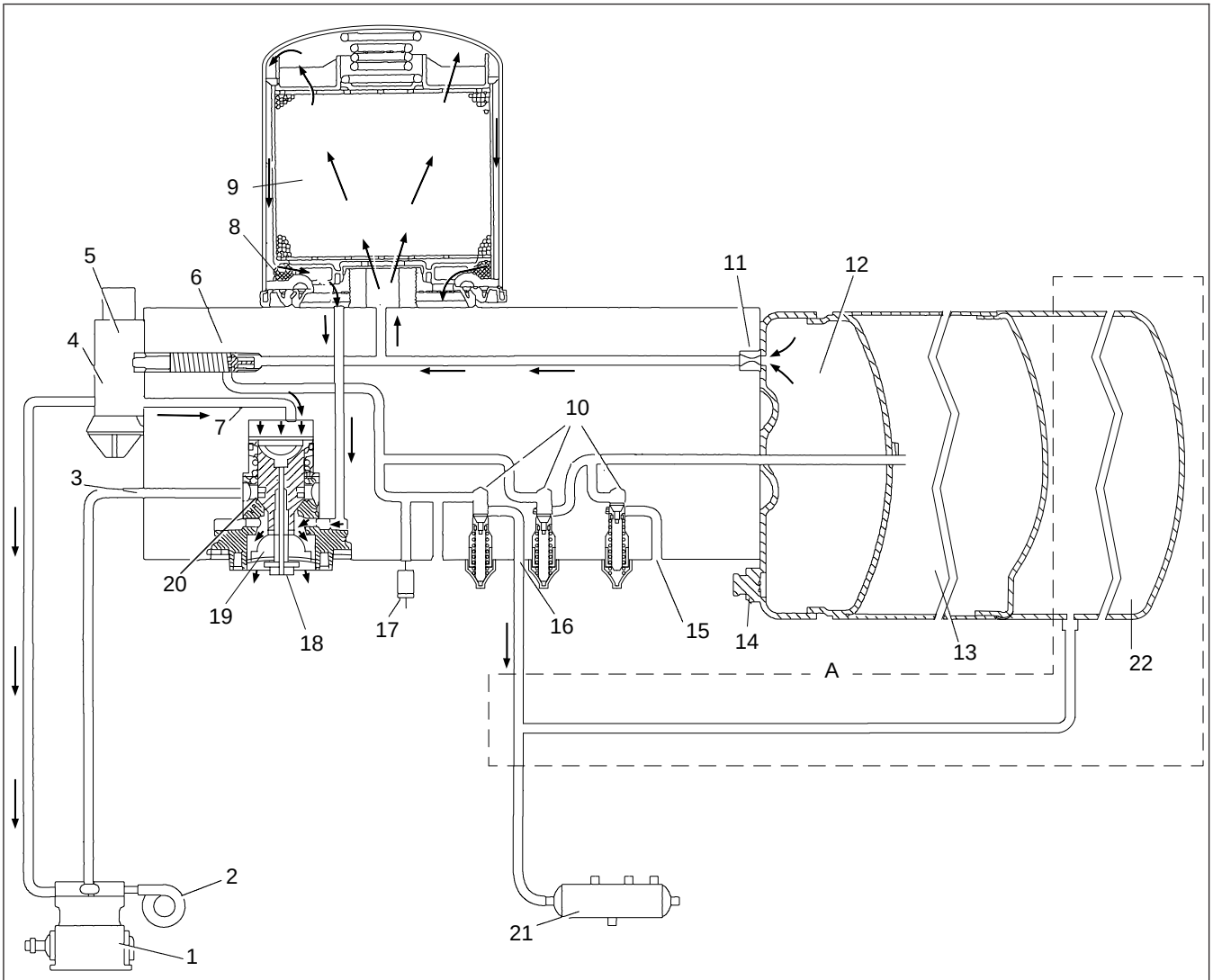
A. Class 8 vehicles have an integrated primary reservoir.

1. Compressor
2. Engine Turbo
3. Inlet Port
4. Unloader Port
5. Governor
6. Delivery Check Valve
7. Purge Control Passage
8. Oil Separator
9. Desiccant Bed
10. Pressure Protection Valves
11. Purge Orifice
12. Integrated Reservoir (Purge Volume)
13. Integrated Reservoir (Secondary Volume)
14. Purge Volume Drain Cock
15. Auxiliary Port
16. Primary Port
17. Safety Valve
18. Purge Valve (closed)
19. Turbo Cutoff Valve (open)
20. Primary Reservoir
21. Integrated Reservoir (Primary Volume)

Fig. 2, Air Dryer Charge Cycle

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General Information



A. Class 8 vehicles have an integrated primary reservoir.

1. Compressor
2. Engine Turbo
3. Inlet Port
4. Unloader Port
5. Governor
6. Delivery Check Valve
7. Purge Control Passage
8. Oil Separator
9. Desiccant Bed
10. Pressure Protection Valves
11. Purge Orifice
12. Integrated Reservoir (Purge Volume)
13. Integrated Reservoir (Secondary Volume)
14. Purge Volume Drain Cock
15. Auxiliary Port
16. Primary Port
17. Safety Valve
18. Exhaust
19. Purge Valve (open)
20. Turbo Cutoff Valve (closed)
21. Primary Reservoir
22. Integrated Reservoir (Primary Volume)

Fig. 3, Air Dryer Purge Cycle

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Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
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- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

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Replacement

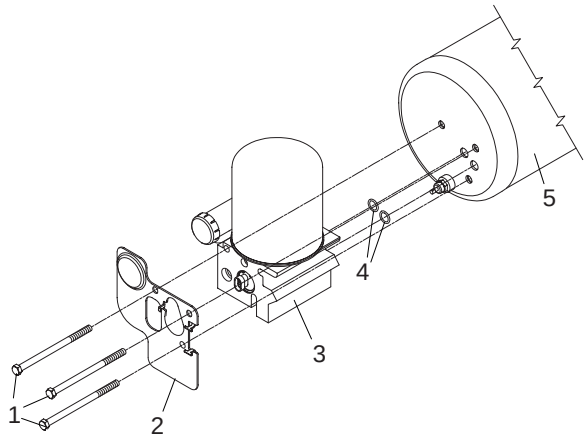
WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs, including the purge reservoir drain valve located under the air dryer.
3. Mark and remove the air lines from the air reservoir.

IMPORTANT: It may be necessary to remove the air reservoir to replace the air dryer. For instructions on air reservoir removal, see **Subject 160**.

4. Unplug the wiring harness from the heater/thermostat assembly.
5. Remove the three capscrews fastening the air dryer to the air reservoir. See **Fig. 1**.
6. Remove the air dryer.



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1. Capscrews
2. Splash Shield
3. Air Dryer
4. O-Rings
5. Reservoir

Fig. 1, Air Dryer Removal and Installation

7. Remove the governor and delivery check valve from the air dryer. For instructions, see **Subject 130**.
8. Remove the desiccant cartridge. For instructions, see **Subject 120**.

Installation

1. Install the delivery check valve and governor onto the air dryer. For instructions, see **Subject 130**.
2. If removed, install the desiccant cartridge. For instructions, see **Subject 120**.
3. Install the air dryer, making sure the two O-rings are installed between the air dryer and air reservoir. Use the three capscrews to fasten the air dryer to the reservoir. Tighten the capscrews 30 to 35 lbf·ft (41 to 47 N·m). See **Fig. 1**.
4. Connect the air lines and plug the wiring harness into the heater/thermostat assembly.
5. Perform the operational tests in **Subject 170**.

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Replacement

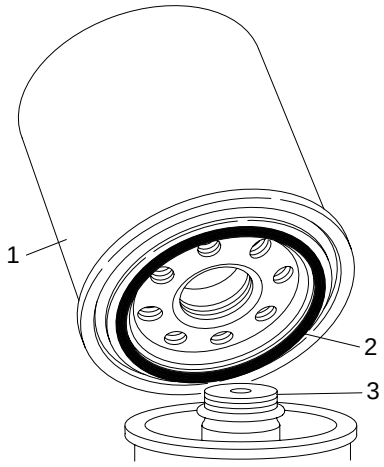
WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Park the vehicle, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs, including the purge reservoir drain valve located under the air dryer.

IMPORTANT: It may be necessary to remove the air reservoir to replace the desiccant cartridge. For instructions on air reservoir removal and installation, see **Subject 160**.

3. Using a strap wrench or equivalent, loosen the desiccant cartridge. Spin the cartridge off by hand and discard it. See **Fig. 1**.



1. Desiccant Cartridge
2. Cartridge Sealing Ring
3. Threaded Base Post

Fig. 1, Desiccant Cartridge Replacement

4. On the new desiccant cartridge, lubricate the sealing rings with silicone grease.

IMPORTANT: Only use the silicone grease supplied with AlliedSignal replacement kits.

5. Screw the desiccant cartridge onto the body, by hand, until the seal makes contact with the body. Rotate the cartridge clockwise about one full turn. If necessary, use a strap wrench to tighten the cartridge.
6. Remove the chocks from the tires.

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Delivery Check Valve and Governor Replacement

Replacement

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs, including the purge reservoir drain valve located under the air dryer.

IMPORTANT: It may be necessary to remove the air reservoir to replace the delivery check valve. For instructions on air reservoir removal and installation, see **Subject 160**.

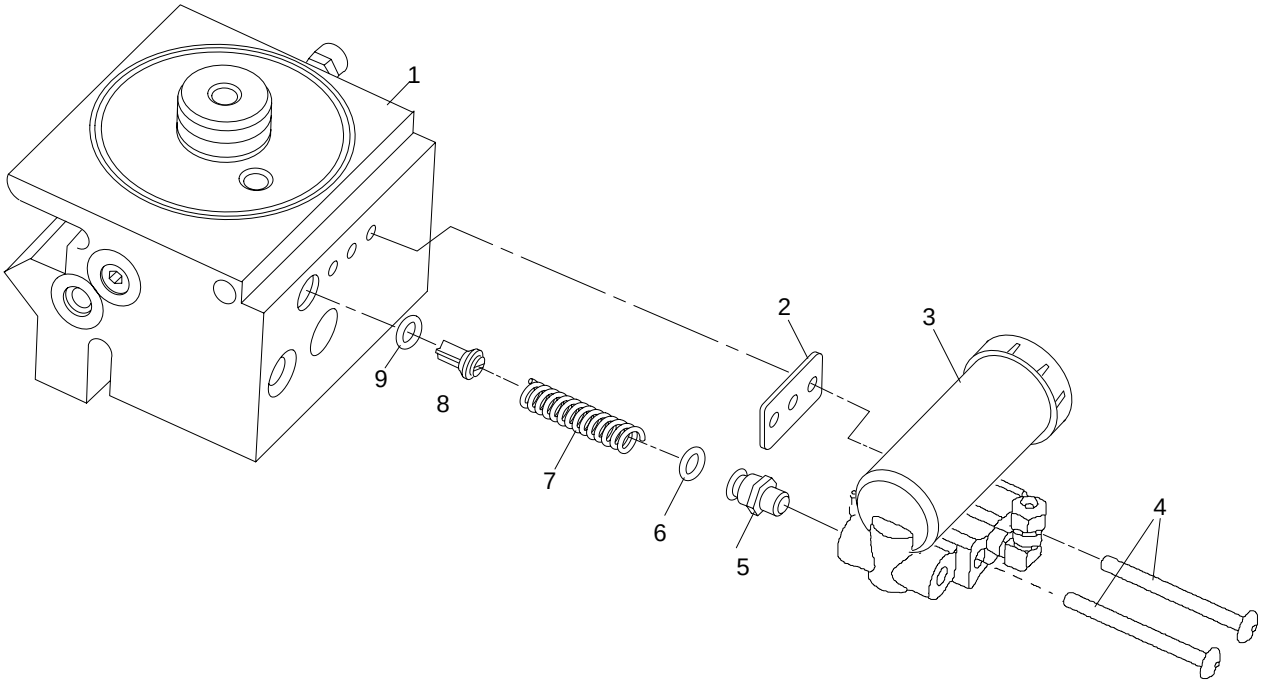
3. Disconnect the air line from the governor and mark it for later reference. Remove the capscrews attaching the governor to the air dryer. See **Fig. 1**.
4. Remove the governor, adaptor fitting, and the adaptor O-ring. Remove the governor gasket and discard.
5. Remove the spring and check valve.
6. Lubricate the new smaller O-ring and check valve body with silicone grease.

IMPORTANT: Only use the silicone grease supplied with AlliedSignal replacement kits.

7. Install the O-ring on the check valve body and push the O-ring down, over the longer set of three guide lands, until it is in the O-ring groove of the check valve body.
8. Install one end of the check valve spring over the check valve's shorter set of three guide lands. Turn the valve about 1/4 turn while holding the spring, if necessary, to secure the valve in place. Install the assembled check valve body, O-ring, and spring in the delivery port so the O-ring rests on its seat and the free end of the spring is visible.
9. Install the adaptor fitting into the governor. Using the silicone grease, lubricate the remaining larger O-ring, and install it into the groove of the adaptor. Install the gasket supplied in the kit. Install the governor and torque the capscrews 10 lbf·ft (14 N·m).
10. Perform the operational tests in **Subject 170**.
11. Remove the chocks from the tires.

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Delivery Check Valve and Governor Replacement



1. Air Dryer Base
2. Gasket
3. Governor
4. Capscrews
5. Adaptor
6. O-Ring
7. Spring
8. Check Valve Body
9. O-Ring

Fig. 1, Delivery Check Valve Replacement

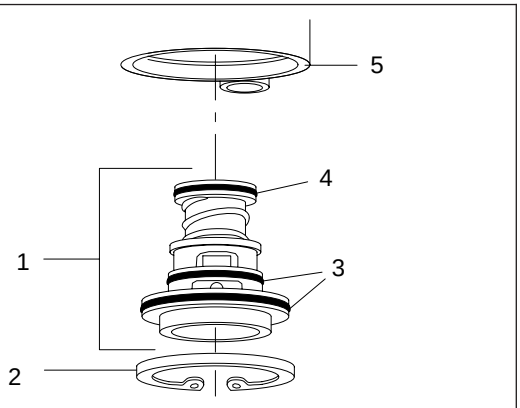
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Replacement

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs, including the purge reservoir drain valve located under the air dryer.
3. Remove the purge valve assembly from the air dryer end cover. See **Fig. 1**.



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1. Purge Valve Assembly
2. Retaining Ring
3. O-Rings
4. Quad-Ring
5. Air Dryer

Fig. 1, Purge Valve Replacement

3.1 Remove and discard the snap ring that secures the purge valve assembly in the end cover.

3.2 Remove the purge valve assembly.

4. Lubricate the new O-rings and O-ring grooves of the new purge valve assembly.
5. Lubricate the end cover bore of the new purge valve assembly.

IMPORTANT: Use only the silicone grease supplied with the AlliedSignal replacement kit.

6. Install the two new O-rings on the purge valve housing cover and the new quad-ring on the purge piston.
7. Install the new purge valve assembly in the end cover while making sure the purge valve housing is fully seated against the end cover.
8. Install the new retaining ring in its groove in the end cover.
9. Perform the operational tests in **Subject 170**.
10. Remove the chocks from the tires.

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Replacement

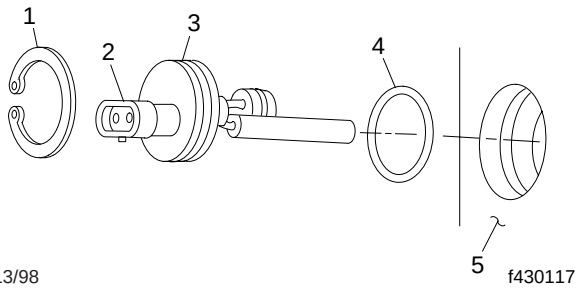
WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Shut down the vehicle, apply the parking brake, and chock the tires.

IMPORTANT: It may be necessary to remove the air reservoir to replace the heater and thermostat. For instructions on air reservoir removal, see **Subject 160**.

2. Remove the splash shield cover. It is secured with three lock tabs.
3. Lift the lock tab on the vehicle wiring harness connector and disconnect it from the air dryer base.
4. Remove and discard the retaining ring that secures the heater and thermostat assembly in the air dryer body.
5. Carefully pull the heater and thermostat assembly straight out of the air dryer body and discard it. See **Fig. 1**.



1. Retaining Ring
2. Heater/Thermostat Connector Plug
3. Heater/Thermostat Assembly
4. O-Ring
5. Air Dryer Body

Fig. 1, Heater and Thermostat Assembly

6. Using the grease provided with the AlliedSignal replacement kit, lubricate the O-ring groove and O-ring of the new assembly with silicone grease.

IMPORTANT: Do not lubricate the heater stick or thermostat.

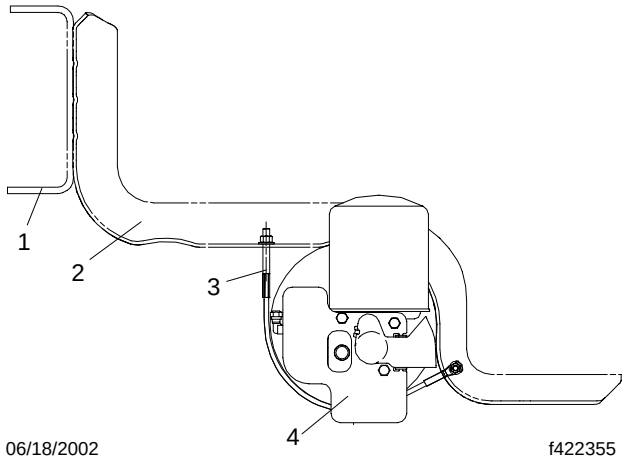
7. Install the O-ring on the heater/thermostat assembly. Then, slide the assembly into the air dryer body, making sure not to scrape insulation from the wires.
8. Install the retaining ring in the groove of the air dryer body, making certain that it is fully seated in the groove.
9. Remove the protective cover from the assembly.
10. Before proceeding, turn the ignition on without starting the engine. Make sure vehicle power is present at the contacts of the vehicle wire harness.
11. Remove the chocks from the tires.

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Replacement

NOTE: The dryer reservoir module (DRM) can be mounted in various locations, depending on the vehicle configuration. The DRM is typically mounted under the driver's-side steps or along the frame rail, behind the cab.

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Drain the air reservoirs, including the purge reservoir drain valve located under the air dryer.
3. Mark and disconnect all reservoir air lines and couplers for later assembly. Cap the exposed ports tightly to keep out contaminants. If access is limited, remove the components after removing the reservoir from its mount.
4. Remove the reservoir.
   - If the DRM is mounted under the drivers steps, remove the nuts securing the u-bolt straps and remove the reservoir (**Fig. 1**). Then, remove the air dryer. For instructions, see **Subject 110**.

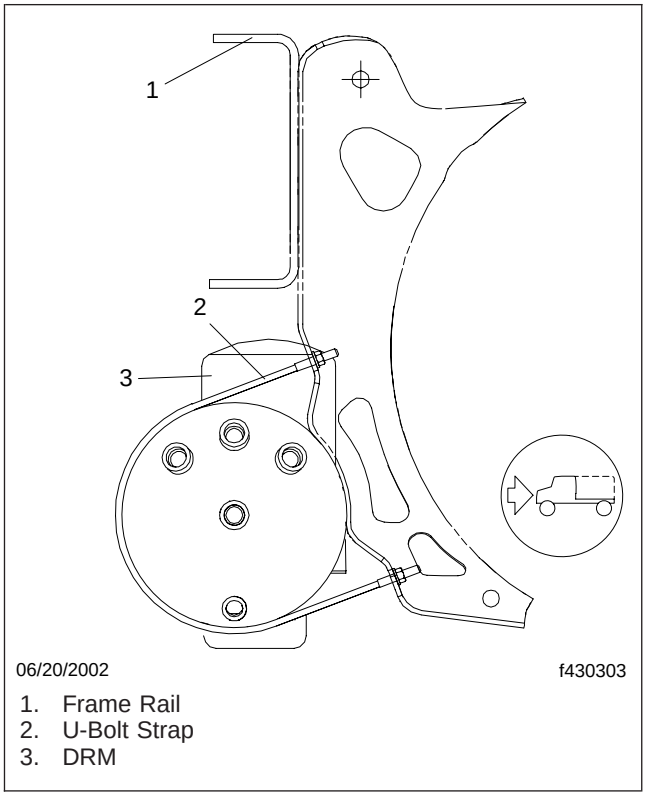


NOTE: Primary reservoir not shown.

1. Frame Rail
2. Stair Mounting Bracket
3. U-Bolt Mounting Strap
4. Air Dryer

Fig. 1, Dryer Reservoir Module (mounted under driver's steps)

   - If the DRM is installed along the frame rail using a strap fastener (**Fig. 2** or **Fig. 3**), remove the air dryer. For instructions, see **Subject 110**. Then, remove the reservoir strap fasteners and remove the reservoir.



1. Frame Rail
2. U-Bolt Strap
3. DRM

Fig. 2, Dryer Reservoir Module (fuel-tank bracket mounted)

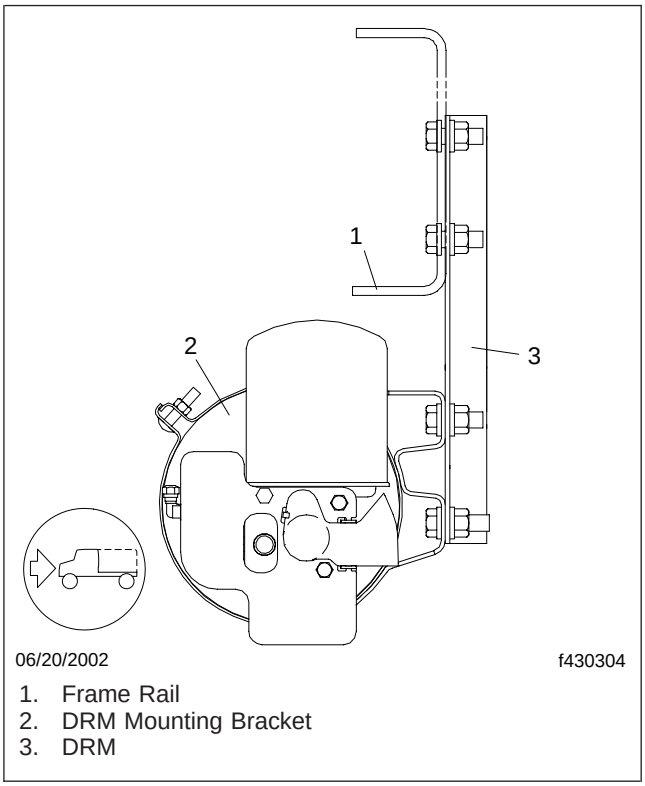
NOTE: If access is limited, connect all air lines and couplers to the new reservoir, removing the caps as each component is installed.

5. If the reservoirs are mounted under the driver's steps, install the air dryer onto the new reservoir and install the reservoir. Secure the U-bolt straps with the nuts. See **Fig. 1**.

   If the reservoir is installed along the frame rail using a strap fastener, install the reservoir using the straps. Tighten the fasteners 30 to 40 lbf·ft (41 to 54 N·m). Tighten the lower strap fastener 136 lbf·ft (184 N·m). Then, install the air dryer. For instructions, see **Subject 110**.
6. As marked earlier, connect all air lines and couplers to the new reservoir, removing the caps as each component is installed. Tighten the connections as instructed elsewhere in this group.

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Air Reservoir Replacement



1. Frame Rail
2. DRM Mounting Bracket
3. DRM

Fig. 3, Dryer Reservoir Module (frame-rail mounted)

Install the air dryer. For instructions, see **Subject 110**.

7. Perform operational test in **Subject 170**.
8. Remove the chocks from the tires.

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Operational Tests

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Park the vehicle, shut down the engine, and chock the tires.
2. Install an accurate pressure gauge in one of the spare governor ports labeled "RES."
3. Close all drain cocks and start the engine. Build the air system to governor cutout and shut down the engine.
4. Check all air lines and fittings leading to and from the air dryer for leakage. Note the pressure on the air gauge after the governor cutout pressure is reached, a rapid loss of pressure could indicate a leak at the delivery check valve, governor, unloader piston in the compressor purge valve (purge piston), D-ring seals between the dryer and the reservoir, reservoirs or points downstream from the reservoirs.
5. Test the delivery check valve for leakage.
   - 5.1 Build system pressure to governor cutout. Wait 2 minutes for completion of purge cycle. Using soap solution at exhaust of purge valve, leakage should not exceed a 1 inch bubble in less than 5 seconds.
   - 5.2 Allow a full minute for the normal dryer purge cycle to empty the purge reservoir, switch off the engine and "fan" the brakes so that the system pressure reaches governor cut-in. The purge valve will return to its closed position. The purge reservoir has a drain valve which is opened by moving the center lever away from its closed position.
   - 5.3 Open the drain valve and wait 10 seconds to allow any residual purge pressure to be released. Release the lever, closing the drain valve.
   - 5.4 Carefully remove the air dryer cartridge using a strap wrench and then test for air leaking through the center of the threaded boss by applying a soap solution to the boss.
   - 5.5 Replace the delivery check valve if there is excessive leakage (exceeding a 1 inch bubble in 5 seconds).
   - 5.6 Regrease the seal on the air dryer cartridge before reinstalling. Be sure the drain valve on the purge reservoir is not leaking before restoring vehicle to service.

NOTE: If after replacing the delivery check valve, rapid loss of system air pressure continues, the delivery check valve and turbo cut-off valve are still leaking. Check the valves.

6. Check for excessive leakage around the purge valve with the compressor in the loaded mode (compressing air). Apply a soap solution to the purge valve exhaust port and observe that leakage does not exceed a 1-inch bubble in 1 second. If the leakage exceeds the maximum specified, refer to **Troubleshooting 300**.
7. Build up system pressure to governor cutout and note that AD-IS purges with an audible escape of air. Fan the service brakes to reduce system air pressure to governor cut-in. Note that the system once again builds to full pressure and is followed by an AD-IS purge. If system does not follow this pattern, refer to **Troubleshooting 300**.
8. Check the operation of the end cover heater and thermostat assembly during cold weather operation as follows:
   - 8.1 Check the electric power to the air dryer. With the ignition or engine kill switch in the ON position, check for voltage to the heater and thermostat assembly using a voltmeter or test-light. Unplug the electrical connector at the air dryer and place the test leads on each of the connections of the female connector on the vehicle power lead. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check to see if a good ground path exists.
   - 8.2 Test the thermostat and heater operation. Turn off the ignition switch and cool the thermostat and heater assembly to below 40°F (4°C). Using an ohmmeter, check

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Operational Tests

the resistance between the electrical pins in the air dryer connector half. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly and 6 to 9 ohms for the 24-volt heater assembly.

Warm the thermostat and heater assembly to about 90°F (32°C) and check the resistance again. The resistance should exceed 1000 ohms. If the resistance values obtained are within the stated limits, the thermostat and heater assembly is operating properly. If the resistance values obtained are outside the stated limits, replace the heater and thermostat assembly. For instructions, see **Subject 150**.

9. Check the pressure protection valves. Observe the pressure gauges of the vehicle as system pressure builds from zero. The primary gauge should rise until it reaches approximately 109 psi (752 kPa), then level off as the second pressure protection valve opens and allow the secondary volume to build. When the secondary pressure gauge passes through approximately 85 psi (586 kPa) there should be an associated leveling off of pressure as the third and fourth pressure protection valves open. Then, both the primary and secondary gauges should reach their full pressure of about 130 psi (896 kPa)
10. Remove the chocks.

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Troubleshooting Tables

Problem—Air Dryer is Constantly Purging (Cycling) or Purging Excessively

Problem—Air Dryer is Constantly Purging (Cycling) or Purging Excessively	
Possible Cause	**Remedy**
There is excessive system leakage.	Using a soap-and-water solution, test for leakage at the air line fittings, drain cock (or valve), and system valves. Repair or replace as necessary. NOTE: A drop of 3 psi (21 kPa) in system air pressure per minute is normal.
The application air lines are leaking excessively.	Check the application air line, brake valve, and the service and parking brake chambers for air leaks. Repair or replace the damaged component(s).
The delivery check valve leaking excessively.	Replace the Check Valve. See **Subject 130**.
The compressor unloader O-rings are leaking excessively.	Troubleshoot the compressor. See **Group 13**.
Defective Governor	Replace the governor. See **Subject 130**.

Problem—There is Water in the Air Reservoirs

Problem—There is Water in the Air Reservoirs	
Possible Cause	**Remedy**
Maximum air dryer inlet temperature is exceeded due to improper discharge line length or improper line material.	Check for excessive build-up in the discharge line. Replace line in necessary.
The air dryer is not purging.	See **Problem—System Will Not Charge**
Purge time is insufficient due to excessive system leakage.	See **Problem—Air Dryer is Constantly Purging (Cycling)**
The air by-passes the desiccant cartridge assembly.	If the vehicle uses a Holset compressor, inspect the feedback check valve for proper installation and operation.
The compressor is running loaded for long periods of time.	Check the vehicle air system for leakage.
The desiccant cartridge requires replacement.	Replace the desiccant cartridge. See **Subject 120**.

Problem—Safety Valve on the Air Dryer is Exhausting Air

Problem—Safety Valve on the Air Dryer is Exhausting Air	
Possible Cause	**Remedy**
There is a defective delivery check valve in the end cover of the air dryer.	Test to determine if air is passing through the check valve. Repair or replace the check valve. For replacement, see **Subject 130**.
The air system pressure is over 140 psi (965 kPa).	Replace the governor.
The safety valve setting is too low.	Replace the safety valve.

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Troubleshooting

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve	
Possible Cause	**Remedy**
The air dryer purge valve is leaking excessively.	Test for leakage. With the compressor loaded, apply soap solution on the purge valve exhaust. If necessary, replace the purge valve. For instructions, see **Subject 140**.
The governor is defective.	Check the governor for proper "cut-in" and "cut-out" pressure, and excessive leakage in both positions. Repair or Replace the governor. For replacement instructions, see **Group 13**.
The purge valve is frozen open. The heater and thermostat, wiring, or blown fuse.	Perform the heater operating test in **Subject 160**.
There is excessive system leakage.	See **Problem—Air Dryer is Constantly Purging (Cycling)**
The air dryer delivery check valve is defective.	See **Problem—Air Dryer is Constantly Purging (Cycling)**
The turbo cutoff valve is leaking.	Repair or replace the turbo cutoff valve. For instructions, see **Subject 140**.
The purge valve control piston is leaking.	Repair or replace the purge valve. For instructions, see **Subject 140**.

Problem—The Air System Will Not Charge

Problem—The Air System Will Not Charge	
Possible Cause	**Remedy**
The inlet and outlet air connections are reversed.	Connect the compressor discharge to the air dryer supply port. Reconnect the lines properly.
Kinked or blocked discharge line.	Check to determine if air passes through the discharge line. Check for kinks, bends, excessive carbon deposits, or ice blockage.
There are excessive bends in the discharge line (water collects and freezes).	The discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
The turbo cutoff valve is stuck closed.	Repair or replace the turbo cutoff valve. For instructions, see **Subject 140**.
The purge valve is leaking excessively.	Repair or replace the purge valve. For instructions, see **Subject 140**.

Problem—The Air Dryer Does Not Purge or Exhaust Air

Problem—The Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
The governor adaptor is plugged.	Test to determine if air flows through the purge control port when the compressor is unloaded. Check for adaptor obstruction. See **Problem—Constant Exhaust of Air at the Air Dryer Purge Valve**.
The air dryer purge valve is faulty.	If air is flowing through the purge valve in the "Remedy" above, repair or replace the purge valve. For replacement instructions, see **Subject 140**.
There are excessive bends in the discharge line (water collects and freezes).	The discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
The governor is defective.	Check the governor for proper "cut-in" and "cut-out" pressure, and excessive leakage in both positions. Repair or Replace the governor. For replacement instructions, see **Group 13**.

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Problem—The Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
The purge valve control piston is leaking.	Repair or replace the purge valve. For instructions, see **Subject 140**.

Problem—Desiccant Material is Being Expelled from the Air Dryer Purge Valve Exhaust

Problem—Desiccant Material is Being Expelled from the Air Dryer Purge Valve Exhaust	
Possible Cause	**Remedy**
The air dryer is not securely mounted.	Replace the air dryer. For instructions, see **Subject 110**.
The desiccant cartridge is saturated or malfunctioning.	Replace the air dryer. For instructions, see **Subject 110**.
The compressor is passing excessive oil.	Troubleshoot the compressor. See **Group 13**. If necessary, replace the air dryer. For instructions, see **Subject 110**.

Problem—"Pinging" Noise is Excessive During Compressor Loading Cycle

Problem—"Pinging" Noise is Excessive During Compressor Loading Cycle	
Possible Cause	**Remedy**
The compressor is a single cylinder with high pulse cycles.	A slight "pinging" sound may be heard during system build up when a single cylinder compressor is used. No remedy is needed.

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General Information

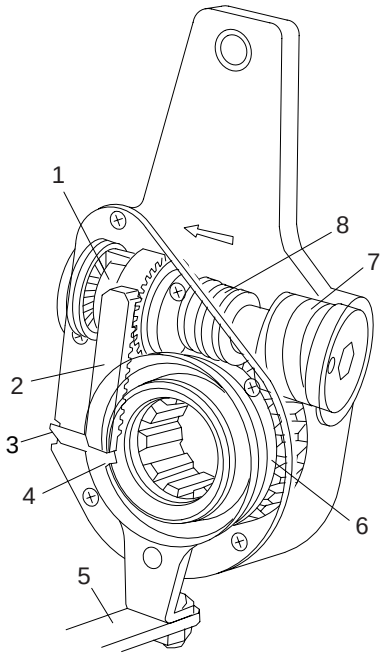
The Haldex automatic slack adjuster serves two main functions:

- As a lever, it converts the straight-line force of the air brake chamber pushrod to torque on the brake camshaft. Rotation of the camshaft spreads the brake shoes out against the brake drum, applying the brakes.
- As an adjuster, it maintains cam brake chamber pushrod stroke and lining-to-drum clearance automatically during normal use.

When the brakes are applied, the slack adjuster rotates and moves the shoes into contact with the drum. The clearance notch corresponds to the normal lining-to-drum clearance. See **Fig. 1**. Different notches are available to meet the requirements of various vehicles and brake duty cycles. As the brake application continues, the rack moves upward and rotates the one-way clutch that slips in this direction.

As the brake torque increases, the coil-spring load is overcome and the wormshaft is displaced axially, releasing the cone clutch.

When the brake begins its return stroke, the coil spring load returns to normal and the cone clutch is again engaged. The rack is pulled back to its original position in the notch. Any additional travel brought about by brake lining wear causes the rack to turn the locked one-way clutch and rotates the wormshaft through the locked cone clutch. The wormshaft then rotates the worm wheel and camshaft, adjusting the brakes.



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NOTE: Older slack adjusters may not have an installation indicator.

1. Clutch Assembly
2. Enclosed Rack
3. Installation Indicator (aligned with indicator notch)
4. Clearance Notch
5. Control Arm Anchor Bracket (design varies depending on the axle)
6. Worm Wheel
7. Coil Spring
8. Wormshaft

Fig. 1, Haldex Slack Adjuster

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Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

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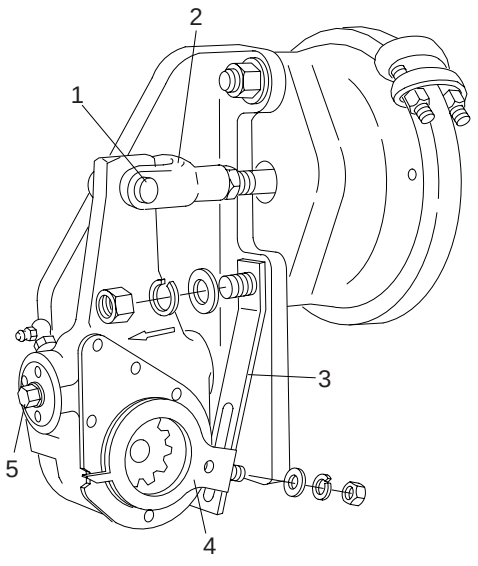
Slack Adjuster Removal and Installation

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. With the vehicle parked on a level surface, set the parking brakes, and shut down the engine. Chock the tires.
2. If a rear-axle slack adjuster will be removed, release the parking brakes and cage the power spring of the parking brake chamber. For instructions, refer to the applicable brake chamber section in this group.
3. Remove the anchor bracket fasteners and the anchor bracket. See **Fig. 1**.



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1. Clevis Pin
2. Clevis
3. Anchor Bracket
4. Control Arm
5. Adjusting Hexnut

Fig. 1, Anchor Bracket Removal/Installation

4. Remove the cotter pin from the clevis pin. Remove the clevis pin.
5. Remove the snap ring that secures the slack adjuster on the camshaft.

⚠ CAUTION

Do not use an impact wrench on the adjusting hexnut. To do so may damage the slack adjuster or camshaft.

6. Using a 7/16-inch box wrench, turn the adjusting hexnut counterclockwise to move the adjuster arm out of the clevis. A minimum of 13 lbf·ft (18 N·m) is required to overcome the internal clutch. You will hear a ratcheting sound.
7. Remove the slack adjuster from the camshaft.

Installation

NOTE: For brake chambers that have pushrods with threaded clevises, measure the pushrod length before installing the new slack adjuster. With the brakes fully released, and no air pressure to the chamber, check the dimension between the chamber face and the centerline of the 1/2 inch clevis pin hole. It should be 2.25 inches (57 mm) for long stroke chambers, and 2.75 inches (70 mm) for standard stroke chambers.

1. Check that the brake-chamber pushrod is fully retracted.
2. Apply antiseize compound to the camshaft splines.

IMPORTANT: When correctly installed, the brake-chamber pushrod pushes in the direction of the arrow on the slack adjuster housing.

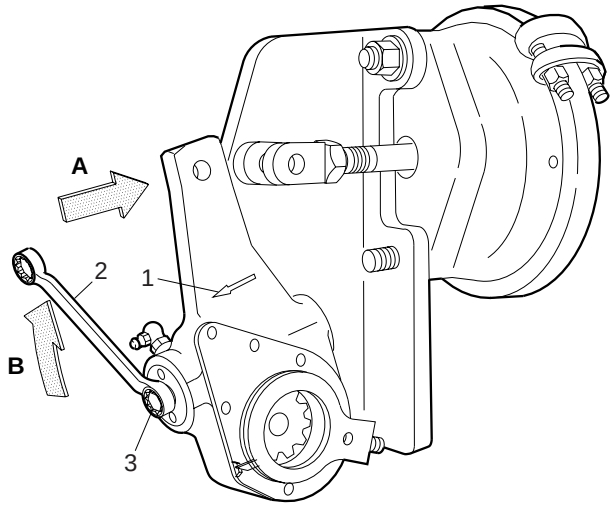
3. Install the slack adjuster on the camshaft, with the adjusting hexnut pointing away from the brake chamber. See **Fig. 2**.
4. Using a snap ring, secure the slack adjuster on the camshaft. Use at least one inner washer and enough outer washers to allow no more than 0.060-inch (1.52-mm) movement on the shaft.

IMPORTANT: Never pull the pushrod out to meet the slack adjuster or push the slack adjuster into position. Always turn the adjusting hexnut for positioning.

5. Using a 7/16-inch box wrench, turn the adjusting hexnut clockwise until the slack adjuster hole is aligned with the pushrod clevis hole. See **Fig. 2**.

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Slack Adjuster Removal and Installation



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A. Use only the adjusting hexnut to align the slack adjuster with the pushrod clevis.
B. Turn the adjusting hexnut clockwise.

1. Direction of Applied Stroke
2. Box Wrench, 7/16 inch
3. Adjusting Hexnut

Fig. 2, Slack Adjuster Installation

6. Apply antiseize compound to the clevis pin, and insert the pin in the clevis hole. Do not install the cotter pin at this time.

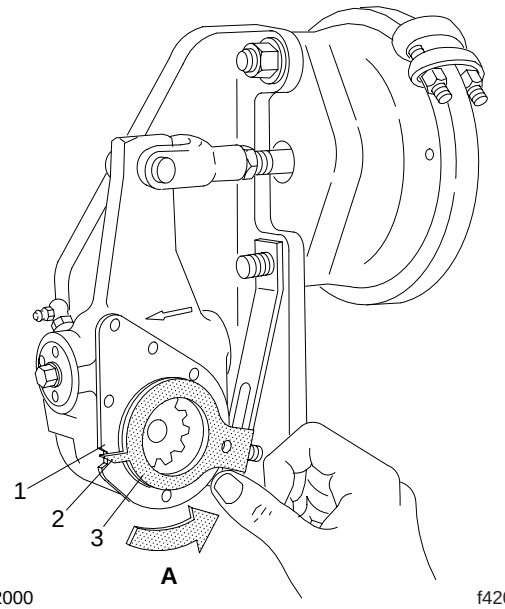
CAUTION

Never hammer the control arm. Hammering may damage the slack adjuster or camshaft splines.

7. Rotate the control arm away from the adjusting hexnut toward the brake chamber until it comes to a definite internal stop. Make sure the installation indicator is in the center of the indicator notch on the slack adjuster. See **Fig. 3**.

IMPORTANT: If the installation indicator is not aligned with the indicator notch, the brakes will be too tight.

NOTE: The anchor bracket and slack adjuster housing design will vary, depending on the axle. The anchor bracket mounting location is determined by the length of the control arm.



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NOTE: The installation indicator must be aligned with the indicator notch.

A. Rotate the control arm counterclockwise until it stops.

1. Indicator Notch
2. Installation Indicator
3. Control Arm

Fig. 3, Aligning the Control Arm

8. Install the control-arm anchor bracket, as follows. See **Fig. 1**.
   - 8.1 Tighten the anchor bracket fastener at the control arm 10 to 15 lbf·ft (14 to 20 N·m), making sure the control arm does not move from its position.
   - 8.2 Tighten the fastener at the brake chamber mounting stud according to the brake chamber manufacturer's specifications.
9. Adjust the brakes. See "Brake Adjustment".

Brake Adjustment

NOTE: A properly working self-adjusting slack adjuster does not require manual adjustment while in service.

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Slack Adjuster Removal and Installation

⚠ WARNING

Manually adjusting an automatic slack adjuster to bring the pushrod stroke within legal limits is likely masking a mechanical problem. Adjustment is not repairing. Before adjusting an automatic slack adjuster, troubleshoot the foundation brake system and inspect it for worn or damaged components. Improperly maintaining the vehicle braking system may lead to brake failure, resulting in property damage, personal injury, or death.

1. Adjust the brake lining clearance by manually turning the adjusting hexnut clockwise until the brake lining contacts the brake drum, then back off the hexnut counterclockwise 1/2 turn. You will hear a ratcheting sound.

IMPORTANT: Incorrect installation can cause dragging brakes.

2. Make sure the brakes are still fully released, then check the position of the installation indicator on the control arm. It must be within the indicator notch on the slack adjuster.

   If the indicator is out of position, loosen the control arm fasteners and repeat the control-arm adjustment procedure. Then, tighten the bracket fasteners.

⚠ WARNING

Install and lock a new cotter pin in the clevis pin. Failure to do so could allow the pushrod to disengage from the slack adjuster, causing a loss of braking ability that could result in personal injury and property damage.

3. Install and lock a new cotter pin in the clevis pin.

IMPORTANT: Ensure that the air system has at least 100 psi prior to uncaging the brake chamber. This will aid in the uncaging of the parking brake since the parking brake should be fully released.

4. If a rear-axle slack adjuster was installed, manually uncage the parking brake. For instructions, refer to the applicable brake chamber section in this group.

⚠ WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

IMPORTANT: To check the brake adjustment, measure both the applied and free strokes.

NOTE: The location of the measurements is the same for both strokes but the applied stroke is measured with the brakes applied, while a lever is used to manually move the slack adjuster to measure the free stroke.

5. Measure the free stroke, as follows. The free stroke is the distance the slack adjuster has to travel to move the brake shoes against the drum.

   5.1 With the brakes released, measure the distance from the bottom of the brake chamber to the far side of the clevis-pin hole. Record the exact distance as measurement A.

   5.2 Using a lever, move the slack adjuster until the brake shoes contact the drum. Measure the distance from the bottom of the brake chamber to the far side of the clevis-pin hole. Record the exact distance as measurement B.

   5.3 Subtract measurement A from measurement B to determine the free stroke. For new brake installations, the free stroke should be 5/8 to 3/4 inch (16 to 19 mm). For in-service brakes, the free stroke should be 1/2 to 5/8 inch (13 to 16 mm). If it is not in this range, refer to **Troubleshooting 300**.

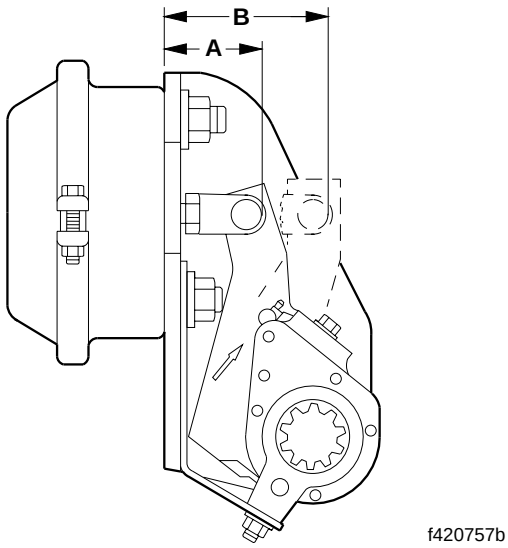
6. Measure the applied stroke, as follows.

   6.1 With the brakes released (pushrod fully retracted), measure the distance from the bottom of the brake chamber to the far side of the clevis-pin hole. See **Fig. 4**. Record the exact distance as measurement A.

   6.2 Apply and hold an 80 psi (551 kPa) brake application. Measure the distance from the bottom of the brake chamber to the far

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Slack Adjuster Removal and Installation



NOTE: Measurements are from the bottom of the brake chamber to the far side of the clevis-pin hole.

A. Measurement with brakes released.
B. Measurement with brakes applied at 80 psi (551 kPa).

Fig. 4, Brake Applied Stroke Check

side of the clevis-pin hole. Record the exact distance as measurement B.

6.3 Subtract measurement A from measurement B to determine the applied stroke. Compare this value to the value in **Table 1**.

6.4 If the stroke varies or is greater than the maximum allowed length, refer to **Section 42.03, Subject 150**.

7. Apply the parking brakes.
8. Remove the chocks from the tires.
9. In a safe area, check for proper brake operation, as follows.

9.1 Apply and release the brakes several times to check for correct operation of the slack adjusters.

9.2 Perform six low-speed stops to ensure correct parts replacement and full vehicle control.

9.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than the others show a lack of braking effort on those wheels.

Chamber Size	Maximum Applied Stroke: inch (mm)	Free Stroke: inch (mm)	
		New Brake Installation	In-Service Brake Installation
16	1-3/4 (44)	5/8–3/4 (16–19)	1/2–5/8 (13–16)
20			
24	1-7/8 (48)		
30	2 (51)		

Table 1, Brake Chamber Stroke Specifications

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Operational Checks and Troubleshooting Tables

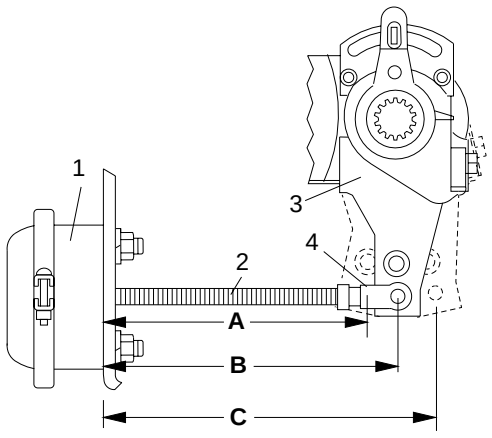
WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Before performing any of the following procedures:

- Chock the wheels to prevent the vehicle from rolling.
- Ensure that the air system tank pressure is 90 to 100 psi (620 to 689 kPa).
- Check that the brake chamber pushrod is fully retracted; apply air to the release spring brake.

Refer to **Fig. 1** when making slack adjuster stroke measurements.



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A. Fully retracted
B. Drum contact using a lever
C. Full brake application at 90 to 100 psi (620 to 689 kPa) reservoir pressure

1. Brake Chamber
2. Pushrod
3. Slack Adjuster
4. Clevis

Fig. 1, Slack Adjuster Stroke Measurement

Applied Stroke

The applied stroke (see **Fig. 1**) of the brake should be checked per Commercial Vehicle Safety Alliance (CVSA) guidelines with full brake applicaton at 90 to 100 psi (620 to 689 kPa) reservoir pressure. The applied stroke should be at or less than the specified adjustment limits listed in **Table 2**.

Free Stroke

Free stroke is the amount of movement of the adjuster arm required to move the brake shoes against the drum. With brakes released, measure from the face of the chamber to the center of the clevis pin "A". Use a lever to move the brake adjuster until the brake shoes contact the drum. The difference between the fully retracted and drum contact measurement "B"-"A" is the free stroke. See **Fig. 1**. The free stroke range should fall between 5/8- and 3/4-inch (16 to 20 mm).

Free Stroke Within Range

If the free stroke is good, but the applied stroke is too long, there is probably a problem with the foundation brake. Check the components listed in **Table 1**, and reference CVSA out-of-service criteria.

Free Stroke Above the Range

If the free stroke is above the range and the applied stroke is too long, there is a problem with the foundation brake or the adjuster. Check the components listed in **Table 3**.

Free Stroke Below the Range

If the free stroke is less than 5/8-inch (16 mm), a dragging brake can occur. Check the components listed in **Table 4**.

Automatic Brake Adjuster Checking Procedures

If the brake adjuster is not maintaining the proper applied stroke, before removing the brake adjuster, check the condition of the foundation brakes. See **Table 1**, **Table 3**, and **Table 4** for procedures. If after inspecting the foundation brakes no apparent problems are found, inspect the automatic brake adjuster to determine if it is operating properly. The inspection can be performed on or off the vehicle using the following procedures.

- Chock the wheels to prevent the vehicle from rolling.
- Ensure that the air system tank pressure is 90 to 100 psi (620 to 689 kPa).

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Troubleshooting

- Check that the brake chamber pushrod is fully retracted; apply air to the release spring brake.
- If air is not available, the spring brake must be manually caged back.
- Do not use air tools on brake adjuster.

See **Table 5** for on-vehicle inspection or **Table 6** for off-vehicle inspection.

Automatic Brake Adjuster Operational Check

Functional operation of the brake adjuster can be performed on the vehicle by using the following procedure:

1. Chock the wheels to prevent the vehicle from rolling.
2. Ensure that the air system tank pressure is 90 to 100 psi (620 to 689 kPa).
3. Check that the brake chamber pushrod is fully retracted; apply air to the release spring brake.

   If air is not available, the spring brake must be manually caged back.
4. Manually de-adjust the brakes (turn adjustment hex counterclockwise one full turn) to create an excessive drum to lining clearance condition. A ratcheting sound should occur.
5. Make a full service brake application.

   On release, allow sufficient time for the brake to fully retract. During the brake release, observe rotation of the adjustment hex by attaching a wrench on the hex or scribing the hex, which will make this rotation easier to see. This rotation indicates that an excessive clearance condition has been determined by the brake adjuster, and it is making an adjustment to compensate. On each subsequent brake release, the amount of adjustment and pushrod travel will be reduced until the desired clearance is achieved.
6. If rotation of the adjustment hex is not observed, refer to the foundation brake operational check and troubleshooting procedures in this subject.
7. If the foundation brake assembly checks out okay and the hex still does not turn, check the control arm and mounting bracket for possible worn, bent, or broken components.
8. If the control arm and mounting bracket function properly, replace the adjuster and hardware. See **Subject 110** for procedure.

Free Stroke Within Range		
Component	**Cause**	**Action**
Brake Drums	Cracked or out of round	Replace or check drum runout
Brake Shoes	Shoe span out of spec	Replace shoes as needed. See **Subject 110**.
	Uneven lining wear	Check spider concentricity
	Shoe pad missing	Remove and replace shoes
	Cracked shoes	
Camshaft Bushing	Excessive movement	Remove and replace cam bushing per OEM specs
Camshaft	Flat spots on cam head	Replace camshaft
	Cracked/broken splines	
	Worn bearing journals	
Chamber Bracket	Broken/bent	Replace bracket
Clevis Yoke and Pin	Worn	Remove and replace
Return Springs	Broken, stretched, or missing	Remove and replace springs
Rollers	Flat spots, grooved pin, worn	Remove and replace roller and pin
	Wrong size	Remove and replace with correct parts

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Free Stroke Within Range		
Component	**Cause**	**Action**
Spider Anchor Pins	Grooved or scored/worn	Replace spider or pins as needed

Table 1, Free Stroke Within Range

Stroke Specifications		
Chamber Size	**Maximum Applied Stroke: Inch (mm)**	**Desired Free Stroke: Inch (mm)**
12	1-3/8 (35)	5/8–3/4 (16–20)
16 and 20	1-3/4 (44)	
24	1-3/4 (44)	
24L	2 (51)	
24LS	2-1/2 (64)	
30	2 (51)	
30LS	2-1/2 (64)	

Table 2, Stroke Specifications

Free Stroke Above the Range		
Component	**Cause**	**Action**
Camshaft	Binding	Remove, replace, lubricate camshaft
Camshaft Bushing	Excessive movement	Remove and replace cam bushings per OEM specs
	Binding shaft	Lubricate camshaft bushings or replace
Air Chamber Return Spring	Broken, weak, missing	Replace chamber
Air Chamber Pushrod	Binding on chamber housing	Check adjuster for proper shimming, and air chamber position for proper adjuster arm length
Air System	Not exhausting completely	Check for cause of air problem and repair
Shoe Return Springs	Broken, weak, missing	Replace springs
Automatic Brake Adjusters	Unknown	Check automatic brake adjuster for proper installation. See **Subject 110**.
		See *Automatic Brake Adjuster Checking Procedures* and *Automatic Brake Adjuster Operational Check* in this subject.

Table 3, Free Stroke Above the Range

Free Stroke Below the Range		
Component	**Cause**	**Action**
Wheel Bearing	Out of adjustment	Readjust wheel bearing. See **Group 33** or **Group 35** for procedures.

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Troubleshooting

Free Stroke Below the Range		
Component	**Cause**	**Action**
Automatic Brake Adjusters	Unknown	Check automatic brake adjusters for proper control arm position. See **Subject 110**.
		See *Automatic Brake Adjuster Checking Procedures* and *Automatic Brake Adjuster Operational Check* in this subject.

Table 4, Free Stroke Below the Range

On-Vehicle Inspection		
Problem	**Cause**	**Action**
Tight or dragging brakes	Control arm mispositioned	Realign the control arm and anchor bracket. See **Subject 110**
Excessive chamber pushrod travel	Improper anchor bracket connection to control arm	If anchor bracket to control arm connection is loose, worn, bent, or broken, re-secure or replace it.
	Low clutch torque	Rotate the 7/16-inch adjustment hex one full turn counterclockwise. If the torque is less than 13 lbf·ft (18 N·m), or no ratcheting sound occurs, replace the adjuster.
	Unknown	See *Automatic Brake Adjuster Operational Check* in this subject.

Table 5, On Vehicle Inspection

Off-Vehicle Inspection		
Problem	**Cause**	**Action**
Adjuster not functioning properly	Low clutch torque	Place the adjuster arm in a vise. Rotate the 7/16-inch adjustment hex counterclockwise one full turn to check de-adjustment torque. After control arm stops rotating, a minimum of 13 lbf·ft (18 N·m) will be required and a ratcheting sound should occur. If the torque is less than 13 lbf·ft (18 N·m), or no ratcheting sound occurs, replace the adjuster.
	Control arm slippage	Place the adjuster arm in a vise. Rotate the control arm counterclockwise until it rotates to an INTERNAL STOP. If the installation indicator goes past the indicator notch or does not stop rotating (arm slips freely), replace the adjuster.
	Unknown	If torque is above 13 lbf·ft (18 N·m), scribe a line on the adjustment hex. Manually pull the brake adjuster control arm clockwise then push back counterclockwise until the installation indicator stops in the indicator notch. The hex should move in a clockwise direction when the control arm of the brake adjuster is pushed back counterclockwise. If the hex does not move, replace the adjuster.
	Worn/missing control arm wear bushing, and/or anchor stud pin	Remove and replace the pin and bushings. If the adjuster has passed the above checks, re-install it on vehicle using new hardware.

Table 6, Off Vehicle Inspection

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Specifications

Approved Slack Adjuster Lubricants	
Adjuster Type	**Lubricant Type**
Low Lube	N/A (sealed unit)
Standard	Standard Chassis Grease

Table 1, Approved Lubricants

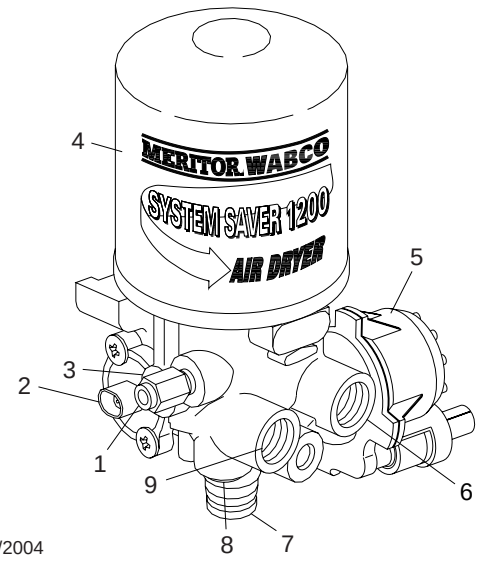
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24	1-3/4 (44)	
24L	2 (51)	
24LS	2-1/2 (64)	
30	2 (51)	
30LS	2-1/2 (64)	

Table 2, Stroke Specifications

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General Information

The System Saver 1200 air dryer (see **Fig. 1**) is a desiccant air dryer, mounted vertically between the air compressor and the supply reservoir. The air dryer receives hot compressed air, which it cools and filters before sending it to the supply reservoir, reducing the build-up of dirt and moisture in the vehicle air system.



1. Pressure Relief Valve
2. Heater/Thermostat Assembly
3. Governor Port (to air governor)
4. Desiccant Canister
5. Regeneration Valve Assembly
6. Outlet Port (to air supply reservoir)
7. Exhaust Port (Purge Valve Assembly)
8. Turbocharger Cutoff Valve
9. Inlet Port (from air compressor)

Fig. 1, WABCO System Saver 1200

The air dryer consists of a light-weight aluminum and steel body. The desiccant cartridge is contained in a spinoff canister at the top of the air dryer.

The following components attach to the body of the air dryer:

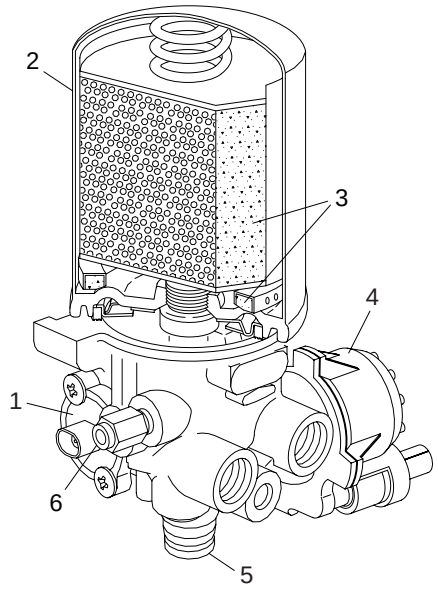
- Pressure Relief Valve—this valve protects the air dryer from over pressurization. The valve is attached directly to the air dryer.
- Desiccant Canister—a cylindrical steel housing that contains the filter elements and the desiccant needed to filter and dry the air that passes through it.
- Heater/Thermostat Assembly—located in the air dryer base, this assembly is designed to prevent the collected moisture from freezing.
- Outlet Check Valve—this valve prevents air in the system from flowing back through the air dryer and escaping out the purge valve during the compressor unload cycle.
- Pressure-Controlled Check Valve—this valve is separate from the air dryer and is installed on the system air tank. The valve allows air to back flow from the system tank to the supply tank as long as air system pressure remains between the normal cut-in and cut-out range of the air governor.
- Purge Valve—this valve allows the collected moisture and contaminants to be expelled from the air dryer during the purge cycle.
- Regeneration Valve—this valve allows air from the supply and system tanks to bypass the outlet check valve and flow into the regeneration valve. Air then flows through an orifice where the air expands and back flushes moisture off of the desiccant. The air is then exhausted through the purge valve.
- Silencer (Muffler)—an optional component that is attached to the purge valve and used to eliminate most of the noise during the air dryer purge cycle.
- Turbocharger Cut-Off Valve—this valve closes the path between the air compressor and the air dryer purge valve to help maintain boost pressure for maximum engine horsepower during the compressor unload cycle.

Principles of Operation

Hot, compressed air enters the air dryer through the inlet port. As the hot air is forced into the desiccant cartridge, the temperature of the compressed air falls to nearly ambient. Oil and water vapor condense and initially settle into the base of the dryer. The moisture-laden air also passes through the desiccant bed, where any remaining moisture is retained by the desiccant. The clean air then passes through the air dryer outlet port to the supply reservoir. See **Fig. 2.**

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General Information



1. Heater/Thermostat Assembly
2. Desiccant Canister
3. Filter
4. Regeneration Valve Assembly
5. Exhaust Port (Purge Valve Assembly)
6. Pressure Relief Valve

Fig. 2, Sectional View

When the compressor reaches about 125 psi (862 kPa), the purge valve opens, allowing the initial decompression of the dryer, and expelling the water and contaminants collected in the base of the dryer. The regeneration valve, along with the pressure-controlled check valve, allows the system air to flow back through the dryer. This back flow dries the desiccant for the next cycle.

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Safety Precautions

⚠ WARNING

When draining the air system, do not look into the air jets or direct them toward another person, as dirt or sludge particles may be in the air-stream. Do not disconnect pressurized hoses because they may whip as air escapes from the line. Failure to take all necessary precautions during service operations of the air brake system can cause personal injury.

When working on or around air brake systems and components, observe the following precautions.

1. Apply the parking brake, chock the tires, and stop the engine when working under the vehicle. Draining the air system may cause the vehicle to roll. Keep hands away from the brake chamber push rods and slack adjusters, which may apply as air system pressure drops.
2. Wear safety goggles.
3. Never connect or disconnect a hose or line containing air under pressure; it may whip as air escapes. Never remove a component or pipe plug unless you are sure all system pressure has been depleted.
4. Don’t disassemble a component before reading and understanding recommended procedures. Use only the correct tools and follow basic tool safety.
5. Replacement hardware, tubing, hose, fittings, etc. should be the same size, type, length, and strength as the original equipment. When replacing tubing or hose, be sure that all of the original supports, clamps, or suspending devices are installed or replaced.
6. Replace any components that have stripped threads or damaged parts. Don’t attempt to repair parts by machining.
7. Never exceed recommended air pressure.

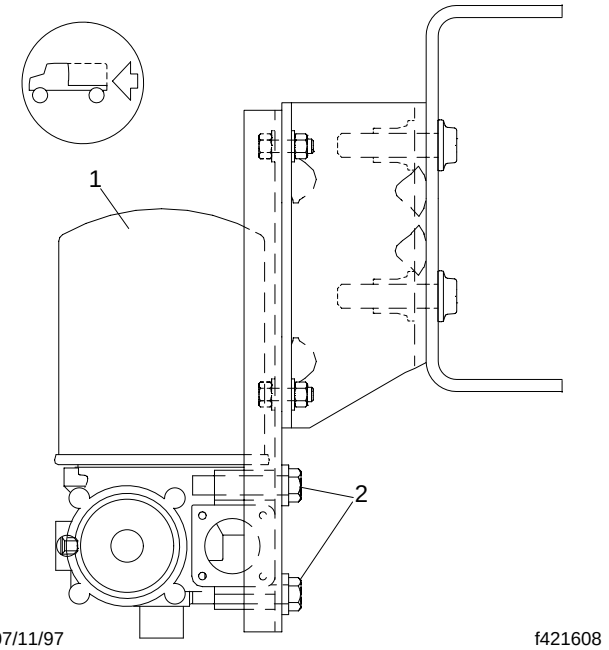
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⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

Removal

1. Drain the air system.
2. Disconnect the wiring harness from the air dryer.
3. Mark the air lines for later reference, then disconnect them from the air dryer.
4. Remove the capscrews, washers, and spacers that attach the air dryer to the mounting bracket.
5. Remove the air dryer. See **Fig. 1**.



1. Desiccant Canister
2. 1/2" Capscrew, Washer, and Spacer

Fig. 1, Air Dryer Installation (outboard rail mounting shown)

Installation

1. Position the air dryer on the mounting bracket. Install the spacers, washers, and capscrews. Tighten them 22 to 30 lbf·ft (30 to 41 N·m). See **Fig. 1** .
2. Make sure the air lines are clean. Replace any line or fitting that is crimped or damaged.
3. Connect the remaining air lines to the air dryer as previously marked. Tighten the nut on each fitting finger-tight. Then, using two wrenches to prevent twisting the hose, further tighten the nut until there is firm resistance.
4. Connect the air dryer wiring harness.
5. Pressurize the air system and check for leaks. Repair as necessary.

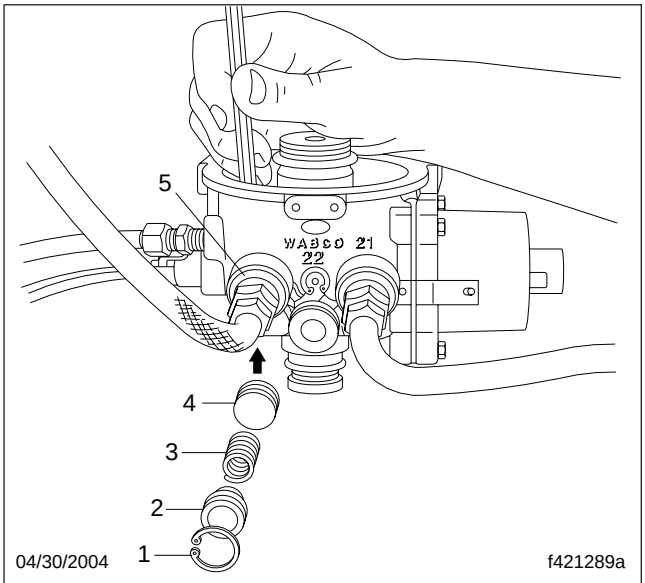
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Replacement

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Remove the snap ring at the bottom of the valve assembly. The valve cover and spring may fall out of the cavity when the snap ring is removed. See **Fig. 1**.



1. Snap Ring
2. Cover
3. Spring
4. Piston
5. Inlet Port

Fig. 1, Push the Piston, Spring, and Cover out of the Valve Cavity

3. Using a strap wrench, turn the desiccant cartridge counterclockwise and remove it.
4. Using a wooden stick, push the piston, spring, and the cover out of the valve cavity.
5. Clean the valve cavity with a commercial cleaning solvent.
6. Install new O-rings on the piston and the cover.
7. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-rings and the valve cavity.
8. Install the new piston with its hollow side facing out.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer.

9. Install the new spring, cover, and snap ring to hold the components in place.
10. Thread the desiccant cartridge onto the dryer base (turn clockwise). When the seal contacts the base, tighten the cartridge one complete turn more. Do not over-tighten.

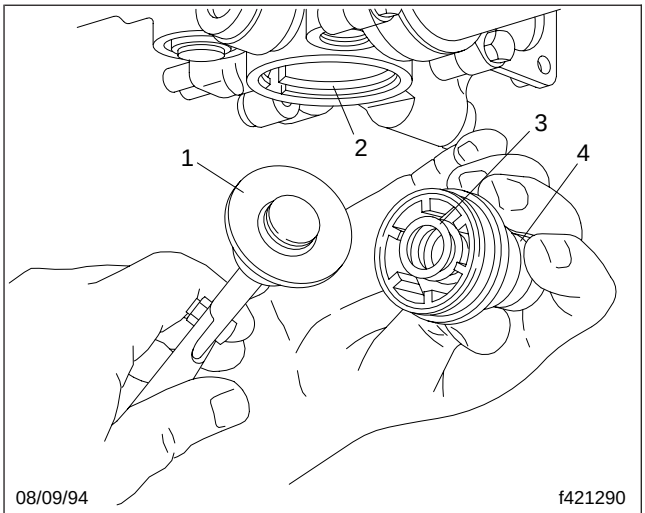
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Replacement

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Remove the snap ring, valve head, and the spring from the exhaust port. See **Fig. 1**.



1. Valve Assembly
2. Exhaust Port
3. Spring
4. Valve Head

Fig. 1, Remove the Valve Assembly

3. Pull the valve assembly out of the exhaust port.
4. Remove the O-ring from the base of the exhaust port.
5. Clean the purge valve cavity area with a commercial cleaning solvent.
6. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the O-rings and the valve cavity. Install the O-rings in the base of the exhaust port and on the valve head.
7. Position the new valve assembly in the valve cavity.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer.

8. Install the spring in the valve head, and position them in the valve cavity.
9. Install the snap ring to secure the valve head in position.

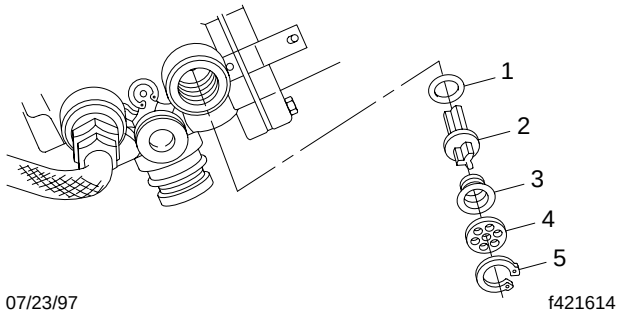
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Replacement

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Disconnect the air line from the outlet port. See **Fig. 1**.



1. O-Ring
2. Valve Body
3. Spring
4. Washer
5. Snap Ring

Fig. 1, Outlet Check Valve Assembly

3. Remove the snap ring, washer, valve body, and the O-ring.
4. Clean the cavity area with a commercial cleaning solvent.
5. Install a new O-ring on the valve body.
6. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-ring and the valve cavity.
7. Install the new valve body. Make sure that the long end of the body is inserted first into the valve cavity.
8. Install the new spring with its small end around the "Y" shaped fins on the valve body.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer.

9. Install a new washer and snap ring to secure the assembly in the valve cavity.
10. Connect the air line to the outlet port. Tighten the nut on the fitting finger-tight. Then, using two wrenches to prevent twisting the hose, further tighten the nut until there is firm resistance. Tighten the nut one-sixth turn more.

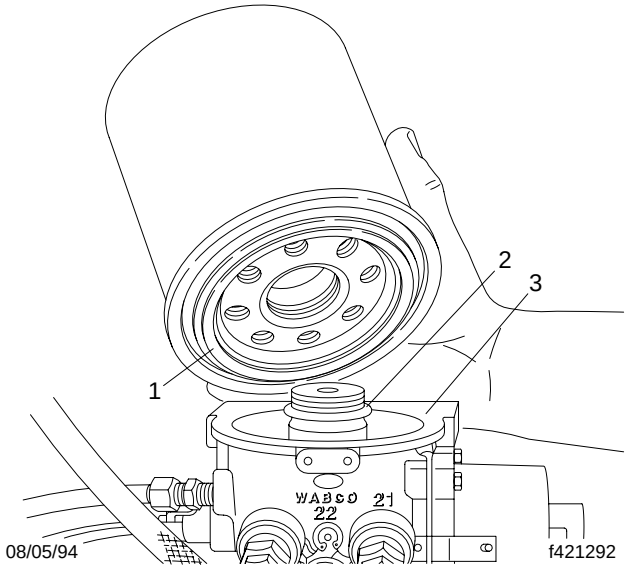
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Replacement

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Using a strap wrench, turn the desiccant cartridge counterclockwise and remove it. See **Fig. 1**.



1. Seal
2. O-Ring
3. Air Dryer Base

Fig. 1, Desicant Cartridge Replacement

3. Remove and discard the O-ring.
4. Clean the top surface of the dryer base with a commercial cleaning solvent.
5. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-ring and the dryer base. Install the O-ring.
6. Thread the desiccant cartridge onto the dryer base (turn clockwise). When the seal contacts the base, tighten the cartridge one complete turn more. Do not over-tighten.

IMPORTANT: If the air dryer base is damaged, preventing a tight seal, replace the air dryer.

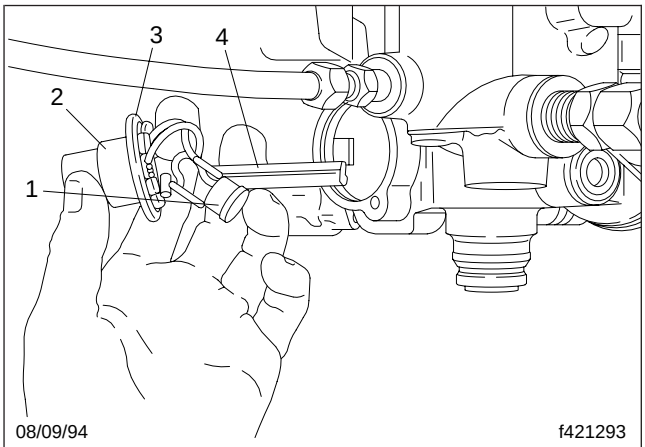
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Replacement

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Disconnect the wiring harness.
3. Remove the screws that attach the heater/thermostat receptacle. Remove the receptacle and the O-ring.
4. Remove the retaining screw that holds the assembly in place. Remove and discard the heater/thermostat assembly. See **Fig. 1**.



1. Thermostat
2. Receptacle
3. O-Ring
4. Heater Element

Fig. 1, Heater/Thermostat Replacement

5. Clean the heater/thermostat assembly area with a commercial cleaning solvent.
6. Position the new heater/thermostat assembly in the cavity. Install the retaining screw.
7. Position the new receptacle and O-ring, and install the screws. Tighten the screws securely.
8. Connect the wiring harness.

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Replacement

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

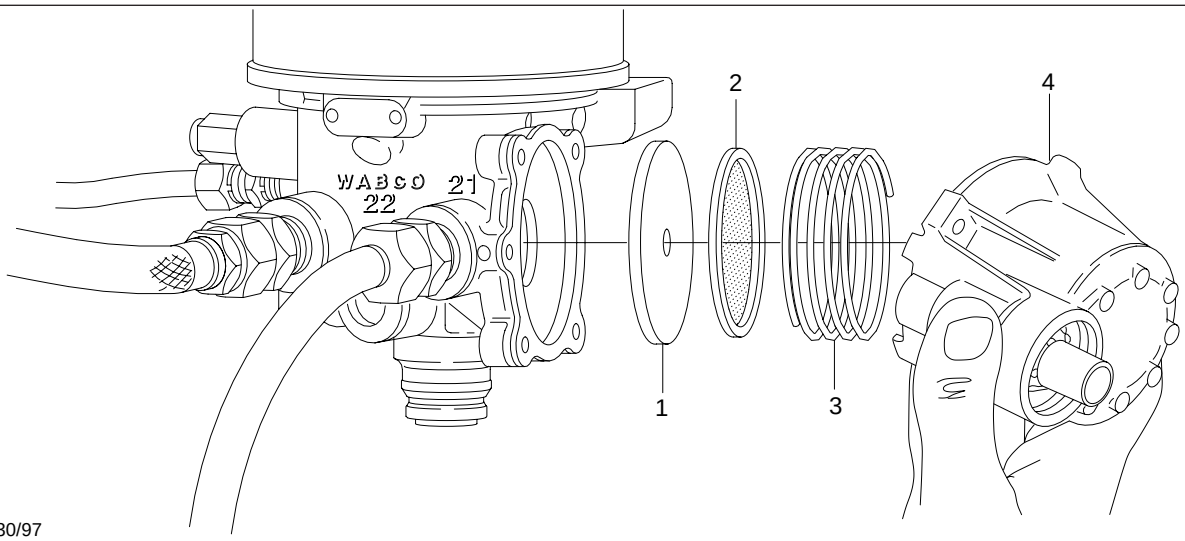
1. Drain the air system.

NOTE: When the valve housing is removed, the spring and the retainer will fall out of the housing. See **Fig. 1**.

2. Remove the four mounting bolts and remove the valve housing assembly.
3. Remove the rubber diaphragm.
4. Using a commercial cleaning solvent, clean the groove where the diaphragm lip fits.
5. Install a new diaphragm with its lip in the groove.

IMPORTANT: If the groove is damaged, preventing a tight seal, replace the air dryer.

6. Install the new spring and retainer (with the retainer lip facing out).
7. Position the valve housing on the air dryer. Install the bolts and tighten them to 53 lbf·in (600 N·cm).



1. Diaphragm
2. Retainer
3. Spring
4. Valve Housing Assembly

Fig. 1, Regeneration Valve Assembly

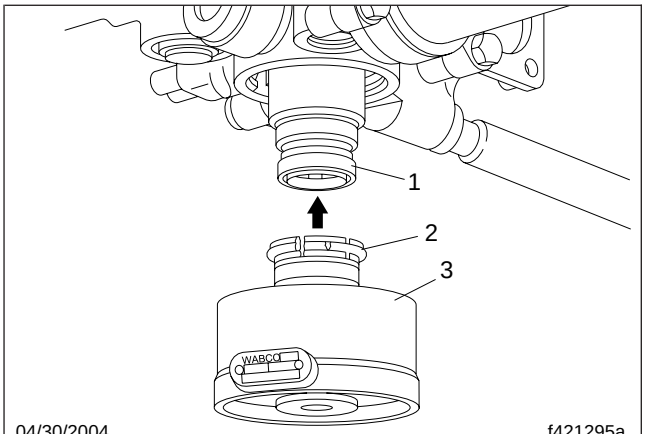
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Replacement

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Using snap ring pliers, expand the snap ring and pull the silencer off of the purge valve head. See **Fig. 1**.



1. Purge Valve Head
2. Snap Ring
3. Silencer

Fig. 1, Silencer Replacement

2. Push the new silencer onto the purge valve head until the silencer snaps into place.

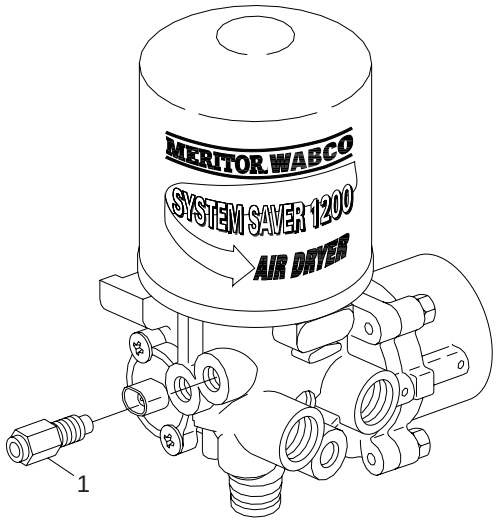
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Replacement

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Unscrew and remove the old valve from the dryer. See **Fig. 1**.



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1. Pressure Relief Valve

Fig. 1, Pressure Relief Valve Replacement

3. Screw the replacement valve into the dryer base. Do not exceed a torque of 30 lbf·ft (41 N·m) for a 3/8-inch thread, or 65 lbf·ft (88 N·m) for a 1/2-inch thread.

NOTE: The threads on the replacement pressure relief valve provided by Meritor WABCO are coated with sealant. They do not require any additional sealant.

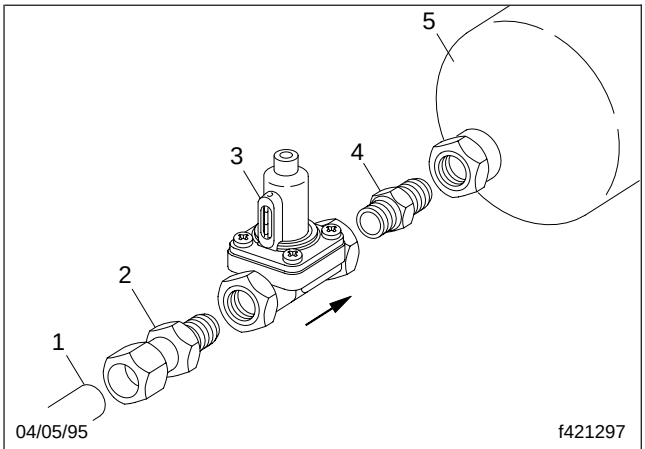
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Replacement

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

1. Drain the air system.
2. Disconnect the air line from the fitting on the valve. See **Fig. 1**.



1. Air Line
2. Nylon Tube Connector
3. Pressure-Controlled Check Valve
4. Hex Nipple Pipe Fitting
5. Air Tank

Fig. 1, Check Valve Assembly Replacement

3. Remove the air-line fitting firm the valve.
4. Remove the valve and the hex nipple fitting from the air tank. Then remove the nipple from the valve.

NOTE: Apply liquid Loctite® Hydraulic Sealant (brown), or an equivalent, to the threads of all fittings before installing them. Always apply sealant to the external threads so that any excess will be scraped off externally rather than internally to the joint.

5. Install the pipe fittings on the new valve. Make sure that the arrow on the valve will be pointing towards the tank when installed.
6. Install the new valve on the air tank.
7. Connect the air line to the air-line fitting on the valve. Tighten the air line securely.

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Operating
Tests210Operating TestsBefore
starting the procedures below, read the information in Safety
Precautions, 100. Failure to follow the safety
precautions during service operations on the air brake system can cause personal injury.Air Dryer Operating Check1.Drain
the air system.2.Start the engine
and build the air pressure to as close to cutout
pressure as possible (about 125 psi [862 kPa]).3.When
the compressor reaches the unload cycle, the air dryer purges,
beginning regeneration of the air dryer.4.During
the purge cycle, which lasts about 10 to 15 seconds, the wet tank
and secondary system tank with pressure-controlled check valve will drop about 10 psi (69 kPa). Check the secondary system air gauge in the cab dash
panel.5.If the secondary gauge
needle does not show a pressure drop of about 10
psi (69 kPa), one of the following problems may exist.A
pressure-controlled check valve is not installed.The
pressure-controlled check valve is installed in the wrong air
tank.The pressure-controlled check valve is installed
on a one-way check
valve, instead of in place of a one-way check valve.There
is an extra check valve located somewhere between the air dryer and
the secondary air tank (usually at the wet tank).The
secondary air gauge is not plumbed to the secondary air
system.6.If
system secondary air pressure drops 25 psi (172 kPa) or more during
the purge cycle, and there are no other air-operated components in use, then there are air leaks or other system problems. Refer to
Troubleshooting,
300 for other possible
causes.Pressure-Control
Check Valve Operating Check1.Start
the engine and build the air pressure to cutout pressure (about 125
psi [862 kPa]). 2.Stop the engine
after the air compressor has unloaded.3.Drain
the supply system air tank down to about 80 psi (552 kPa) or
lower.4.Check the secondary air
gauge. It should read 95 ±5 psi (655

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±34 kPa). If the gauge reading is less that 90 psi (621 kPa), either the
pressure-control check valve is installed backwards, it is damaged, or there are air leaks in the secondary air system.If the secondary gauge reading does not change, or the reading does not
fall below 100 psi (689 kPa):There is no pressure-controlled check valve installed, or it is installed
in the wrong tank.The pressure-controlled check valve is installed into a one-way check
valve, rather than in place of a one-way check valve.There is another check valve located between the air dryer and the secondary air tank.The secondary air gauge is not plumbed to the secondary air
system.

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Troubleshooting Table

Meritor WABCO System Saver 1200 Troubleshooting

Meritor WABCO System Saver 1200 Troubleshooting		
Condition	**Possible Cause**	**Solution**
Dryer leaks from purge valve during compressor-loaded cycle. The leak may cause excessive compressor cycling or prevent the system from building air pressure.	Purge valve frozen open (cold weather operation).	Check heater. Repair/replace if necessary. Make sure governor to dryer port 4 line is free of water/oil.
		Remove and inspect purge valve and clean water/oil from top of piston.
	Debris under purge valve seat, such as particles from fittings or air inlet line.	Disassemble and clean purge valve.
	Purge valve washer installed upside-down.	Remove cartridge and clean dryer sump area. Ensure lip on aluminum washer faces DOWN, away from dryer.
	Wrong air-line connected to dryer port 4 (unloader port).	Verify correct air-line installation and correct as needed.
	Purge valve snap-ring not fully seated in groove.	Seat snap-ring fully into groove.
Slight leak from purge valve. After several hours, the supply tank may be empty.	Outlet check valve not seating or regeneration valve not shutting off regeneration airflow.	Remove, inspect, and clean outlet check valve and regeneration valve diaphragms. Replace if worn or damaged.
Regeneration cycle too long (more than 30 seconds), accompanied by loss of pressure in the supply tank.	Outlet check valve not seating.	Inspect and replace outlet check valve as needed.
	Regeneration valve not shutting off regeneration airflow.	Replace regeneration valve.
Regeneration cycle too short (less than 10 seconds).	High air system demands during compressor unloaded cycle.	Increase air system capacity or reduce air demands.
	Pressure-controlled check valve not installed in system or not working properly.	Check and replace pressur-econtrolled check valve as needed.
	One-way check valve installed in system reservoir instead of, or with, pressure-controlled check valve.	Remove one-way check valve. Make sure pressure-controlled check valve is installed correctly.
	Regeneration valve not working.	Remove regeneration valve and clean oil from diaphragm.
		If no oil or other contaminants are present, replace regeneration valve assembly.
	Air governor not working properly.	Inspect per manufacturer's instructions and repair/replace as needed.

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Troubleshooting

Meritor WABCO System Saver 1200 Troubleshooting		
Condition	**Possible Cause**	**Solution**
No regeneration cycle. No airflow from purge valve after initial purge blast (dryer decompression).	Air dryer not connected to supply tank or connections reversed at dryer.	Verify proper dryer installation per system diagram.
	Regeneration valve not working.	Replace regeneration valve.
	One-way check valve installed in supply tank.	Remove one-way check valve.
	Alcohol evaporator installed between dryer and supply tank.	Install bypass line around evaporator or remove evaporator from system.
Air dryer does not purge when compressor unloads (no blast of air from purge valve).	Air line between governor and air dryer port 4 kinked or plugged.	Repair air line.
	Purge valve stuck closed.	Replace purge valve.
	Air governor not working properly.	Inspect air governor. Repair/replace per manufacturer's instructions.
	Cut-out pressure never achieved by air compressor.	Check for air leaks in system and repair as needed. If no leaks in system, check compressor output. Repair/replace per manufacturer's instructions.
Air dryer purges too often, perhaps as frequently as every 15 seconds, accompanied by excessive cycling of the compressor.	Leak in line between governor and dryer port 4.	Repair air line.
	Leak in line between supply tank and governor.	Repair air line.
	Excessive air system leaks.	Repair leaks.
	Excessive air system demands.	Increase air system capacity or reduce air demand.
	Outlet check valve not seating.	Inspect and replace outlet check valve as needed.
	Regeneration valve not shutting off properly.	Replace regeneration valve.
	Air governor has less than 16 psi range.	Replace air governor.
	Leaking air compressor unloader(s).	Inspect compressor. Repair/replace per manufacturer's instructions.
Air flows out of purge valve entire time compressor is unloaded.	Turbo cut-off valve not sealing.	Replace turbo cut-off valve.
	NOTE: With U Series air dryers the compressor unloads through the dryer, so a steady flow of air is normal.	
Rapid "spitting" of air from purge valve in small amounts. Frequency varies with engine speed.	Holset E-type compressor used, but no Econ valve installed.	Install Econ valve to provide make-up air to compressor.
	Compressor not completely unloading when cut-out pressure is reached.	Inspect compressor. Repair/replace per manufacturer's instructions.

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Meritor WABCO System Saver 1200 Troubleshooting		
Condition	**Possible Cause**	**Solution**
Air leak at turbo cut-off valve vent. Hole burned in piston.	Temperature of air coming into dryer is too high—not enough cooling takes place before dryer inlet.	Move dryer farther from compressor. Add additional compressor discharge line before air dryer. Add cooling coil or heat exchanger before air dryer. NOTE: Inlet air temperature must not exceed 175°F (80°C).
Air leak at turbo cut-off valve vent.	Lip seal installed upside-down on piston. Lip must face UP (towards dryer).	Install lip seal correctly.
	Valve bore worn excessively.	Inspect valve bore for wear. If a new turbo cut-off valve does not seal in a clean, lubricated bore, replace the air dryer.
Air dryer frozen (water collecting in base of dryer is freezing).	No electrical power to heater connector.	Check for a blown fuse. Repair heater circuit. NOTE: There must be power to the heater connector the entire time the vehicle's ignition is ON.
	Low voltage to heater connector.	Repair cause of low voltage, such as poor electrical ground, bad connections, corroded wire splices, etc.
	Heater assembly not working.	Replace heater assembly.
	Wrong voltage air dryer used; i.e., 12-volt air dryer used in a 24-volt system.	Replace with correct voltage air dryer.
No air pressure build-up in system.	Air dryer not plumbed correctly (connections reversed).	Ensure compressor discharge line is plumbed to air dryer port 1, and air dryer port 21 is connected to vehicle's supply tank.
	Wrong air line connected to dryer port 4.	Ensure dryer port 4 line is connected to the "UNL" port of the air governor.
	Air governor not working properly.	Inspect governor per manufacturer's instructions. Repair or replace as needed.
	Air system leaks, such as compressor discharge line, air dryer, reservoirs, brake or suspension valves, etc.	Locate leak(s) and repair.
	Air dryer leaks from purge valve.	Refer to purge valve conditions listed in this chart.
Water in tanks; often following aftermarket installation or when dryer is a replacement for a competitive brand.	Pressure-controlled check valve not installed in correct tank or not installed at all.	Install pressure-controlled check valve in secondary tank.
	Pressure-controlled check valve properly installed, but one-way check valve not removed.	Remove one-way check valve so that only the pressure-controlled check valve is installed between the secondary tank and supply tank.

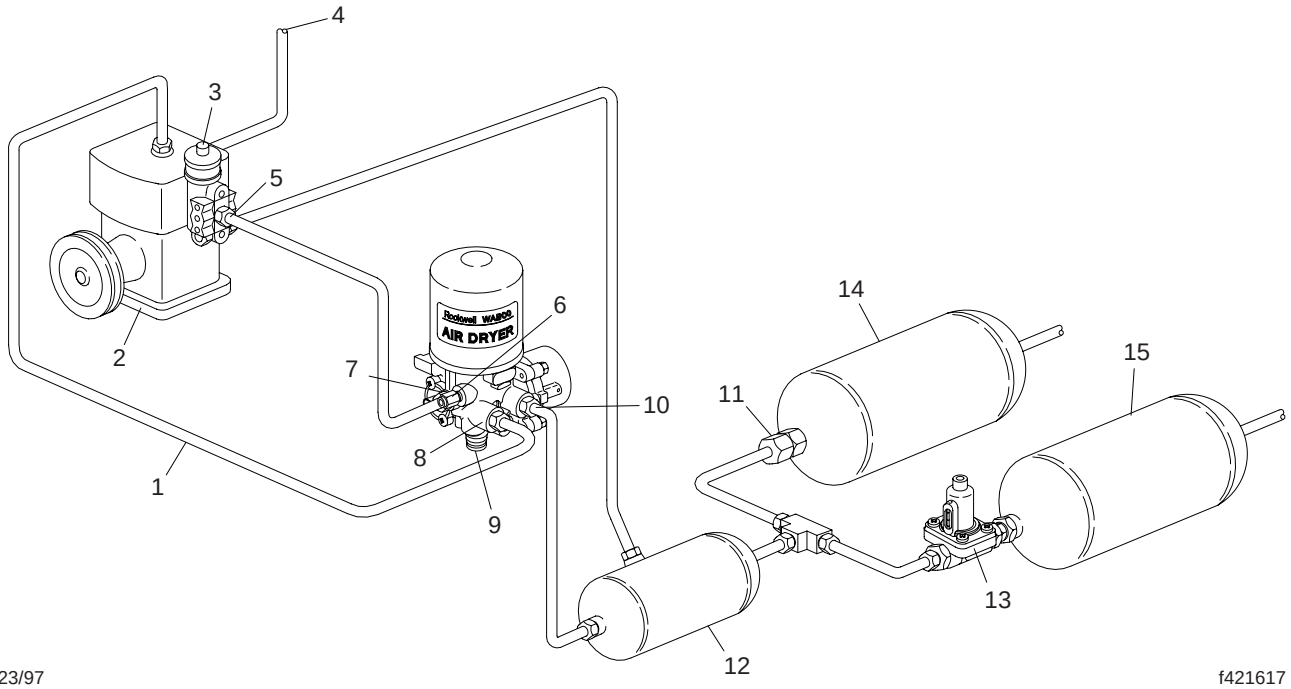
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Troubleshooting

Meritor WABCO System Saver 1200 Troubleshooting		
Condition	**Possible Cause**	**Solution**
Water, oil, or sludge in air system tanks.	Desiccant contaminated with oil.	Replace desiccant. Inspect compressor per manufacturer's instructions.
Water in system tanks, everything else checks out okay.	Dryer not suitable for application.	Review application guidelines. For assistance, call Arvin Meritor's Customer Service Center at 800-535-5560.

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See **Fig. 1** for the plumbing diagram.



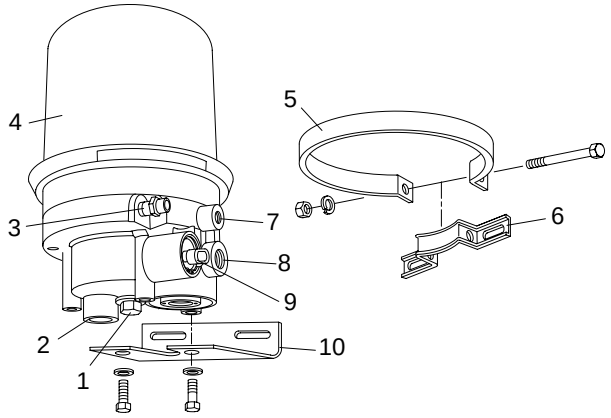
1. Compressor Discharge Line
2. Air Compressor
3. Air Governor
4. Compressor Intake Line
5. Unloader Port
6. Pressure Relief Valve
7. Air Governor Port
8. Air Dryer Inlet
9. Purge Valve
10. Air Dryer Outlet
11. Check Valve
12. Supply Tank
13. Pressure-Controlled Check Valve
14. Primary Reservoir
15. Secondary Reservoir

Fig. 1, Air Dryer Plumbing Diagram

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General Information

The function of the AD–IP, Integral Purge, air dryer (see **Fig. 1**) is to collect and remove air system contaminants in solid, liquid, and vapor form before they enter the brake system. It provides clean, dry air to the components of the brake system, which increases the life of the system and reduces maintenance costs. Daily manual draining of the reservoirs is eliminated.



1. Cartridge Bolt
2. Delivery Port
3. Safety Valve Assembly
4. Desiccant Cartridge
5. Mounting Strap
6. Saddle Bracket
7. Control Port
8. Supply Port
9. Heater and Thermostat Connection
10. Lower Mounting Bracket

Fig. 1, Bendix AD-IP Air Dryer

The air dryer consists of a desiccant cartridge secured to a die-cast aluminum end cover with a single, central bolt. The end cover contains a check valve assembly, safety valve, heater and thermostat assembly, three pipe thread air connections, and the purge valve assembly. The removable purge valve assembly incorporates the purge valve mechanism and a turbocharger cutoff feature that is designed to prevent loss of engine turbocharger boost pressure during the purge cycle of the air dryer. For ease of serviceability, all replaceable assemblies can be replaced without removal of the air dryer from its mounting on the vehicle.

To ease servicing, the desiccant cartridge and discharge check valve assembly are screw-in types. The purge valve housing assembly, which includes the heater and thermostat assembly, and the discharge check valve assembly, can be serviced without removing the air dryer from the vehicle. The screw-in desiccant cartridge requires removal of the air dryer assembly from the vehicle.

The air dryer has three female pipe thread air connections identified in **Table 1**.

Port I.D.	Function/Connection
CON 4	Control Port (purge valve control and turbo cutoff)
SUP 11	Supply Port (air in)
DEL 2	Delivery Port (air out)

Table 1, Air Dryer Port Identification

Principles of Operation

The AD–IP air dryer, alternates between two operational modes or cycles during operation: the charge cycle (see **Fig. 2**) and the purge cycle (see **Fig. 3**).

Charge Cycle

When the compressor is loaded (compressing air), compressed air, along with oil, oil vapor, water and water vapor flows through the compressor discharge line to the supply port of the air dryer body.

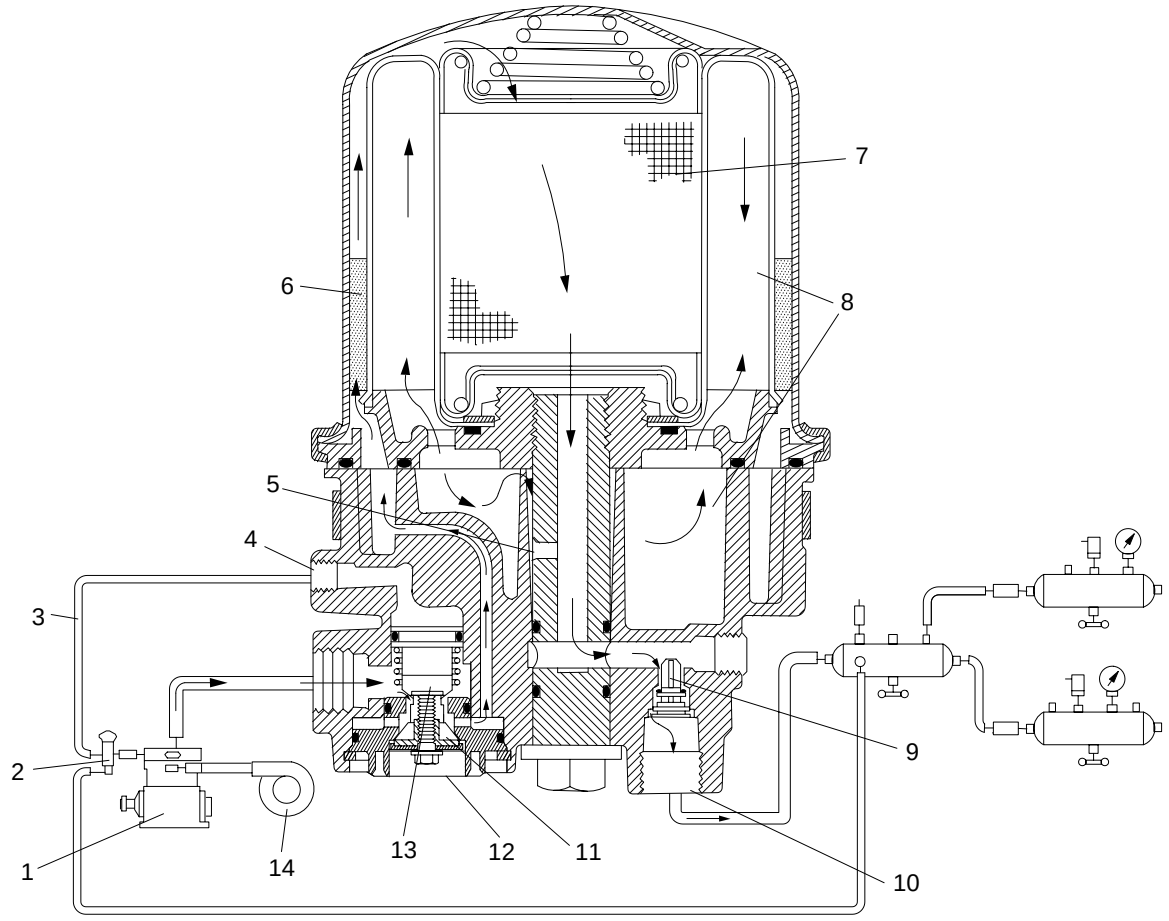
As air travels through the end cover assembly, its direction of flow changes several times, reducing the temperature, causing contaminants to condense and drop to the bottom or sump of the air dryer end cover.

After exiting the end cover, the air flows into the desiccant cartridge. Once in the desiccant cartridge, air first flows through an oil separator located between the outer and inner shells of the cartridge. The separator removes water in liquid form as well as oil and solid contaminants.

Air, along with the remaining water vapor, is further cooled as it exits the oil separator and continues to flow upward between the outer and inner shells. Upon reaching the top of the cartridge the air re-

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General Information



1. Compressor
2. Governor
3. Purge Control Line
4. Control Port
5. Purge Orifice
6. Oil Separator
7. Desiccant Bed
8. Purge Volume
9. Delivery Check Valve
10. Discharge Port
11. Purge Valve
12. Exhaust
13. Turbo Cutoff Valve
14. Engine Turbocharger

Fig. 2, AD-IP Charge Cycle

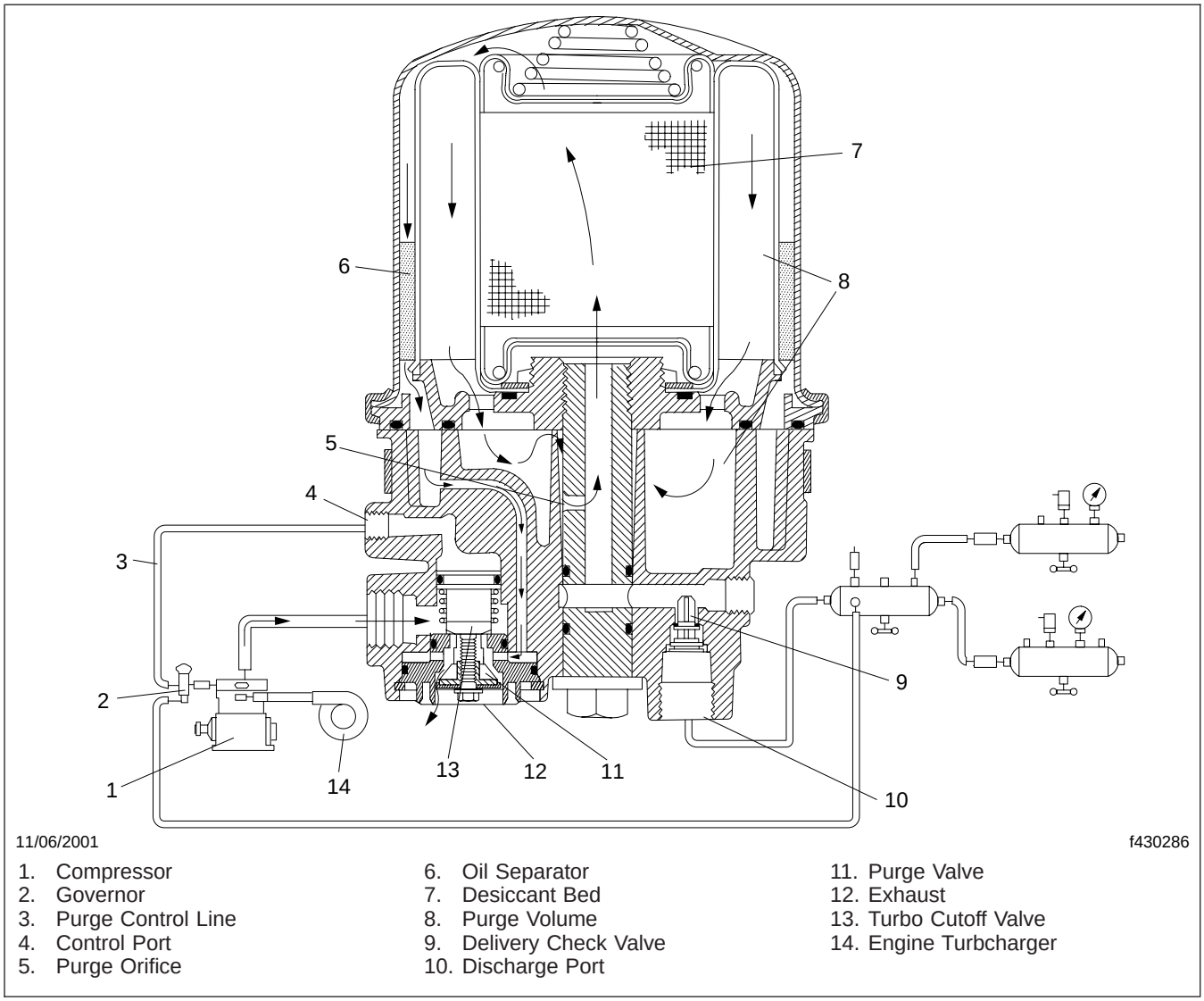
verses its direction of flow and enters the desiccant drying bed. Air flowing down through the column of desiccant becomes progressively dryer as water vapor adheres to the desiccant material in a process known as *"adsorption"*. The desiccant cartridge using the adsorption process typically removes most of the water vapor from the pressurized air.

Dry air exits the bottom of the desiccant cartridge and flows through the center of the bolt used to secure the cartridge to the end cover. Air flows down the center of the desiccant cartridge bolt, through a cross-drilled passage, and exits the air dryer delivery port through the delivery check valve.

Dry air flowing through the center of the desiccant cartridge bolt also flows out the cross-drilled purge orifice and into the purge volume.

The air dryer will remain in the charge cycle until the air brake system pressure builds to the governor cut-out setting.

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1. Compressor
2. Governor
3. Purge Control Line
4. Control Port
5. Purge Orifice
6. Oil Separator
7. Desiccant Bed
8. Purge Volume
9. Delivery Check Valve
10. Discharge Port
11. Purge Valve
12. Exhaust
13. Turbo Cutoff Valve
14. Engine Turbcharger

Fig. 3, AD-IP Purge Cycle

Purge Cycle

As air brake system pressure reaches the cutout setting of the governor, the governor unloads the compressor (air compression is stopped) and the purge cycle of the air dryer begins. When the governor unloads the compressor, it pressurizes the compressor unloader mechanism and the line connecting the governor unloader port to the AD–IP end cover control port. The purge piston moves in response to air pressure, causing the purge valve to open to the atmosphere and the turbo cutoff valve to close off the supply of air from the compressor (this will be further discussed in **Turbocharger Cutoff Feature**). Water and contaminants in the end cover sump are expelled immediately when the purge valve opens. Also, air which was flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected by the oil separator are removed by air flowing from the purge volume through the desiccant drying bed to the open purge valve.

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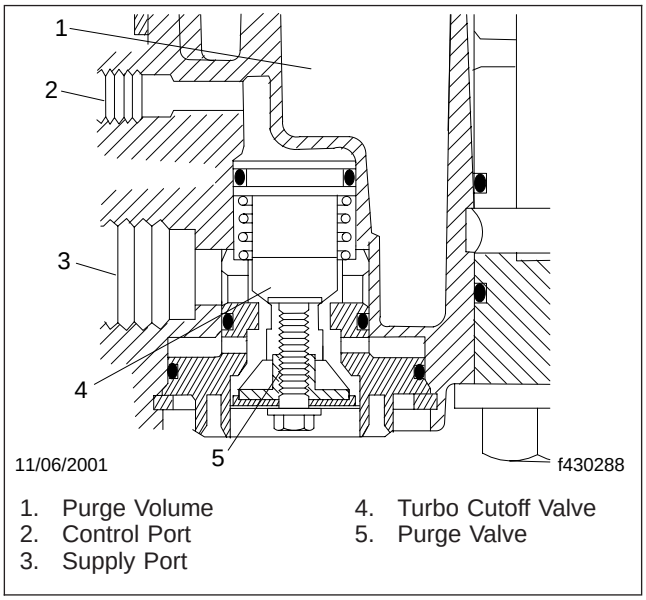
General Information

The initial purge and desiccant cartridge decompression lasts only a few seconds and is evidenced by an audible burst of air at the AD–IP exhaust.

The actual reactivation of the desiccant drying bed begins as dry air flows from the purge volume through the purge orifice in the desiccant cartridge bolt, then through the center of the bolt and into the desiccant bed. Pressurized air from the purge volume expands after passing through the purge orifice; its pressure is lowered and its volume increased. The flow of dry air through the drying bed reactivates the desiccant material by removing the water vapor adhering to it. Generally 30 seconds are required for the entire purge volume of a standard AD–IP to flow through the desiccant drying bed.

The delivery check valve assembly prevents air pressure in the brake system from returning to the air dryer during the purge cycle. After the 30 second purge cycle is complete, the desiccant has been reactivated or dried. The air dryer is ready for the next charge cycle to begin. However, the purge valve will remain open and will not close until air brake system pressure is reduced and the governor signals the compressor to charge the system.

NOTE: The air dryer should be periodically checked for operation and tested for leaks. Refer to **Group 42** of the *Acterra Maintenance Manual* for intervals and procedures.



1. Purge Volume
2. Control Port
3. Supply Port
4. Turbo Cutoff Valve
5. Purge Valve

Fig. 4, AD-IP Turbo Cutoff

Turbocharger Cutoff Feature

The primary function of the turbo cutoff valve is to prevent loss of engine turbocharger air pressure through the AD–IP in systems where the compressor intake is connected to the engine turbocharger. The turbo cutoff valve also removes the "puffing" of air out the open purge exhaust when a naturally aspirated, single-cylinder compressor, equipped with an inlet check valve, is in use. See **Fig. 4**.

At the beginning of the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve (tapered portion of purge piston) contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the compressor discharge line and AD–IP inlet port cannot enter the air dryer. In this manner the turbo cutoff effectively maintains turbocharger boost pressure to the engine.

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Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

1. Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber push rods and slack adjusters, which may apply as air pressure drops.
2. Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
3. Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
4. Don't disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
5. Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.

   Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
6. Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.

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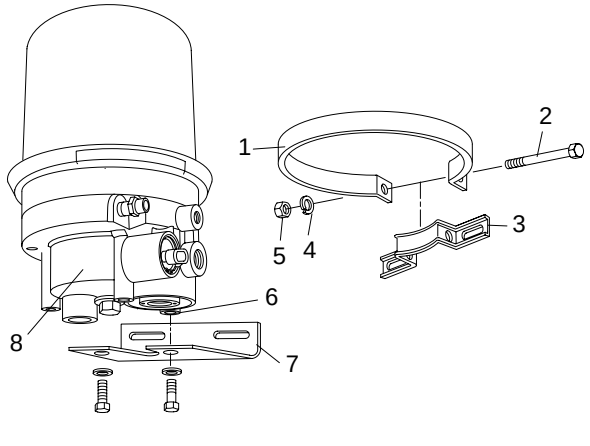
Air Dryer Removal and Installation

Removal

WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

1. Park the vehicle on a level surface and chock the tires.
2. Completely drain all of the reservoirs.
3. Remove the air dryer. See **Fig. 1**.



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1. Mounting Strap
2. 5/16-Inch Capscrew
3. Saddle Bracket
4. Lockwasher
5. Nut
6. End Cover Mounting Holes
7. Lower Mounting Bracket
8. Air Dryer
9. Lockwasher
10. 3/8-Inch Capscrew

Fig. 1, Bendix AD-IP Air Dryer

3.1 Mark and disconnect the three air lines from the end cover, and note the position of end cover ports relative to the vehicle.

3.2 Unplug the vehicle wiring harness from the heater and thermostat assembly connector on the purge valve assembly.

3.3 Remove the four bolts that secure both the upper and lower mounting brackets to the vehicle, and remove the air dryer from the vehicle.

3.4 Mark the relationship of the saddle bracket to the end cover assembly. Remove the 5/16-inch capscrew, washer, and nut securing the upper mounting strap to the saddle bracket. Remove the upper mounting strap from the end cover assembly.

3.5 Mark the relationship of the lower bracket to the end cover assembly. Remove the two 3/8-inch end cover capscrews and two washers that attach the lower mounting bracket to the end cover.

3.6 Remove the air dryer from its mounting brackets.

Installation

WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

1. Install the assembled air dryer on the vehicle. See **Fig. 1**.

   1.1 Install the lower mounting bracket on the end cover and secure it using the two 3/8-inch capscrews and washers. Tighten the capscrews 25 to 30 lbf·ft (34 to 40 N·m).

   1.2 Install the saddle bracket and mounting strap on the end cover, and using the 5/16-inch capscrew, washer, and nut secure the strap to the saddle bracket. Tighten the 5/16-inch nut on the upper mounting bracket to 60 to 96 lbf·in (678 to 1085 N·cm).

   1.3 Install the dryer on the vehicle using the four bolts that secure both the upper and lower mounting brackets.
2. As marked earlier in "Removal," connect the three air lines to the ports on the end cover.
3. Connect the vehicle wiring harness to the air dryer heater and thermostat assembly connector by plugging it into the air dryer connector until its lock tab snaps in place.
4. Test the air dryer following instructions in **Group 42** of the *Acterra Maintenance Manual*.
5. Remove the chocks from the tires.

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Air Dryer Disassembly, Cleaning and Inspection, and Assembly

NOTE: As a convenience when rebuilding the air dryer, several replacement parts and maintenance kits are available that do not require full disassembly. Use the instructions provided with these parts or kits.

Disassembly

NOTE: Refer to **Fig. 1** during disassembly.

⚠ WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

⚠ CAUTION

While servicing the air dryer, don't use a clamping device (vise, C-clamp, etc.) to hold any die cast aluminum part, as damage may result. To hold the end cover, install a pipe nipple in the supply port, and clamp the nipple in a vise.

1. Remove the air dryer from the vehicle. See **Subject 110**.
2. Using an adjustable or socket wrench, loosen the desiccant cartridge bolt, then separate the desiccant cartridge from the end cover. Pull the desiccant cartridge bolt out of the end cover. See **Fig. 1**.

⚠ CAUTION

Disassembly of the desiccant cartridge assembly should not be attempted! Detail parts for the cartridge are not available and the cartridge contains a 150 lb spring which can not be mechanically caged. Releasing the spring could cause serious personal injury.

3. Remove both O-rings from the desiccant cartridge bolt.
4. Remove the retaining ring that secures the purge valve assembly in the end cover.
5. Using a 3/8-inch socket wrench, and a large-blade screwdriver inserted in the slot on top of the purge piston, remove the 1/4-inch shoulder bolt from the bottom of the purge valve housing assembly. Remove the exhaust diaphragm and the purge valve from the purge valve housing.
6. Remove the O-rings from the purge valve housing.
7. Remove the purge piston and the return spring. Remove the O-ring from the purge piston.
8. Remove the retaining ring that secures the delivery check valve assembly in the end cover. Remove and separate the perforated plate, spring, check-valve body, and O-ring.
9. Remove the retaining ring that secures the heater and thermostat assembly in the end cover. Gently pull the heater and thermostat out of the end cover and remove the O-ring.
10. Using a 9/16-inch wrench, remove the safety valve assembly from the end cover.

Cleaning and Inspection

⚠ WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

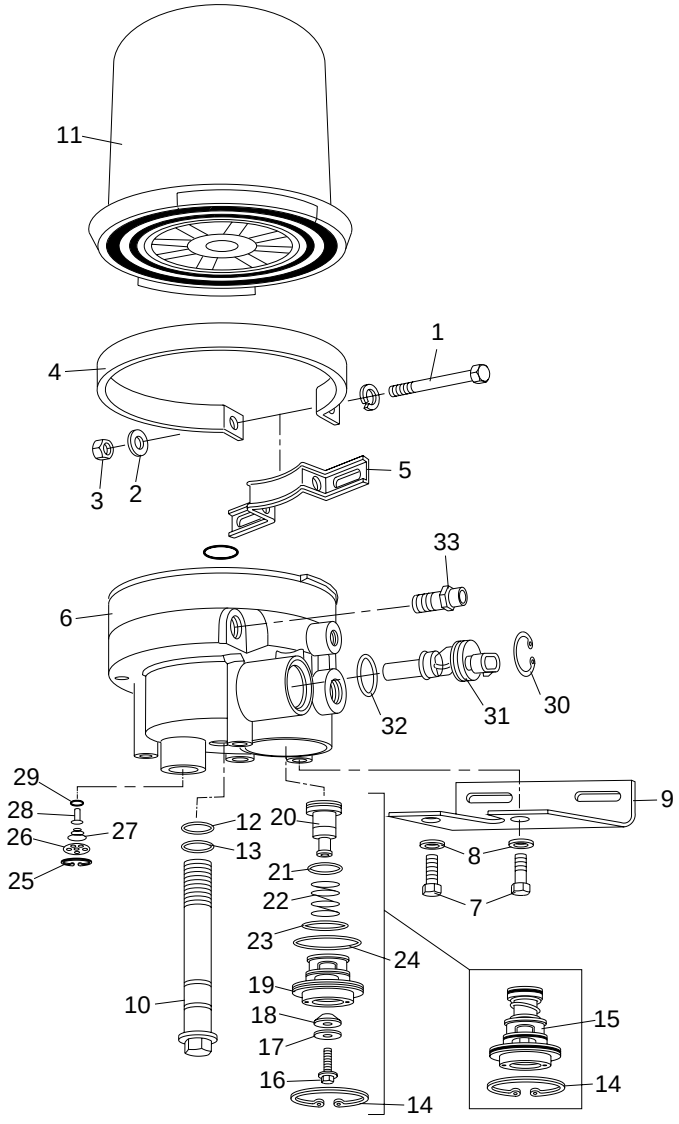
1. Wash all metal parts thoroughly, using a quality commercial solvent, such as mineral spirits.

NOTE: Don't clean the desiccant cartridge.

2. Check for severe corrosion, pitting, and cracks on the inside and outside of all metal parts that will be reused. Superficial corrosion and pitting on the outside of the upper and lower body halves is acceptable.
3. Inspect the bores of both the end cover and the purge-valve housing for deep scuffing or gouges.
4. Make sure that all purge-valve housing and end cover passages are open and free of blockages.
5. Inspect the pipe threads in the end cover. Make sure they are clean and free of thread sealant.
6. Inspect the purge-valve housing bore and seats for excessive wear and scuffing.
7. Inspect the purge valve piston seat for excessive wear.

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Air Dryer Disassembly, Cleaning and Inspection, and Assembly



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1. 5/16-Inch Capscrew
2. 5/16-Inch Lockwasher
3. 5/16-Inch Locknut
4. Upper Bracket Strap
5. Saddle Bracket
6. End Cover
7. 3/8-Inch Capscrew
8. 3/8-Inch Lockwasher
9. Lower Mounting Bracket
10. Cartridge Bolt
11. Desiccant Cartridge
12. O-Ring
13. O-Ring
14. Retaining Ring
15. Purge Valve Cartridge Assembly
16. Shoulder Bolt
17. Exhaust Diaphragm
18. Purge Valve
19. Purge Valve Housing
20 Purge Valve Piston
21 O-Ring
22. Piston Return Spring
23. O-Ring
24. O-Ring
25. Retaining Ring
26. Perforated Plate
27. Check Ring Spring
28. Check Valve
29. O-Ring
30. Retaining Ring
31. Heater/Thermostat Assembly
32. O-Ring
33. Safety Valve Assembly

Fig. 1, AD-IP (exploded view)

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8. Make certain that the purge orifice in the cartridge bolt is open and free of obstructions.
9. Inspect all air line fittings for corrosion. Clean all old thread sealant from the pipe threads.
10. Replace all removed O-rings with new ones that are provided in the kits.

    Replace parts that show any of the conditions described in the previous steps.

Assembly

⚠ WARNING

Before working on or around air brake systems and components, read Safety Precautions 100. Failure to do so could result in personal injury.

1. Before assembly, coat all O-rings, O-ring grooves, and bores with a generous amount of barium-base lubricant. See **Fig. 1** during assembly unless otherwise advised.
2. Install and center the exhaust diaphragm over the shoulder bolt making certain that the diaphragm i.d. is over the bolt shoulder. Then install the purge valve on the shoulder bolt making certain its metal support side is against the diaphragm.
3. Push the purge piston into the housing until it bottoms and insert a large-blade screwdriver in the piston's slotted head. While depressing the purge piston with the screwdriver, install the shoulder bolt with exhaust diaphragm and purge valve in the piston. Torque the shoulder bolt 60 to 80 lbf·in (678 to 900 N·cm).
4. Install the two O-rings on the purge valve housing placing each in its appropriate location. Install the assembled purge valve housing in the end cover while making certain the purge valve housing is fully seated against the end cover. Secure the purge valve housing in the end cover using the retaining ring. Make certain the retaining ring is fully seated in its groove in the end cover.
5. Using a 9/16-inch wrench, install the safety valve assembly into the end cover.
6. Install the O-ring on the check valve body and push the O-ring down, over the three guide lands until it is in the O-ring groove of the check valve body. Install the check valve spring on the check valve body so that the small coils of the spring slip over the check valve body. Install the assembled check valve body, O-ring, and spring in the end cover so that the O-ring rests on its seat in the end cover and the spring is visible.
7. Install the O-ring on the heater and thermostat assembly. After making certain the sponge rubber cushion is positioned between the connector body and thermostat, gently push the heater and thermostat assembly into the end cover, making certain the heating element enters the small diameter bore in the larger heater and thermostat bore in the end cover. Secure the heater and thermostat assembly in the body using the retaining ring. Make certain the retaining ring is fully seated in its groove in the end cover.
8. Install both O-rings on the desiccant cartridge bolt and using a twisting motion, insert the assembled desiccant cartridge bolt in the end cover.
9. Install the desiccant cartridge on the end cover making certain the cartridge is properly seated and flush on the end cover.

NOTE: It may be necessary to rotate the cartridge slightly until the anti-rotation lugs are properly aligned and allow the cartridge to rest flush against the end cover.

10. Using an adjustable wrench or a socket, tighten the desiccant cartridge bolt, to secure the desiccant cartridge to the end cover. Torque the desiccant cartridge bolt to 50 lbf·ft (65 N·m).
11. Install the air dryer. For instructions, see **Subject 110**.
12. Remove the chocks from the tires.

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AD–IP Air Dryer Heater/Thermostat Assembly Testing and Replacement

Testing

During cold-weather operation, check the operation of the end cover heater and thermostat assembly. Before placing the vehicle in service, perform the following tests.

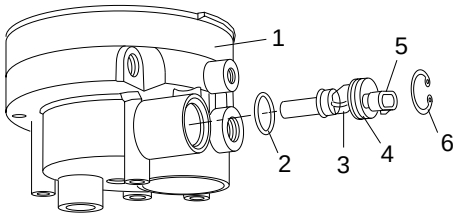
1. With the ignition on, check for voltage to the heater and thermostat assembly. Unplug the electrical connector at the air dryer, and place the test leads on each of the pins of the male connector. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check that a good ground path exists.
2. Check the thermostat and heater operation. Turn off the ignition switch and cool the end cover assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the female connector. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly, and 6.8 to 9.0 ohms for the 24-volt heater assembly.
3. Warm the end cover assembly to over 90°F (32°C) and again check the resistance. It should exceed 1000 ohms. If it does, the thermostat and heater assembly is operating properly. If it doesn't, replace the heater and thermostat assembly.

Replacement

Refer to **Fig. 1** when replacing the heater/thermostat assembly.

1. Disconnect the wire connector.
2. Remove the retaining ring.
3. Gently pull the heater/thermostat assembly out of the end cover.
4. Install a new O-ring on the new heater and thermostat assembly.
5. After making certain the sponge rubber cushion is positioned between the connector body and thermostat, gently push the heater/thermostat assembly into the end cover, making certain the heating element enters the small diameter bore in the larger heater and thermostat bore in the end cover.
6. Secure the heater/thermostat assembly in the body using the retaining ring making certain the retaining ring is fully seated in its groove in the end cover.
7. Connect the wire harness to the heater/thermostat assembly.
8. Test the new heater/thermostat assembly.

A two-lead wire harness with attached weather-resistant connector is suppled with all replacement and retrofit AD–IP air dryers. One of the two leads is connected to the engine "kill switch" or ignition, while the other must be connected to a good vehicle ground. A fuse is installed in the lead carrying vehicle power; install a 10 amp fuse for 12 volt heaters and a 5 amp fuse for the 24 volt heater. Use 14 AWG wire if it is necessary to lengthen the wire harness leads. Make certain all splices are weather-proofed. Tie-wrap or support all electrical wires leading to the AD–IP dryer. See **Fig. 2**.



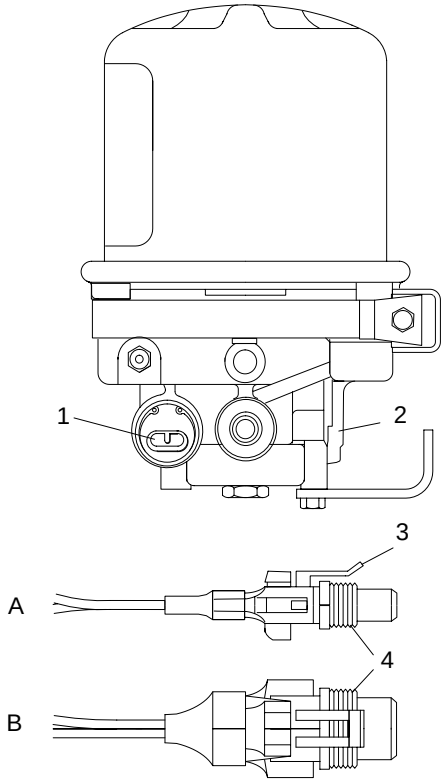
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1. End Cover
2. O-Ring
3. Sponge Rubber Cushion
4. Heater/Thermostat Assembly
5. Connector
6. Retaining Ring

Fig. 1, Heater/Thermostat Assembly Installation

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AD–IP Air Dryer Heater/Thermostat Assembly Testing and Replacement



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A. Side View of the Connector
B. Top View of the Connector
1. Heater and Thermostat Connector
2. AD–IP End Cover
3. Locking Latch
4. Weatherproof Accordion Seal

Fig. 2, AD-IP Heater and Thermostat Connector

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Problem—Air Dryer Is Constantly Cycling or Purging

Problem—Air Dryer Is Constantly Cycling or Purging	
Possible Cause	**Remedy**
Excessive system leakage.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
There is excessive leakage in the fittings, hoses, and tubing connected to the compressor, air dryer, and wet tank.	Using a soap solution, test for leakage at the fittings, drain valve, and safety valve in the wet tank. Repair or replace as needed.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5 cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Governor is inoperative.	Test the governor for proper cut-in or cut-out pressures and excessive leakage in both positions.
Leaking purge-valve housing assembly or O-rings in the air dryer end cover.	With the supply port open to atmosphere, apply 120 psi (830 kPa) at the control port. Apply a soap solution to the supply port and exhaust port (purge valve seat area). Permissible leakage is a 1-inch (2.5 cm) bubble in 5 seconds. Repair or replace as needed.
Compressor unloader mechanism is leaking excessively.	Remove the air strainer or fitting from the compressor inlet cavity. With the compressor unloaded, check for unloader piston leakage. Slight leakage is allowed.
Holset "E" type compressor.	Test the air dryer system. For instructions, refer to Bendix Product Bulletin PRO-08-19 entitled *"Troubleshooting the Holset "E" Compressor System with Bendix Air Dryer."*
Lack of air at the governor RES port (rapid cycling of the governor).	Test the governor for proper pressure at the RES port. Pressure should not drop below cut-in pressure when the compressor begins the unloaded cycle. If the pressure does drop, check for kinks or restrictions in the line connected to the RES port. The line connected to the RES port on the governor must be the same diameter, or larger than the lines connected to the UNL ports on the governor.

Problem—Water in the Vehicle Reservoirs

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Desiccant cartridge assembly contains excessive contaminants.	Replace the desiccant cartridge.
Discharge line is of improper length or material.	Discharge line must consist of at least 6 ft. (1.8 m) of wire braid Teflon hose, copper tubing, or a combination of both between the discharge port of the compressor and the air dryer supply port. Discharge line lengths and inside diameter requirements are dependent on the vehicle application. Contact your local Bendix representative for further information.
Air system was charged from an outside air source that did not pass through an air dryer.	If the system must have an outside air fill provision, the outside air should pass through an air dryer. This practice should be minimized.
Air dryer is not purging.	See *"Problem—Air Dryer Does Not Purge or Exhaust Air."*

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Troubleshooting

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Purge (air exhaust) is insufficient due to excessive system leakage.	See *"Problem—Air Dryer Is Constantly Cycling or Purging."*
Air bypasses the desiccant cartridge assembly.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed.
Purge (air exhaust) time is significantly less than the minimum allowable.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed. Replace the desiccant cartridge assembly.
Excessive air usage—air dryer not compatible with vehicle air system.	Install an accessory bypass system. Consult your Bendix representative for additional information.

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air	
Possible Cause	**Remedy**
Desiccant cartridge is plugged or saturated.	Check the compressor for excessive oil passing, or incorrect installation. Repair or replace as needed. Replace the desiccant cartridge.
Defective discharge check valve in end cover of the AD-IP.	Test to determine if air is passing through the check valve. Repair or replace as needed.
There is a problem in the fittings, hose, or tubing between the air dryer and the wet tank.	See if air is reaching the first reservoir. Inspect for kinked tubing or hose. Check for undrilled or restricted hose or tubing fittings.
Safety valve setting is lower than the maximum system pressure.	Reduce the system pressure, or install a safety valve with a higher pressure setting.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Air dryer purge valve is leaking excessively.	With the compressor loaded, apply a soap solution on the purge valve exhaust to test for excessive leakage. Repair the purge valve as needed.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Purge control line is connected to the reservoir or exhaust port of the governor.	Connect the purge control line to the unloader port of the governor.
Purge valve is frozen open due to an inoperative heater or thermostat, bad wiring, or a blown fuse.	Test the heater and thermostat, following instructions in this manual.
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
System is leaking excessively.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir

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Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Purge valve stays open; supply air leaks to control side.	Replace the purge valve and housing.

Problem—Unable to Build System Pressure

Problem—Unable to Build System Pressure	
Possible Cause	**Remedy**
Inlet and outlet air connections reversed.	Connect compressor discharge to air dryer supply port. Reconnect lines properly.
Check valve between air dryer and wet tank.	Test check valve for proper operation. Repair or replace as necessary.
Kinked or blocked (plugged) discharge line.	Check to determine if air passes through discharge line. Check for kinks, bends, excessive carbon deposits, or ice blockage.
Excessive bends in discharge line (water collects and freezes).	Discharge line should be constantly sloping from compressor to air dryer with as few bends as possible. See *Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure*

Problem—Air Dryer Does Not Purge or Exhaust Air

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
Purge control line is broken, kinked, frozen, plugged, or disconnected.	See if air flows through the purge control line when the compressor is unloaded. The purge control line must be connected to the unloader port of the governor.
Air dryer purge valve isn't working.	See if air reaches the purge valve. If it does, repair the purge valve.
Also See - *Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure*	

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (May Look Like Whitish Liquid, Paste, or Small Beads); or, Unsatisfactory Desiccant Life

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads) or Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
This problem usually occurs with one or more of the previous problems.	Refer to the appropriate corrections listed previously.
Air dryer is not securely mounted; there is excessive vibration.	Vibration should be held to a minimum. Tighten the mounting fasteners.
Malfunctioning or saturated desiccant cartridge.	Replace desiccant cartridge assembly.
Compressor is passing excessive oil.	Check for proper compressor installation; if symptoms persist, replace the compressor.
Desiccant cartridge not attached properly to the end cover.	Check the torque and tighten if necessary. Refer to **Subject 120** for instructions.

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Troubleshooting

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle	
Possible Cause	**Remedy**
Pinging noise is due to a single cylinder compressor with high pulse cycles.	A slight pinging sound may be heard during system build-up when a single cylinder compressor is used. If this sound is deemed objectionable, it can be reduced substantially by increasing the discharge line volume. This is done by adding a 90 in^3 (1475 cm^3) reservoir between the compressor and the air dryer.

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)	
Possible Cause	**Remedy**
Leaking Turbo Cutoff valve.	Repair or replace purge valve assembly.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5 cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Leaking purge valve control piston O-ring.	Repair or replace purge valve assembly.

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode

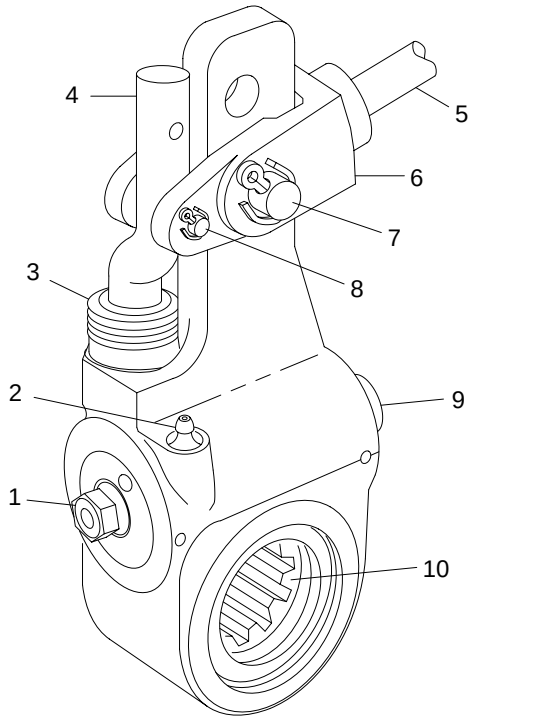
Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode	
Possible Cause	**Remedy**
Compressor does not "unload."	Check the governor installation: there is no air line from the governor to the compressor, or the line is restricted. Repair or replace as needed.

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General Information

The Gunite automatic slack adjuster (see **Fig. 1**) has two main functions:

- As a lever it converts the straight-line force of the brake chamber pushrod to torque on the brake camshaft. Rotation of the camshaft forces the brake shoes against the drum.



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1. 7/16-Inch Adjusting Hexnut
2. Grease Fitting
3. Boot
4. Link
5. Brake Chamber Pushrod
6. Clevis
7. 1/2-Inch Clevis Pin
8. 1/4-Inch Clevis Pin
9. Grease Relief Opening
10. Slack Adjuster Spline

Fig. 1, Gunite Slack Adjuster

- As an automatic slack adjuster, it maintains the lining-to-drum clearance needed for proper brake chamber pushrod stroke.

The slack adjuster is installed between the brake chamber pushrod and the brake camshaft. A clevis is either welded to the brake chamber pushrod or screwed on. The clevis is connected to the top of the slack adjuster. The bottom of the slack adjuster is splined to the brake camshaft. The splines hold the slack adjuster internal gear to the camshaft so that the camshaft turns when the slack adjuster moves. When the brakes are applied, the brake chamber pushrod moves outward forcing the slack adjuster and camshaft to rotate. This movement forces the brake shoes against the drum.

The brakes are adjusted when the slack adjuster senses an increase in the lining-to-drum clearance. The slack adjuster's internal worm shaft and ratchet shorten excessive lining-to-drum clearance. This provides maximum leverage for the brake chamber pushrod. The automatic slack adjuster adjusts the brakes at the beginning of the brake application.

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Safety Precautions

⚠ WARNING

When draining the air system, do not look into the air jets or direct them toward another person, as dirt or sludge particles may be in the air-stream. Do not disconnect pressurized hoses because they may whip as air escapes from the line. Failure to take all necessary precautions during service operations of the air brake system can cause personal injury.

When working on or around air brake systems and components, observe the following precautions.

1. Apply the parking brake, chock the tires, and stop the engine when working under the vehicle. Draining the air system may cause the vehicle to roll. Keep hands away from the brake chamber push rods and slack adjusters, which may apply as air system pressure drops.
2. Wear safety goggles.
3. Never connect or disconnect a hose or line containing air under pressure; it may whip as air escapes. Never remove a component or pipe plug unless you are sure all system pressure has been depleted.
4. Don’t disassemble a component before reading and understanding recommended procedures. Use only the correct tools and follow basic tool safety.
5. Replacement hardware, tubing, hose, fittings, etc. should be the same size, type, length, and strength as the original equipment. When replacing tubing or hose, be sure that all of the original supports, clamps, or suspending devices are installed or replaced.
6. Replace any components that have stripped threads or damaged parts. Don’t attempt to repair parts by machining.
7. Never exceed recommended air pressure.

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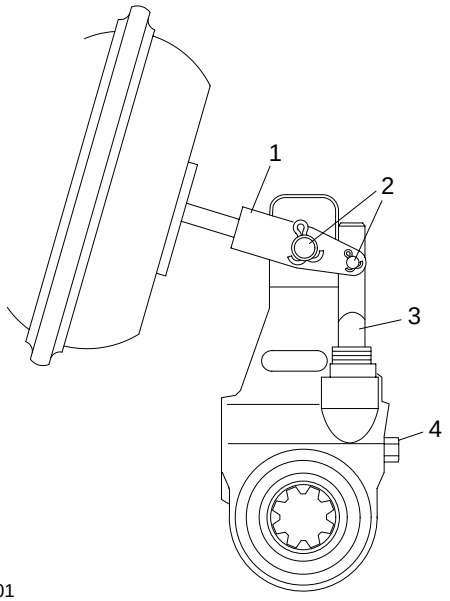
Slack Adjuster Removal and Installation

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the air brake system can cause personal injury.

IMPORTANT: This automatic slack adjuster cannot be rebuilt. If it is damaged or inoperative, replace the unit.

Factory-installed brake chambers have welded clevises on the pushrod. See **Fig. 1**. On a replacement brake chamber, the clevis is threaded onto the pushrod, and has a jam nut installed. See **Fig. 2**.



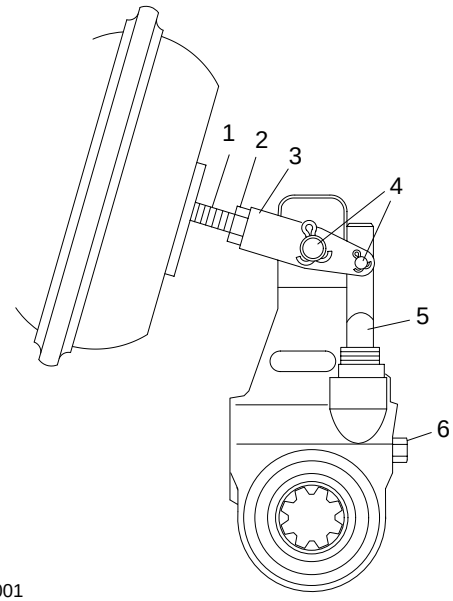
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1. Brake Chamber Pushrod and Clevis Assembly
2. Cotter Pins and Clevis Pins
3. Link
4. Adjusting Hexnut

Fig. 1, Slack Adjuster (attached to welded clevis)

Removal

1. With the vehicle parked on a level surface, chock the tires. If you are removing a rear slack adjuster, cage the parking brake power spring. For instructions, refer to the applicable brake chamber section in this group.



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1. Brake Chamber Pushrod (threaded)
2. Jam Nut
3. Threaded Clevis
4. Cotter Pins and Clevis Pins
5. Link
6. Adjusting Hexnut

Fig. 2, Slack Adjuster (attached to threaded clevis)

2. Remove the cotter pins and clevis pins.
3. Rotate the adjusting hexnut counterclockwise until the slack adjuster clears the clevis.
4. Remove the snap ring from the brake camshaft, then slide the slack adjuster off the camshaft.

Installation

NOTE: For brake chambers that have pushrods with threaded clevises, measure the pushrod length before installing the new slack adjuster. With the brakes fully released, and no air pressure to the chamber, check the dimension between the chamber face and the centerline of the 1/2 inch clevis pin hole. It should be 2.25 inches (57 mm) for long stroke chambers, and 2.75 inches (70 mm) for standard stroke chambers.

1. Coat the camshaft splines, and the splines of the slack adjuster gear with an anticorrosive grease.

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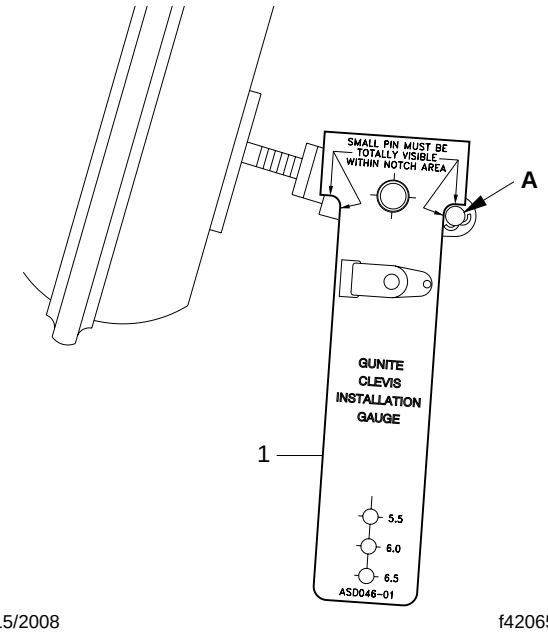
Slack Adjuster Removal and Installation

2. Using the old snap ring, install the automatic slack adjuster on the brake camshaft.
3. Turn the adjusting hexnut clockwise to rotate the slack adjuster toward the brake chamber until the holes line up.
4. Install the clevis pins and cotter pins.

⚠ WARNING

Manually adjusting an automatic slack adjuster to bring the pushrod stroke within legal limits is likely masking a mechanical problem. Adjustment is not repairing. Before adjusting an automatic slack adjuster, troubleshoot the foundation brake system and inspect it for worn or damaged components. Improperly maintaining the vehicle braking system may lead to brake failure, resulting in property damage, personal injury, or death.

5. If the pushrod has a threaded clevis, use the gauge supplied with the new slack adjuster to check the adjustment of the clevis, as follows. See **Fig. 3**.



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A. Adjust the clevis in or out to position the 1/4-inch clevis pin within the notched area of the gauge.

1. Installation Gauge

Fig. 3, Checking the Clevis Adjustment

5.1 Position the 1/2-inch hole in the gauge over the end of the 1/2-inch clevis pin.

5.2 Align the applicable 1/4-inch hole in the bottom of the gauge over the center of the camshaft.

5.3 Check that the 1/4-inch pin is visible in the notched area of the gauge. If the pin is not in the right location, back off the slack adjuster and adjust the pushrod length, then repeat this step.

NOTE: Make sure there is clearance between the slack adjuster and other vehicle components when the brakes are applied and the pushrod travels its maximum stroke.

6. Set the initial free-stroke, as follows.

6.1 Turn the adjusting hexnut clockwise until the brake linings contact the drum.

6.2 Turn the adjusting hexnut counterclockwise one-half turn. There should be about 30 lbf·ft (41 N·m) resistance, and a ratcheting sound will be heard.

7. Measure the brake chamber applied stroke, as follows.

7.1 With the brakes fully released, use a ruler to measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 4**.

7.2 Build air pressure to at least 85 psi (586 kPa). Apply the brakes, then measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 4**. The difference between the measurements is the brake chamber stroke.

7.3 The brake chamber stroke must be within the range shown in **Table 1**. If it is not, check the foundation brakes for problems such as worn cams, bushings, pins and rollers, or broken springs. Repair or replace as needed. For instructions, refer to the applicable brake section in this group. Then, repeat the two previous steps.

8. If a rear axle slack adjuster was installed, manually uncage the parking brake. Refer to the applicable brake chamber section in this group for instructions.

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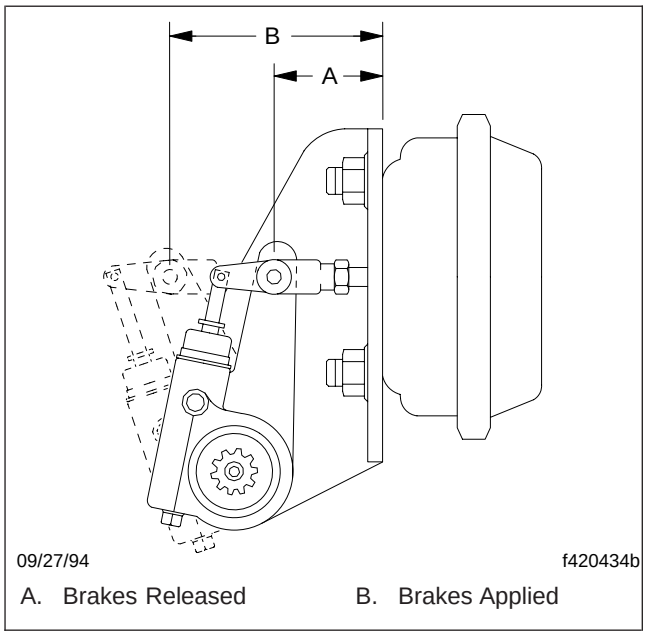


Fig. 4, Stroke Measurements

9. Apply the parking brakes.
10. Remove the chocks from the tires.
11. In a safe area, check for proper brake operation, as follows.
    - 11.1 Apply and release the brakes several times to check for correct operation of the slack adjusters.
    - 11.2 Perform six low-speed stops to ensure correct parts replacement and full vehicle control.
    - 11.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than the others show a lack of braking effort on those wheels.

Brake Chamber Stroke Specifications			
Chamber Type (Size)	**Maximum Applied Stroke*: inch (mm)**	**Free-Stroke: inch (mm)**	
		New Brake Installation	**In-Service Brake**
Long Stroke†			
16 and 20	2-1/2 (64)	5/8 to 3/4 (16 to 19)	1/2 to 5/8 (13 to 16)
24 and 30	3 (76)		

* Specifications are relative to a brake application with 80–90 psi (550–620 kPa) air pressure in the brake chambers.

† Long stroke design is indicated by a tag, or embossing, on the brake chamber.

Table 1, Brake Chamber Stroke Specifications

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Specifications

Lubricant Type	Temperature
Lubriplate Aero	Above –40°F (–40°C)
Texaco Multifak EP–2 Mobil Grease 77	Above –20°F (–29°C)

Table 1, Approved Lubricants

Standard Clamp Type Brake Chamber Data			
Type	**Outside Diameter: inches (cm)**	**Rated Stroke: inches (cm)**	**Maximum Stroke at Which Brakes Must be Readjusted: inches (cm)**
9	5-1/4 (13.3)	1.75 (4.5)	1 3/8 (3.5)
12	5 11/16 (14.4)	1.75 (4.5)	1 3/8 (3.5)
16	6 3/8 (16)	2.25 (5.7)	1 3/4 (4.5)
20	6 25/32 (17)	2.25 (5.7)	1 3/4 (4.5)
24	7 7/32 (18.3)	2.25 (5.7)	1 3/4 (4.5)
30	8 3/32 (20.5)	2.50 (6.35)	2 (5)
36*	9 (22.8)	3.00 (7.6)	2 1/4 (5.7)

* If type 36 chamber is used, slack length should be less than 6 inches.

Table 2, Standard Clamp Type Brake Chamber Data

Long Stroke Clamp Type Brake Chamber Data			
Type	**Outside Diameter: inches (cm)**	**Rated Stroke: inches (cm)**	**Maximum Stroke at Which Brakes Must be Readjusted: inches (cm)**
16	6 3/8 (16)	2.50 (6.35)	2 (5)
20	6 25/32 (17)	2.50 (6.35)	2 (5)
24	7 7/32 (18.3)	2.50 (6.35)	2 (5)
24*	7 7/32 (18.3)	3.00 (7.6)	2 1/2 (6.35)
30*	8 3/32 (20.5)	3.00 (7.6)	2 1/2 (6.35)

* Identified by square air port bosses.

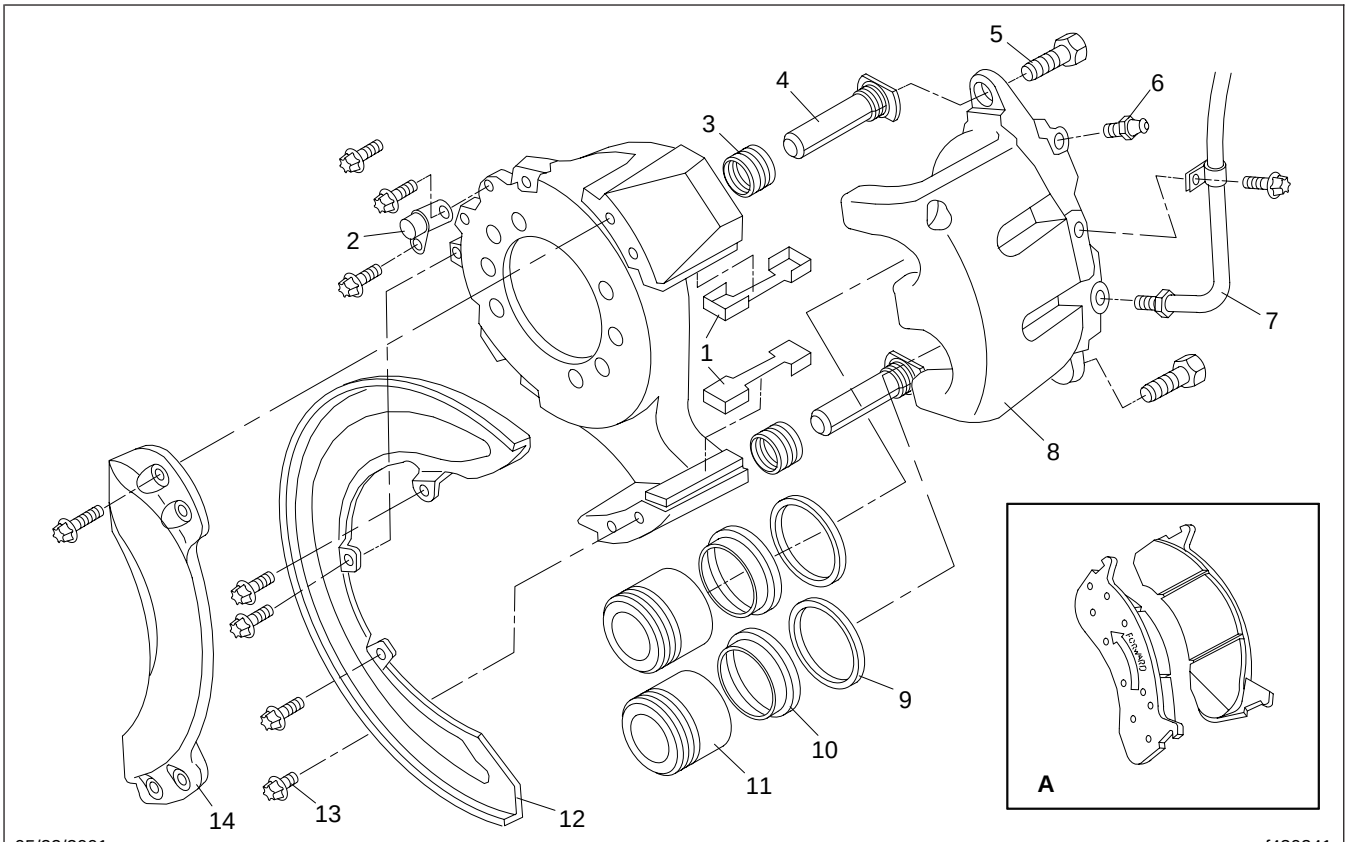
Table 3, Long Stroke Clamp Type Brake Chamber Data

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General Information

Bosch® hydraulic pin slide disc brakes are two-piston sliding caliper brakes for use at both front and rear wheels. See **Fig. 1**. Each pin slide caliper disc brake wheel installation is comprised of three major components. See **Fig. 2**.

Disc Brake Pads



A. Brake Pads
1. Slipper
2. Antilock Brakes Sensor Bracket
3. Guide Pin Boot
4. Guide Pin
5. Guide Pin Bolt
6. Bleed Screw
7. Brake Line
8. Caliper
9. Caliper Boot Seal
10. Piston Boot
11. Caliper Piston
12. Splash Shield
13. Plug (66 mm only)
14. Tie Bar (73 mm only)

Fig. 1, Pin Slide Brake (exploded view)

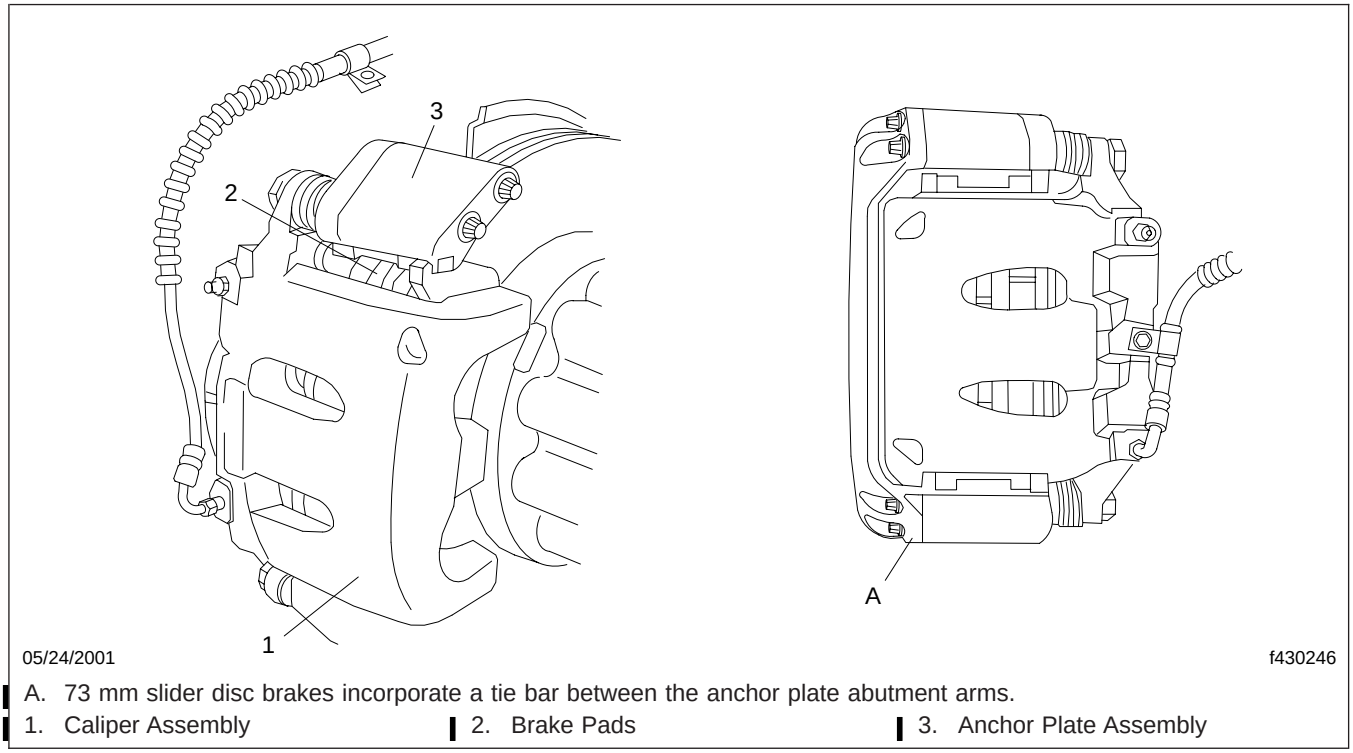
Caliper Assembly

The caliper assembly includes two hydraulic piston bores. The piston bores contain the pistons, piston seals, and piston boots. The caliper assembly attaches to and slides on sealed pins located in an anchor plate. The anchor plate is mounted on the steering knuckle flange on front axles, or on the axle flange on rear axles. Two sizes of calipers are used: 66 mm Twin (2 piston) and 73 mm Twin (2 piston). See **Fig. 3**.

The inboard and outboard disc brake pads are positioned with both ends mounted on the anchor plate pad abutments. The pads rest on stainless steel slippers covering the anchor plate pad abutments. Inboard and outboard disc brake pads may be chamfered, and if so are marked with an arrow and the

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General Information



A. 73 mm slider disc brakes incorporate a tie bar between the anchor plate abutment arms.
1. Caliper Assembly
2. Brake Pads
3. Anchor Plate Assembly

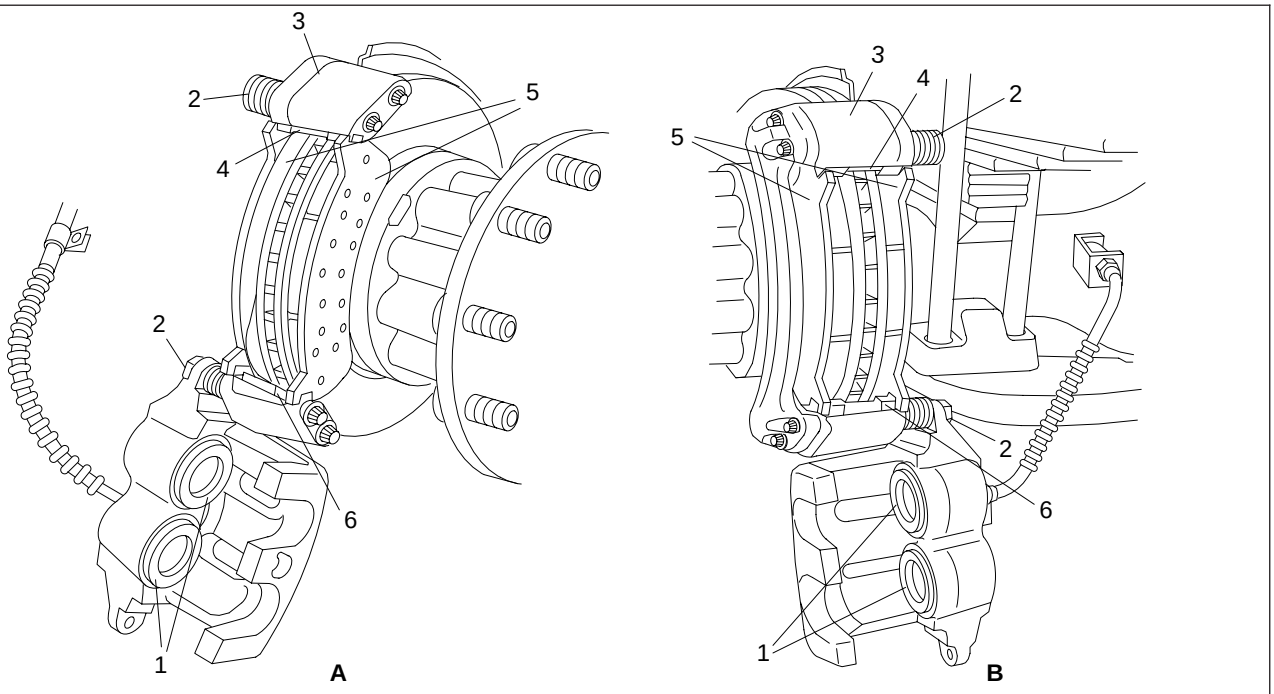
Fig. 2, Bosch Pin Slide Brakes Major Components

word "FORWARD" for proper installation. Brake pads may not be interchangeable inner to outer, so correct location is required during assembly.

Anchor Plate Assembly

The anchor plate includes lubricated floating guide pins sealed by rubber boots, and anchor plate pad abutments protected by stainless steel slippers. A tie bar, which spans the anchor plate abutment arms, is used on 73 mm pin slide disc brake installations only. A splash shield on the back of the rotor helps protect the brake assembly from road contamination. Bosses are provided for mounting an antilock brake system speed sensor. See **Fig. 4**.

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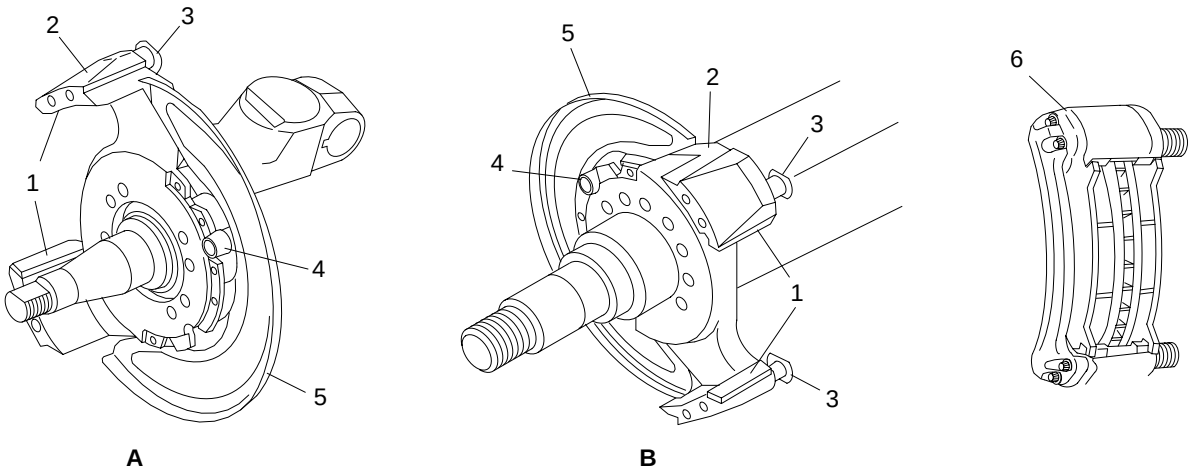
A. Front (66 mm shown)
1. Hydraulic Pistons with Seals and Boots
2. Sealed Pins
3. Anchor Plate
4. Upper Slipper

B. Rear (73 mm shown)
5. Brake Pads
6. Lower Slipper

Fig. 3, Bosch Pin Slide Brakes System Components

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General Information



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A. Front
B. Rear
1. Pad Abutment
2. Anchor Plate
3. Floating Guide Pin
4. Antilock Braking System Sensor Mounting
5. Splash Shield
6. Tie Bar (73 mm brakes only)

Fig. 4, Anchor Plate and Splash Shield

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General Safety Precautions

⚠ WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- Disconnect the batteries.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

⚠ WARNING

Hydraulic brake fluid is hazardous, and can cause blindness if it gets in your eyes. Always wear safety glasses when handling brake fluid or bleeding brake components. Brake fluid may also be a skin irritant. If you get it on your skin, wash it off as soon as possible.

Special care must be taken when disposing of used brake fluid. Put the fluid in a sealed plastic container and label it "Used Brake Fluid." Then dispose of it in an approved manner. Check with local and state regulations as to the correct disposal procedure.

IMPORTANT: During service procedures, keep grease and other foreign material away from caliper assemblies, disc brake pads, brake rotors and external surfaces of the hub. Handle parts carefully to avoid damage to the caliper, rotor, disc brake pads or brake lines.

Asbestos and Non-Asbestos Safety

⚠ WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH.

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the

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Safety Precautions

brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

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Brake Pad Removal, Inspection, and Installation |

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

IMPORTANT: It is recommended that all disc brake pads on the vehicle be replaced at the same time. This will maintain balanced braking. If complete replacement is not desirable or necessary, make sure that at a minimum all disc brake pads on one axle (both ends) are replaced at the same time.

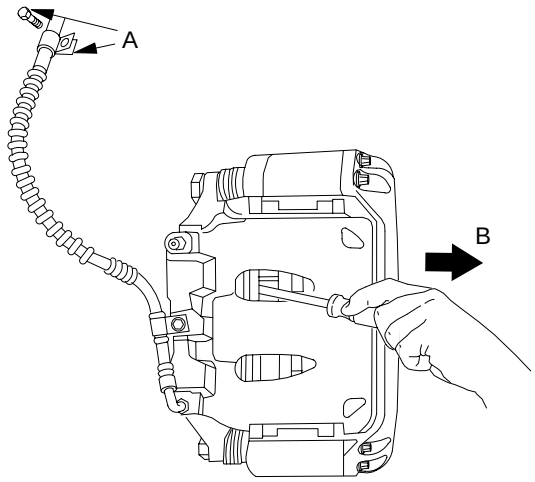
Removal

1. Park the vehicle on a level surface. Shut down the engine and apply the parking brake. Chock the front or rear tires, depending on which axle is being worked on.
2. Open the hood.
3. If removing rear axle wheel pads, remove about half of the fluid from the rear section of the master cylinder reservoir. If removing front axle wheel pads, remove about half of the fluid from the front section. Removing the fluid from the reservoir keeps the reservoir from overflowing when retracting pistons into the caliper.
4. Jack up the axle to be worked on and support it with jackstands.
5. Remove the tires.
6. Visually inspect all brake pad linings. Lining pads should be replaced when the remaining lining reaches 3/16-inch (5-mm) thickness or less.

⚠ CAUTION

Care must be taken when positioning the pry bar. Incorrect positioning of the pry bar could result in damage to the caliper.

7. Insert a pry bar in one of the rotor cooling fin slots and pry the caliper outboard, pushing the caliper pistons into the piston bores. See **Fig. 1**.
8. On front axles only, remove the brake line retaining clip from its support mounting. This will allow the brake line hose to hang free. See **Fig. 1**.



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A. Remove this screw and clip on front axles only.
B. Move the caliper outboard to push the pistons in.

Fig. 1, Piston Retraction and Brake Line Clip Removal

IMPORTANT: When servicing disc brake pads only, loosen and remove the upper (top) caliper pin mounting bolt. Do not loosen the lower (bottom) pin mounting bolt.

9. Remove only the upper (top) pin mounting bolt. See **Fig. 2**.

⚠ CAUTION

Do not pull on the guide pins. This may dislodge the guide pin boot from the guide pin or anchor plate grooves, which could damage the guide pin boot.

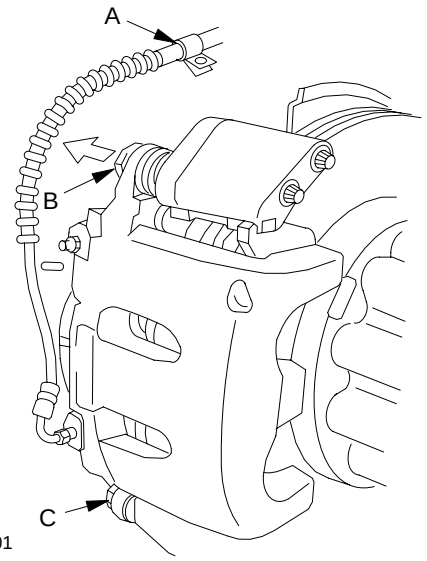
10. Swing the caliper assembly away from the rotor by carefully rotating the caliper on the lower pin mounting bolt and guide pin. See **Fig. 3**. Do not allow the brake line hose to become pinched or kinked.
11. Remove the inboard and outboard disc brake pads from the anchor plate pad abutment slippers.

IMPORTANT: Do not mark on the pad face.

12. If the original disc brake pads are to be reused, be sure to mark them in some manner so that they are installed in the same location.

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Brake Pad Removal, Inspection, and Installation



A. Make sure this clip is detached from the support bracket.
B. Remove the upper pin mounting bolt.
C. Do not loosen the lower pin mounting bolt.

Fig. 2, Remove Upper Pin Mounting Bolt

Inspection

IMPORTANT: Do not damage or dislodge the guide pin boots while cleaning the machined surfaces.

1. Inspect the machined surfaces of the caliper, guide pin mounting face, and anchor plate. If rust or corrosion is present, use a hand-held wire brush to clean the surfaces.
2. Inspect the caliper, piston seals, and pistons for leakage or damage. If leakage or damage is found, repair or replace the piston(s) as required.
3. Inspect the anchor plate for damage to the mating surfaces at the anchor plate pad abutment slippers and guide pin heads. If damage is found, repair or replace as required.
4. Inspect the rotor for scoring, warping, cracks, bluing, heat spots, or other damage. See **Fig. 4**. If any damage is found, repair or replace the rotor. For instructions, see **Subject 140**.

Installation

1. Position a metal plate across both caliper pistons. Use a C-clamp to push both pistons into the caliper to provide clearance for the new disc brake pads. See **Fig. 5**.

CAUTION

When replacing disc brake pads, make sure to use the same lining material on both axle ends. Mixing lining types can result in unbalanced braking, increased pad wear, or degraded stopping performance.

IMPORTANT: Inboard and outboard brake pads may not be interchangeable. The word "Forward" and an arrow, indicating the forward rotation of the rotor, may appear on each pad backing plate. Orient the pads as indicated by the arrow.

2. Position the inboard and outboard disc brake pads onto the anchor plate pad abutment slippers with the lining facing toward the rotor. See **Fig. 6**.

CAUTION

Use care when positioning the caliper over the disc brake pads, rotor, and upper guide pin head to avoid tearing, cutting, or dislodging the piston boots or guide pin boot.

3. Carefully swing the caliper into position over the brake pads and rotor. Do not allow the brake line hose to become pinched or kinked. Align the flat on the upper guide pin head with the flat on the caliper upper guide pin boss. See **Fig. 7**.

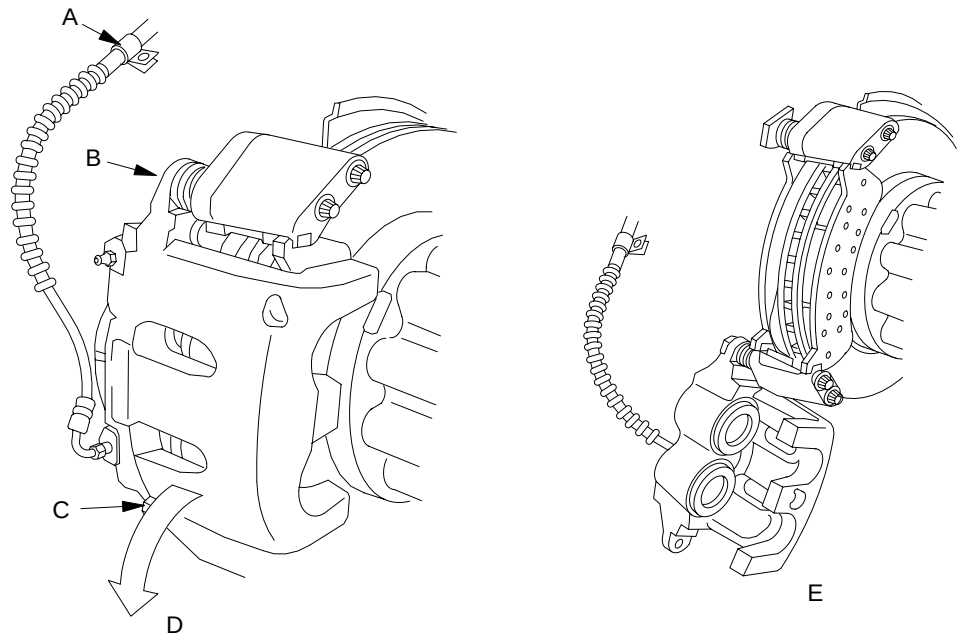
CAUTION

Always tighten caliper pin mounting bolts in the proper sequence. Do not overtighten caliper pin mounting bolts. Increased brake drag may result from incorrect tightening.

IMPORTANT: If the lower mounting bolt was loosened, determine the proper tightening sequence, as shown in **Fig. 8**, before tightening either the upper or lower mounting bolt.

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Brake Pad Removal, Inspection, and Installation |



A. Make sure this clip is detached from the support bracket.
B. Guide pin bolt has been removed.
C. Do not loosen the lower pin mounting bolt.
D. Swing the caliper down until it stops.
E. Caliper in the lowered position.

Fig. 3, Open Caliper to Access Brake Pads and Pistons

4. Hold the caliper in the closed position with the caliper upper guide pin boss hole aligned with the threaded hole in the upper guide pin head. Hand thread the pin mounting bolt. Tighten the bolt 93 to 107 lbf·ft (126 to 145 N·m). See **Fig. 8**.
5. On front axles only, install the previously removed brake line retaining clip. Make sure the brake line hose is not pinched or kinked.
6. Visually inspect all components serviced. Make sure the mounting pins are torqued according to the specifications in this procedure. Make sure the pads are seated and positioned to slide along the pad abutment slippers.
7. Install the tires, remove the jackstands, and lower the vehicle.
8. Fill the applicable section of the master cylinder reservoir with new DOT 3 approved brake fluid. The brake fluid level should be even with the raised seam on the outside circumference of the reservoir.
9. Pump the brake pedal until it feels firm. If it does not get firm, check for leaks or air in the brake system. Repair any leaks, if needed, then bleed the system. See **Subject 160** for brake bleeding procedures.

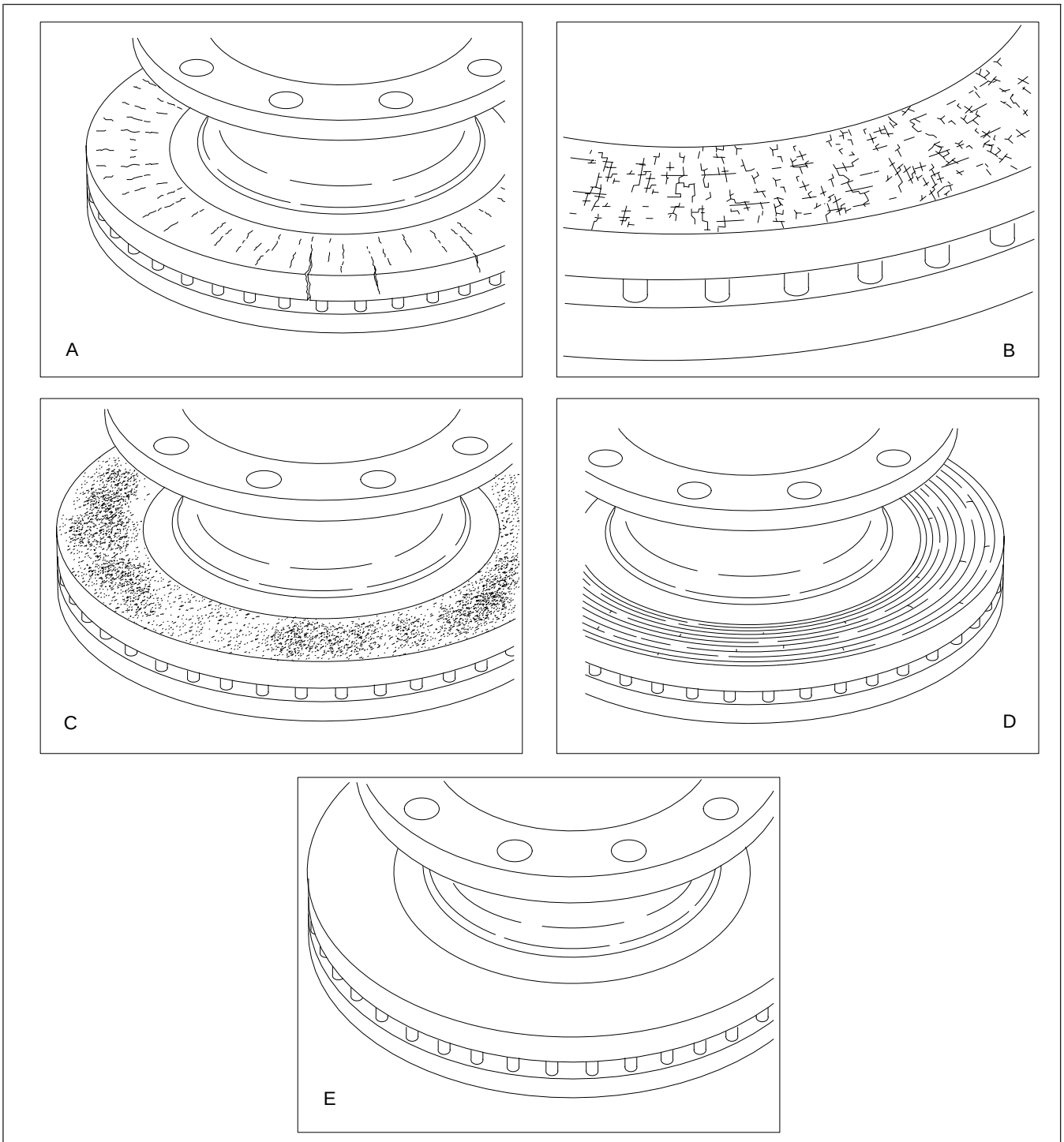
⚠ WARNING

Do not move the vehicle until the brake pedal feels firm. To do otherwise could result in loss of vehicle control, causing an accident resulting in personal injury or property damage.

10. Close the hood and remove the chocks from the tires.
11. Road test the vehicle and seat the brake pads.
    11.1 Accelerate the vehicle to 30 mph (50 km/h), then brake to a stop, using medium brake pedal pressure. *Do not slam on the brakes.*

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Brake Pad Removal, Inspection, and Installation



A. Cracking
B. Heat Checking
C. Discoloration
D. Scoring
E. Normal Finish

Fig. 4, Rotor Surface Check

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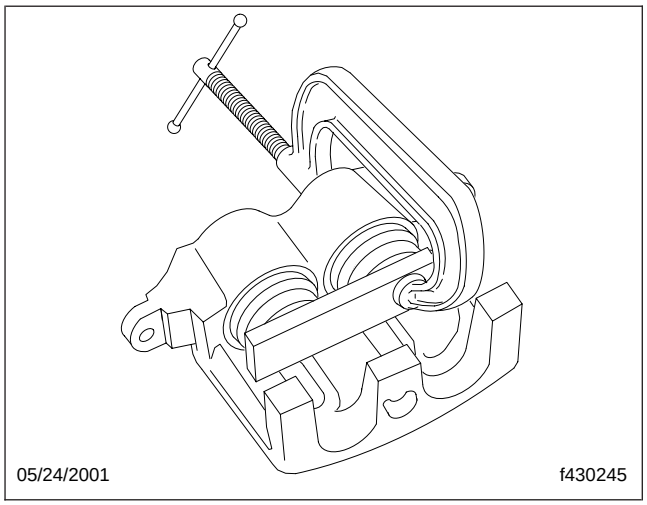
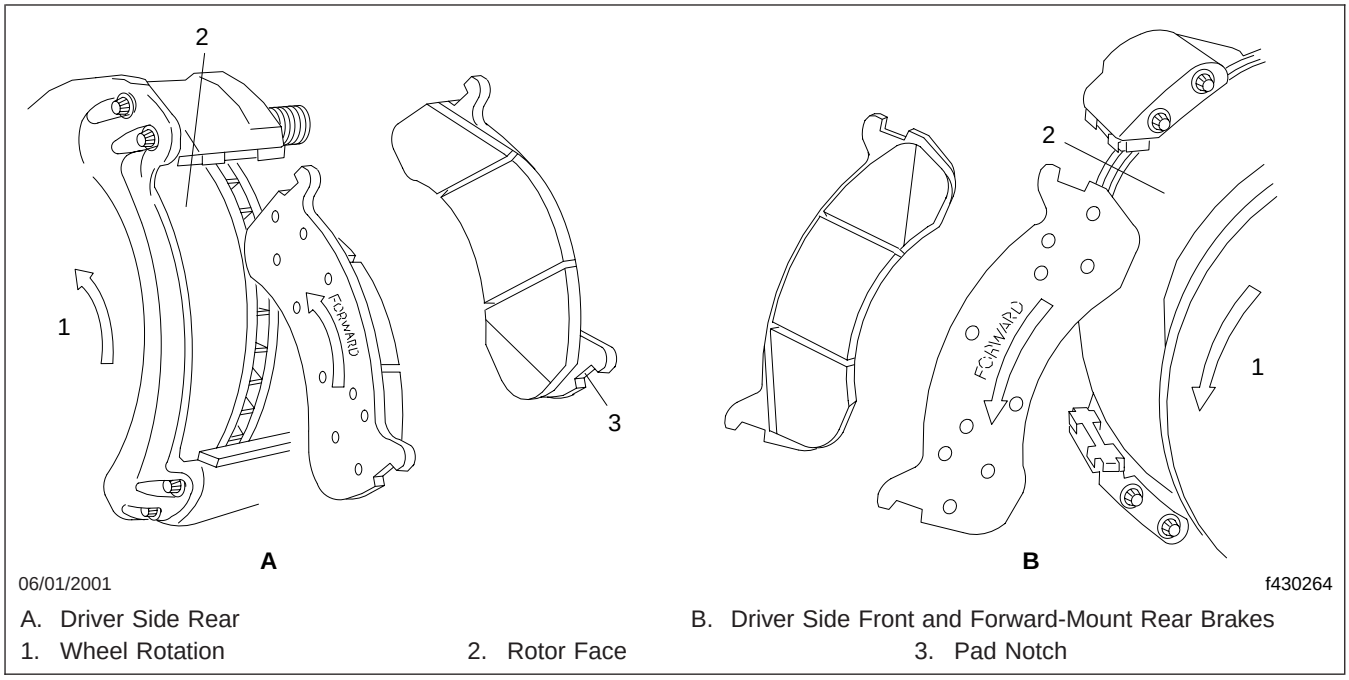


Fig. 5, Retract Pistons Into Caliper



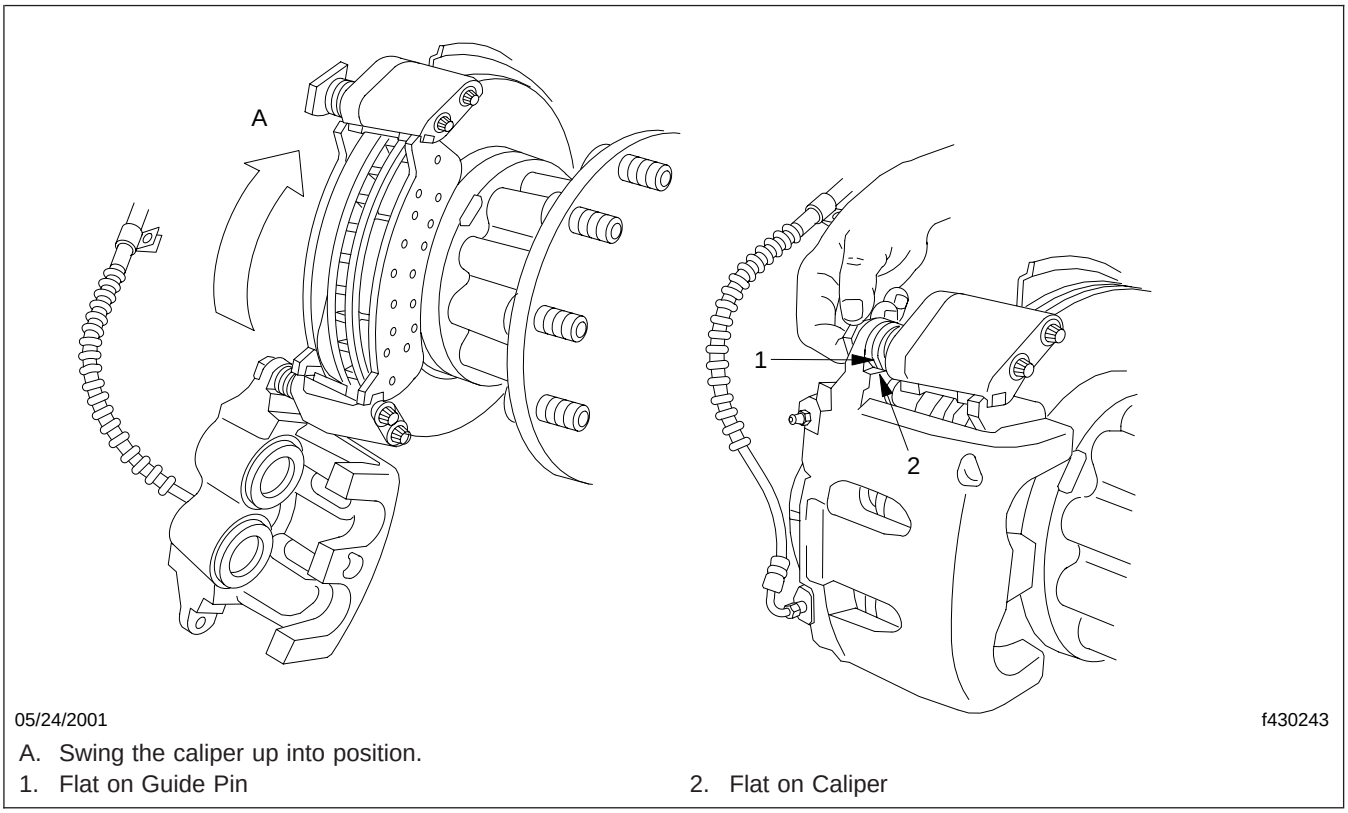
A. Driver Side Rear
B. Driver Side Front and Forward-Mount Rear Brakes
1. Wheel Rotation
2. Rotor Face
3. Pad Notch

Fig. 6, Replacing Brake Pads on Front and Rear Brakes

11.2 Repeat this step 4 or 5 times, allowing a 1-minute interval between brake applications.

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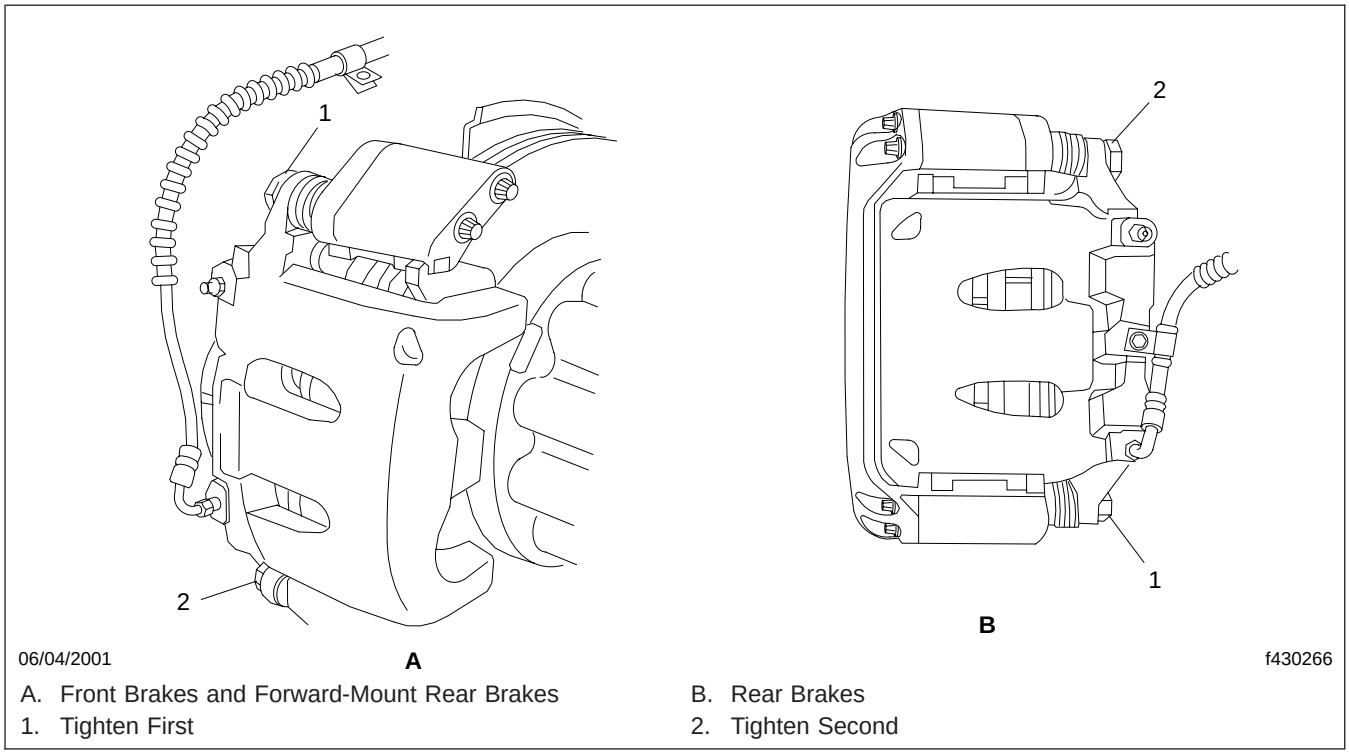
Brake Pad Removal, Inspection, and Installation



A. Swing the caliper up into position.
1. Flat on Guide Pin
2. Flat on Caliper

Fig. 7, Swing the Caliper Over the Brake Pads and Rotor

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A. Front Brakes and Forward-Mount Rear Brakes
B. Rear Brakes
1. Tighten First
2. Tighten Second

Fig. 8, Tightening Sequence for Caliper Mounting Bolts

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Brake Caliper Removal and Installation

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

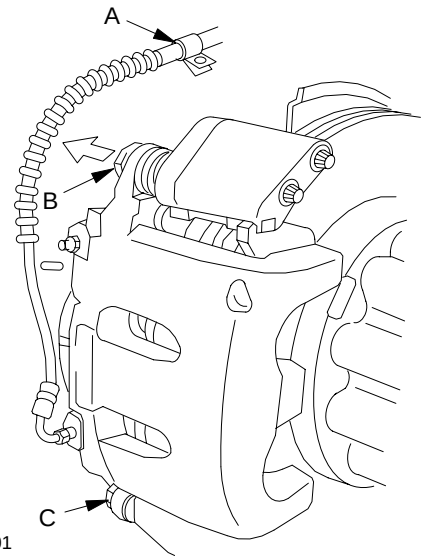
Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the front or rear tires, depending on which axle is being worked on.
2. Open the hood.
3. If removing the rear wheel caliper(s), remove half the fluid from the rear section of the master cylinder reservoir. If removing the front wheel caliper(s), remove half the fluid from the front section. Removing the fluid from the reservoir keeps the reservoir from overflowing when retracting pistons into the caliper.
4. Jack up the axle to be worked on and support it with jackstands.
5. Remove the tires.
6. On front axles only, remove the brake line retaining clip from its support mounting. This will allow the brake line hose to hang free. See **Fig. 1**.
7. Remove the upper (top) guide pin mounting bolt. See **Fig. 1**.

⚠ CAUTION

Do not pull on the guide pins. This may dislodge the guide pin boot from the guide pin or anchor plate grooves, which could damage the guide pin boot.

8. Swing the caliper assembly away from the rotor by carefully rotating the caliper on the lower pin mounting bolt and guide pin. See **Fig. 2**. Do not allow the brake line hose to become pinched or kinked.
9. Disconnect the brake fluid line from the caliper. See **Fig. 3**.
10. Remove the lower guide pin mounting bolt and remove the caliper from the anchor plate.



A. Make sure this clip is detached from the support bracket.
B. Remove the upper guide pin mounting bolt.
C. Do not loosen the lower pin mounting bolt.

Fig. 1, Upper Guide Pin Mounting Bolt Removal

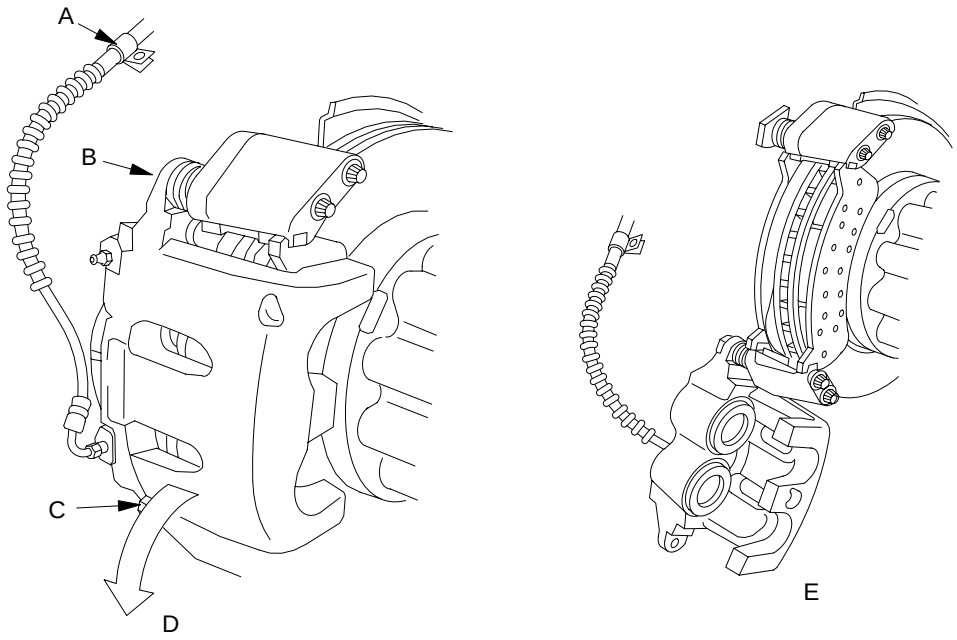
Installation

NOTE: Use isopropyl alcohol to clean brake seals, boots, and pistons. Do not soak components for an extended period of time.

1. Clean contamination, dirt, and debris from the exterior of the caliper, machined faces, and around the caliper piston boots.
2. Visually inspect the caliper for brake fluid leakage or damage to pistons or piston boots. If there is leakage or damage, the caliper should be repaired or replaced. For repair instructions, see **Subject 130**.
3. Make sure the pistons are fully retracted into the caliper. Piston boots must be fully seated in the piston boot groove and the boot grooves in the caliper face.
4. Position the caliper on the anchor plate with the caliper lower guide pin boss hole aligned with the threaded hole in the lower guide pin head. Hand thread the pin mounting bolt through the caliper and into the anchor plate.

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Brake Caliper Removal and Installation



05/24/2001 f430244

A. Make sure this clip is detached from the support bracket.
B. Guide pin bolt has been removed.
C. Lower Guide Pin Bolt
D. Swing the caliper down until it stops.
E. Caliper in the lowered position.

Fig. 2, Rotating the Caliper Away From the Rotor

⚠ CAUTION

Use care when positioning the caliper over the disc brake pads, rotor, and upper guide pin head to avoid tearing, cutting, or dislodging the piston boots or guide pin boot.

5. Carefully swing the caliper up into position over the pads and rotor. Align the flat on the upper guide pin head with the flat on the caliper upper guide pin boss. See **Fig. 4**.

⚠ CAUTION

Always tighten caliper pin mounting bolts in the proper sequence. Do not overtighten caliper pin mounting bolts. Increased brake drag may result from incorrect tightening.

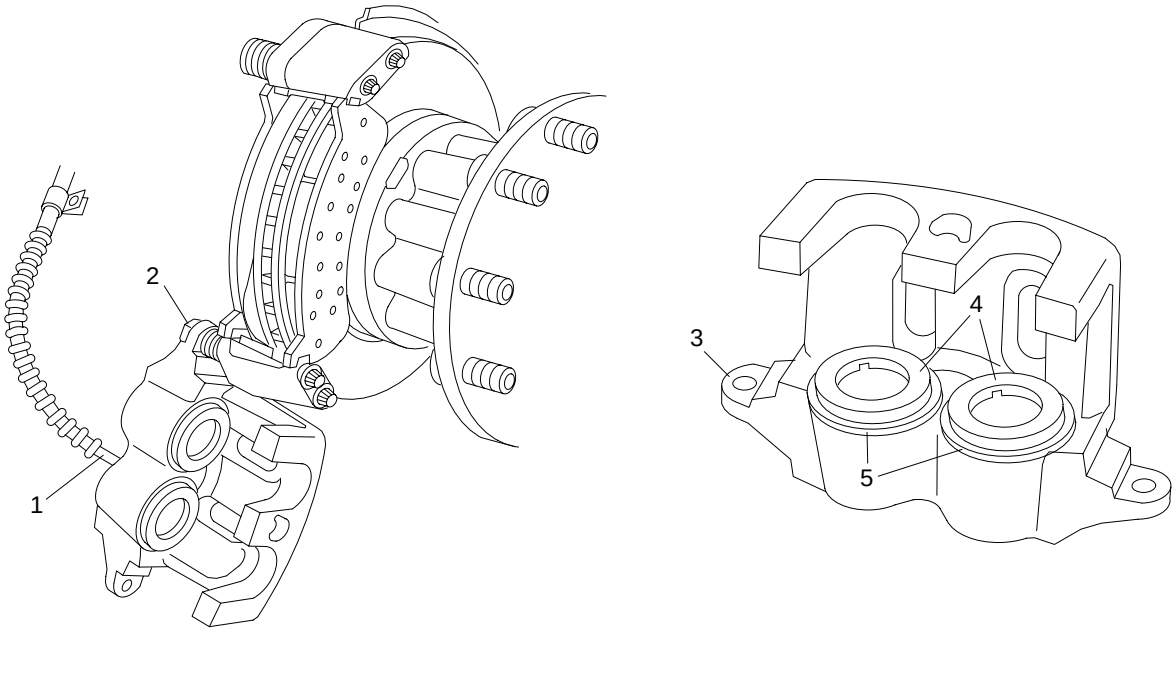
6. Hold the caliper in the closed position with the caliper upper guide pin boss hole aligned with the threaded hole in the upper guide pin head. Hand-thread the upper pin mounting bolt.

IMPORTANT: See **Fig. 5** and **Fig. 6** before tightening either the upper or lower mounting bolt.

7. Tighten the bolts 93 to 107 lbf·ft (126 to 145 N·m) in the sequence shown in **Fig. 5** and **Fig. 6**.
8. On front axles only, install the previously removed brake line retaining clip. Make sure the brake line hose is not pinched or kinked.
9. Connect the brake fluid line to the caliper. Do not allow the brake line hose to become pinched or kinked.
   - 9.1 Tighten the brake line hose fitting 15 lbf·ft (20 N·m).
   - 9.2 Bleed the brake line to the caliper, following the instructions in **Subject 160**. If you have removed more than one brake caliper, bleed the entire brake system.
10. Install the tires, remove the jackstands, and lower the vehicle.

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Brake Caliper Removal and Installation



1. Brake Line
2. Lower Guide Pin Bolt
3. Machined Face
4. Pistons
5. Piston Boots

Fig. 3, Caliper Removal from Anchor Plate

11. Fill the applicable section of the master cylinder reservoir with new DOT 3 approved brake fluid. The brake fluid level should be even with the raised seam on the outside circumference of the reservoir.
12. Close and latch the hood.
13. Remove the chocks from the tires.

⚠ WARNING

Do not move the vehicle until the brake pedal feels firm. To do otherwise could result in loss of vehicle control, causing an accident resulting in personal injury or property damage.

14. Seat the brake pads by pressing firmly on the brake pedal several times.

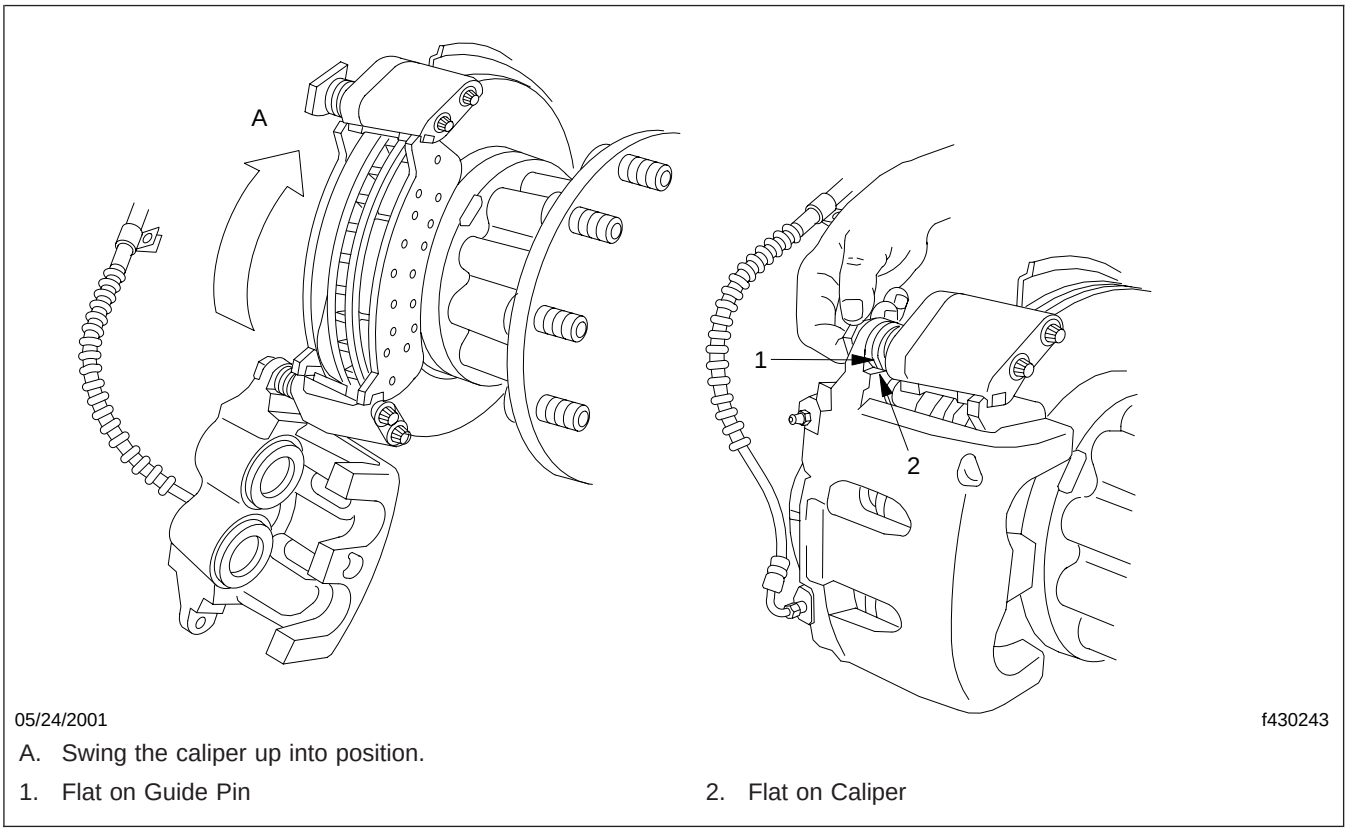
    If new brake pads were installed, road test the vehicle to seat the brake pads.

    14.1 Accelerate the vehicle to 30 mph (50 km/h), then brake to a stop, using medium brake pedal pressure. *Do not slam on the brakes.*

    14.2 Repeat this step 4 or 5 times, allowing a 1-minute interval between brake applications.

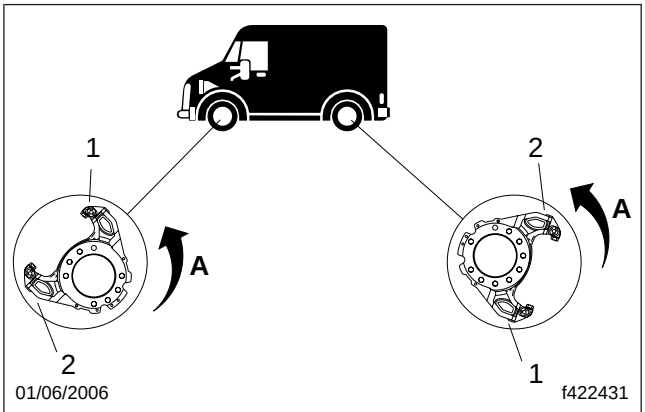
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Brake Caliper Removal and Installation



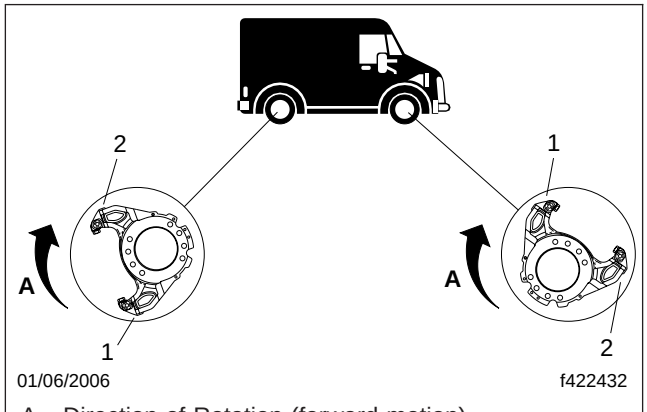
A. Swing the caliper up into position.
1. Flat on Guide Pin
2. Flat on Caliper

Fig. 4, Rotating the Caliper Over the Brake Pads and Rotor



A. Direction of Rotation (forward motion)
1. Tighten First
2. Tighten Second

Fig. 5, Tightening Sequence for Caliper Mounting Bolts, Left Side



A. Direction of Rotation (forward motion)
1. Tighten First
2. Tighten Second

Fig. 6, Tightening Sequence for Caliper Mounting Bolts, Right Side

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Brake Rotor Runout and Parallelism Check

Runout Check

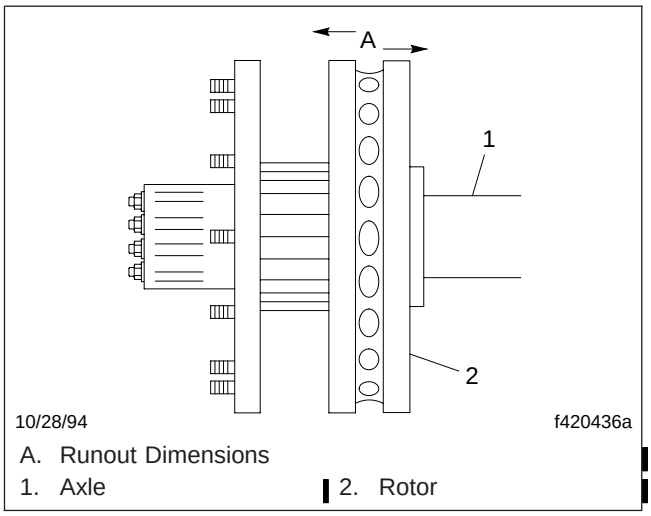
Brake rotor runout refers to the amount of lateral wobble the rotor has when it is turning, with the wheel bearings correctly adjusted. See **Fig. 1**. Check the rotor runout whenever you replace the brake pads.

1. If not already done, chock the tires, jack up the axle you are working on, and support it with jackstands. Remove the wheels and tires.
2. If working on the rear axle, put the transmission in neutral.
3. Using a dial indicator, measure the amount of runout while spinning the rotor, as shown in **Fig. 2**. Make sure the indicator is centered on the rotor face (between the outer and inner edges).
4. If the runout is more than 0.015 inch (0.38 mm), check that the rotor is securely mounted to the hub. Also check the wheel bearing end-play, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
5. Repeat the runout measurement. If the runout is still more than 0.015 inch (0.38 mm), replace the rotor.

Parallelism Check

Parallelism is the difference in rotor thickness at different points around the rotor. It should be checked whenever the brake pads are replaced.

1. Using a micrometer, measure the thickness of the rotor (between the inboard and outboard faces) at four or more equally spaced points around the rotor. See **Fig. 3**.
2. If there is a difference of more than 0.005 inch (0.13 mm) between any two measurements, have the rotor resurfaced. If resurfacing will decrease the overall thickness of the rotor to 1.32 inches (33.5 mm) or less, replace the rotor.



A. Runout Dimensions
1. Axle
2. Rotor

Fig. 1, Brake Rotor Runout

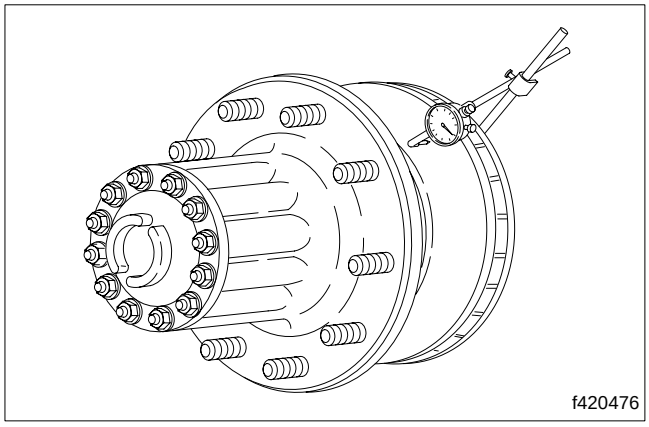
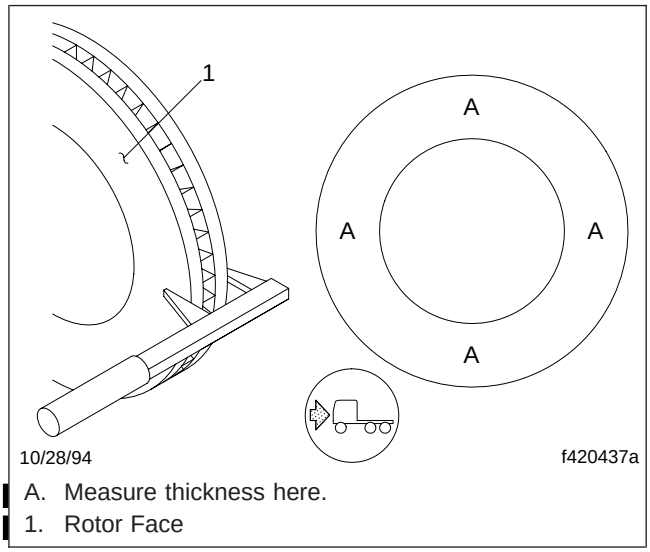


Fig. 2, Measure Runout

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Brake Rotor Runout and Parallelism Check



A. Measure thickness here.
1. Rotor Face

Fig. 3, Measure Rotor Thickness

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Anchor Plate Disassembly, Cleaning and Inspection, and Assembly

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Disassembly

1. Park the vehicle on a level surface. Shut down the engine. Chock the rear or front tires, as required.
2. Jack up the vehicle. Support the axle with jackstands.
3. Remove the tire.
4. Remove the brake caliper from the anchor plate following the instructions in **Subject 120**.
5. Remove the tie bar from the anchor plate on 73 mm brakes, or remove the plugs from the anchor plate on 66 mm brakes.
6. Remove the brake pads from the anchor plate. For instructions, see **Subject 110**.
7. Remove the wheel hub and rotor assembly from the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
8. Remove the three screws that hold the dust shield to the anchor plate and remove the dust shield.
9. Remove the antilock braking system sensor bracket from the anchor plate. See **Fig. 1**.
10. Remove the hexbolts, washers, and nuts that hold the anchor plate to the axle. See **Fig. 2**, and remove the anchor plate from the axle.
11. Remove the brake pad abutment slipper using a blunt-nose drift pin or screwdriver and a light hammer. Avoid marring the anchor plate abutment surfaces. See **Fig. 3**.
12. Remove the guide pins and guide pin boots by pulling out the guide pin with a slight twisting motion.

Cleaning and Inspection

1. Clean the anchor plate with a brush and solvent. Make sure the anchor plate abutments, anchor plate tie bar mounting surfaces, axle flange mounting surface, and anchor plate boot grooves are clean and free of any rust or corrosion. See **Fig. 4**. Use a hand-held wire brush to clean these surfaces. It is important to clean these areas of the anchor plate. Also make sure the tie bar bolt hole threads are clean and free of foreign matter.
2. Clean the guide pin bores with a bore brush and solvent. Use compressed air to clean out and dry the guide pin bores. Check the guide pin bores for excessive wear. Replace the anchor plate, if necessary.
3. Clean the guide pin boots with isopropyl alcohol. Do not use solvent to clean the boots. Inspect each guide pin boot for cracks, tears, holes, and flexibility. If damage is found, the boot must be replaced. See **Fig. 5**.
4. Clean the guide pins with isopropyl alcohol. Make sure the guide pins, and the threads in the guide pins, are free of foreign matter and corrosion. Use compressed air to clean out and dry the guide pins and the bolt threads in the guide pins. Check the guide pins for wear. Replace them if excessive wear is detected.
5. Inspect the pad abutment slippers for damage or wear and clean them with solvent. Replace them if damage or excessive wear is detected.
6. Inspect the anchor plate for worn or damaged slipper mounts, and worn or damaged guide pin bores. If signs of wear or damage are found, the anchor plate should be repaired or replaced.

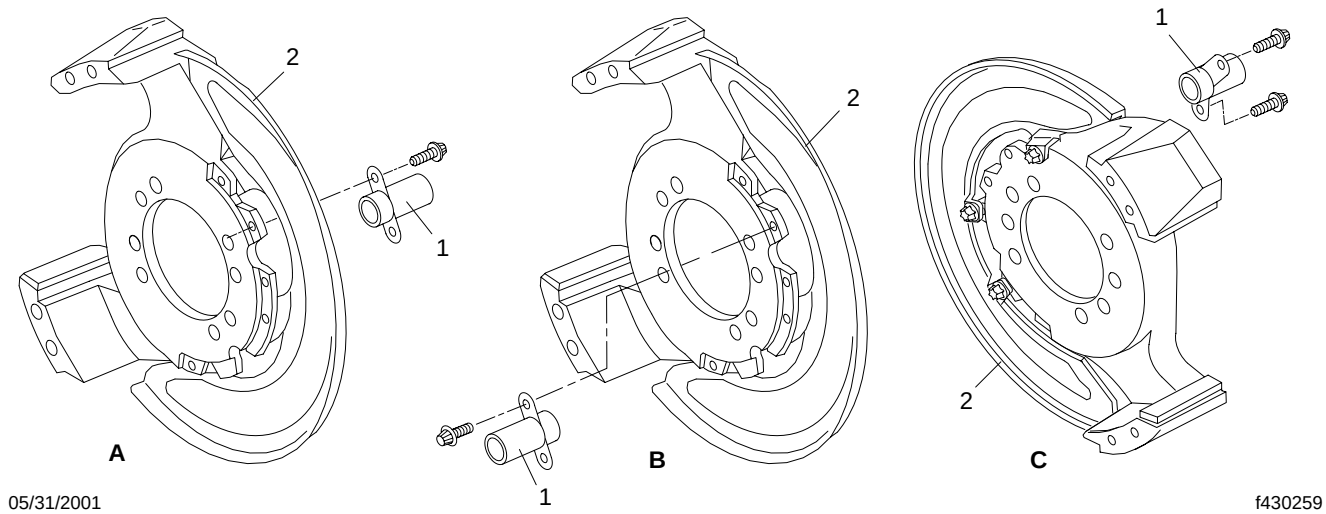
Assembly

NOTE: All brake parts must be clean and completely dry of cleaning fluids before assembly.

1. Uniformly apply Aeroshell Grade 5 grease to the entire guide pin bore and on the guide pin shaft. Use 1/8 ounce (3 grams) of grease to thoroughly lube each guide pin and guide pin bore set. See **Fig. 6**.
2. Apply a thin coat of Aeroshell Grade 5 grease to the inside opening at each end of the boot.
3. Slide the guide pin into the guide pin boot.
4. Insert the guide pin with the boot into the anchor plate guide pin bore until the boot is completely compressed.

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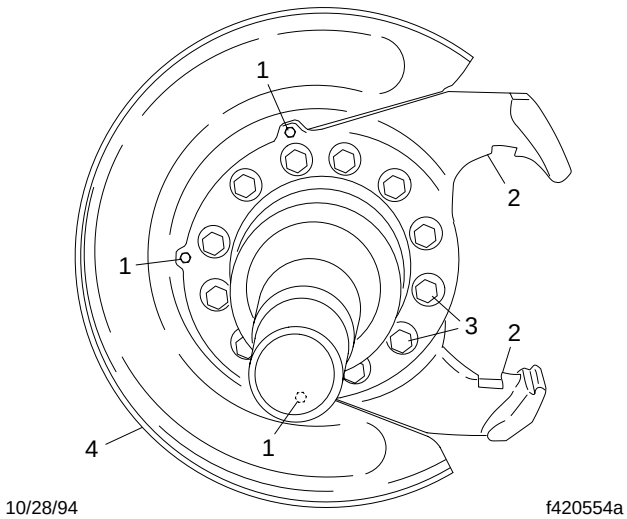
Anchor Plate Disassembly, Cleaning and Inspection, and Assembly



A. Driver Side Front Anchor Plate Assembly (66 mm brakes)
B. Driver Side Front Anchor Plate Assembly (73 mm brakes)
C. Driver Side Rear Anchor Plate Assembly (typical)

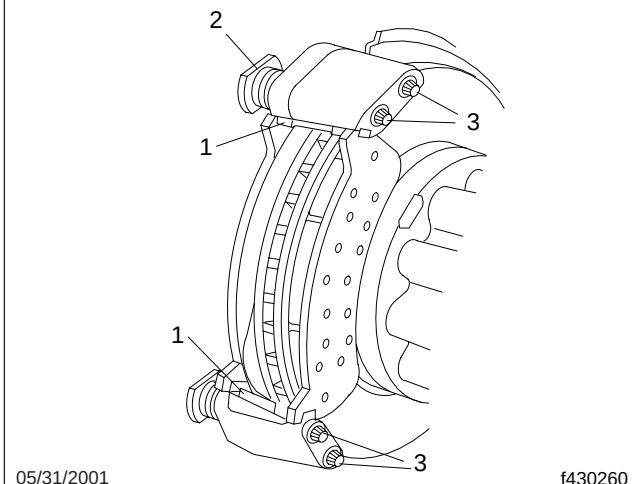
1. Sensor Bracket
2. Dust Shield

Fig. 1, Dust Shield and Sensor Mounting Bracket



1. Dust Shield Screw
2. Anchor Plate
3. Mounting Hexbolts
4. Dust Shield

Fig. 2, Axle End (typical)



1. Pad Abutment Slipper
2. Guide Pin and Pin Boot
3. Plugs (66 mm brakes only)

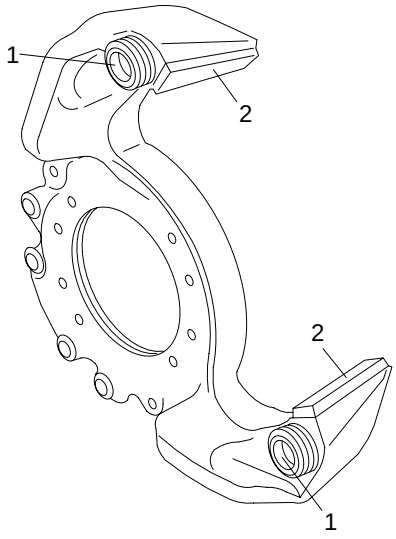
Fig. 3, Anchor Plate Components

5. Rotate the guide pin 1/4- to 1/2-turn back and forth in order to seat the guide pin boot.

6. Inspect the guide pin boot to make sure the boot is fully seated all around the guide pin and the anchor plate retaining grooves.

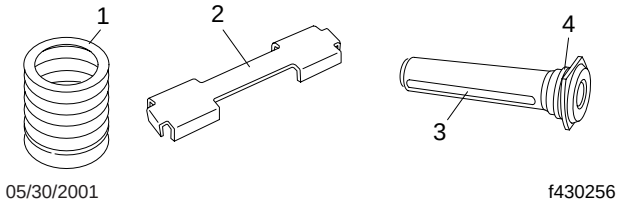
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Anchor Plate Disassembly, Cleaning and Inspection, and Assembly



1. Guide Pin Bore and Boot Groove
2. Pad Abutment Slipper Mounting

Fig. 4, Anchor Plate Machined Surfaces



1. Guide Pin Boot
2. Pad Abutment Slipper
3. Guide Pin
4. Boot Groove

Fig. 5, Loose Anchor Plate Components

7. Install an anchor plate pad abutment slipper onto each anchor plate abutment. See **Fig. 7**. Use a soft brass or other light hammer to be sure the slipper is seated on the abutment. Avoid marring anchor plate abutment slipper surfaces.
8. Install the dust shield and antilock braking system sensor bracket on the anchor plate.

   When installing the dust shield and sensor bracket on the anchor plate for 66 mm front and all rear brakes, the splash shield and sensor bracket are mounted on the inboard side of the anchor plate and the five bolts are installed from the inboard side. Tighten the bolts 12 to 16 lbf·ft (17 to 21 N·m).

   For 73 mm front brakes, the dust shield and sensor bracket are mounted on the outboard side of the anchor plate and the five bolts are installed from the outboard side. Tighten the bolts 12 to 16 lbf·ft (17 to 21 N·m).
9. Remove all traces of dirt, grease, and oil from the knuckle and axle brake flange.
10. Install the anchor plate on the axle.

    10.1 Position the anchor plate against the outboard side of the axle flange, making sure the holes in both are lined up.

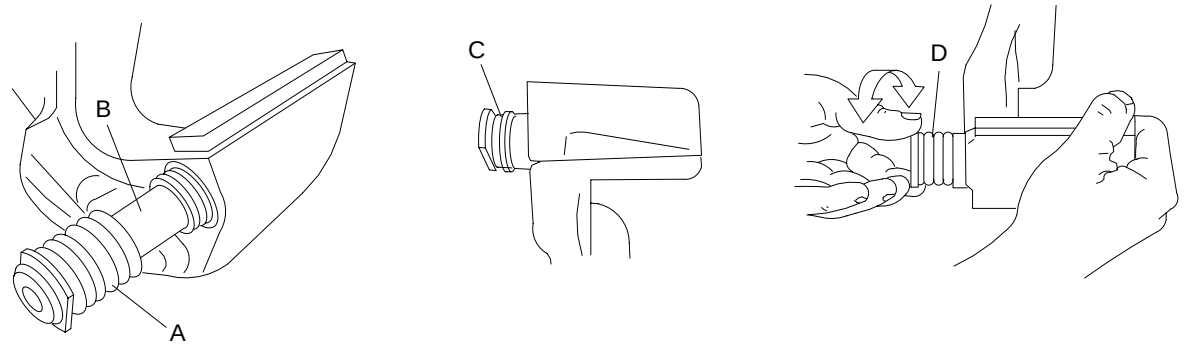
    10.2 From the outboard side of the anchor plate, install the hexbolts and washers. Install the nuts and remaining washers. See **Fig. 2**. Using a star pattern, tighten the hexnuts as follows:

    - Rear Axle; 97 to 123 lbf·ft (132 to 167 N·m)
    - Front Axle Type FC; 70 to 89 lbf·ft (95 to 121 N·m)
    - Front Axle Type FD/FF; 134 to 172 lbf·ft (182 to 233 N·m)
11. Install the wheel hub and rotor assembly on the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
12. On 66 mm brakes, install the four bolt plugs into the anchor plate face. Tighten 16 to 27 lbf·ft (22 to 37 N·m). See **Fig. 8**.

    On 73 mm brakes, install the anchor plate tie bar and the four tie bar bolts to the anchor plate face. Tighten 40 to 50 lbf·ft (54 to 68 N·m).
13. Install the brake caliper on the anchor plate following the instructions in **Subject 120**.
14. Install the brake pads in the anchor plate. For instructions, see **Subject 110**.
15. Install the tire.
16. Remove the jackstands. Lower the vehicle.
17. Remove the chocks.

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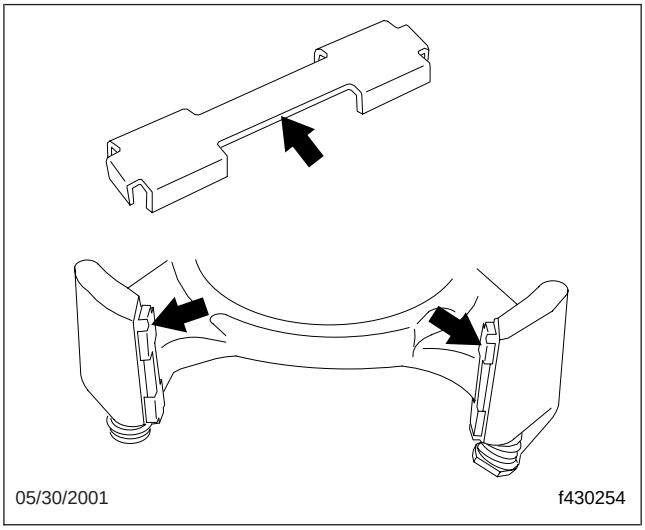
Anchor Plate Disassembly, Cleaning and Inspection, and Assembly



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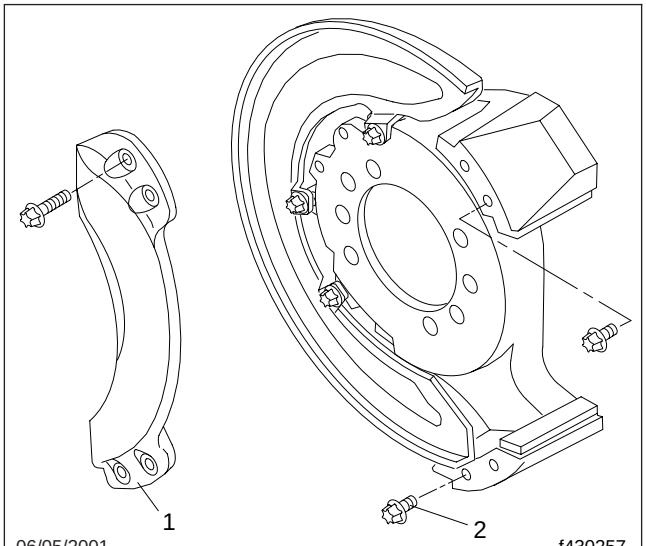
A. Lube the inside of the boot, both ends.
B. Apply Aeroshell Grade 5 grease to the bore and the pin.
C. Boot and pin in place.
D. Twist to seat in the groove.

Fig. 6, Install Guide Pins and Boots



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Fig. 7, Pad Abutment Slipper



06/05/2001 f430257

1. Tie Bar (73 mm brakes only)
2. Plug (66 mm brakes only)

Fig. 8, Plugs and Tie Bar

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General Information

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Whenever any hydraulic system fitting is loosened or disconnected, the entire system must be bled to remove any air that may have entered it. Always bleed the master cylinder first, then bleed the calipers starting at the caliper furthest away from the master cylinder then bleed the next furthest, etc., untill you get to the closest.

⚠ CAUTION

Power steering fluid and brake fluid are incompatible. Never mix these two fluids or serious damage to both hydraulic systems will result. Use only brake fluid for the master cylinder and brake lines. Use only power steering fluid for the power booster.

Always use new, clean brake fluid that meets DOT 3 specifications when bleeding the master cylinder and service brake system. Never reuse brake fluid and do not use brake fluid containers for any other purpose. Keep brake fluid containers tightly closed to keep new brake fluid clean and dry.

IMPORTANT: Do not let brake fluid touch any painted surfaces, as it will remove the paint. Brake fluid may also damage certain non-metal surfaces. Do not let it get on brake pads or rotors.

NOTE: Pressure bleeding is the preferred method for bleeding the service brake system. It requires the use of a special pressure bleeder kit, consisting of a tank, pressure pump and valve, gauge, tubing, and an adapter. These are available from a number of manufacturers and include instructions for their use. See **Fig. 1**. If you do not have pressure bleeding equipment, you can use the manual bleeding procedure shown later in this subject.

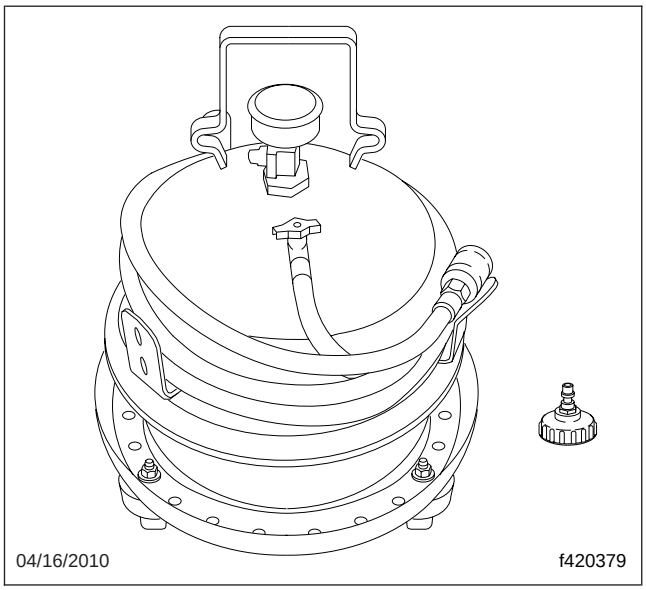


Fig. 1, Pressure Bleeder Kit

Pressure Bleeding

1. Fill the pressure bleeder with new DOT 3 approved brake fluid. Pressurize it according to the manufacturer's instructions.
2. Using the supplied adapter, connect the pressure bleeder to the rear compartment of the master cylinder reservoir.
3. Put a wrench on the bleeder fitting at the right rear caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.
4. Loosen the bleeder fitting about 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.
5. Move to the left rear caliper and repeat the steps for bleeding the caliper.
6. Disconnect the pressure bleeder from the rear compartment of the master cylinder reservoir. Connect it to the front compartment of the reservoir.
7. Put a wrench on the bleeder fitting at the right front caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

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System Bleeding

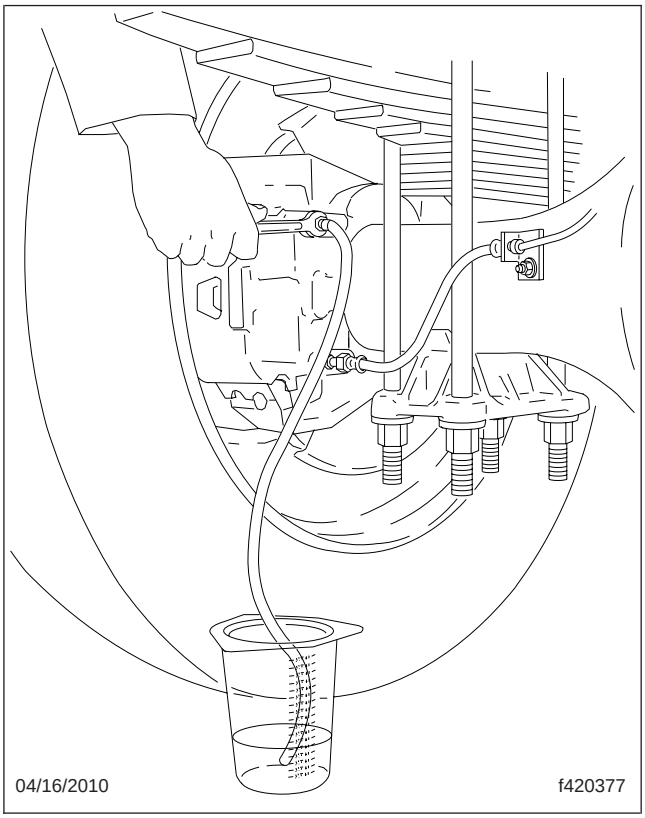


Fig. 2, Bleed the Hydraulic Connection

8. Loosen the bleeder fitting about 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.
9. Move to the left front wheel caliper and repeat the steps for bleeding the caliper.
10. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.
11. Check the operation of the brakes by depressing the brake pedal several times, until if feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting 300** and find the problem.

Manual Bleeding

WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

IMPORTANT: Do not let the brake master cylinder run dry during manual bleeding operations. Keep the master cylinder reservoir filled with new DOT 3 approved brake fluid. Failure to keep the brake reservoir filled could result in more air entering the system, making it impossible to effectively bleed the system.

1. Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the rear outlet port on the master cylinder. See **Fig. 3**. Loosen the fitting about one turn.

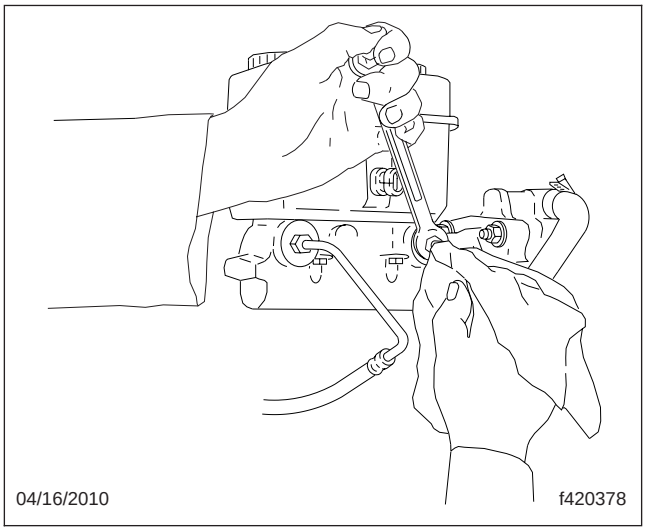


Fig. 3, Rear Outlet Port

2. Have someone push the brake pedal down slowly by hand to the floor. Brake fluid, and any air in the master cylinder, will squirt from the fitting.
3. *With the brake pedal held down*, tighten the rear hydraulic line fitting firmly.

IMPORTANT: Do not release the brake pedal until the fitting is tightened, or more air will get into the system.

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4. Release the brake pedal.
5. Loosen the fitting again, and repeat the steps for bleeding as required until no air escapes from the fitting, and the brake pedal feels firm.
6. Check the level of the rear compartment of the reservoir, then add new DOT 3 approved brake fluid if needed.
7. Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the front outlet port on the master cylinder. See **Fig. 4**. Loosen the fitting about one turn.

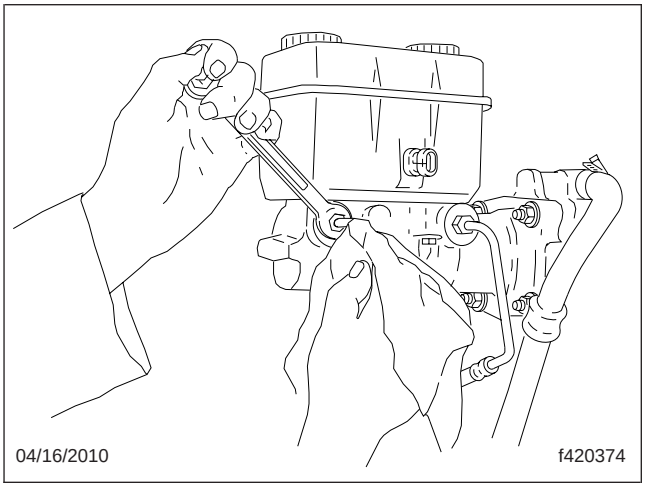


Fig. 4, Front Outlet Port

8. Repeat the steps as required for the front outlet port.
9. Check the brake fluid level in the front compartment of the reservoir. Add new DOT 3 approved brake fluid if needed.
10. Starting at the right rear wheel caliper, put a wrench on the bleeder fitting at the caliper, then attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.
11. Loosen the bleeder fitting about 3/4 turn.
12. Have someone slowly push the brake pedal to the floor.

IMPORTANT: Make sure the brake pedal stays depressed while you tighten the fitting. If it is released before you tighten the fitting, more air will get into the system.

13. *With the brake pedal depressed*, tighten the bleeder fitting.
14. Release the brake pedal.
15. Check the fluid in the tube. If there are air bubbles present, repeat the steps as required until the fluid in the tube is completely free of air bubbles.
16. Check the brake fluid level in the reservoir. Add new DOT 3 approved brake fluid if needed.
17. Repeat the steps for bleeding the connections for the left rear caliper, the right front caliper and the left front caliper.
18. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.
19. Check the operation of the brakes by depressing the brake pedal several times, until if feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting 300** and find the problem.

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Troubleshooting Tables

IMPORTANT: See **Section 42.00** for detailed hydraulic brake system troubleshooting procedures.

Problem—Noise and Chatter

Problem—Noise and Chatter	
Possible Cause	**Remedy**
Bent, damaged, or incorrect pads	Replace with the correct pads in axle sets.
Worn out lining plates (plates rubbing rotor)	Resurface or replace the rotor. Replace the pads in axle set.
Rotor polished or linings glazed	Remove the polish or glaze.
Foreign material embedded in linings	Replace the pads in axle sets.
Excessive rotor thickness variations or lateral runout	Resurface or replace the rotor.

Problem—Brakes Grab

Problem—Brakes Grab	
Possible Cause	**Remedy**
Incorrect pads or pads loose on plate	Replace with the correct pads in axle sets.
Grease or brake fluid on linings	Repair the grease seal or caliper. Replace the pads in axle sets.
Loose caliper at anchor plate pins	Tighten to specifications.
Excessive rotor lateral runout	Check the bearing adjustment. Resurface or replace the rotor.

Problem—Vehicle Pulls to One Side

Problem—Vehicle Pulls to One Side	
Possible Cause	**Remedy**
Incorrect pads or loose lining on plates	Replace with the correct pads in axle sets.
Grease or brake fluid on linings	Repair the grease seal or caliper. Replace the pads in axle sets.
Loose caliper or anchor plate	Tighten to specifications.
Caliper piston sticking	Repair or replace the piston or replace the caliper.
Caliper guide pins sticking	Repair or replace the guide pins and boots. Clean the pin bores and lubricate.
Excessive rotor lateral runout	Check the bearing adjustment. Resurface or replace the rotor.

Problem—Pulsating Brake Pedal

Problem—Pulsating Brake Pedal	
Possible Cause	**Remedy**
Worn or damaged front wheel bearings	Replace the wheel bearings.
Excessive variation in rotor thickness	Resurface or replace the rotor.

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Troubleshooting

Problem—Springy or Spongy Pedal

Problem—Springy or Spongy Pedal	
Possible Cause	**Remedy**
Poor quality brake fluid (low boiling point)	Drain and clean the system. Refill with the approved brake fluid.
Weak brake hoses that expand under pressure	Replace the hoses.
Air in hydraulic system	Bleed the system. For instructions, see **Subject 160**.

Problem—All Brakes Drag (or Both Brakes on Same Axle)

Problem—All Brakes Drag (or Both Brakes on Same Axle)	
Possible Cause	**Remedy**
Binding brake pedal	Free-up and lubricate the pedal.
Soft or swollen rubber parts caused by incorrect or contaminated brake fluid	Replace rubber parts. Flush the system and refill with approved brake fluid. For instructions, see **Subject 160**.
Trapped pressure in brake lines caused by master cylinder and/or booster not fully releasing	Repair or replace the master cylinder and/or booster as necessary.

Problem—One Brake Drags

Problem—One Brake Drags	
Possible Cause	**Remedy**
Loose or worn front wheel bearings	Adjust to specifications or replace.
Defective brake hose or hydraulic tube (preventing return of fluid)	Replace the hose or tube.
Sticking caliper piston	Repair or replace the caliper.
Swollen caliper piston seal	Replace the seal. Drain and flush the system. Refill with the approved brake fluid.
Sticking caliper guide pin(s)	Repair or replace the pin(s). Lubricate the pins and boots.

Problem—Low Pedal

Problem—Low Pedal	
Possible Cause	**Remedy**
Leak in hydraulic brake system	Check the master cylinder, calipers, hoses, and tubes. Replace as necessary.
Air in hydraulic brake system	Bleed the system. For instructions, see **Subject 160**.
Poor quality brake fluid (low boiling point)	Drain the system. Flush and refill with approved brake fluid.
Weak brake hoses that expand under pressure	Replace the defective hoses.

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Specifications

Kent-Moore Tools	
Kent-Moore Part Number	**Tool**
ZTSE4417	Seating Tool for 66 mm Caliper Pistons
ZTSE4418	Seating Tool for 73 mm Caliper Pistons

Table 1, Kent-Moore Tools

Fastener Torques			
Fastener Description	**Size**	**Grade**	**Torque: lbf·ft (N·m)**
Caliper Pin Mounting Bolts	M12 x 1.25	—	93 to 107 (126 to 145)
Brake Supply Hose Fitting	—	—	15 (20)
Tie Bar-to-Anchor Plate Mounting Bolt (73 mm only)	M10 x 1.5	—	40–50 (54–68)
Tie Bar-to-Anchor Plate Hole Plug (66 mm only)	M10 x 1.5	—	16–27 (22–37)
Dust Shield, ABS Sensor Mounting Bracket and Brake Line Clip Screw	5/16–18	—	12–16 (17–22)
Anchor Plate Mounting Hexnuts	—	—	Rear Axle: 97–123 (132–167) Front Axle Type FC: 70–89 (95–121) Front Axle Type FD/FF: 134–172 (182–233)
Caliper Bleed Screw	7/16–24	—	8–15 (10–20)
Rotor Mounting Hexbolts	9/16–12	8	130 (175)

Table 2, Fastener Torques

Approved Brake Fluid for Brake System	
Fluid Type	**Recommended Fluids**
DOT 3	Wagner-Premium Plus Super HD
	Delco Supreme II
	Dow HD 50-4

Table 3, Approved Brake Fluid for Brake System

Approved Brake System Grease	
Component	**Recommended Grease**
Anchor Plate Guide Pins, Guide Pin Boots, Guide Pin Bores	Aeroshell Grade 5 (ES-1246)
Caliper Piston Bores	Dow Corning DC-4

Table 5, Approved Brake System Grease

Rotor Specifications	
Outside Diameter	15.0 inch (381 mm)
Thickness, New	1.435 inch (36.45 mm)
Thickness, Discard	1.320 inch (33.53 mm)
Surface Finish	40–120 micro inch (40–100 micro inch preferred)

Table 4, Rotor Specifications

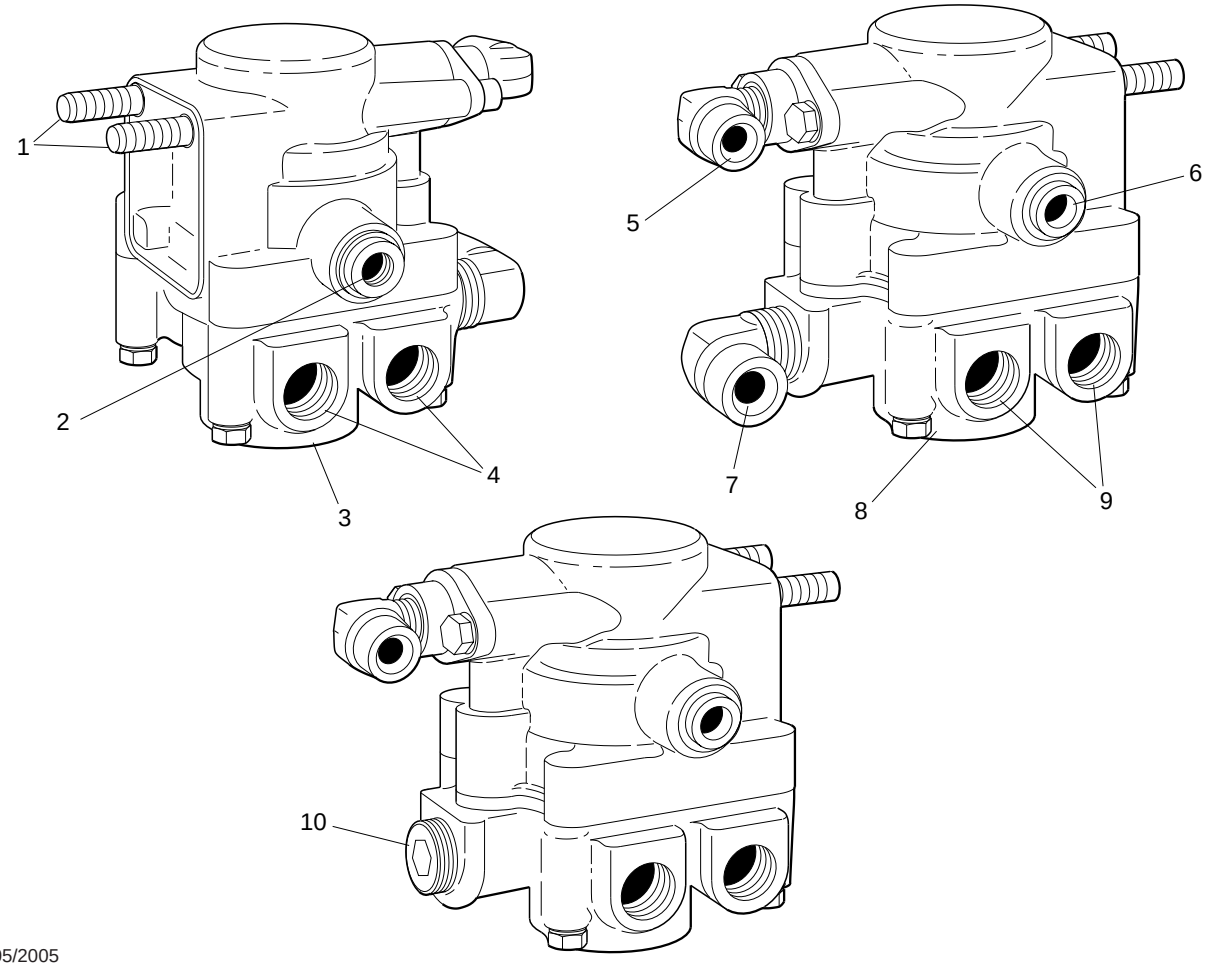
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Description

The Bendix SR-7™ spring brake modulating valve (see **Fig. 1** and **Fig. 2**) is used in conjunction with a dual air brake system and spring brake actuator, and performs the following functions:

- Provides a rapid application of the spring brake actuator when parking.
- Modulates the spring brake actuator application using the dual brake valve should a primary failure occur in the service brake system.
- Prevents compounding of service and spring brake forces.

The SR-7 valve has one park control, one service control, one supply, one balance, four delivery NPT ports, and an exhaust port protected by an exhaust diaphragm. The valve incorporates two mounting studs for mounting the valve to the frame rail or crossmember.

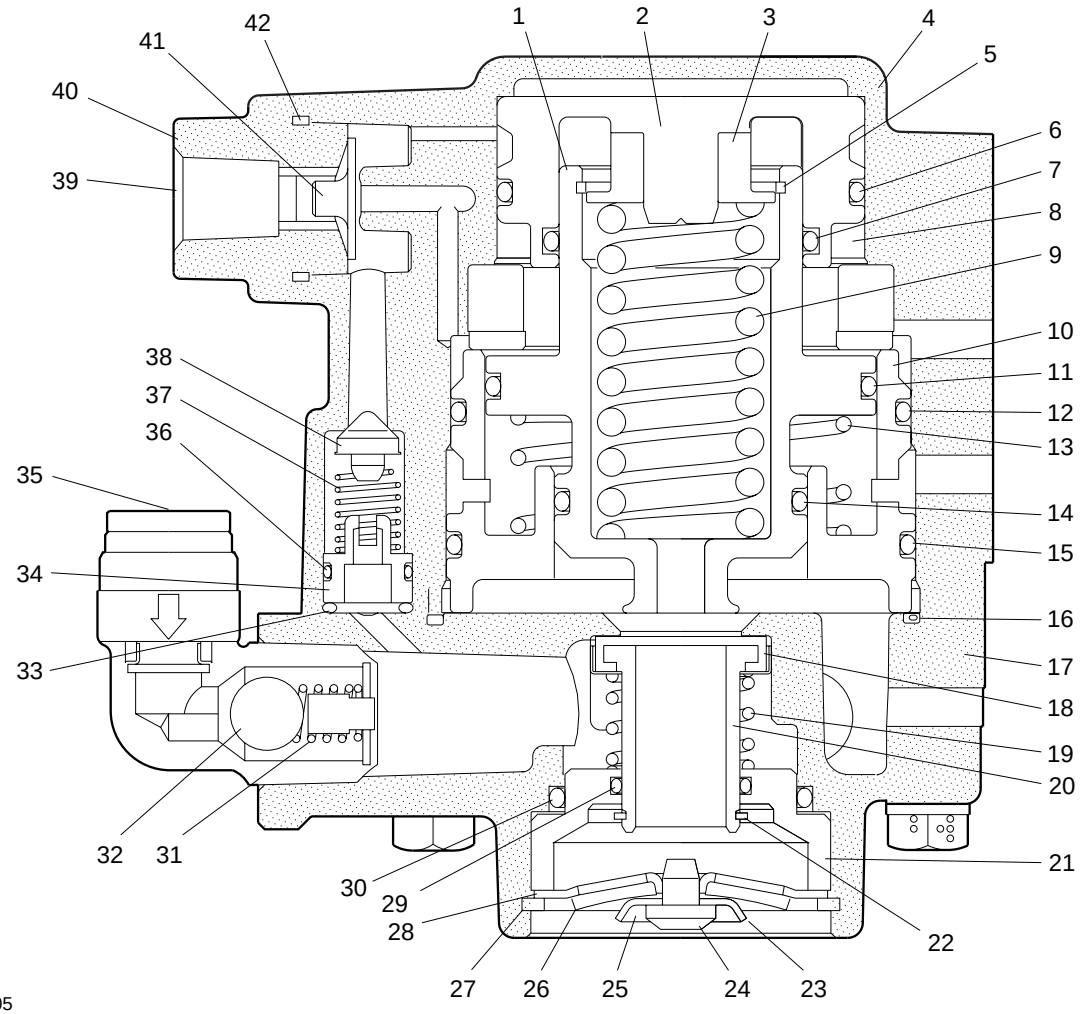


1. Mounting Studs
2. 42 Control Port
3. Exhaust
4. Delivery
5. 41 Park Control (from dash valve)
6. 41 Balance Port
7. Supply Port
8. Exhaust
9. Delivery
10. Pipe Plug (QRV applications only)

Fig. 1, SR-7 Spring Brake Modulating Valve (exterior views)

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General Information



10/07/2005 f422420

1. Main Piston
2. Control Piston
3. Spring Guide
4. Upper Body
5. Retaining Ring
6. O-Ring
7. O-Ring
8. Spacer
9. Main Piston Spring
10. Static Piston
11. O-Ring
12. O-Ring
13. Static Piston Spring
14. O-Ring
15. O-Ring
16. O-Ring
17. Lower Body
18. Valve Retainer
19. Spring
20. Inlet/Exhaust Valve
21. Lower Valve Guide
22. Retaining Ring
23. Exhaust Port
24. #10 Torx Screw
25. Diaphragm Washer
26. Diaphragm
27. Retaining Ring
28. Valve Seat
29. O-Ring
30. O-Ring
31. Spring
32. Ball Check Valve
33. O-Ring
34. Check Valve Guide
35. Supply Port
36. O-Ring
37. Spring
38. Inline Single Check Valve
39. Park Control Port
40. Check Valve Cover
41. Double Check Valve
42. O-Ring

Fig. 2, SR-7 Spring Brake Modulating Valve (sectional view)

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CAUTION

Do not attempt to disassemble the SR-7 valve. The valve contains high spring forces that could result in personal injury if disassembly is attempted.

Operation

The operation guidelines in this subject represent the relay-valve-based SR-7. A quick-release-based valve functions similarly to the relay-valve-based version with the exception that all air delivered to the spring brakes passes through the park control port through the inline single check valve. The SR-7 quick release style can be easily identified by the pipe plug in the supply port of the valve. See **Fig. 1**. For vehicle-specific plumbing diagrams, go to **EZWiring**.

Charging the Spring Brake Actuators Below 107 psi (737 kPa)

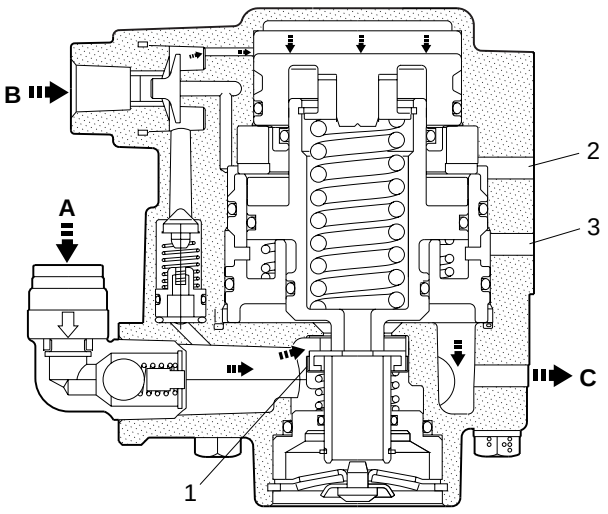
With the air brake system charged and the parking brakes released (by pushing in the dash valve button), air enters the park control port. This opens the SR-7 valve, to supply air pressure to the spring brake chambers. As illustrated, air pressure in the chambers is below 107 psi (737 kPa) (nominal). See **Fig. 3**.

Charging the Spring Brake Actuators Above 107 psi (737 kPa)

Once the SR-7 valve delivery pressure reaches 107 psi (nominal), the inlet and exhaust are closed (valve lap position). This maintains the spring brake hold-off pressure at 107 psi (nominal). See **Fig. 4**.

Normal Service Application

During a service brake application, the valve remains in the lap position. The SR-7 valve monitors the presence of air pressure in both primary and secondary delivery circuits. See **Fig. 5**.



10/11/2005 f422421

A. Secondary reservoir constant pressure
B. Control line pressure
C. Delivery to spring brakes
1. Inlet/Exhaust Valve Open
2. Balance Port
3. Control Port

Fig. 3, Charging the Spring Brake Actuators Below 107 psi (737 kPa)

Parking

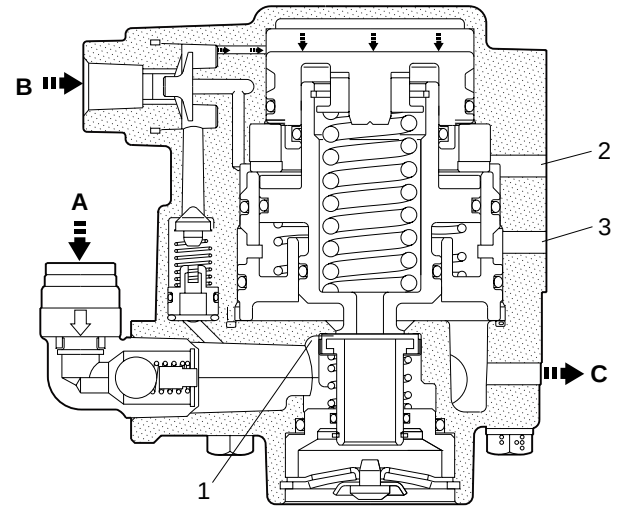
Actuating the park brakes (by pulling out the dash valve button) exhausts spring brake air pressure through the SR-7 valve exhaust port. See **Fig. 6**.

Service Application with Loss of Air in Primary Circuit

With the parking brakes released (dash valve button in) and the absence of air in the primary circuit delivery, a service brake application from the secondary circuit causes the pressure in the spring brakes to be exhausted proportionally to this application. This is known as spring brake modulation. A 30 psi (207 kPa) service brake application will exhaust the spring brake pressure to approximately 60 psi (414 kPa). See **Fig. 7**.

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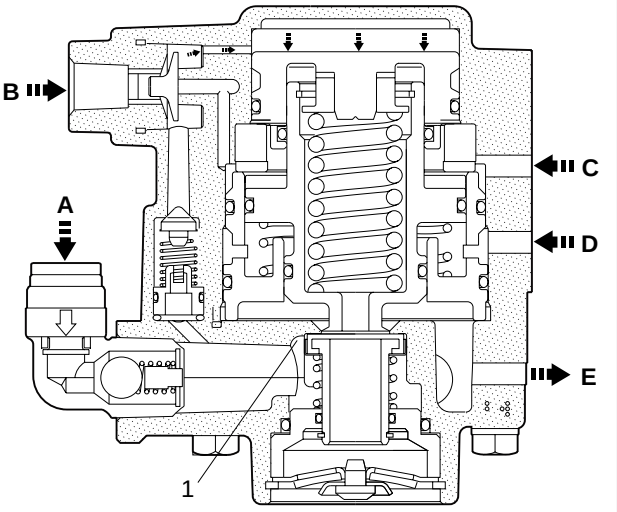
General Information



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A. Secondary reservoir constant pressure
B. Control line pressure
C. Delivery to spring brakes
1. Inlet/Exhaust Valve Seated
2. Balance Port
3. Control Port

Fig. 4, Charging the Spring Brake Actuators Above 107 psi



10/11/2005 f422423

A. Secondary reservoir constant pressure
B. Control line pressure
C. Balance port—primary circuit pressure
D. Control port—secondary circuit pressure
E. Delivery to spring brakes
1. Inlet/Exhaust Valve Seated

Fig. 5, Normal Service Application

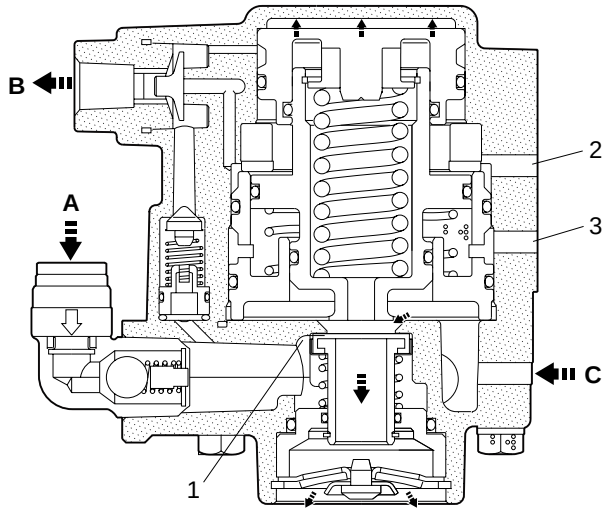
Service Application with Loss of Air in Secondary Circuit

With the parking brakes released (dash valve button in) and the absence of air in the secondary circuit reservoir, the external single check valve in the supply port seals to prevent air leakage to atmosphere from the SR-7 valve. The dash valve delivery air flows through the inline single check valve and becomes SR-7 valve supply air. This air is delivered to maintain at least 107 psi (737 kPa) (nominal) in the spring brake chambers. See **Fig. 8**.

Anti-Compounding

The SR-7 valve provides anti-compounding of the service and spring brake forces. When the park brakes are actuated (by pulling out the dash valve button), a service brake application will cause the SR-7 valve to deliver air pressure to the spring brake chambers. Thus the vehicle is held stationary using a service brake application. When the service brake application is released, the delivery pressure is exhausted from the spring brake chambers and the vehicle remains parked using the spring brake actuators. See **Fig. 9**.

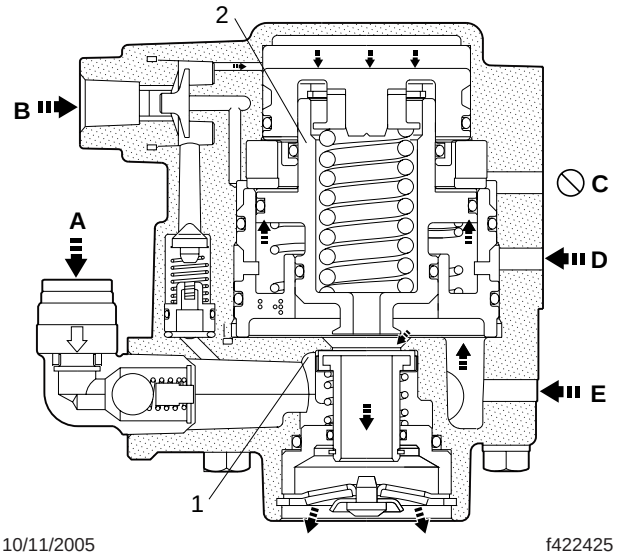
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A. Secondary reservoir constant pressure
B. Control line pressure
C. Delivery to spring brakes
1. Inlet/Exhaust Valve Seated
2. Balance Port
3. Control Port

Fig. 6, Parking



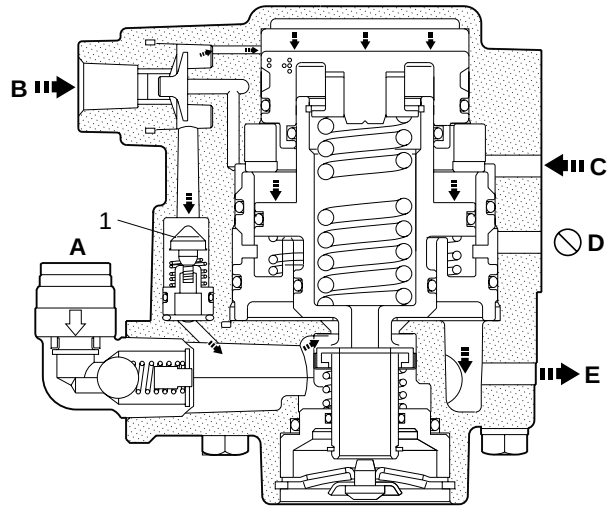
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A. Secondary reservoir constant pressure
B. Control line pressure
C. Balance port—loss of primary circuit pressure
D. Control port—secondary circuit pressure
E. Delivery to spring brakes
1. Inlet Valve Seated
2. Main Piston Moves Up

Fig. 7, Service Application with Loss of Air in Primary Circuit

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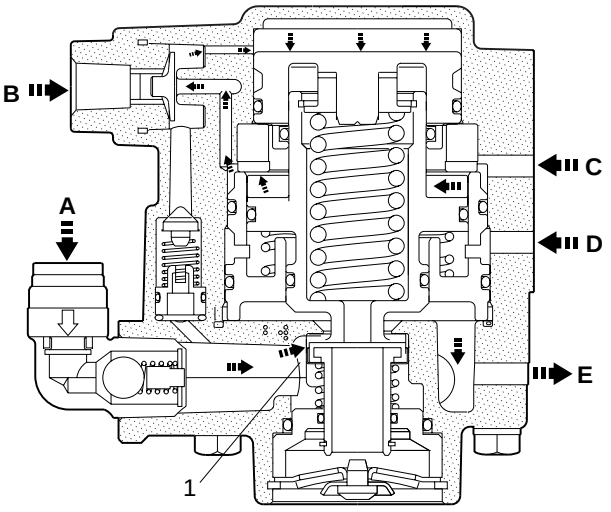
General Information



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A. Secondary reservoir no pressure
B. Control line pressure
C. Balance port—primary circuit pressure
D. Control port—loss of secondary circuit pressure
E. Delivery to spring brakes
1. Inline Single Check Valve

Fig. 8, Service Application with Loss of Air in Secondary Circuit



10/11/2005 f422427

A. Secondary reservoir constant pressure
B. Control line pressure
C. Balance port—primary circuit pressure
D. Control port—secondary circuit pressure
E. Delivery to spring brakes
1. Inlet/Exhaust Valve Open

Fig. 9, Anti-Compounding

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Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized. The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements, in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured, in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

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Removal

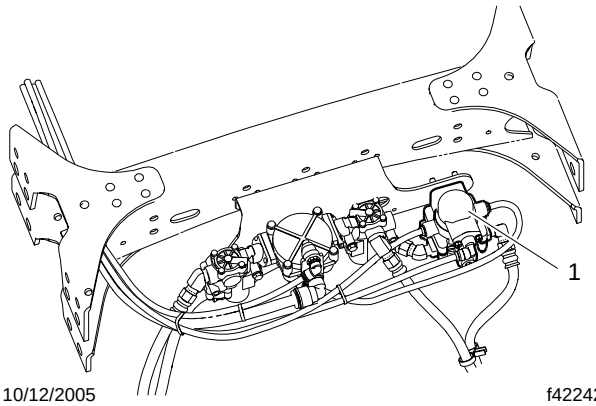
⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so could result in personal injury.

⚠ CAUTION

Do not attempt to disassemble the SR-7 valve. The valve contains high spring forces that could result in personal injury if disassembly is attempted.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the tires.
2. Drain the air system.
3. Identify all the air lines attached to the valve, for reinstallation. See **Fig. 1** for a view of a typical installation, or access EZWiring for vehicle-specific plumbing diagrams.



1. SR-7 Valve

Fig. 1, SR-7 Spring Brake Modulating Valve Installation (typical)

4. Disconnect all the air lines from the valve.
5. Remove the two mounting nuts that secure the valve to the crossmember bracket, and remove the valve.
6. If the valve is being replaced, note the orientation of all fittings, then remove the fittings for use on the new valve.

Installation

1. If a new valve is being installed, install the fittings removed from the old valve.
2. Position the valve on the crossmember bracket and install the mounting nuts. Tighten to 15 to 18 lbf·ft (20 to 24 N·m).
3. Attach all the air lines as noted during removal.
4. Before returning the vehicle to service, perform the operating and leakage tests in **Subject 120**, *Tests*.

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Operating Test

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so could result in personal injury.

⚠ CAUTION

Do not attempt to disassemble the SR-7 valve. The valve contains high spring forces that could result in personal injury if disassembly is attempted.

1. Chock the tires.
2. Charge the air brake system to governor cut-out pressure.
3. Place the parking control valve in the PARK position. Observe that the spring brake actuators apply promptly.
4. Remove one line from a delivery port of the SR-7 valve and install a test gauge that is known to be accurate. See **Fig. 1** for the port locations.
5. Place the parking control valve in the RELEASE position. Observe that the spring brake actuators fully release.
6. With the parking control valve still in the RELEASE position, note the gauge pressure reading. Correct spring brake actuator hold-off pressure is 107 psi (737 kPa) nominal.
7. Place the parking control valve in the PARK position. The gauge reading should drop to zero promptly. A lag (more than 3 seconds) in the drop of pressure would indicate faulty operation.
8. With the parking control valve still in the PARK position, gradually apply the foot brake valve and note a pressure reading increase on the gauge installed in the SR-7 valve delivery port.
9. Place the parking control valve in the RELEASE position.
10. Drain the reservoir that supplies the rear service brake circuit; apply the foot brake valve several times and note that the pressure reading on the gauge decreases each time the foot brake valve is applied (spring brake modulation). After the foot brake valve has been applied several times, the pressure reading on the gauge will drop to the point where release of the spring brake actuators will no longer occur.

NOTE: The SR-7 valve is not serviceable. If the valve does not function as described, replace it.

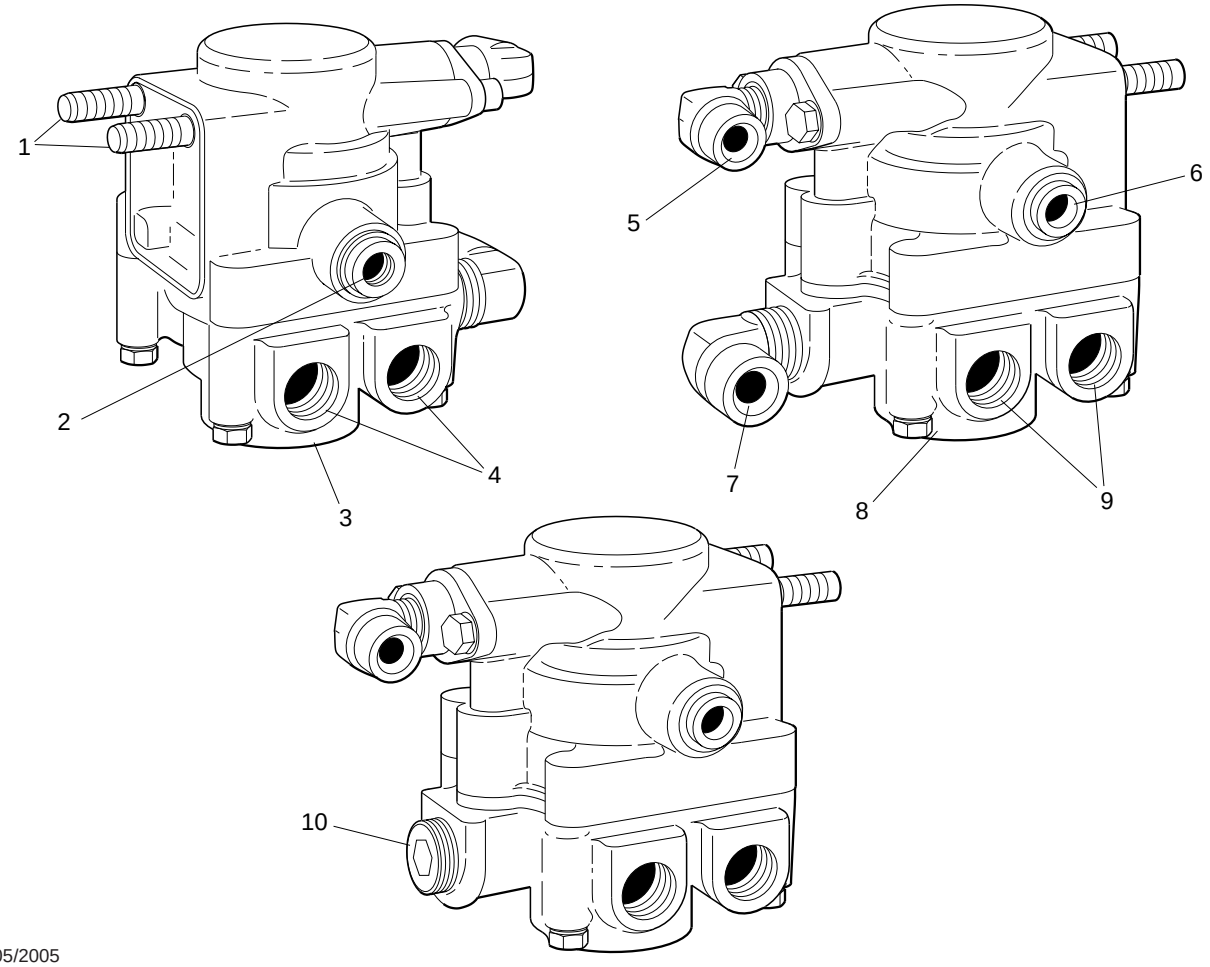
Leakage Test

Place the park control valve in the RELEASE position; using a soap solution, coat all ports including the exhaust port. A 1-inch (25-mm) bubble in three seconds is permitted.

NOTE: The SR-7 valve is not serviceable. If the valve does not function as described, or if leakage is excessive, replace it.

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Tests



1. Mounting Studs
2. 42 Control Port
3. Exhaust
4. Delivery
5. 41 Park Control (from dash valve)
6. 41 Balance Port
7. Supply Port
8. Exhaust
9. Delivery
10. Pipe Plug (QRV applications only)

Fig. 1, SR-7 Spring Brake Modulating Valve (exterior views)

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General Information

The steering driveline connects the steering column and jacket assembly to the steering gear by means of a telescoping shaft with an integral lower yoke, a lower end yoke and a lower universal joint. See **Fig. 1**.

The driveline shaft consists of a tubular lower section, splined on the inside, which mates with an externally splined upper section. The telescoping shaft eases installation and removal of the steering column, steering driveline and steering gear. It also compensates for changes in distance between the steering column and steering gear, which occur when the relative positions of the frame rails and cab change during vehicle operation.

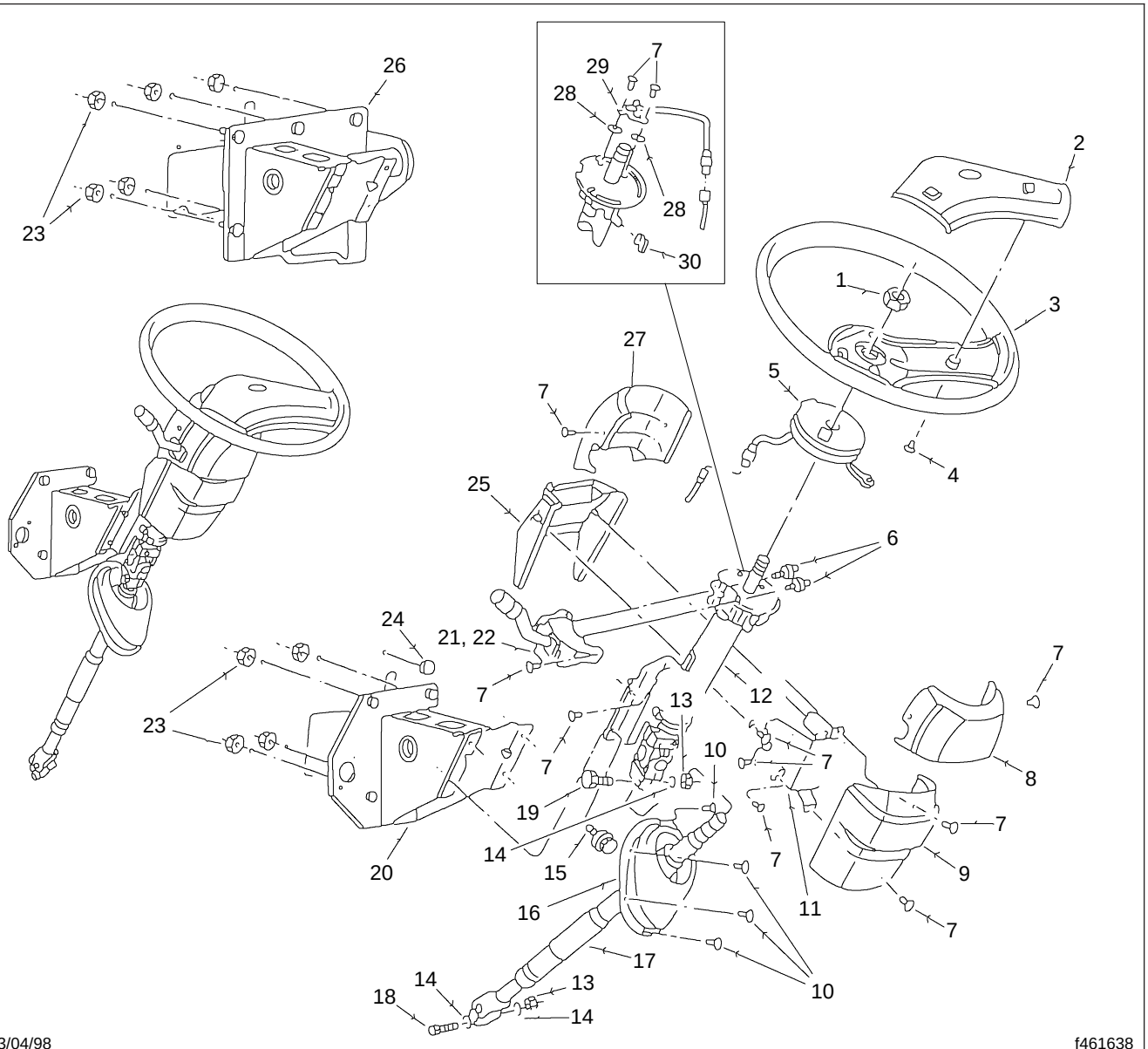
The upper end of the shaft is serrated to match the internal serrations of the steering column end yoke; the lower end yoke is internally serrated to match the external serrations on the steering gear input shaft.

The universal joint at the lower end of the steering driveline and the steering column universal joint allow the transfer of steering motion from the steering column shaft to the steering driveline and to the steering gear input shaft, even though the driveline is at an angle to both of the other shafts. The lower universal joint cross rides in four needle bearing cups, two carried in the end yoke and two carried in the steering driveline's integral yoke. The needle bearing cups are held in place in each yoke by snap rings.

The lower end yoke of the steering driveshaft is secured to the steering gear input shaft by a pinch bolt that engages a notch in the shaft. The upper end of the driveshaft is inserted into the steering column end yoke and secured by a pinch bolt.

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General Information



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1. Steering Wheel Nut
2. Horn Pad
3. Steering Wheel
4. Screw
5. Clockspring
6. Screw
7. Screw
8. Shroud (upper front)
9. Shroud (lower front)
10. Screw
11. Shroud Bracket (front and back)
12. Steering Column
13. Nut
14. Washer
15. Screw and Washer
16. Steering Column Floor Seal
17. Steering Column Coupling Shaft
18. Bolt
19. Bolt and Retainer
20. Steering Column Support Bracket (automatic transmission)
21. Turn Signal Switch Assembly (with Signal-Stat turn signal)
22. Turn Signal Switch Assembly (with windshield wiper)
23. Nut
24. Button Plug
25. Shroud (lower front)
26. Steering Column Support Bracket (manual transmission)
27. Shroud (upper back)
28. Washer
29. Horn Brush Assembly
30. U-Nut

Fig. 1, Steering Driveline

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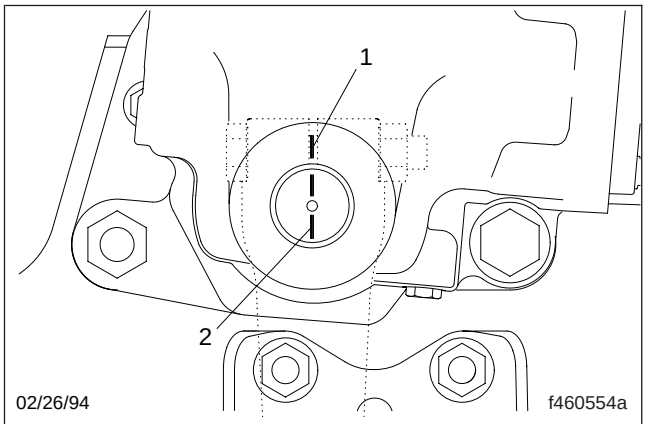
Removal

NOTE: It is not necessary to loosen the steering wheel and column assembly to do this procedure.

1. Position the front tires straight ahead. If possible, drive the vehicle in a straight line for a short distance, stopping at the spot where service operations will be done.
2. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
3. Open the hood.
4. Disconnect the lower end yoke.
   - 4.1 Remove and discard the pinch bolt and nut from the lower end yoke.
   - 4.2 Remove the yoke from the steering gear input shaft. Do not turn the steering gear input shaft when removing the lower end yoke. Push the driveline shaft into the driveline tube as you remove the lower end yoke.
5. Disconnect the upper end yoke.
   - 5.1 Remove and discard the pinch bolt and nut from the upper end yoke. If necessary, knock out the pinch bolt with a brass hammer.
   - 5.2 Remove the steering driveline from the steering column yoke.

Installation

1. Clean the steering gear input shaft, steering column, and end yokes.
   - 1.1 Thoroughly clean the end yokes, the steering column shaft, and the steering gear input shaft with a clean, dry cloth.
   - 1.2 Apply a thin film of grease to the yoke splines. Use lithium-based grease, NLGI grade 2.
2. Install the driveline from outside the cab into the front cab panel hole.
3. Slide the upper end of the steering driveline into the steering column yoke. Install a new pinch bolt. Before installing the nut, make sure the pinch bolt is centered in the steering column shaft notch. The pinch bolt is centered if it can slip in and out of the end yoke with ease. Install a new nut and tighten it to one of the following torque specs:
   - 55 to 65 lbf·ft (75 to 88 N·m) for a 7/16 pinch bolt and nut
   - 30 to 35 lbf·ft (41 to 47 N·m) for an M10 pinch bolt and nut
4. Apply torque seal, OGP F900WHITE, to the exposed bolt thread and to the nut.
5. Before attaching the lower end yoke to the steering gear input shaft, be sure the front tires are straight ahead and the steering gear is centered with the timing mark on the end of the sector shaft in line with the mark on the housing trunnion. See **Fig. 1**. Be sure the arrows on the driveline shaft and the driveline tube are aligned.



1. Timing Mark (Housing Trunnion)
2. Timing Mark (Sector Shaft)

Fig. 1, Gear Alignment

CAUTION

If the arrow on the driveline shaft is not aligned with the arrow on the driveline tube, the U-joints will not be correctly oriented. Assembling the driveline with the U-joints incorrectly oriented could cause binding at the U-joints.

6. Install the lower end yoke on the steering gear input shaft. Before installing the nut, make sure the pinch bolt is centered in the steering gear input shaft notch. The pinch bolt is centered if it

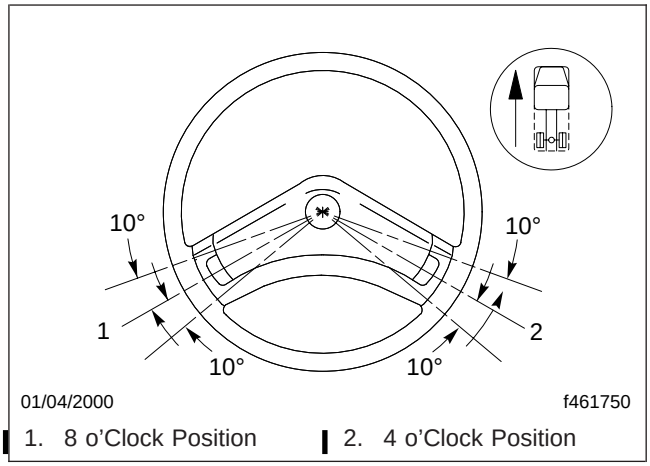
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Removal and Installation

can slip in and out of the end yoke with ease. Install a new nut and tighten it to one of the following torque specs:

- 55 to 65 lbf·ft (75 to 88 N·m) for a 7/16 pinch bolt and nut
- 30 to 35 lbf·ft (41 to 47 N·m) for an M10 pinch bolt and nut

7. Apply torque seal, OGP F900WHITE, to the exposed bolt thread and to the nut.
8. Lubricate the driveline tube and both U-joints with lithium-based grease, NLGI grade 2. Apply until grease appears at the lower end of the tube splines and all four U-joint cross seals.
9. With the front tires pointing straight ahead, check the position of the steering wheel spokes. They must be within ±10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 2**. If they are not, remove the steering wheel and install it in the correct position. For instructions, see the applicable section in this group.



1. 8 o'Clock Position
2. 4 o'Clock Position

Fig. 2, Steering Wheel Alignment

10. Close and latch the hood. Leave the parking brakes applied and the chocks at the rear tires.
11. Raise the front of the vehicle so that the front tires are off the ground. Place safety stands under the frame.

⚠ WARNING

Driving a vehicle with hard steering or binding in the steering system is hazardous and could result in partial or complete loss of steering control during vehicle operation.

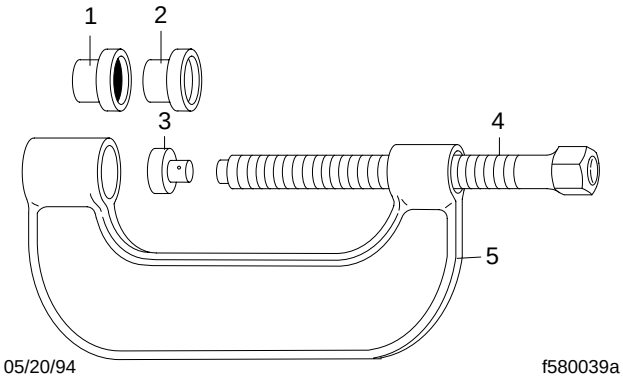
12. Turn the steering wheel through full travel, checking for hard steering or binding. If there is difficulty, check the assembly and installation of the driveline parts. If the cause is not the driveline, see the applicable steering gear section in this group.
13. Remove the safety stands, lower the vehicle to the ground, and remove the chocks from the tires.

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Disassembly

1. Remove the steering driveline from the vehicle. See **Subject 100** for instructions.
2. Slide the driveline shaft out of the driveline tube and yoke assembly.
3. Remove the steering driveline U-joint.

   3.1 Clamp the frame of a U-joint tool in a vise. See **Fig. 1**.



1. Bushing Adaptor
2. Bearing Driver
3. Expansion Plug
4. Pressure Screw
5. Frame

Fig. 1, Universal Joint Tool

   3.2 Wearing safety goggles, remove the needle bearing cup snap rings from the needle bearing cups by pushing an open end of each snap ring with a screwdriver.

⚠ WARNING

Snap rings can become potentially harmful projectiles when they are being removed. Wear safety goggles to prevent eye injury.

   3.3 Select a U-joint tool expansion plug of slightly smaller diameter than the needle bearing cup, and place it on the pressure screw. Select a bushing adapter of slightly larger inside diameter than the needle bearing cup, and place it on the opposite end of the tool.

   3.4 Place the integral yoke of the driveline tube in the U-joint tool. Position the bushing adapter to receive a needle bearing cup and place the expansion plug against the opposite needle bearing cup.

   3.5 Tighten the pressure screw to press one needle bearing cup out of the driveline yoke. Remove the cup. In some cases, it might be necessary to give the pressure screw a sharp blow with a brass hammer while the screw is under pressure.

   3.6 Reverse the driveline tube and yoke assembly, and press against the U-joint cross to force out the other needle bearing cup.

   3.7 Remove the driveline tube and yoke assembly from the U-joint tool. Remove the upper end yoke and the U-joint cross from the driveline yoke.

   3.8 Place the upper end yoke in the U-joint tool. Position the bushing adapter to receive a needle bearing cup and place the expansion plug against the opposite needle bearing cup.

   3.9 Tighten the pressure screw to press one needle bearing cup out of the upper end yoke. Remove the cup. In some cases, it might be necessary to give the pressure screw a sharp blow with a brass hammer while the screw is under pressure.

   3.10 Reverse the upper end yoke in the U-joint tool and press against the U-joint cross to force out the other needle bearing cup.

   3.11 Remove the upper end yoke from the U-joint tool. Remove the U-joint cross from the upper end yoke.

Assembly

1. Install the steering driveline U-joint.

   1.1 Clamp the frame of a U-joint tool in a vise. See **Fig. 1**.

   1.2 Select a U-joint tool expansion plug of a slightly smaller diameter than the needle bearing cup and place it on the pressure screw. Place a bearing driver on the opposite end of the tool.

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Disassembly and Assembly

1.3 Position the U-joint cross in the upper end yoke so that the U-joint cross lube fitting points toward one of the yoke ears.

1.4 Make certain the U-joint cross seals are in place on the needle bearing cups. Start both needle bearing cups into the yoke ears from the outside. Place the upper end yoke in the U-joint tool with the bearing driver against one of the needle bearing cups and the expansion plug against the opposite needle bearing cup.

1.5 Tighten the pressure screw making sure that both needle bearing cups press straight and true into the yoke ears. Work the U-joint cross during this operation to ensure free movement. If the needle bearing cups do not seat correctly, or if the U-joint binds, give the yoke shoulder near each cup a sharp blow with a brass hammer.

1.6 Press the needle bearing cup on the screw end of the U-joint tool all the way in until there is enough clearance to insert a new needle bearing cup snap ring. Insert the snap ring and fully seat it in its groove.

⚠ WARNING

Use new snap rings when assembling the U-joints. Used snap rings are often distorted and overstressed from disassembly. Snap rings not fully seated in their grooves could work loose possibly resulting in partial or complete loss of steering control during vehicle operation.

1.7 Reverse the upper end yoke in the U-joint tool and push the other needle bearing cup until there is clearance to insert the other snap ring. Insert the snap ring. Remove the upper end yoke from the U-joint tool.

1.8 With the U-joint cross lube fitting facing away from the base of the upper end yoke, position the U-joint cross and the upper end yoke in the driveline tube and yoke assembly.

NOTE: The U-joint cross lube fitting should face away from the base of the upper end yoke to provide access for lubrication when the steering driveline is installed on the vehicle.

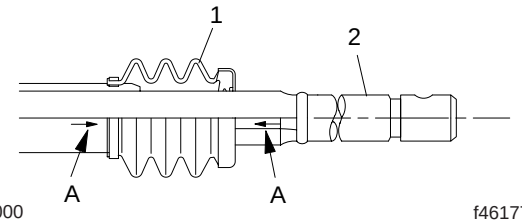
1.9 Make certain the U-joint cross seals are in place on the needle bearing cups. Start both needle bearing cups into the yoke ears. Place the driveline tube and yoke assembly in the U-joint tool with the bearing driver against one of the needle bearing cups and the expansion plug against the opposite needle bearing cup.

1.10 Tighten the pressure screw, making sure that both needle bearing cups press straight and true into the yoke ears. Work the U-joint cross during this operation to ensure free movement. If the needle bearing cups do not seat correctly, or if the U-joint binds, give the yoke shoulder near each cup a sharp blow with a brass hammer.

1.11 Press the needle bearing cup on the screw end of the U-joint tool all the way in until there is enough clearance to insert a needle bearing cup snap ring. Insert the snap ring. Reverse the driveline tube and yoke assembly in the U-joint tool and push the other needle bearing cup until there is clearance to insert the other snap ring. Insert the snap ring.

2. Remove the driveline tube and yoke assembly from the U-joint tool.

3. Slide the lower driveline shaft into the driveline tube so that the arrow on the driveline shaft yoke is aligned with the arrow on the driveline tube. See **Fig. 2**.



A. Align arrows.
1. Driveline Tube
2. Driveline Shaft

Fig. 2, Driveline Alignment

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CAUTION

If the arrow on the driveline shaft yoke is not aligned with the arrow on the driveline tube, the U-joints will be out of phase. Assembling the driveline with the U-joints out of phase could result in binding at the U-joints.

4. Install the steering driveline in the vehicle. See **Subject 100** for instructions.

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General Information

The drag link is nonadjustable, with non-removable socket ball studs at both ends. See **Fig. 1**.

The drag link connects the pitman arm to the front axle steering arm. The socket ball studs, one located at each end, rotate to allow for changing angles between the pitman arm and steering arm as the vehicle is steered and the suspension articulates.

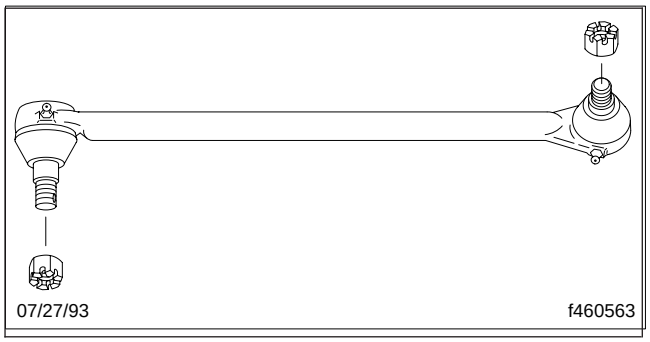


Fig. 1, Drag Link

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Removal

1. Before removing the drag link, if ball stud wear or looseness is suspected, check for wear of the ball studs. See **Subject 110** for instructions.
2. Position the tires straight ahead. If possible, drive the vehicle in a straight line for a short distance, stopping at the spot where service operations are to be performed. *Do not turn the steering wheel at any time while the drag link is still attached to both the pitman arm and the axle steering arm.* If the steering wheel is turned, the front tires will not be straight ahead.
3. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
4. Release the hood latches, and tilt the hood.
5. Remove the left-hand bumper extension or rotate it out of the way. See **Fig. 1**.

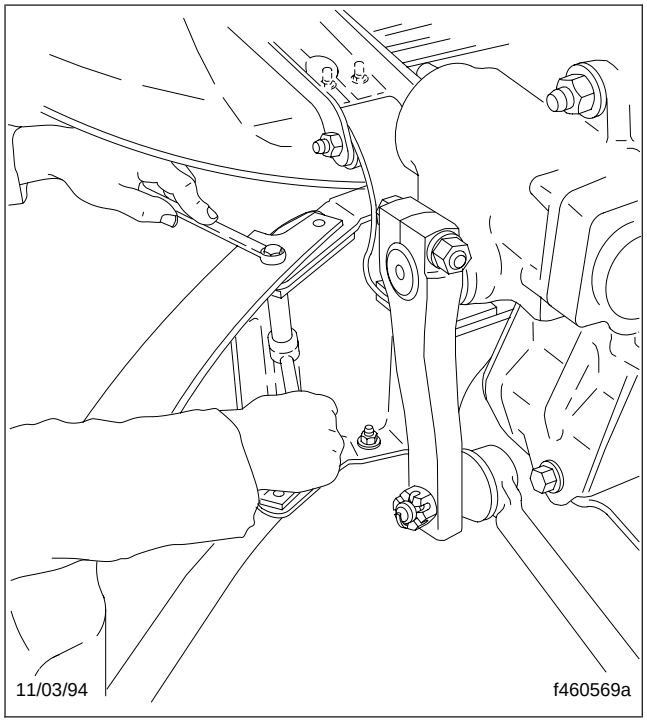


Fig. 1, Left Hand Bumper Extension

6. Remove the drag link from the vehicle.
   - 6.1 At both ends of the drag link, remove the cotter pins and loosen the nuts on the socket ball studs. See **Fig. 2** and **Fig. 3**. Be sure the nuts are loosened far enough to allow use of a ball stud removal tool.

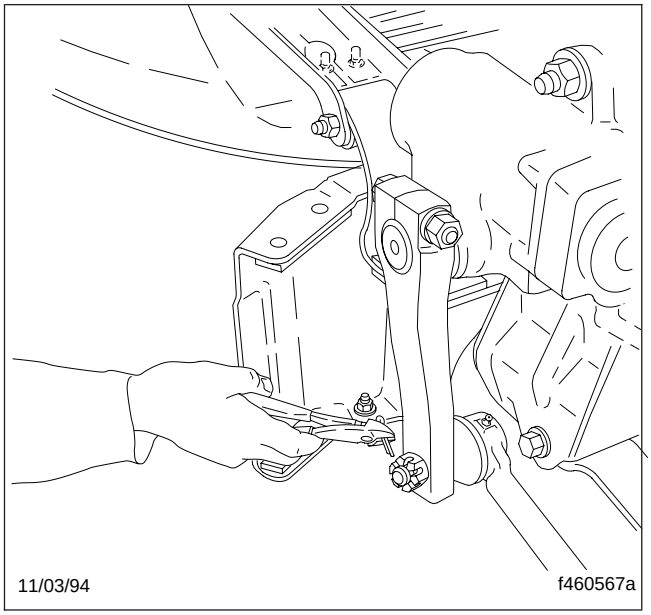


Fig. 2, Removing Cotter Pins

   - 6.2 Using a ball stud removal tool, loosen the drag link from the pitman arm and the axle steering arm. See **Fig. 4**, **Fig. 5**, and **Fig. 6**.
   - 6.3 Remove the nuts and drag link.

IMPORTANT: Do not steer the gear with the linkage removed; unintended setting of the automatic poppets may result.

Installation

1. Before installing the drag link, check for damage or wear. Replace parts as needed.
   - 1.1 Check the ball stud covers or dust caps for extreme wear, cuts, or other damage; replace the covers (seals) if needed.
   - 1.2 Inspect the socket ball studs, ball stud nuts, drag link rod, and grease fittings for wear or damage. Replace the components as needed.
2. Install the drag link.

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Removal and Installation

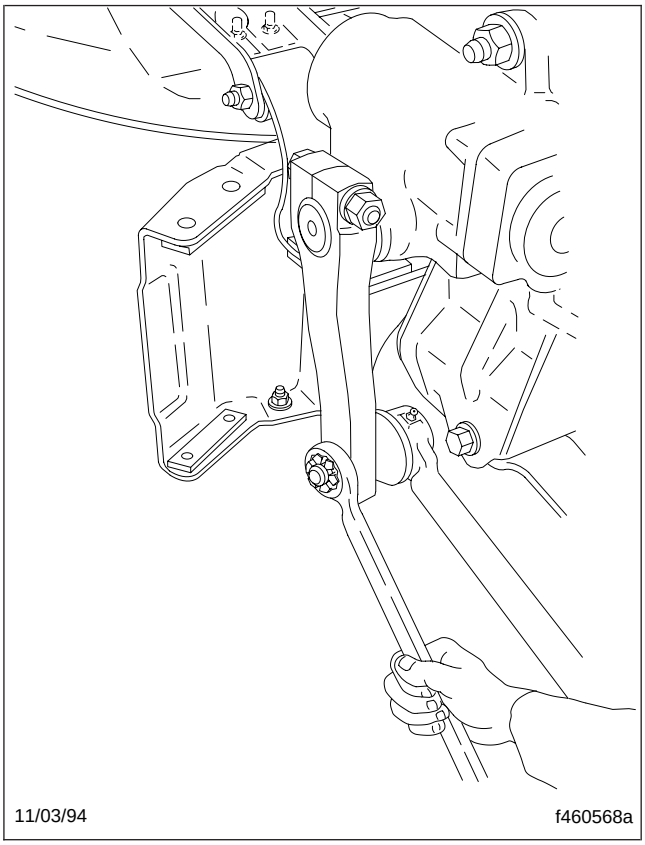


Fig. 3, Loosening Nuts

2.1 When installing the drag link, if needed, slightly turn the steering wheel to change the distance between the pitman arm and the steering arm.

2.2 Tighten the ball stud nuts as follows:

- 3/4–16, 90 to 170 lbf·ft (122 to 230 N·m);
- 7/8–14, 160 to 300 lbf·ft (217 to 407 N·m).

2.3 If required, continue tightening each nut until a slot on the nut aligns with the hole in the ball stud. *Don't back off the nut when locating the cotter pin hole.*

2.4 Install new cotter pins through the ball studs and nuts, and lock the cotter pins in place.

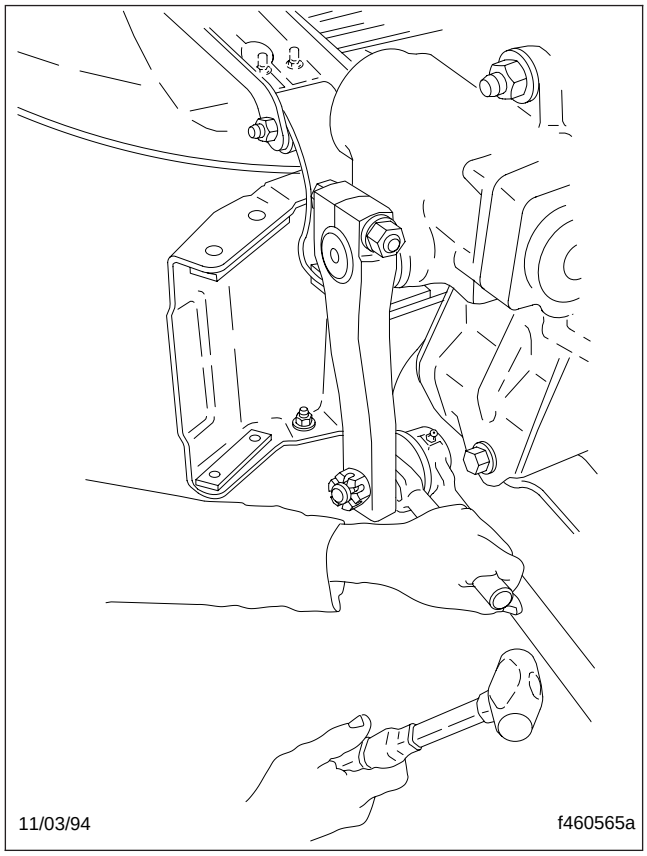


Fig. 4, Loosening the Ball Stud

⚠ WARNING

Failure to install and lock new cotter pins in the ball studs and nuts could result in disengagement of the parts and loss of steering control.

3. Wipe the dirt from the grease fittings. Apply chassis grease until the old grease is forced out.
4. Install the left-hand bumper extension.
5. Lower the hood, and fasten the hood latches.
6. Align the steering wheel spokes. With the front tires pointing straight ahead, check the position of the steering wheel spokes. They must be pointing within ±10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 7**. If not, remove the steering wheel and install it in the correct position. For instructions, see the applicable section in this group.
7. Remove the chocks from the rear tires.

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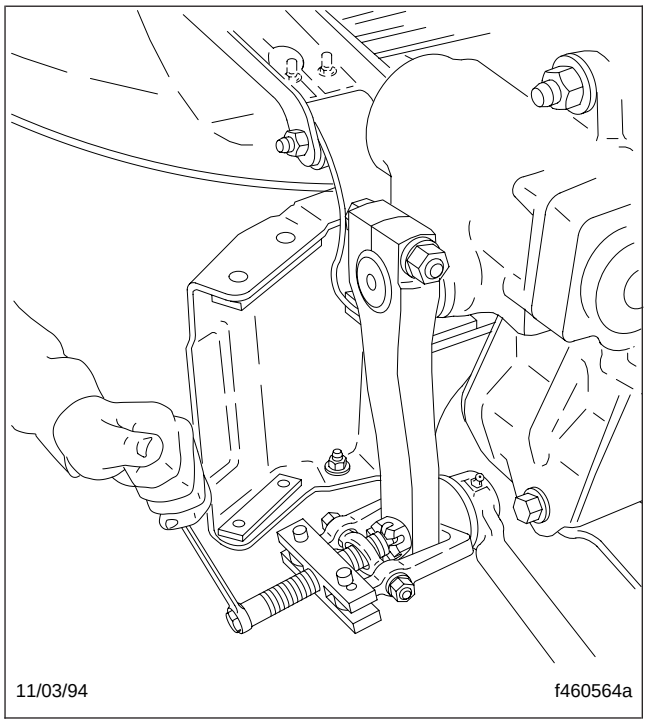


Fig. 5, Ball Stud Removal Tool on Pitman Arm

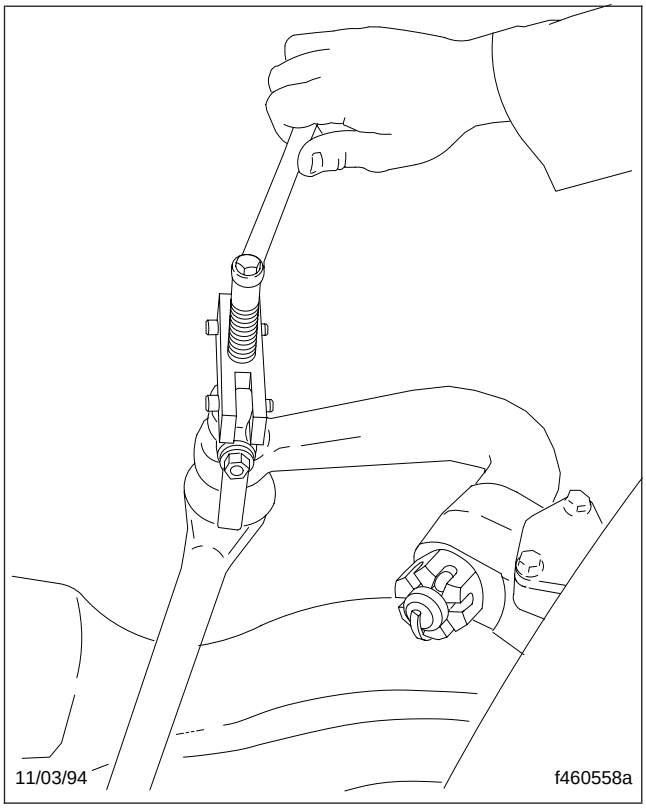
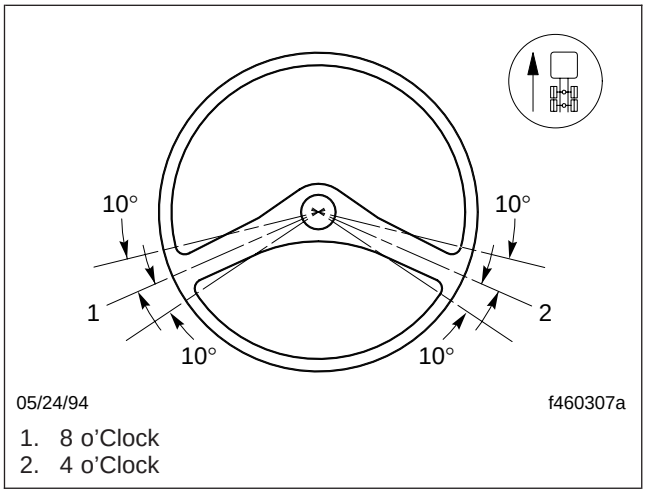


Fig. 6, Ball Stud Removal Tool on Steering Arm



1. 8 o'Clock
2. 4 o'Clock

Fig. 7, Steering Wheel Centered

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Testing

Check for wear of the drag link ball stud end, and nut tightness as follows:

Have someone gently turn the steering wheel back and forth; check for looseness between the ball stud end, and both the pitman arm and steering arm. Also check for looseness of the ball stud nut.

If the ball stud *end* is loose, replace the drag link. If the ball stud *nut* is loose, replace the nut and cotter key. Tighten the ball stud nut as follows:

- 3/4–16, 90 to 170 lbf·ft (122 to 230 N·m);
- 7/8–14, 160 to 300 lbf·ft (217 to 407 N·m).

Grasp the drag link near the pitman arm end, push and pull laterally to check for axial looseness in the ball stud end. If there is looseness, replace the drag link. For instructions, see **Subject 100**. If there is 1/8 inch (3 mm) looseness or more, do not drive the vehicle until the drag link is replaced.

Grasp the drag link near the steering arm end. Push and pull vertically to check for axial looseness in the ball stud end. If there is looseness, replace the drag link. For instructions, see **Subject 100**. If there is 1/8 inch (3 mm) looseness or more, do not drive the vehicle until the drag link is replaced.

Grease the drag link until the old grease is purged.

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Specifications

Torque Values	
Nut Size	**Torque lbf·ft (N·m)**
3/4–16	90–170 (122–230)
7/8–14	160–300 (217–407)

Table 1, Torque Values

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General Information

The steering wheel is cushioned and has two spokes. A horn button is mounted in the center of the steering wheel.

A turn signal switch is attached to the left side of the column, just below the steering wheel. If the vehicle is equipped with the optional trailer brake air switch, it is installed on the right side of the column.

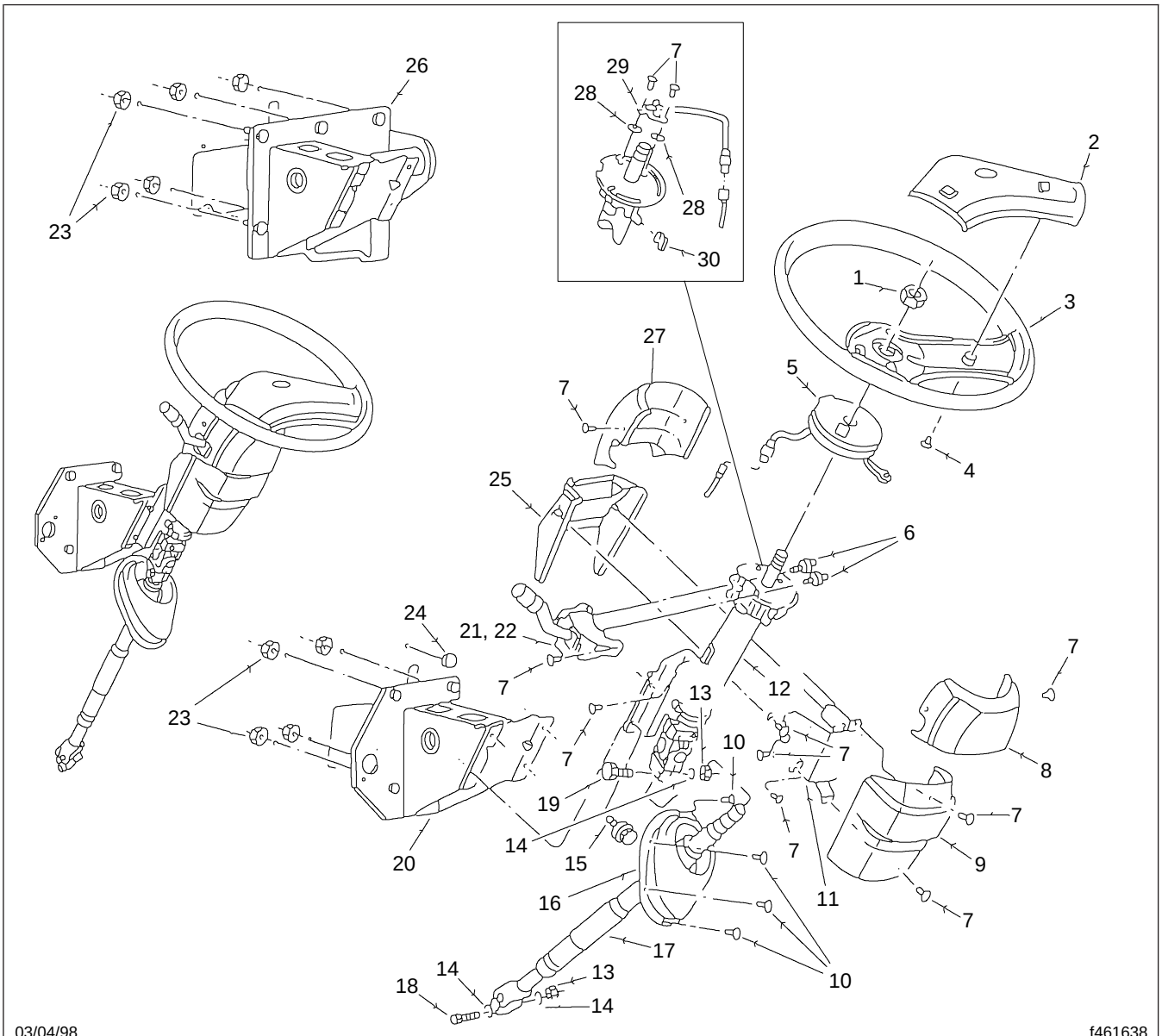
The major parts of the steering column assembly are the shaft, the bearings, and the tube assembly. See **Fig. 1**.

The steering shaft is installed in the tube assembly and held in place by bearings. The upper end of the shaft is threaded. Below the threads are splines that correspond to those in the steering wheel. The lower end of the shaft is splined for the steering driveline end yoke and has a groove for the end yoke pinch bolt.

The steering column assembly is held in place by capscrews that attach the bracket end of the assembly to the lower dash and the pedal support bracket.

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General Information



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1. Steering Wheel Nut
2. Horn Pad
3. Steering Wheel
4. Screw
5. Clockspring
6. Screw
7. Screw
8. Shroud (upper front)
9. Shroud (lower front)
10. Screw
11. Shroud Bracket (front and back)
12. Steering Column
13. Nut
14. Washer
15. Screw and Washer
16. Steering Column Floor Seal
17. Steering Column Coupling Shaft
18. Bolt
19. Bolt and Retainer
20. Steering Column Support Bracket (automatic transmission)
21. Turn Signal Switch Assembly (with Signal-Stat turn signal)
22. Turn Signal Switch Assembly (with windshield wiper)
23. Nut
24. Button Plug
25. Shroud (lower back)
26. Steering Column Support Bracket (manual transmission)
27. Shroud (upper back)
28. Washer
29. Horn Brush Assembly
30. U-Nut

Fig. 1, Fixed Steering Column

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Steering Wheel Removal and Installation

Removal

1. Position the vehicle front wheels straight ahead. If possible, drive the vehicle in a straight line for a short distance, stopping at the place where the work will be done. Mark the steering wheel and column with a grease pencil for alignment reference.
2. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
3. Disconnect the battery ground cable(s).
4. Remove two horn pad retaining screws. See **Fig. 1**.

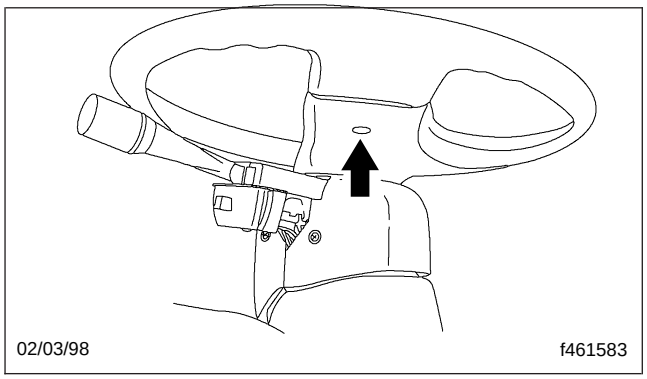


Fig. 1, Horn Pad Retaining Screw

5. Tilt the horn pad upward and disconnect the horn pad/speed control connector (if so equipped). See **Fig. 2**.

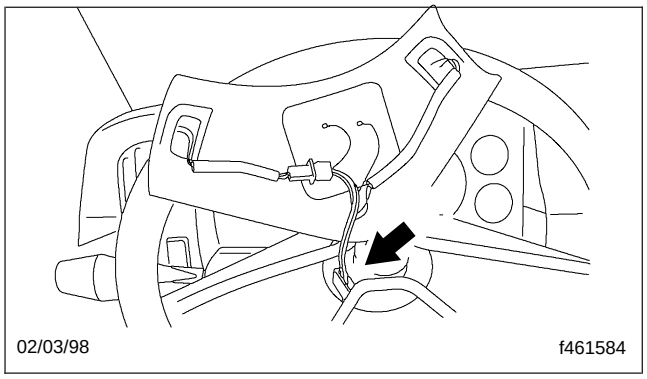


Fig. 2, Horn Pad/Speed Control Connector

6. Remove the steering wheel retaining nut. See **Fig. 3**.

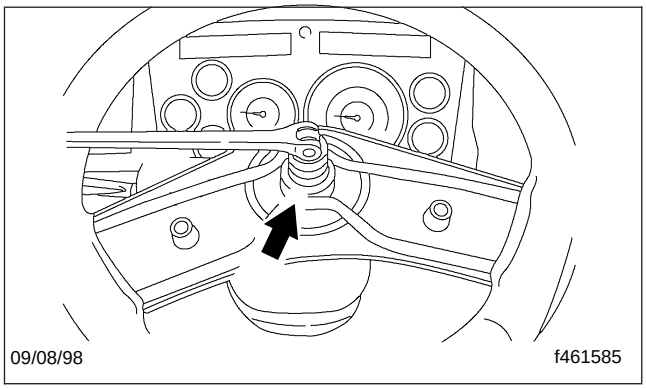


Fig. 3, Remove the Steering Wheel Retaining Nut

7. Install the steering wheel puller and remove the steering wheel. See **Fig. 4**.

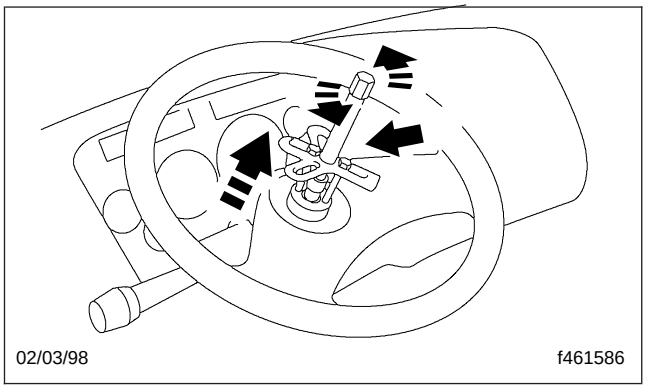


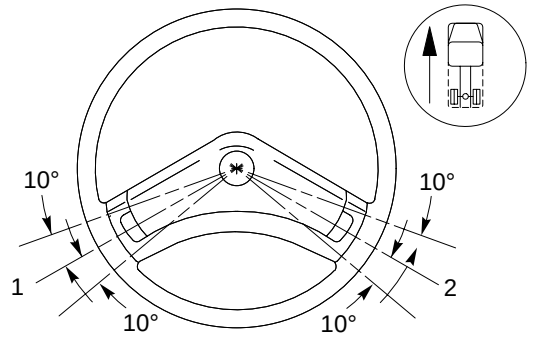
Fig. 4, Install the Steering Wheel Puller

Installation

1. Remove the steering wheel puller and replace the steering wheel.
2. Check the steering wheel spoke position. With the front tires pointing straight ahead, check the position of the steering wheel spokes. They must be pointing within ±10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 5**. If not, remove the steering wheel and install it in the correct position.
3. Tighten the steering wheel nut 45 to 65 lbf·ft (61 to 88 N·m). See **Fig. 6**.
4. Apply torque seal OGP F900WHITE to the exposed thread and to the locknut.
5. Connect the horn pad/speed control connector (if so equipped).

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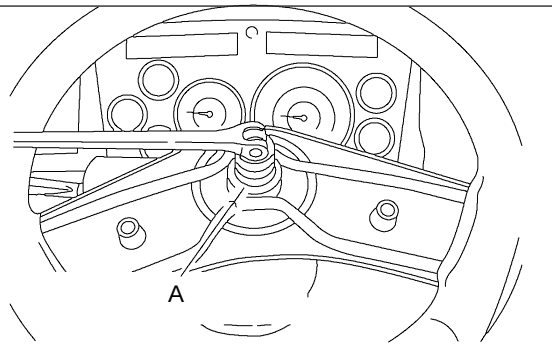
Steering Wheel Removal and Installation



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1. 8 o'Clock 2. 4 o'Clock

Fig. 5, Steering Wheel Centered



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A. Tighten 45 to 65 lbf·ft (61 to 88 N·m).

Fig. 6, Tighten the Steering Wheel Nut

6. Install two horn pad retaining screws.
7. Connect the battery ground cable(s).
8. Remove the chocks from the rear tires.
9. Test drive the vehicle, or take a ride with the driver.

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Steering Column Removal and Installation

Removal

1. Position the front tires straight ahead. If possible, drive the vehicle in a straight line for a short distance, stopping at the spot where service work will be done. Do not move the tires from the straight-ahead position during removal or at any time while the steering column is removed.
2. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
3. Disconnect the batteries at the negative terminals or at the battery shutoff switch.
4. Remove the steering wheel. For instructions, see **Subject 100**.
5. Remove the clockspring. For instructions, see **Subject 130**.
6. Remove the under steering panel. For instructions, see **Section 60.07**.
7. If equipped, remove the SmartShift™ transmission shift control.
8. Disconnect the multifunction switch electrical connectors. See **Fig. 1**.
9. Remove the screws that secure the multifunction switch, then remove the switch. See **Fig. 2**.

NOTE: Before disconnecting the steering driveline from the steering column yoke, mark the steering driveline in a manner that will allow it to be installed in the same orientation as when removed.

10. Mark the steering driveline/steering column yoke orientation. Remove and discard the steering column yoke pinch bolt, washer, and nut. Slide the steering driveline out of the way. See **Fig. 3**.
11. Remove the four bolts that attach the steering column to the support bracket. See **Fig. 4**.
12. Remove the steering column from the vehicle.

Installation

1. Position the steering column on the steering column mounting bracket.

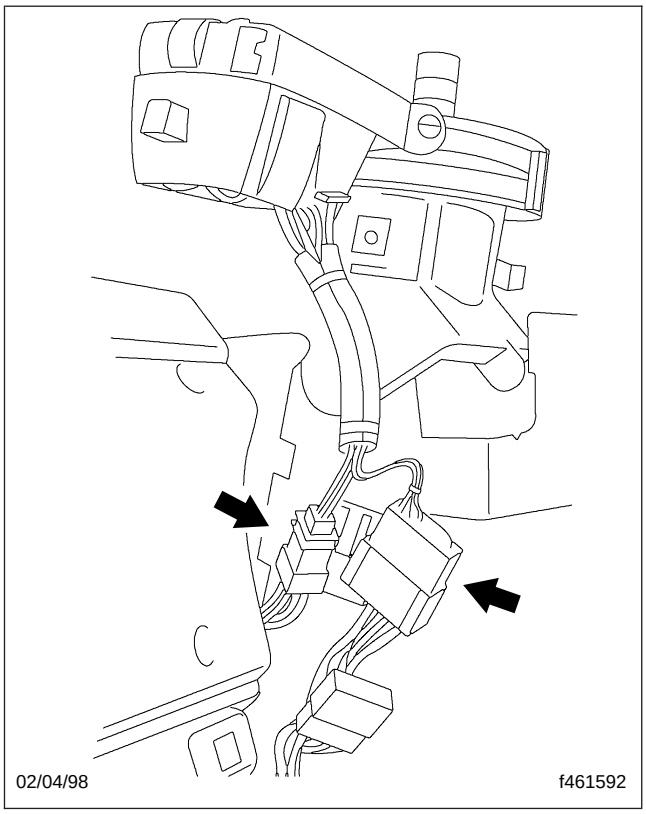
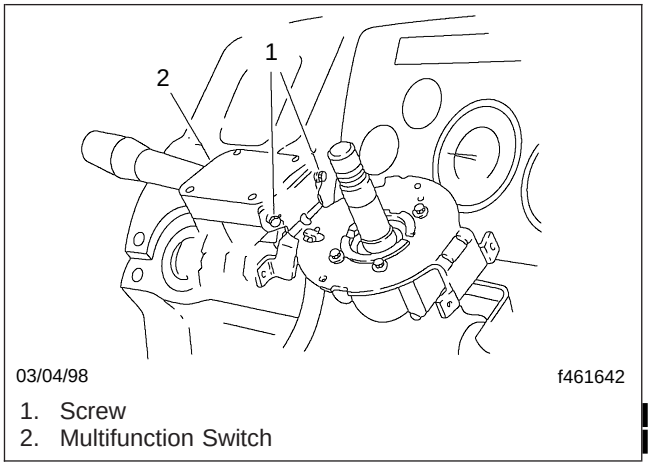


Fig. 1, Multifunction Switch Electrical Connectors



1. Screw
2. Multifunction Switch

Fig. 2, Remove the Multifunction Switch

2. Install the four bolts that attach the steering column to the support bracket. Tighten the bolts 32 to 41 lbf·ft (43 to 55 N·m).

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Steering Column Removal and Installation

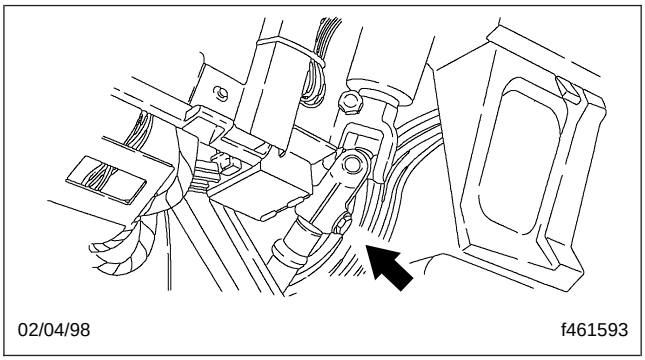


Fig. 3, Steering Column Yoke Pinch Bolt

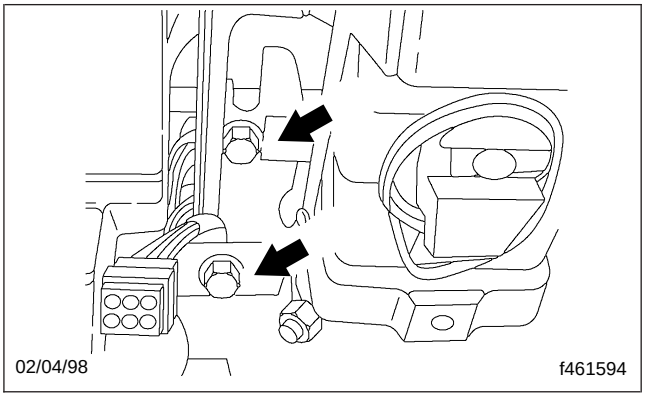


Fig. 4, Support Bracket Bolts

NOTE: The steering column yoke must be installed in the same orientation as when removed.

3. Slide the upper end of the steering driveline into the steering column yoke. Install a new pinch bolt. Before installing the nut, make sure the pinch bolt is centered in the steering column shaft notch. The pinch bolt is centered if it can slip in and out of the end yoke with ease. Install a new nut and tighten the nut to one of the following torque specs:
   - 55 to 65 lbf·ft (75 to 88 N·m) for a 7/16 pinch bolt and nut
   - 30 to 35 lbf·ft (41 to 47 N·m) for an M10 pinch bolt and nut
4. Apply torque seal, OGP F900WHITE, to the exposed bolt threads and to the nut.
5. Install the multifunction switch.
6. Connect the electrical connectors to the multifunction switch.
7. If equipped, install the SmartShift™ transmission shift control.
8. Install the under steering panel. For instructions, see **Section 60.07**.
9. Install the clockspring. For instructions, see **Subject 130**.
10. Install the steering wheel and check the position of the steering wheel spokes. They must be within ±10 degrees of the 4 o'clock and 8 o'clock positions. For instructions, see **Subject 100**.
11. Connect the batteries at the negative terminals or at the battery switch.
12. Remove the chocks from the tires.

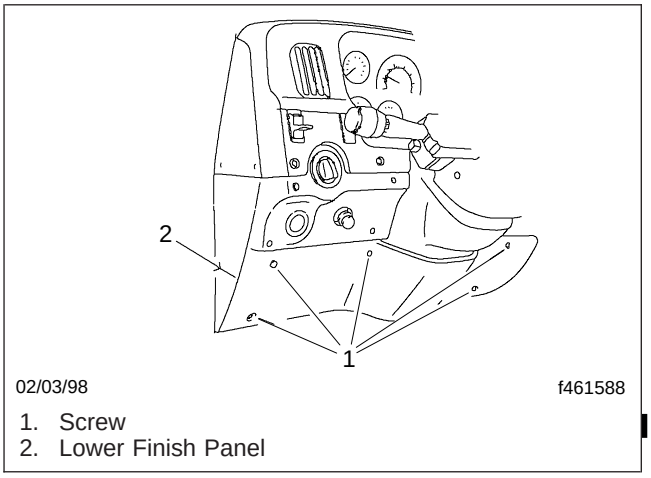
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Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.

NOTE: Make sure the front wheels are in the straight-ahead position.

2. Remove the instrument panel lower finish panel. See **Fig. 1**.



1. Screw
2. Lower Finish Panel

Fig. 1, Instrument Panel

2.1 Remove the screws.

2.2 Remove the instrument panel lower finish panel.

NOTE: Before removing the U-joint, mark it so that it can be installed in the same orientation it was in when removed. The short yoke must be installed on the output shaft of the column.

3. Mark the U-joint/shaft orientation. Remove and discard the pinch bolt, washer, and nut that attach the coupling shaft to the steering column. Slide the coupling shaft out of the way. See **Fig. 2**.

4. Mark the U-joint/shaft orientation. Remove and discard the pinch bolt, washers, and nut that hold the U-joint in place. See **Fig. 3**.

5. Remove the U-joint. Inspect the U-joint for damage and replace it if necessary. See **Fig. 4**.

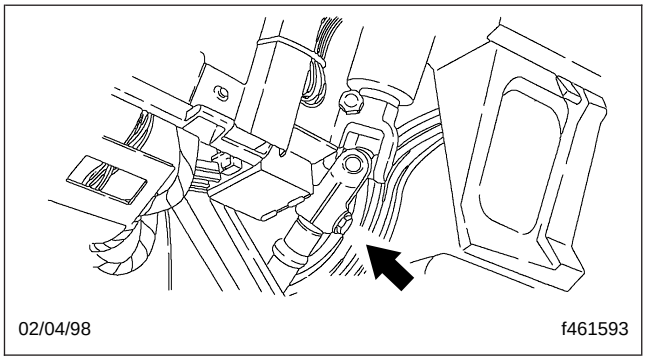


Fig. 2, Coupling Shaft Pinch Bolt

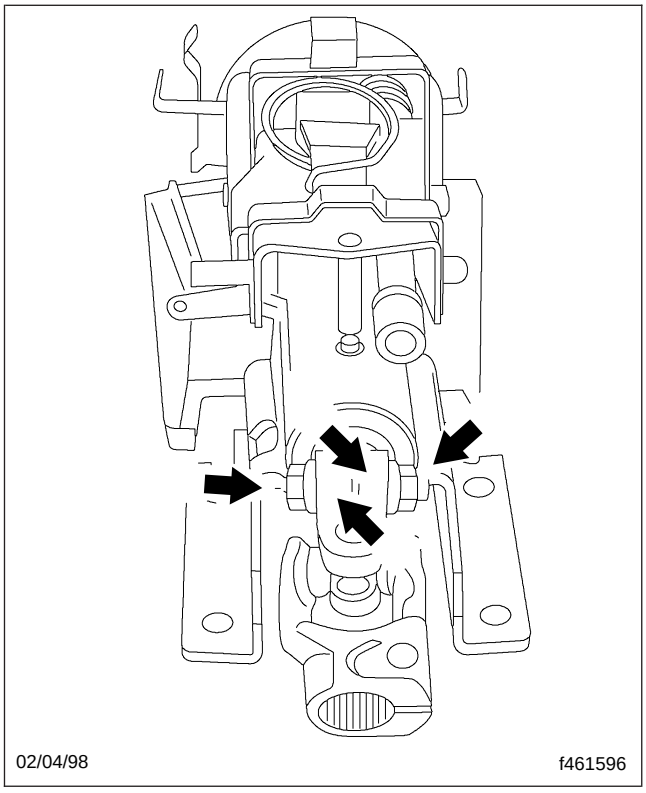


Fig. 3, U-Joint Retaining Points

Installation

NOTE: The U-joint must be installed in the same orientation it was in when removed. The short yoke must be installed on the output shaft of the column.

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U-Joint Removal and Installation

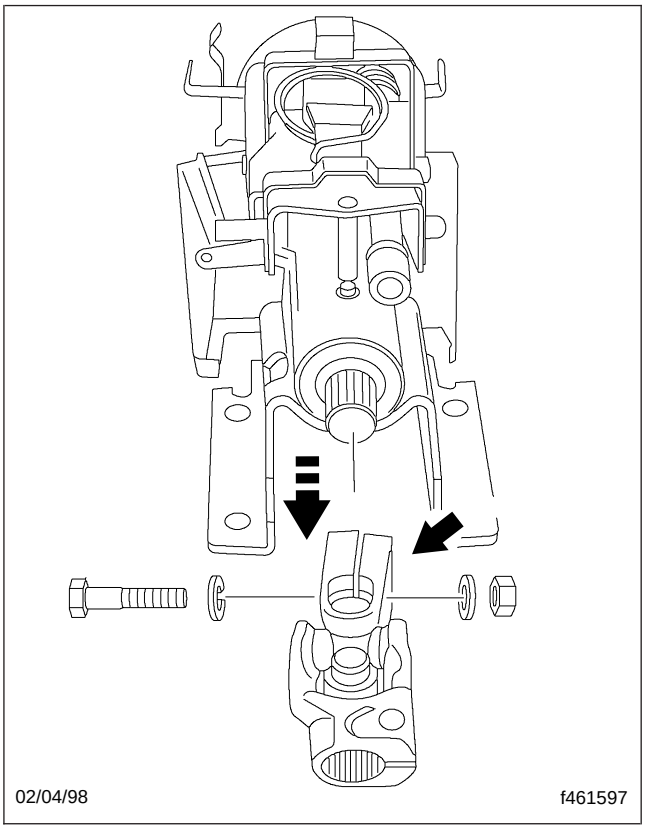


Fig. 4, Remove the U-Joint from the Steering Shaft

1. Position the U-joint and install a new pinch bolt, washers, and nut to secure the U-joint to the steering driveline. Tighten the nut to one of the following torque specs:
   - 55 to 65 lbf·ft (75 to 88 N·m) for a 7/16 pinch bolt and nut
   - 30 to 35 lbf·ft (41 to 47 N·m) for an M10 pinch bolt and nut
2. Position the coupling shaft and install a new pinch bolt, washer, and nut to secure the coupling shaft to the steering column. Tighten the nut to one of the following torque specs:
   - 55 to 65 lbf·ft (75 to 88 N·m) for a 7/16 pinch bolt and nut
   - 30 to 35 lbf·ft (41 to 47 N·m) for an M10 pinch bolt and nut
3. Install the instrument panel lower finish panel.
4. Remove the chocks from the tires.

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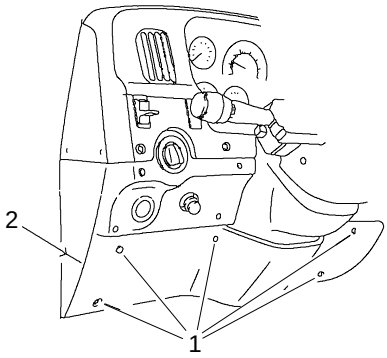
Clockspring Removal and Installation

Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.

NOTE: Make sure the front wheels are in the straight-ahead position.

2. Remove the steering wheel. See **Subject 100**.
3. Remove the upper steering column shrouds.
4. Remove the instrument panel lower finish panel. See **Fig. 1**.



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1. Screws
2. Lower Finish Panel

Fig. 1, Instrument Panel

4.1 Remove the screws.

4.2 Remove the instrument panel lower finish panel.

5. Remove the lower shroud. See **Fig. 2**.

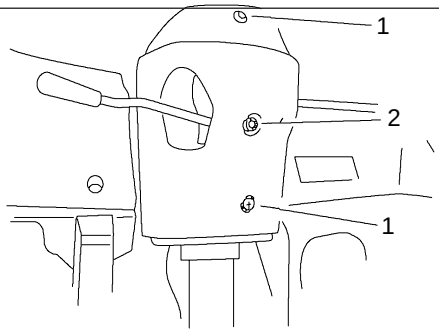
5.1 Remove the screws.

5.2 Remove the Allen screw.

6. Disconnect the clockspring electrical connector. See **Fig. 3**.

NOTE: The clockspring retaining tabs are located at the 12 o'clock, 6 o'clock and the 9 o'clock positions.

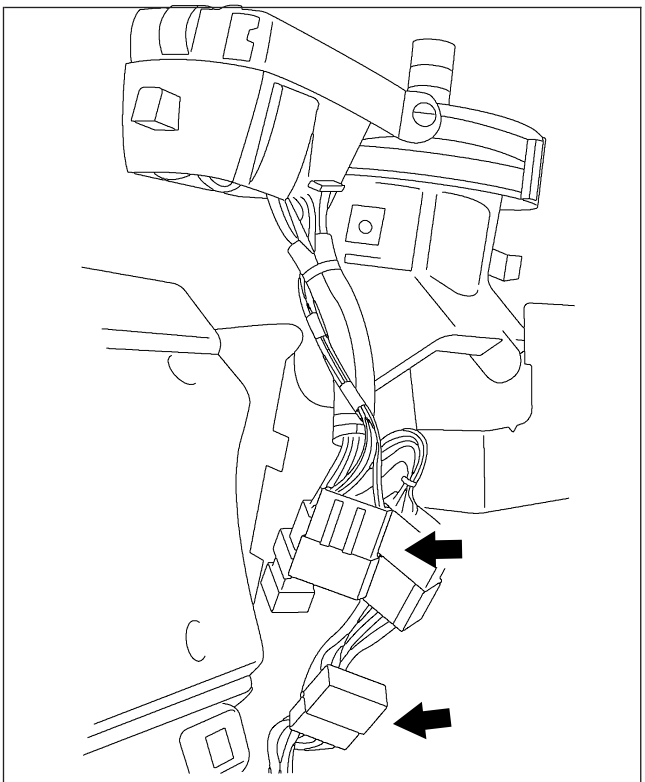
7. Depress the three clockspring retaining tabs (located at the bottom of the clockspring adapter plate) while slightly lifting the clockspring off the steering column shaft. See **Fig. 4**.



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1. Shroud Fastener
2. Allen Screw

Fig. 2, Lower Steering Column Cover



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Fig. 3, Clockspring Electrical Connector

Installation

NOTE: The clockspring retaining tabs are located at the 12 o'clock, 6 o'clock and the 9 o'clock positions.

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Clockspring Removal and Installation

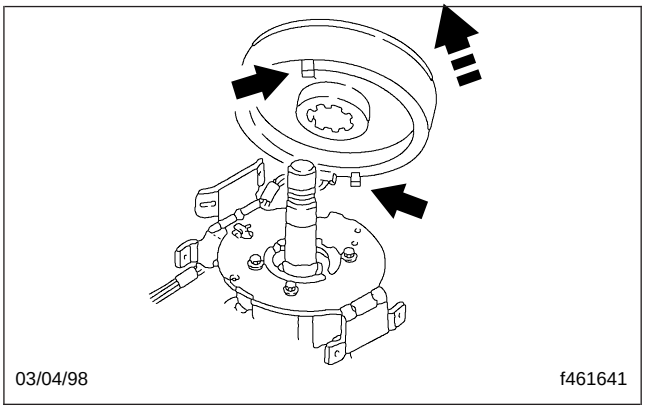
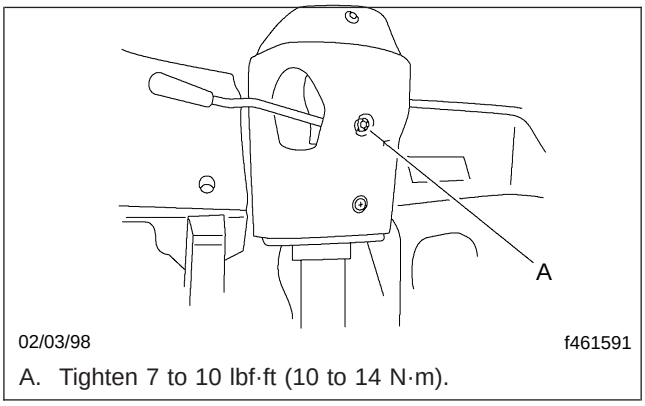


Fig. 4, Clockspring Retaining Tabs

1. Depress the three clockspring retaining tabs (located at the bottom of the clockspring adapter plate) while pushing the clockspring back on the steering column shaft.
2. Connect the clockspring electrical connector.
3. Install the lower shroud.
   - 3.1 Install the Allen screw.

     Tighten the lower shroud Allen screw 7 to 10 lbf·ft (10 to 14 N·m). See **Fig. 5**.



A. Tighten 7 to 10 lbf·ft (10 to 14 N·m).

Fig. 5, Tightening the Allen Screw

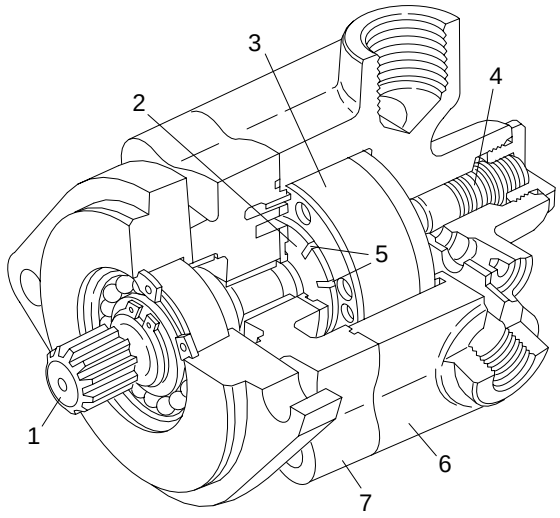
   - 3.2 Install the screws.
4. Install the instrument panel lower finish panel.
   - 4.1 Position the instrument panel lower finish panel.
   - 4.2 Install the screws.
5. Install the upper steering column shrouds.
6. Install the steering wheel. See **Subject 100**.
7. Remove the chocks from the tires.

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General Information

The LuK Automotive Hydraulics VT 7 Series power steering pump supplies power steering fluid for the operation of the power steering gear, and in vehicles so equipped, for the hydraulic brake power booster.

On Cummins ISB and ISC Series engines, the pump is mounted on the left side of the engine at the rear of the gear case. It is powered by an adaptor gear in the engine. The main parts of the power steering pump are the housing, driveshaft, cam ring, rotor, vanes, and control valve. See **Fig. 1**.



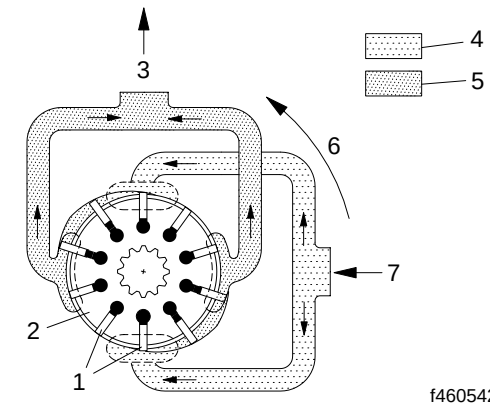
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1. Driveshaft
2. Rotor
3. Cam Ring
4. Control Valve
5. Vane
6. Housing
7. Flange Assembly

Fig. 1, Power Steering Pump Components

The driveshaft, powered by the adaptor gear in the engine gear case or by the crankshaft pulley, turns the rotor, which is inside the cam ring. See **Fig. 2**. As the rotor turns, centrifugal force pushes the vanes out toward the surface of the cam ring. As fluid enters the cam ring through the inlet port, the rotor vanes force it out through the outlet port and into the system. The fluid operates the steering gear and if the vehicle is so equipped, the hydraulic brake power booster. Eventually the fluid returns to the power steering reservoir, then back to the power steering pump.

If the system pressure gets too high, a poppet inside the control valve is forced off its seat, shunting fluid into a relief passage connected to the inlet port. The fluid then recirculates inside the pump instead of going to the outlet port. When the system pressure drops to the correct level, the poppet seats, closing off the relief passage to the inlet port. The fluid flow returns to normal, flowing from the inlet port to the outlet port and then into the power steering system.



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1. Vane
2. Rotor
3. Outlet
4. Low Pressure Fluid
5. High Pressure Fluid
6. Rotation
7. Inlet

Fig. 2, Power Steering Fluid Flow

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Removal

1. Turn off the engine, apply the parking brakes, and chock the rear tires.
2. Open the hood.
3. Clean all dirt from around the fittings and hose connections.
4. Place a drain pan under the power steering pump, then disconnect the hoses from the pump. Plug the hoses and cap the fittings to keep out dirt and to prevent fluid from leaking.
5. Remove the power steering pump.
   - 5.1 Remove the capscrews that attach the pump to the engine accessory drive mounting flange.
   - 5.2 Pull the pump straight out from the engine.
6. Turn the pump upside down over the drain pan, and let the fluid drain out.
7. Discard the gasket, washers, and capscrews from the pump mounting flange.

Installation

1. Using engine oil, lightly lubricate a new gasket and the pump shaft.
2. Install the power steering pump.

   Install a new gasket on the pump mounting flange, then place the pump on the engine accessory drive mounting. Install new washers and capscrews. Torque the capscrews 27 to 32 lbf·ft (37 to 43 N·m).
3. Connect the inlet hose, from the power steering reservoir, to the inlet port. Torque the hose 20 lbf·ft (27 N·m).
4. Connect the outlet hose, from the power steering gear, to the outlet port. Install and tighten the hose clamp.
5. Bleed the power steering system.
   - 5.1 Check the fluid level in the power steering reservoir. If needed, fill it to the correct level with Dexron® III automatic transmission fluid (ATF).
   - 5.2 Start the engine and let it idle for several minutes.
   - 5.3 Turn the wheels to a full-left and full-right turn. Repeat about three times.
   - 5.4 Check the fluid level in the power steering reservoir. If needed, add automatic transmission fluid.
   - 5.5 Shut down the engine.
6. Close the hood.
7. Remove the chocks from the tires.

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Disassembly

⚠ WARNING

Wear safety goggles or glasses when disassembling the power steering pump. Some of the parts are held in place by springs or snap rings, which can release with considerable force, possibly causing injury.

⚠ CAUTION

Be careful when working on the pump housing; it is aluminum and can be easily damaged. When putting it in a vise, pad the vise jaws. Tighten the vise just enough to hold the pump.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the power steering pump from the engine. For instruction, see **Subject 100**.
3. Carefully remove the end plug from the pump body, and the spring behind it. Carefully slide out the control valve so that it does not get scratched. See **Fig. 1**.
4. Remove and discard the O-ring from the plug.
5. Put the pump housing in a padded vise. Remove the capscrews that hold the housing and the flange assembly together.
6. Remove the flange assembly from the pump housing.
7. Remove the pressure plate from the flange assembly.
8. Remove the cam ring.
9. Remove the rotor and vanes.
10. Remove the wear plate.
11. Remove the two guide pins from their seats.
12. Remove the large O-ring from the flange assembly.
13. Remove the driveshaft from the flange assembly.
    - 13.1 Remove the snap ring that holds the shaft bearing in place.
    - 13.2 Put the flange assembly in a vise. Carefully tap out the driveshaft.
14. Check the driveshaft bearing. If it is damaged or worn, remove it from the driveshaft. Otherwise, go to the next step.
    - 14.1 Remove the small snap ring from the driveshaft.
    - 14.2 Being careful to push only on the inner ring of the bearing, press the bearing off the driveshaft.
15. Remove and discard the shaft seal from the flange assembly.
16. Remove and discard the two O-rings and backup rings from the pump housing.

Inspection

1. Using a solvent compatible with the power steering fluid, clean all the parts. Using filtered compressed air, dry all the parts.
2. Check all the parts. Replace any that are damaged or worn.
3. Check the vanes on the rotor for damage or too much play in the rotor slots. If you can move the vanes from side to side in the slots, replace the whole rotor assembly.
4. Check the control valve. If obvious damage or wear is present, replace the control valve. If the control valve does not need replacing, continue with the next step.

⚠ CAUTION

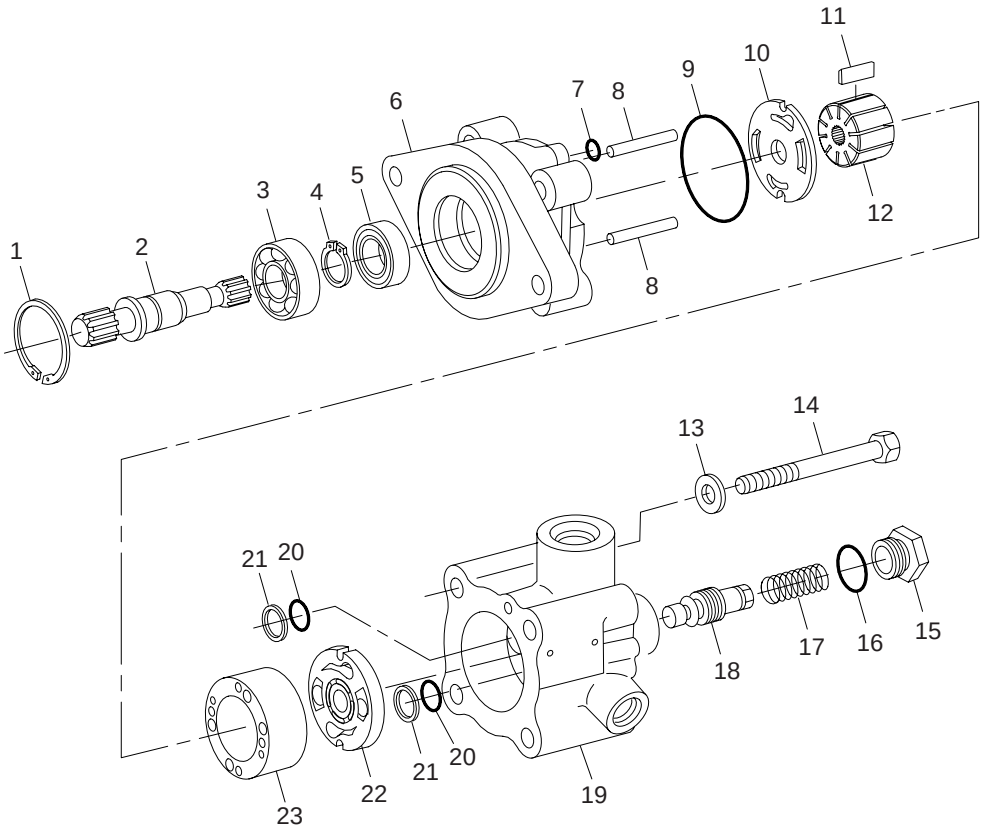
When putting the control valve in a vise, put only the bottom part (opposite the hex plug) of the valve into the vise. Do not clamp the sealing surfaces (outer rings) or you will damage the valve.

5. Carefully put the control valve in a padded vise. See **Fig. 2**. Do not damage the sealing surfaces.

   Test the torque of the seat (hex) plug. It should be 72 to 96 lbf·in (813 to 1085 N·cm). If it is not, replace the control valve.
6. Coat the control valve with Dexron® III automatic transmission fluid (ATF). Fit it into the bore in the pump housing.

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Disassembly, Inspection, and Assembly



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1. Snap Ring
2. Driveshaft
3. Driveshaft Bearing
4. Snap Ring
5. Shaft Seal
6. Flange Assembly
7. O-Ring
8. Guide Pin
9. O-Ring
10. Wear Plate
11. Vane
12. Rotor
13. Washer
14. Capscrew
15. End Plug
16. O-Ring
17. Spring
18. Control Valve
19. Pump Housing
20. O-Ring
21. Backup Ring
22. Pressure Plate
23. Cam Ring

Fig. 1, Power Steering Pump

7. Spin the control valve all the way around in the bore, while moving it in and out. If there is any binding, replace the control valve.

Assembly

1. Coat all the parts in ATF.

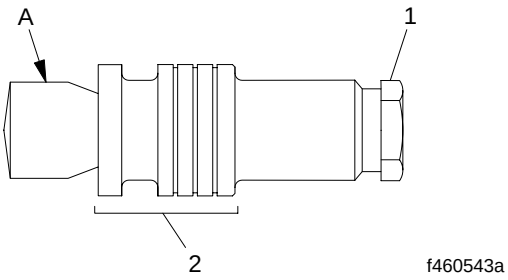
NOTE: To correctly install the driveshaft seal and bearing, it is necessary to make suitable drivers from tubular stock. See **Specifications 400** for the applicable dimensions.

2. Using a suitable driver, install the shaft seal into the bore in the flange assembly. Make sure the spring side of the seal faces the flange. See **Fig. 3**. Seat the seal firmly against the shoulder in the bore.

⚠ CAUTION

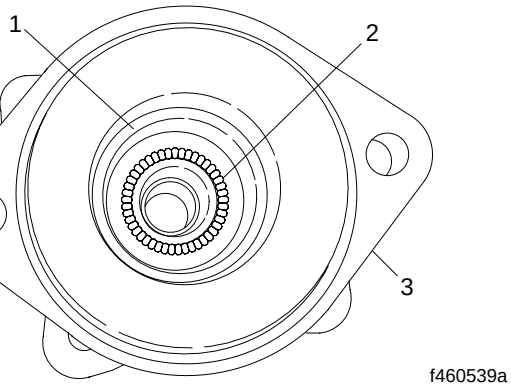
When installing the driveshaft bearing, make sure that pressure is exerted only on the inner race of

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A. Clamp vise here.
1. Hex Plug
2. Sealing Surfaces

Fig. 2, Control Valve Components



1. Shaft Seal
2. Garter Spring
3. Flange

Fig. 3, Seal Placement

the bearing. Do not use any pressure on the outer race or you may damage the bearing assembly.

3. If it was removed, install a new bearing on the driveshaft, using a suitable driver and an arbor press.

   Install the small snap ring in the groove on the drive shaft, with the sharp edge facing toward the bearing.

4. Install the driveshaft and bearing assembly in the flange assembly.

   4.1 Lubricate the shaft with ATF.

   4.2 Being careful not to damage the shaft seal, slide the driveshaft into the bore of the flange assembly.

   4.3 Install the large snap ring into the groove in the flange assembly.

5. Using ATF, lubricate the new O-rings and backup rings. Install them in the pump housing.

6. Put the flange assembly in a padded vise. Install a new large O-ring in the flange assembly.

7. Install a new small O-ring in the flange assembly.

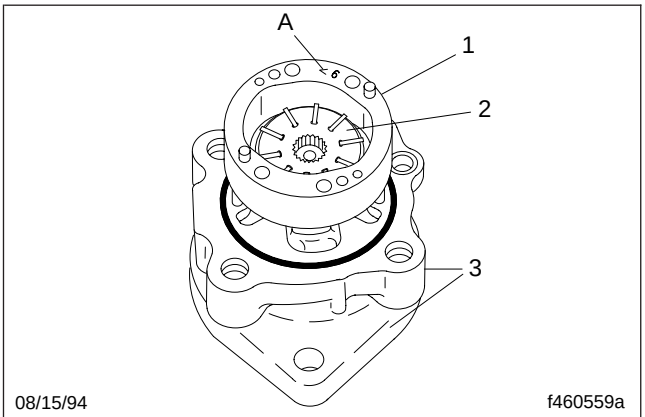
8. Install the two guide pins in their seats in the flange assembly.

9. Install the wear plate, bronze side up, on the flange assembly.

10. Install the rotor on the driveshaft.

11. Install the vanes, rounded edges outboard, in the rotor. Make sure that none of them are binding.

12. Install the cam ring over the rotor, onto the flange assembly and over the guide pins. Make sure the arrow on the face of the cam ring is pointing in the direction of the shaft rotation. With the flange held shaft side down, the arrow should be pointing in a counterclockwise direction. See **Fig. 4**.



A. Stamped arrow indicates rotation direction.
1. Cam Ring
2. Rotor
3. Flange Assembly

Fig. 4, Cam Ring Placement

13. Install the pressure plate, bronze side down, on the rotor and cam ring assembly.

14. Lining up the mounting holes, install the pump housing over the flange assembly.

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Disassembly, Inspection, and Assembly

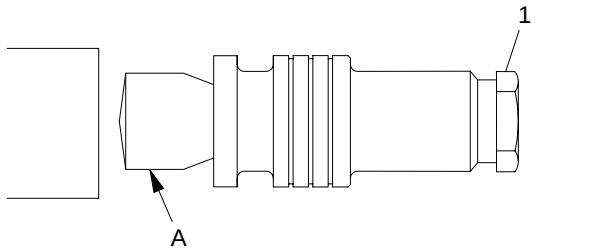
15. Install the capscrews and washers in the pump housing. Tighten them in a cross pattern 29 to 37 lbf·ft (40 to 50 N·m).

16. Install the control valve in the pump housing.

CAUTION

Make sure that you install the control valve correctly in the bore. If it is installed backwards, the power steering pump will not work and will quickly overheat, which could cause severe damage to the pump.

16.1 Lubricate the control valve. Install it, with the hex plug end up, in the bore in the pump housing. See **Fig. 5**.



A. Insert this end first.
1. Hex Plug

Fig. 5, Control Valve Installation

16.2 Install the spring over the hex plug end of the control valve.

16.3 Install a new O-ring on the end plug. Install the end plug. Tighten it 33 to 40 lbf·ft (45 to 54 N·m).

17. Install the power steering pump on the engine. For instructions, see **Subject 100**.

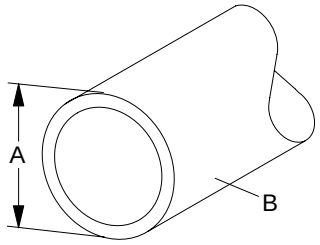
18. Remove the chocks from the tires.

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Dexron® III automatic transmission fluid (ATF) is the only hydraulic fluid approved for use in the power steering system.

See **Fig. 1** for the bearing installation tool specifications.

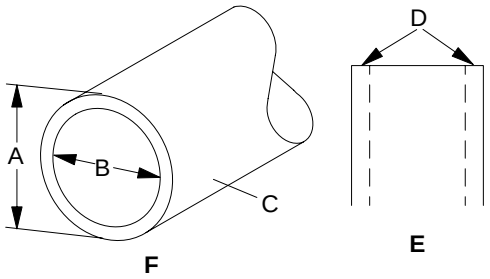
See **Fig. 2** for the shaft seal installation tool specifications.



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A. Slightly smaller than the o.d. or slightly larger than i.d. of the bearing.
B. To be made of tubular stock.

Fig. 1, Bearing Installation Tool



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A. Slightly smaller than the o.d. of the shaft seal.
B. Slightly larger than the o.d. of the driveshaft.
C. To be made of tubular stock.
D. The ends must be square.
E. Front View
F. End View

Fig. 2, Shaft Seal Installation Tool

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General Information

The TRW TAS40, TAS55, and TAS65, power steering gears use pressurized hydraulic fluid to help the driver turn the front wheels. All three models mount on the left frame rail, and all operate in the same way.

The difference between the three gears is size. The TAS40 can be installed on vehicles with front axle capacities up to 8000 pounds (3629 kg). The TAS55 is for vehicles with front axle capacities up to 10,000 pounds (4536 kg). The TAS65 is for front axle capacities up to 14,000 pounds (6350 kg).

All three gears use more pressurized fluid when the driver turns the steering wheel quickly than when the driver turns the steering wheel slowly, but the minimum amount of power steering fluid is different for each model. With the driver turning the steering wheel 1-1/2 turns per second, the TAS40 needs at least 2.2 gallons (8.3 liters) of fluid per minute. At the same turning speed, the TAS55 needs 2.6 gpm (9.8 L/min), and the TAS65 needs 3.0 gpm (11.4 L/min).

⚠ CAUTION

Never steam clean or high-pressure wash the steering gear. Internal damage to gear seals and ultimately the steering gear can result.

When the driver turns the steering wheel, that force travels down through the steering driveline to the steering gear input shaft. See **Fig. 1**. The input shaft turns the worm shaft which moves the rack piston forward or backward in the gear housing by means of a series of recirculating balls in the spiral channels of the worm shaft. See **Fig. 2**.

Grooves in the rack piston mesh with teeth in the sector shaft, and as the piston slides back and forth, it turns the sector shaft. See **Fig. 2**. The sector shaft swings the pitman arm. See **Fig. 1**. The pitman arm pulls or pushes the drag link, and the drag link moves the axle steering arm, steering the vehicle.

Pressurized power steering fluid helps the worm shaft slide the rack piston forward or backward in the gear housing.

The input shaft is not connected directly to the worm shaft. Instead, a thin bar, the torsion bar, holds the input shaft to the worm shaft. See **Fig. 2**. The outside end of the torsion bar is fastened to the input shaft, and the inside end is fastened to the worm shaft; thus, the force of the driver turning the steering wheel travels from the input shaft to the worm shaft through the torsion bar.

With the force of the driver alone, the front axle would be difficult to steer. The weight on the front wheels, the friction of the tires against the road, and the inertia of the vehicle traveling in its current direction all combine to hold the sector shaft and the rack piston in place.

To overcome this resistance, the steering gear has a valve for directing pressurized hydraulic fluid either in front of the rack piston or behind it, thus using the fluid to push the rack piston in the direction the worm shaft is trying to slide it.

The torsion bar controls the hydraulic fluid. As the driver turns the steering wheel to turn the input shaft, and the front wheels resist turning and hold the rack piston and worm shaft in place, the torsion bar connecting the input shaft and worm shaft twists slightly. That twisting aligns holes in the hydraulic control valve with channels that carry hydraulic fluid. See **Fig. 2**. Depending on the direction the driver turns the steering wheel—the direction the torsion bar twists—the valve aligns the channels to direct hydraulic fluid in front of the rack piston or behind it. The fluid provides the extra force the worm shaft needs to overcome the resistance from the front wheels, and the worm shaft can then slide the rack piston in the gear housing.

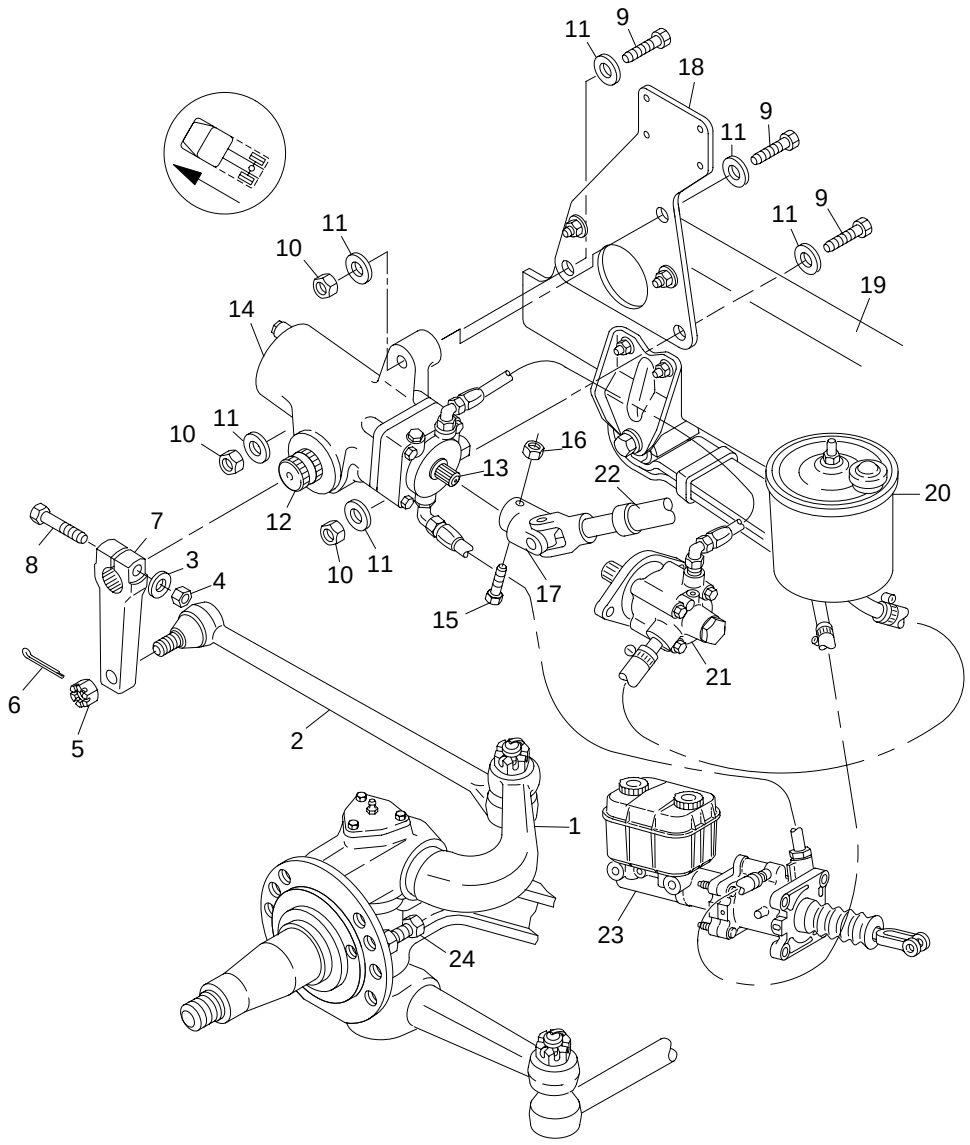
The rack piston slides, and turns the sector shaft. The sector shaft swings the pitman arm. The pitman arm pulls or pushes the drag link. The drag link moves the axle steering arm, and the front wheels turn.

As the front wheels reach the axle stop—the farthest the wheels can turn in that direction—a poppet (unloading valve) in the rack piston trips to prevent steering gear damage. The tripped poppet reduces steering fluid pressure, heat generated by the power steering fluid pump, and outside forces from acting on the steering linkage. See **Fig. 2**.

The hydraulic fluid around the rack piston also prevents road shocks from moving the steering wheel. When the vehicle hits an obstacle, the shock travels up through the front tires and the steering linkage to the steering gear. There, the sector shaft would transmit the shock to the rack piston, but the power steering fluid helps to hold the piston in place and

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General Information



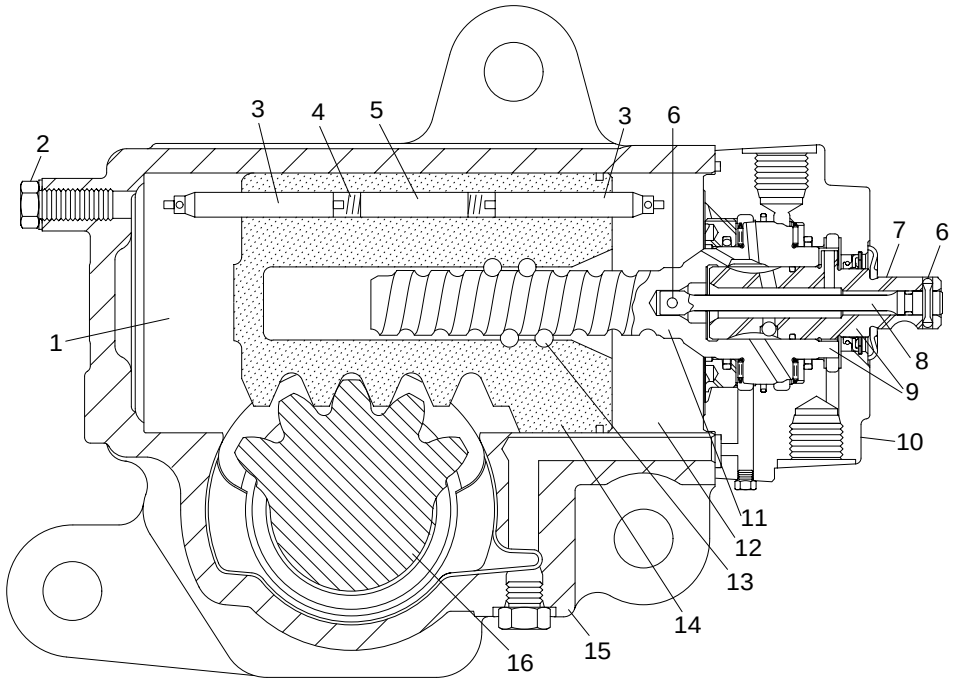
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1. Axle Steering Arm
2. Drag Link
3. Pitman Arm Washer
4. Pitman Arm Pinch Bolt Nut
5. Castle Nut
6. Cotter Pin
7. Pitman Arm
8. Pitman Arm Pinch Bolt
9. Mounting Capscrew
10. Locknut
11. Hardened Washer
12. Sector (output) Shaft
13. Input Shaft
14. Steering Gear
15. Lower End Yoke Pinch Bolt
16. Lower End Yoke Pinch Bolt Nut
17. Lower End Yoke
18. Steering Gear Mounting Plate
19. Left Frame Rail
20. Power Steering Reservoir
21. Power Steering Pump
22. Steering Driveline
23. Brake Booster
24. Axle Stop

Fig. 1, TRW TAS40/55/65 Power Steering Installation (vehicles with hydraulic brakes)

dampen the shock before it can move up the worm shaft to the steering driveline and the steering wheel.

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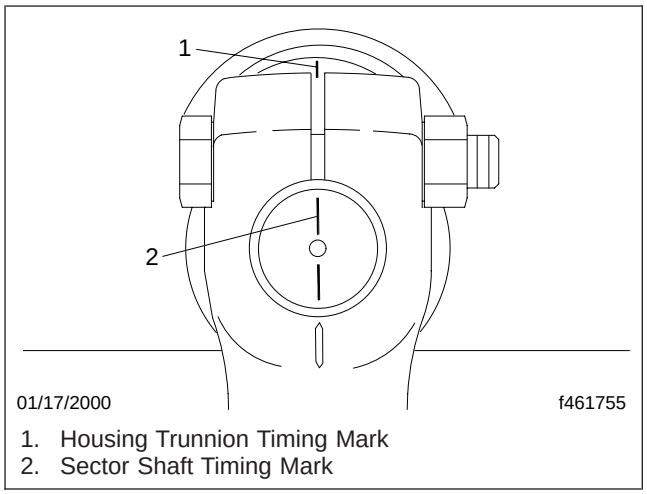
1. Lower Cylinder Cavity
2. Poppet Fixed Stopscrew
3. Poppet Assembly
4. Poppet Spring
5. Push Tube
6. Pin
7. Input Shaft
8. Torsion Bar
9. Control Valve
10. Valve Housing
11. Worm Shaft
12. Upper Cylinder Cavity
13. Ball (recirculating)
14. Rack Piston
15. Gear Housing
16. Sector Shaft

Fig. 2, Steering Gear Section View

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Sector Shaft Adjustment

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Position the sector (output) shaft at its center of travel by turning the steering wheel until the alignment mark on the sector shaft is at a right angle to the input shaft centerline, and in line with the timing mark on the end of the housing trunnion. See **Fig. 1**.



1. Housing Trunnion Timing Mark
2. Sector Shaft Timing Mark

Fig. 1, Timing Mark Placement

3. Disconnect the drag link from the pitman arm. Do not turn the input shaft/valve/worm assembly more than 1-1/2 turns in either direction from its center of travel while the drag link is disconnected from the pitman arm. Turning the input shaft more than 1-1/2 turns from center will cause misadjustment of the automatic poppets. This may require the installation of a service poppet adjustment tool to manually reset the poppets.
4. With the sector shaft in the center position, grasp the pitman arm and gently try to move it back and forth. Fingertip force is adequate to detect lash (free play) of a loose sector shaft. See **Fig. 2**. There should be no movement of the input shaft or sector shaft. Loosen the sector shaft adjusting screw jam nut. See **Fig. 3**. If no lash was detected, turn the shaft adjusting screw counterclockwise until lash is detected.

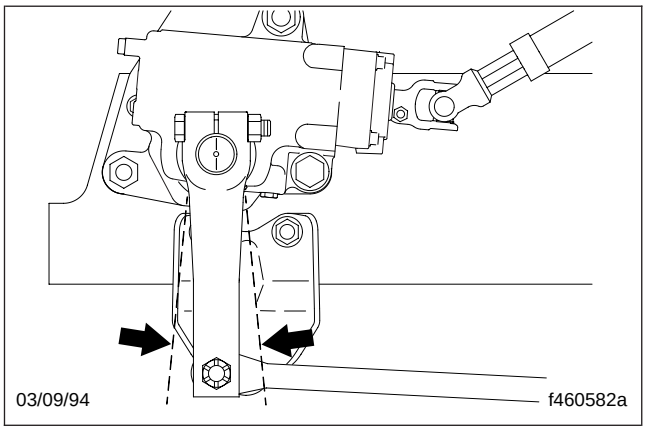


Fig. 2, Free Play Check

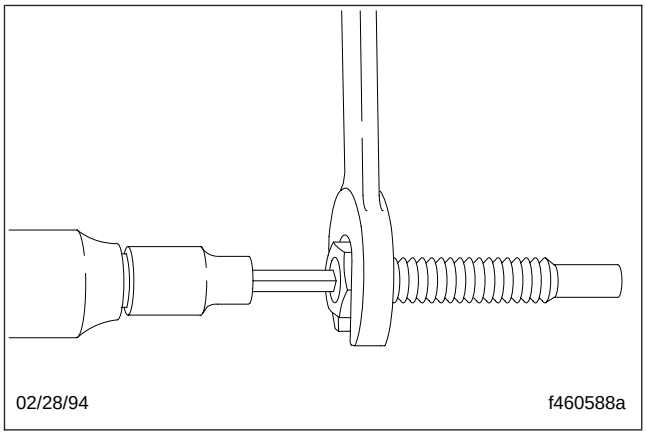


Fig. 3, Jam Nut

5. To adjust, move the adjusting screw clockwise until no lash is felt at the pitman arm. Use no more than 10 lbf·ft (14 N·m) of torque. Slowly turn the adjusting screw clockwise an additional one-eighth turn. Hold the adjusting screw in place and tighten the jam nut 40 to 45 lbf·ft (54 to 61 N·m).
6. Again, check the pitman arm for lash. Turn the steering wheel one-quarter turn each side of center. No lash should be felt. If lash exists, readjust the sector shaft.
7. Connect the drag link to the pitman arm. For instructions, see the applicable section in this group.

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In-Vehicle Adjustments

Poppet Valves Adjustment

TAS40, TAS55, and TAS65 steering gears have automatic poppet valves that reset themselves if the axle stops are reset for increased steering travel. However, if the axle stops are reset for **decreased** steering travel, the poppet valves must be reset manually, through the use of a special service poppet adjusting screw and sealing jam nut kit, unless they were reset for automatic adjustment while the steering gear was disassembled.

Use the following procedure for manually resetting the poppet valves:

1. Verify correct axle stop adjustment. For instructions, see **Group 33**.

IMPORTANT: The axle stops must be set so that there are at least 1-3/4 steering wheel turns from a straight-ahead position to both a full-left and a full-right turn; otherwise the poppet valves will not work.

2. If both axle stops were set for increased travel, the steering gear poppets have reset automatically and gear adjustments are complete. No further action is required.

   If either axle stop was set for decreased travel, the steering gear poppets must be set manually. Continue with the following steps.

3. Install the steering gear manual poppet adjusting screw.

   3.1 Screw the special poppet adjusting screw (from TRW kit 021407-X1) into the non-sealing end of the sealing jam nut, until the drive end of the screw is flush with the nut. See **Fig. 3**.

   3.2 With the vehicle unloaded, the engine off, and the front wheels in the straight-ahead position, remove and discard the poppet fixed stopscrew and washer from the lower end of the steering gear housing. See **Fig. 4**.

   NOTE: With the wheels straight ahead, and the timing marks on the sector shaft and gear housing aligned, the steering gear is centered. See **Fig. 1**.

   3.3 Using an Allen wrench turn the adjusting screw and nut without rotating the nut, into the steering gear housing until the nut is firmly against the housing. See **Fig. 5**. Tighten the nut 33 to 37 lbf·ft (45 to 50 N·m).

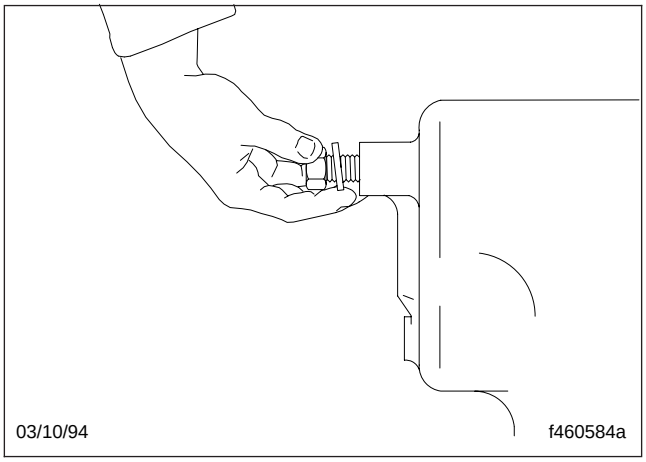


Fig. 4, Poppet Fixed Stopscrew

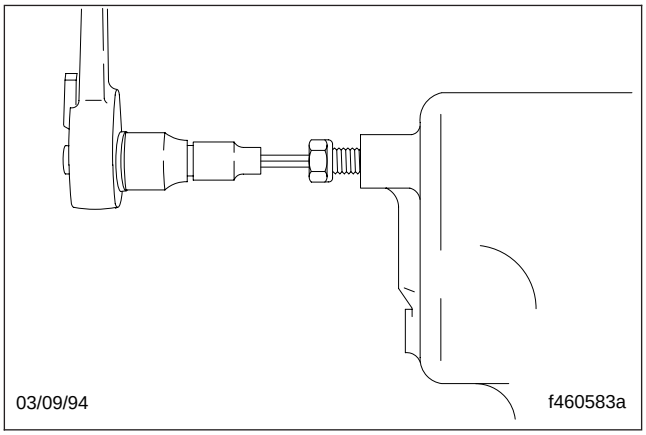


Fig. 5, Stopscrew Adjustment

NOTE: It may be necessary to move the sector shaft slightly from the straight-ahead position to assemble the service adjusting screw as instructed and then return it to straight-ahead.

4. Adjust the poppets manually.

   4.1 Check the fluid level and fill the power steering reservoir with the power steering fluid specified in **Specifications 400**.

   4.2 Make sure the engine is off.

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4.3 Place a jack under the center of the front axle, and raise the steer tires off the ground.

4.4 Turn the steering wheel to the right until the axle stopscrew contacts the axle stop, or the end of the gear travel is reached. This pushes out the left-hand turn poppet to prepare it for setting. See **Fig. 6**.

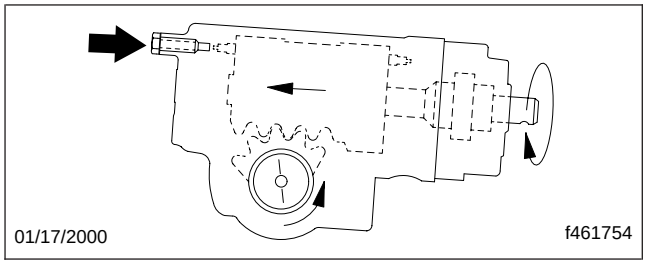


Fig. 6, Adjustable Poppet Screw/Stopscrew Contact

4.5 Turn the steering wheel to the left until the left-hand stop makes contact. This sets the left-turn poppet. Release the steering wheel, and do not steer again until the adjusting screw has been backed out and the sealing nut tightened.

4.6 Loosen the sealing nut on the gear housing, and back out the adjusting screw until it is 1 to 1-1/16 inches (25 to 27 mm) beyond the sealing nut. See **Fig. 7**. Tighten the sealing nut 33 to 37 lbf·ft (45 to 50 N·m).

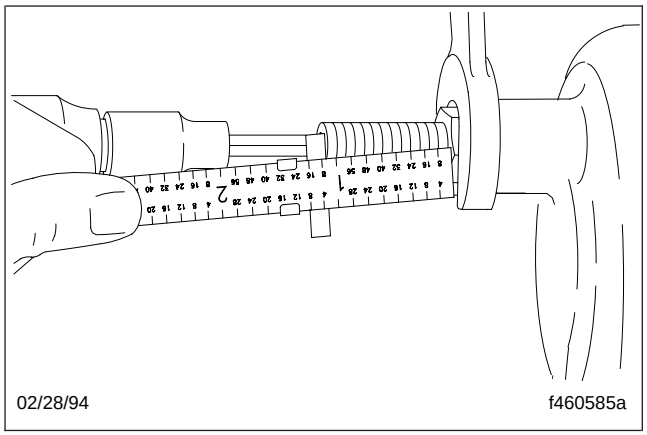


Fig. 7, Backing Out the Adjusting Screw

IMPORTANT: Make sure the adjusting screw does not protrude more than 1-1/16 inches (27 mm) beyond the sealing nut.

4.7 Have someone turn the steering wheel all the way to the right, and hold in place when the axle stops are contacted.

4.8 With the steering wheel held in place, loosen the sealing nut one turn, and while holding the sealing nut, turn the adjusting screw using an Allen wrench. Do not force the screw. Use one or two fingers and turn the Allen wrench until it comes to a stop. When this happens contact has been made with the poppet seat; **do not turn it any further**. Back out the screw 3-1/4 turns. Have the steering wheel released at this time.

4.9 While holding the adjusting screw in place, tighten the sealing nut firmly against the gear housing. See **Fig. 8**. Tighten it 33 to 37 lbf·ft (45 to 50 N·m).

Check the adjusting screw. If it extends more than 1-1/16 inches (27 mm) from the sealing nut, loosen the sealing nut, and turn the adjusting screw in as needed. Tighten the sealing nut 33 to 37 lbf·ft (45 to 50 N·m). See **Fig. 7** and **Fig. 8**.

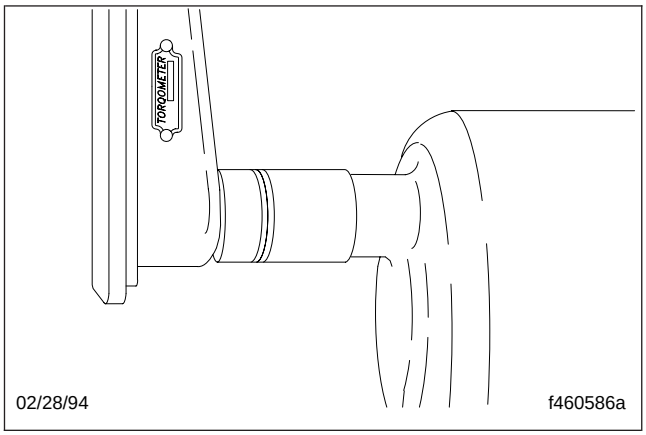


Fig. 8, Tighten the Sealing Nut

⚠ WARNING

If the adjusting screw protrudes more than 1-1/16 inches (27 mm) from the sealing nut, the screw could fall out of the steering gear, resulting in

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In-Vehicle Adjustments

loss of power steering. This could cause an accident resulting in serious personal injury or property damage.

IMPORTANT: Once the poppet adjusting screw and sealing nut are in place and the poppet valves have been manually adjusted, the adjustment procedure must be repeated if steering travel is either increased or decreased in the future.

5. Remove the chocks from the tires.

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Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Verify correct axle stop adjustment. For instructions, see **Group 33**. Ensuring correct axle stop adjustment now will eliminate the possibility of resetting steering gear poppet valves after the gear is installed.
3. Place the front tires in the straight-ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping at the spot where the work is to be done. Apply the parking brakes and chock the tires.

CAUTION

Do not turn the steering wheel or the steering shaft more than half a turn (except for alignment purposes) during the removal and installation procedures. Doing so may damage the clockspring in the steering column.

4. Remove the left-side bumper extension.
5. Clean all outside dirt from around the fittings and hose connections.
6. Drain the power steering system. Disconnect all hydraulic lines from the gear, marking the lines for later assembly reference. Seal the lines and the fittings to keep out dirt.
7. Disconnect the pitman arm from the steering gear sector shaft. See **Fig. 1**.
   - 7.1 Remove and discard the pinch bolt, washer, and nut from the pitman arm.
   - 7.2 Remove the pitman arm using a suitable puller, and swing the pitman arm and drag link out of the way.
8. Disconnect the steering driveline from the steering gear input shaft.
   - 8.1 Remove and discard the pinch bolt and nut from the steering driveline lower end yoke.

CAUTION

Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

   - 8.2 Remove the lower end yoke from the input shaft.
9. Clean the entire assembly before removing the gear.

WARNING

The steering gear is heavy. Use caution when removing, lifting, or carrying the steering gear. Failure to do so could cause personal injury.

10. Remove the fasteners that attach the steering gear to the frame rail. Remove the steering gear.

Installation

1. Install the steering gear and fasteners as shown in **Fig. 2**.

   Torque the fasteners 278 to 352 lbf·ft (377 to 477 N·m).
2. If not previously done, center the steering gear. The sector (output) shaft alignment mark must be at a right angle to the steering gear input shaft centerline. Make sure the steering gear remains centered as the service work continues.
3. Install the pitman arm.
   - 3.1 Position the pitman arm on the steering gear, aligning the timing mark as shown in **Fig. 3**.

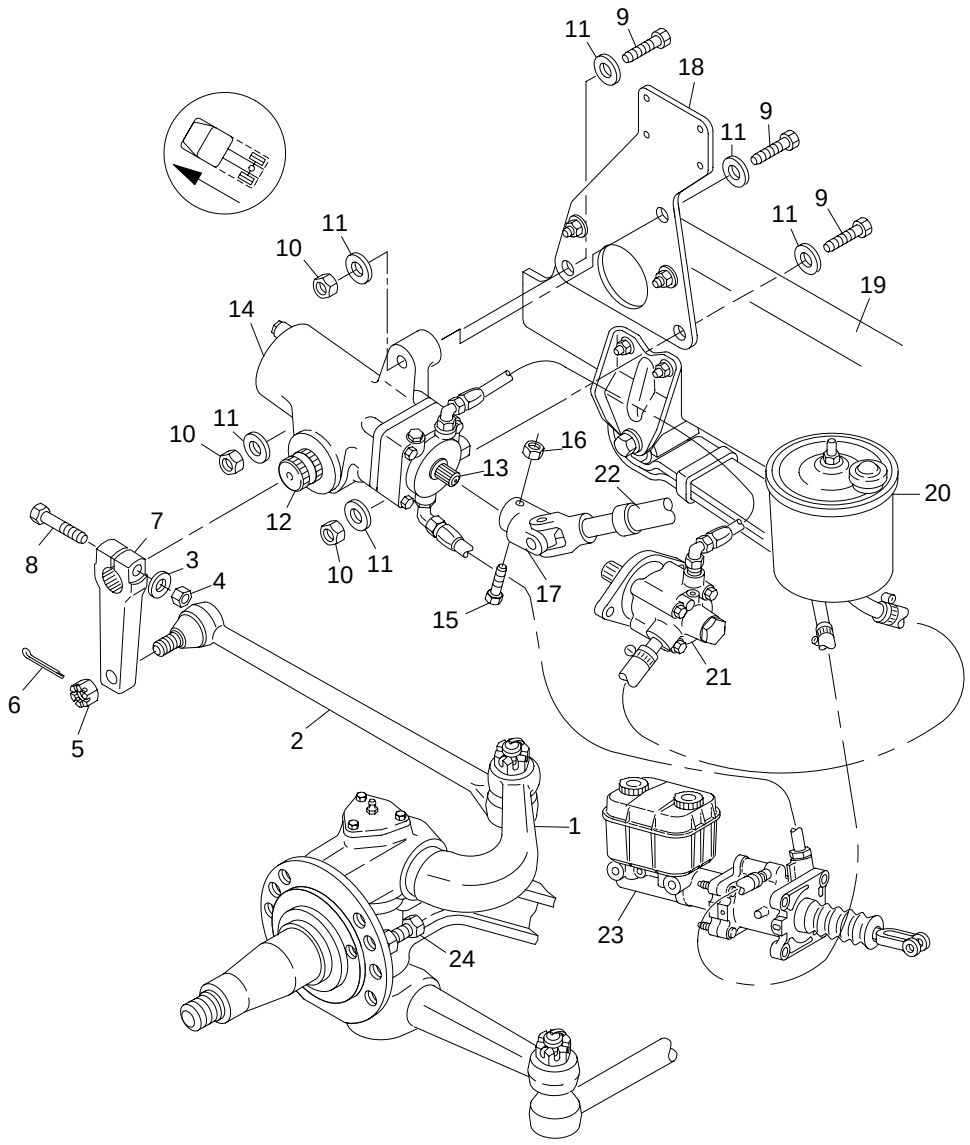
WARNING

Never leave a chisel wedged in the pitman arm slot. When using a chisel to spread the slot in the pitman arm, maintain a firm grip on the chisel at all times. Otherwise the chisel may fly loose, which could cause an injury.

NOTE: The pitman arm may not fit over the splines on the sector shaft without spreading the slot in the arm. Use a ball-peen hammer to drive a chisel into the slot. Hold the chisel

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Steering Gear Removal and Installation



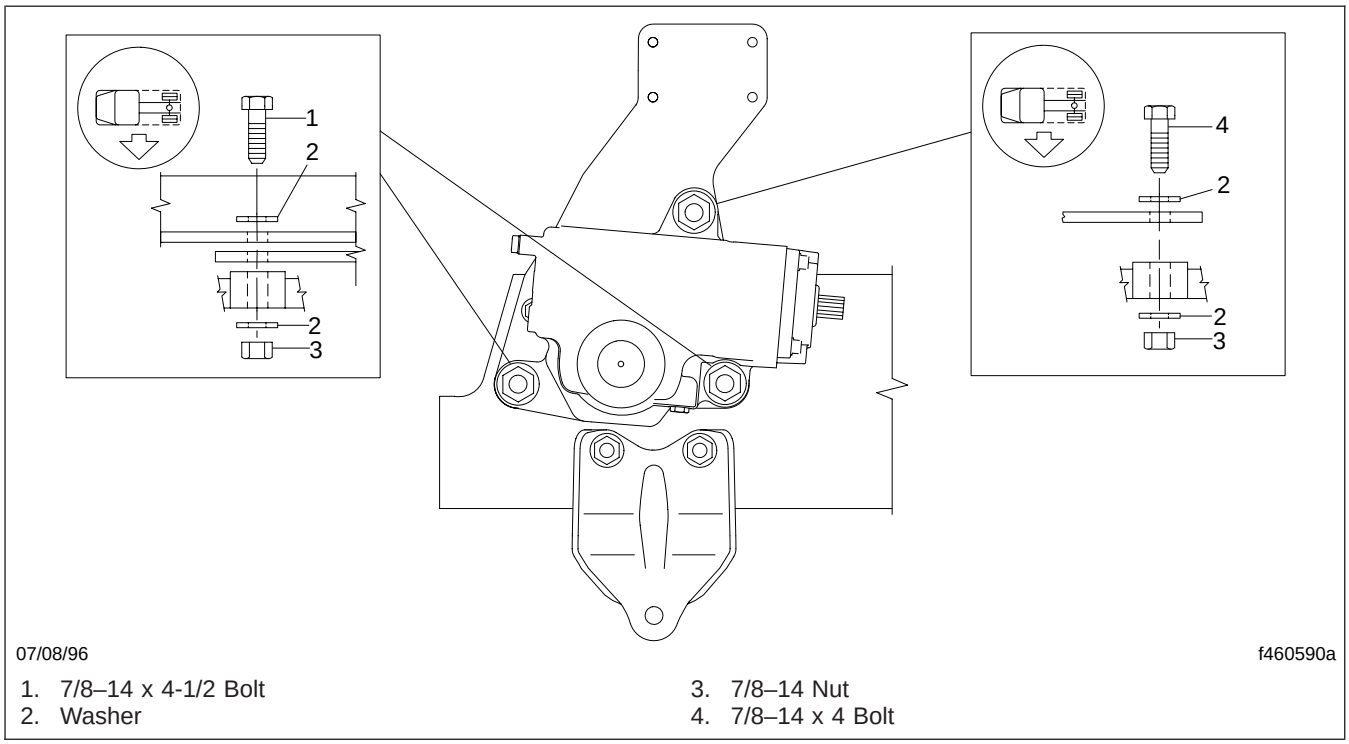
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1. Axle Steering Arm
2. Drag Link
3. Washer
4. Nut
5. Castle Nut
6. Cotter Pin
7. Pitman Arm
8. Pinch Bolt
9. Mounting Capscrew
10. Nut
11. Washer
12. Sector (output) Shaft
13. Input Shaft
14. Steering Gear
15. Lower End Yoke Pinch Bolt
16. Lower End Yoke Nut
17. Lower End Yoke
18. Steering Gear Mounting Plate
19. Left Frame Rail
20. Power Steering Reservoir
21. Power Steering Pump
22. Steering Driveline
23. Brake Booster
24. Axle Stop

Fig. 1, TRW TAS40/55/65 Power Steering Installation (vehicles with hydraulic brakes)

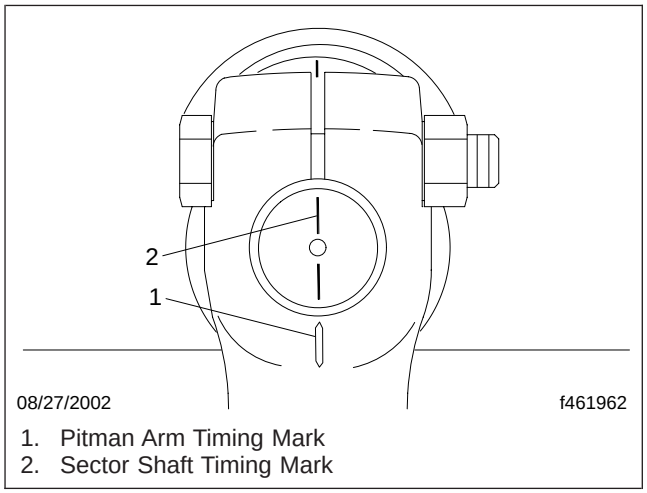
in place. Install the pitman arm on the sector shaft. Remove the chisel from the slot.

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1. 7/8–14 x 4-1/2 Bolt
2. Washer
3. 7/8–14 Nut
4. 7/8–14 x 4 Bolt

Fig. 2, Steering Gear Installation, TAS40/55/65



1. Pitman Arm Timing Mark
2. Sector Shaft Timing Mark

Fig. 3, Typical Pitman Arm and Timing Marks

3.2 Install a new pitman arm pinch bolt, washer, and nut. Tighten the nut using one of the following torque specs:

- 130 to 155 lbf·ft (177 to 211 N·m) for a 5/8–18 pinch bolt and nut
- 200 to 230 lbf·ft (272 to 313 N·m) for a 3/4–16 pinch bolt and nut

3.3 Apply torque seal, OGP F900WHITE, to the exposed threads and to the nut.

4. Connect the steering driveline to the steering gear input shaft.

4.1 Clean the steering gear input shaft and the inside of the driveline yoke.

4.2 Apply a thin film of grease to the yoke spline.

4.3 Slide the yoke on the input shaft, and install a new pinch bolt and nut. Tighten the nut to one of the following torque specs:

- 55 to 65 lbf·ft (75 to 88 N·m) for a 7/16 pinch bolt and nut
- 30 to 35 lbf·ft (41 to 47 N·m) for an M10 pinch bolt and nut

4.4 Apply torque seal, OGP F900WHITE, to the exposed bolt threads and to the nut.

5. Connect the hydraulic lines.

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Steering Gear Removal and Installation

5.1 If they were removed, attach the hydraulic line elbow fittings to the steering gear. Tighten the fittings 42 lbf·ft (57 N·m).

5.2 Remove the plugs from the hydraulic lines. Connect the lines to the steering gear as previously marked. Tighten the nut on each fitting finger-tight. Then, use a wrench to tighten the nut until there is firm resistance. Tighten one-sixth turn more.

6. Fill and bleed the steering system.

IMPORTANT: Do not turn the steering wheel until instructed. Doing so can cause air to enter the system, which can make it more difficult and time-consuming to bleed air from the system.

6.1 Fill the power steering reservoir with the power steering fluid specified in **Specifications 400** until nearly full. Crank the starter for 10 seconds without allowing the engine to start. If the engine does start, shut it down immediately. Check and fill the reservoir as needed. Repeat this procedure three times, each time checking and filling the reservoir.

6.2 Start the engine and let it idle for two minutes. Shut down the engine and check the fluid level in the reservoir.

6.3 Start the engine again. Steer the vehicle from full left to full right several times. As necessary, add fluid to the full line on the reservoir dipstick.

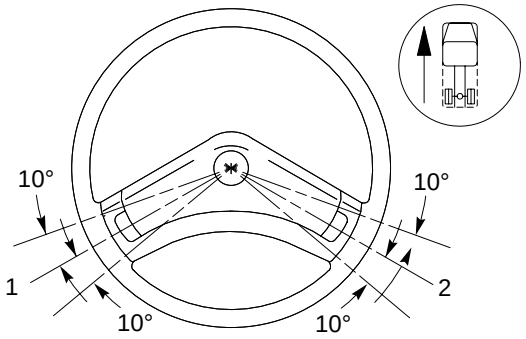
IMPORTANT: If the poppet adjuster seat and sleeve assemblies were not set for automatic adjustment during the assembly of the steering gear, **and** if the axle stops have been adjusted for decreased steering travel or the steering gear is installed on a different vehicle, the poppets must be set manually following the procedure in **Subject 100**.

7. Go to **Subject 140** and do the checks as instructed.

8. Install the left-side bumper extension.

9. Test drive the vehicle or take a ride with the driver.

Check the steering wheel spoke position. With the front tires pointing straight ahead, check the position of the steering wheel spokes. They must be within ±10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 4**. If not, remove the steering wheel and install it in the correct position. For instructions, refer to the applicable section in this group.



1. 8 o'Clock Position 2. 4 o'Clock Position

Fig. 4, Steering Wheel Centered

10. Remove the chocks from the tires.

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

Disassembly

⚠ WARNING

All steering mechanisms are safety items. Because of this, follow the instructions in this subject to the letter. Failure to do so may result in the loss of steering, which could cause an accident resulting in personal injury or property damage.

Be sure that required tools are available before beginning the service procedures described here. See the special tools table in **Specifications 400**. The special tools required for disassembly and assembly of the steering gear components are available from SPX Kent-Moore or an affiliated dealer.

IMPORTANT: When the sector shaft is disconnected from the vehicle steering linkage, do not allow the input shaft to move more than 1-1/2 turns from the straight-ahead position. If the input shaft moves more than 1-1/2 turns, the initial setting of the poppet valves will be changed.

Make sure that the steering gear is placed on a clean surface. Clean and dry the gear before disassembly. As the gear is disassembled, clean all parts in a clean, petroleum-based solvent, and blow-dry them only.

Never steam clean or high-pressure wash the hydraulic steering components. Do not force or abuse closely fitted parts. Doing so could cause damage to steering system parts.

Keep each part separate to avoid nicks and burrs. Discard all seals, O-rings, and gaskets, and replace them with new parts.

1. Place the steering gear in a vise so that the output shaft is horizontal. Clamp the gear at the mounting flange.
2. Put a basin under the hydraulic ports, and remove both hydraulic port plugs from the gear. See **Fig. 1**.
3. Using a 3/4-inch or 11/16-inch socket wrench, turn the input shaft so that the timing mark on the end of the sector shaft is lined up with the timing mark on the end of the housing trunnion. See **Fig. 2**.
4. Remove sector shaft/side cover assembly.
   - 4.1 Using a small screwdriver, remove and discard the water seal from the housing trunnion. See **Fig. 3**. Remove any dirt, paint, or corrosion from the sector shaft with a piece of fine emery cloth. See **Fig. 4**.
   - 4.2 Tape the splines and the bolt groove of the sector shaft, using one layer of masking tape. See **Fig. 5**.
   - 4.3 Using a 3/4-inch socket, remove the jam nut from the sector shaft adjusting screw.
   - 4.4 Put a container under the side cover to catch any drainage. Remove the special bolts from the side cover.

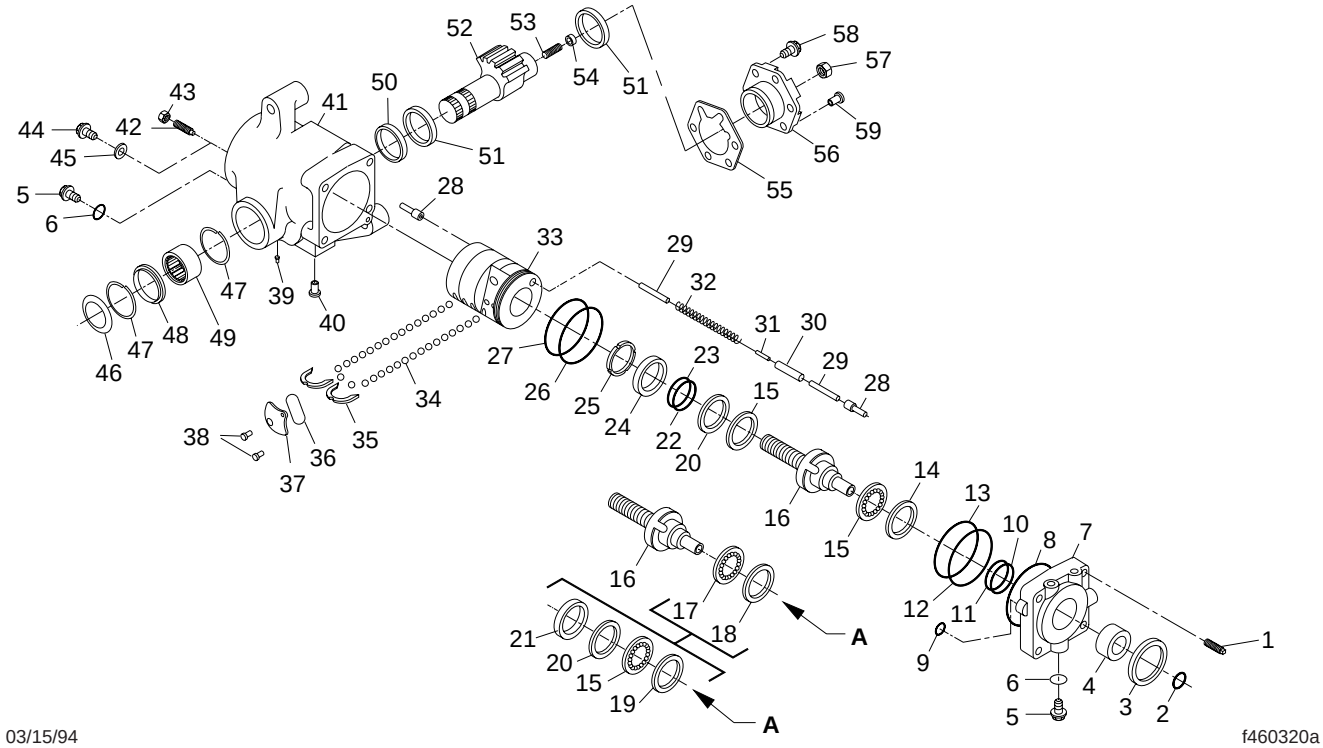
     IMPORTANT: These special bolts are equipped with either an integral ring or washer on the underside of the head. See **Fig. 6**. If replacing one or more bolts, use bolts of the **same special type and length as those that were removed**. Do not use a substitute; do not mix different types of bolts.
   - 4.5 Remove the side cover and the sector shaft assembly, as a unit, from the steering gear housing. If necessary, start the removal by tapping the end of the sector shaft with a rubber or wooden mallet. Remove and discard the side cover gasket.
5. Disassemble the sector shaft/side cover assembly.
   - 5.1 Using a screwdriver, screw the sector shaft adjusting screw into the side cover and remove.
   - 5.2 Remove the sector shaft from the side cover.
   - 5.3 Remove the side cover seal as follows:

     IMPORTANT: Be careful when you are removing the side cover seal; you may damage the side cover bore or the DU bushing.
   - 5.4 Screw a 1/2–20 x 3 bolt into the hole in the side cover where the sector shaft adjusting screw was.

     Make sure the bolt is in far enough so that it will support a rolling head (lady-foot) type pry bar. See **Fig. 7**.

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments



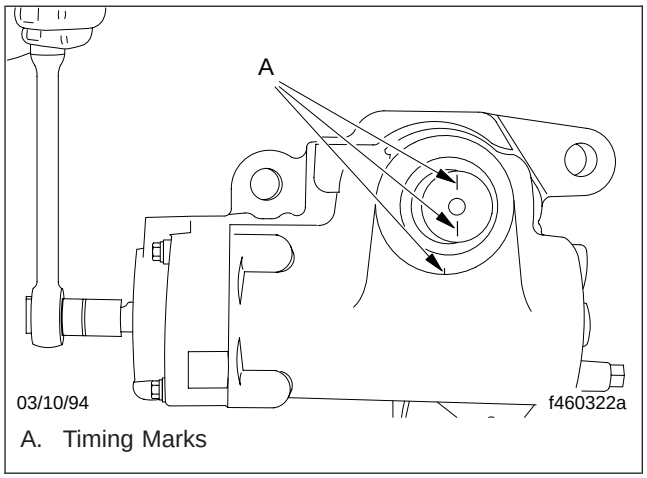
1. Bolts, Valve Housing
2. Dirt and Water Seal
3. Retaining Ring
4. Seal
5. Auxiliary Port Plug
6. O-Ring, Auxiliary Port Plug
7. Valve Housing and Ball Plug Assembly
8. Large Seal Ring
9. Small Seal Ring
10. O-Ring
11. Seal Ring
12. Valve Housing O-Ring
13. Seal Ring
14. Thick Thrustwasher
15. Roller Thrust Bearing
16. Input Shaft/Valve/Worm Assembly
17. Ball Bearing Assembly (valve/worm)
18. Ball Bearing Race
19. Thick Thrustwasher
20. Thin Thrustwasher
21. Spacer Sleeve
22. Seal Ring
23. O-Ring
24. Bearing Adjuster
25. Adjuster Locknut
26. Rack Piston Seal Ring
27. O-Ring, Backup
28. Poppet Adjuster Seat and Sleeve Assembly
29. Poppet
30. Push Tube
31. Spacer Rod
32. Poppet Spring
33. Rack Piston
34. Steel Ball
35. Ball Return Guide Halves
36. Ball Return Guide Cap Seal
37. Ball Return Guide Cap
38. Torx Screws
39. Grease Fitting
40. Auto-Bleed Plug
41. Gear Housing
42. Service Poppet Adjusting Screw
43. Service Sealing Jam Nut
44. Fixed Stopscrew, Poppet
45. Washer, Stopscrew
46. Dirt and Water Seal (trunnion)
47. Retaining Ring
48. Dirt Seal
49. Roller Bearing
50. Washer (spacer)
51. Output Seal
52. Sector Shaft
53. Sector Shaft Adjusting Screw
54. Adjusting Screw Retainer
55. Side Cover Gasket
56. Side Cover and Bushing Assembly
57. Jam Nut
58. Special Bolts, Side Cover
59. Side Cover Vent Plug

Fig. 1, Steering Gear Assembly

5.5 With the pry bar supported by the bolt end, pry up the side cover seal, and remove it. Discard the side cover seal, and remove the 3-inch bolt from the side cover.

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments



A. Timing Marks

Fig. 2, Line Up the Timing Marks

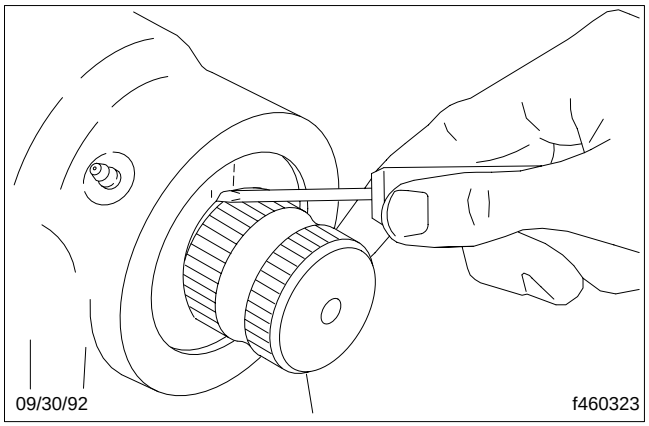


Fig. 3, Remove the Water Seal

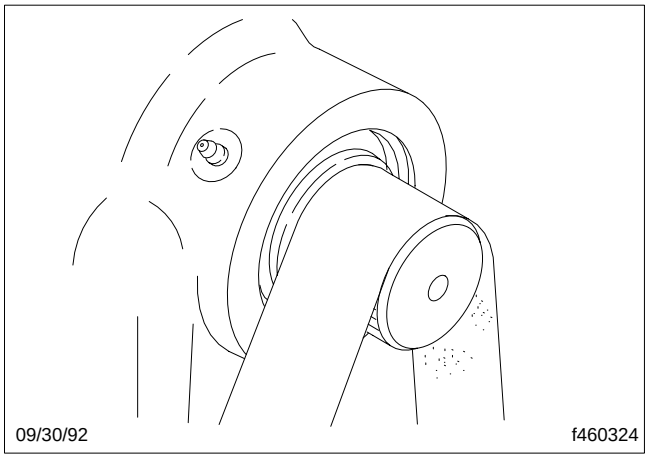


Fig. 4, Clean the Sector Shaft

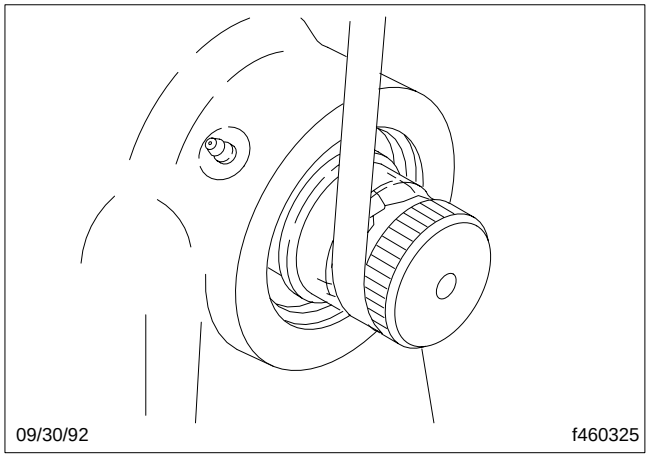
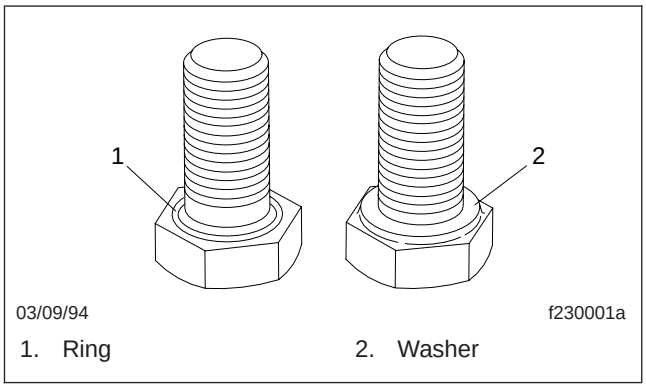


Fig. 5, Tape the Splines and the Bolt Groove



1. Ring
2. Washer

Fig. 6, Bolts With Ring or Washer

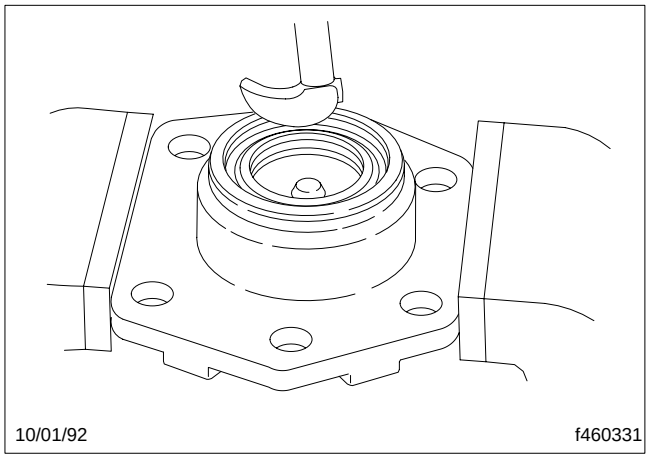


Fig. 7, Rolling Head Pry Bar

5.6 Remove and discard the vent plug from the side cover.

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

6. Remove the adjusting screw if required. Removal is required only if deemed necessary after the inspection procedure.

   6.1 Put the sector shaft in a padded vise and, using a chisel, unstake the adjusting screw retainer. See **Fig. 8**.

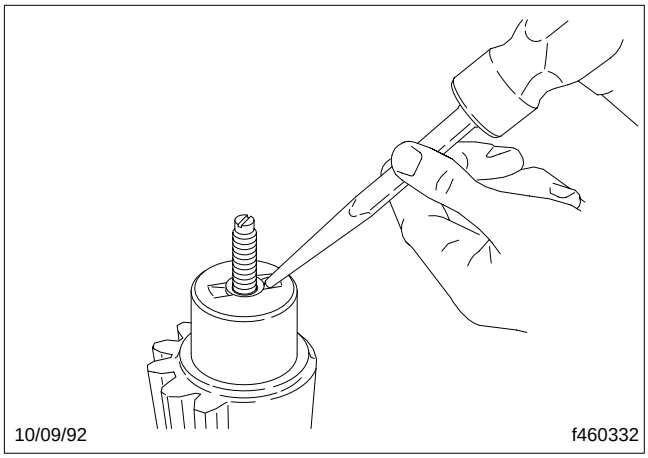


Fig. 8, Unstake the Adjusting Screw Retainer

   6.2 Unscrew the retainer and remove it from the sector shaft.

   6.3 Remove the adjusting screw. Discard the retainer.

7. Remove the relief valve components, if equipped: relief valve cap, O-ring, and the two-piece relief valve from the valve housing. Discard the O-ring.

8. Remove the input shaft, valve housing, and rack piston.

   8.1 Remove and discard the dirt and water seal from the input shaft. Clean the exposed part of the input shaft, using a fine grade emery cloth. See **Fig. 9**.

   8.2 Using an E-16 Torx® socket wrench, remove the four valve housing bolts.

   8.3 Remove the valve housing from the main gear housing, together with the worm shaft and rack piston assembly. Set the assembly on a clean bench.

   8.4 Remove and discard the seal rings from the valve housing.

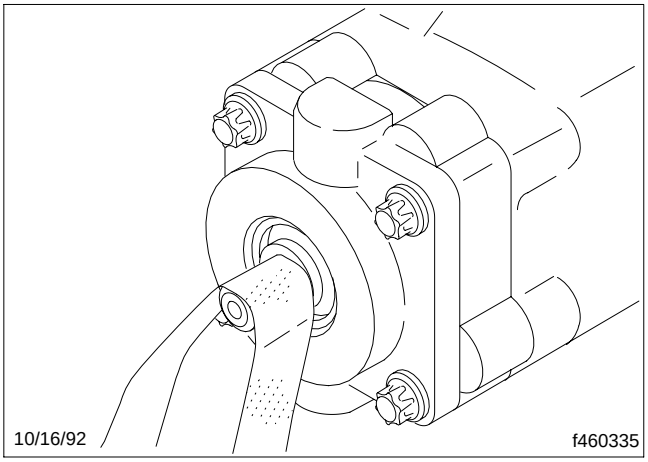


Fig. 9, Clean the Input Shaft

IMPORTANT: If you are not going to remove, reset, or replace the poppet valves on the steering gear, make sure that the setting for them is not accidentally changed. Mark the gear, identifying the vehicle from which it was removed, and note that the poppet valve adjustments are for that particular vehicle.

9. Remove the steel balls.

   9.1 Remove the two sealing screws holding the ball return guide cap to the rack piston. See **Fig. 10**.

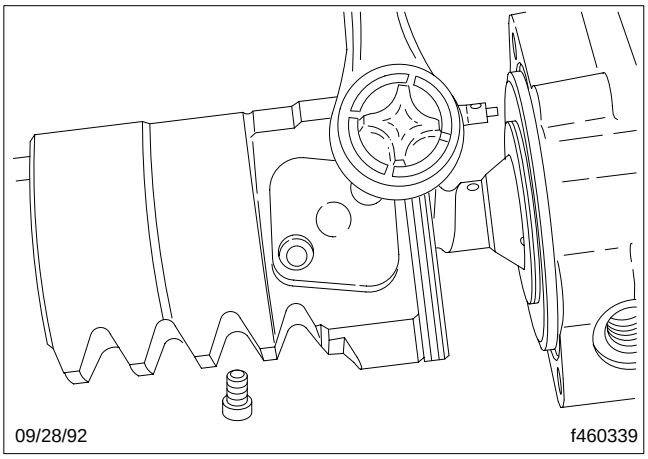


Fig. 10, Remove the Sealing Screws

   9.2 Remove the cap and its seal. Discard the two screws and the seal.

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

9.3 Remove the ball return guide halves from the rack piston by carefully prying up on them with a screwdriver. See **Fig. 11**.

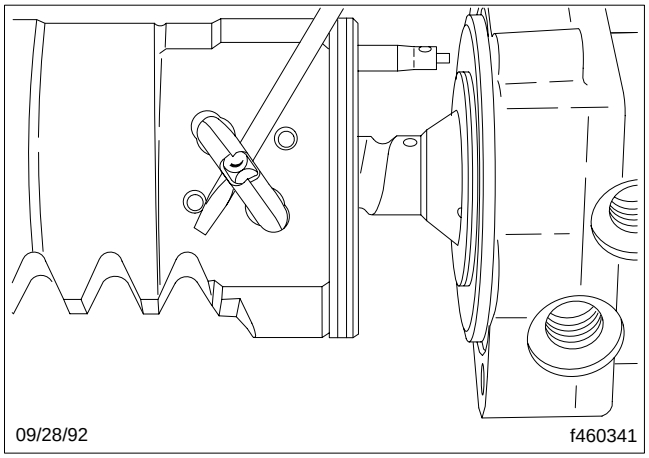


Fig. 11, Remove the Ball Return Guide Halves

9.4 Remove the 29 (TAS40), 31 (TAS55), or 32 (TAS65) steel balls from the rack piston by turning the worm shaft until all of them are out. See **Fig. 12**. **Do not lose any of these balls, or you will have to replace the entire set.**

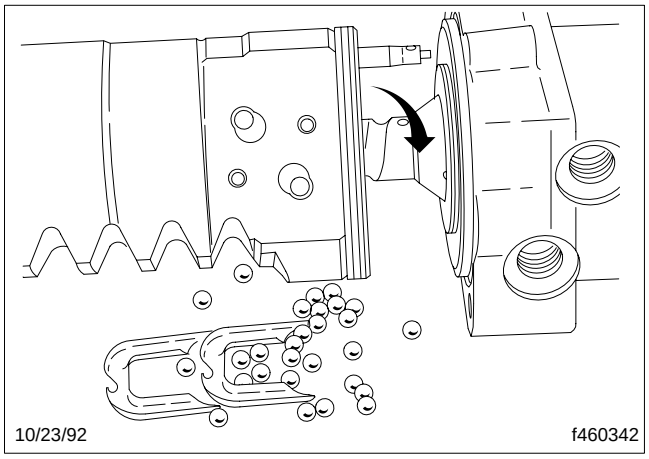


Fig. 12, Remove the Steel Balls

⚠ WARNING

Never mix different sets of steel balls. To do so may cause a loss of steering control, which could cause an accident resulting in serious injury or property damage.

10. Remove the worm shaft and valve housing assembly from the rack piston.
11. Cut and remove the Teflon® seal ring and the O-ring from the rack piston. See **Fig. 13**.

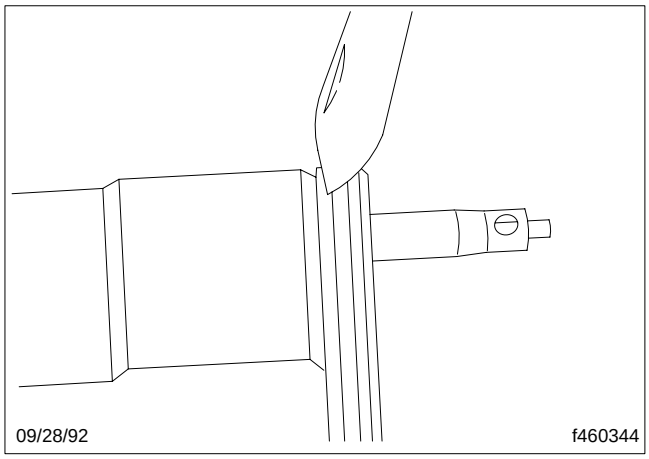


Fig. 13, Remove the Seal Ring and the O-Ring

12. If replacing poppet assemblies, remove the poppet valve assemblies.

⚠ CAUTION

The poppet valve assemblies are installed with Loctite®. Be careful when removing them, and use only special tool J36452 or J38713 (preferred). Failure to do so may damage the rack piston, which would require replacing the rack piston, steel ball kit, and the poppet valve assemblies.

IMPORTANT: Do not use special tool J38713 on a rack piston that does not have a counterbore in the hole for the seat and sleeve assembly.

12.1 Put the rack piston in a padded vise.

12.2 Slide the special tool J38713 (preferred) or J36452 over the poppet adjuster seat. See **Fig. 14**. Turn the tool so that its prongs fit into the slot on the threaded adjustment sleeve. Hit the end of the tool firmly four or five times with a 16-ounce hammer to loosen the Loctite®. See **Fig. 15**.

12.3 Using a breaker bar, unscrew the adjuster seat and sleeve assemblies from the rack

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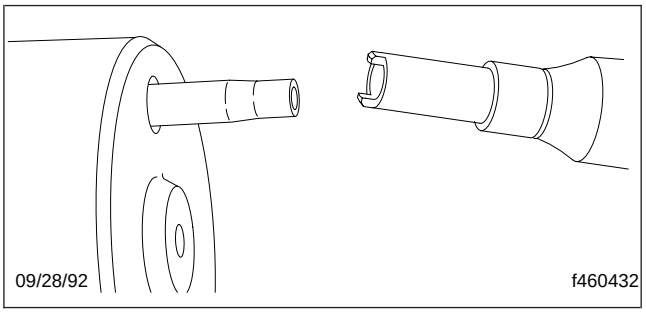


Fig. 14, Slide the Tool Over the Poppet Adjuster

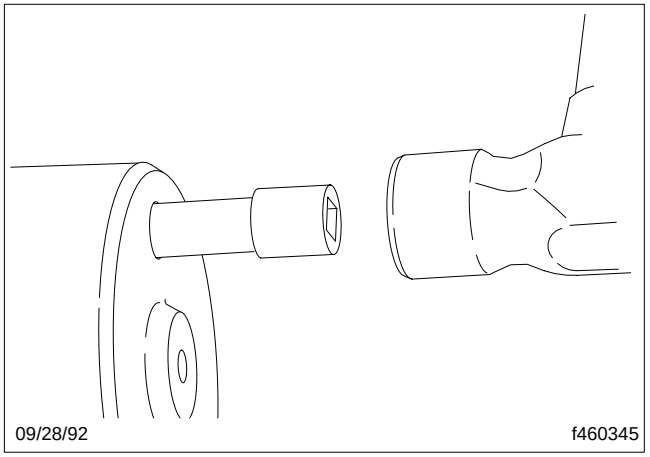


Fig. 15, Use the Tool to Loosen the Loctite®

piston. If the assembly will not loosen, hit the end of the tool several more times with a hammer.

12.4 Remove both poppets, and the spring, spacer rod, and push tube. See **Fig. 16**.

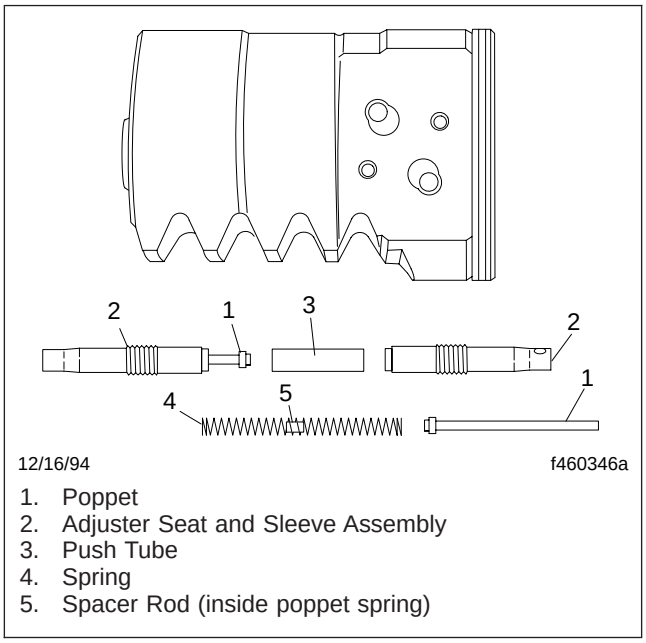
Repeat the above steps for the other poppet adjuster seat and sleeve assembly.

13. Disassemble the valve housing, if needed.

IMPORTANT: Do not disassemble the valve housing unless you find signs of extreme heat, internal leakage, bearing damage or roughness, or if the worm shaft preload adjustment is needed.

13.1 Put the worm shaft and valve housing assembly into a padded vise, with the worm shaft in a vertical position as shown in **Fig. 17**.

13.2 Unstake the adjuster locknut, using a punch. See **Fig. 17**.



1. Poppet
2. Adjuster Seat and Sleeve Assembly
3. Push Tube
4. Spring
5. Spacer Rod (inside poppet spring)

Fig. 16, Remove the Poppets Spring, Spacer Rod, and Push Tube

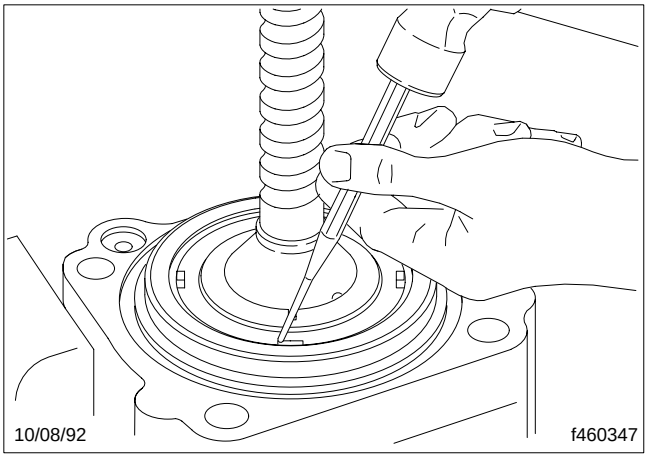


Fig. 17, Unstake the Adjuster Locknut

13.3 Using special tools J37464 and J37070 with a breaker bar, unscrew the adjuster locknut, then the bearing adjuster from the valve housing. See **Fig. 18**.

NOTE: The bearing adjuster has either two slots or two drill points on its face. Special tool J37070 can be used for removing and installing either style of bearing adjuster.

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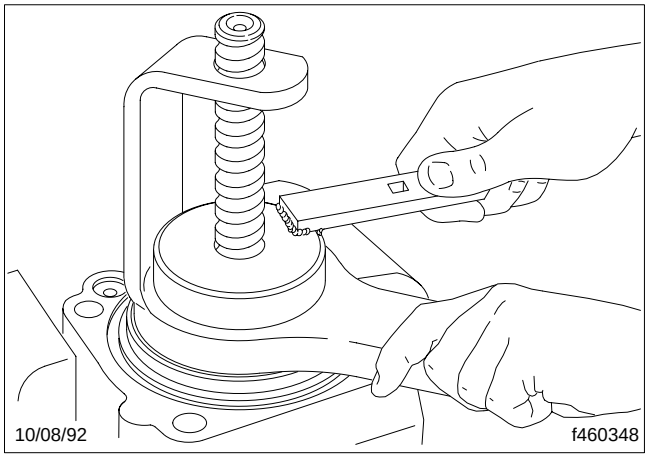


Fig. 18, Unscrew the Adjuster Locknut

13.4 Remove and discard the seal ring and the O-ring from the bearing adjuster. See **Fig. 19**.

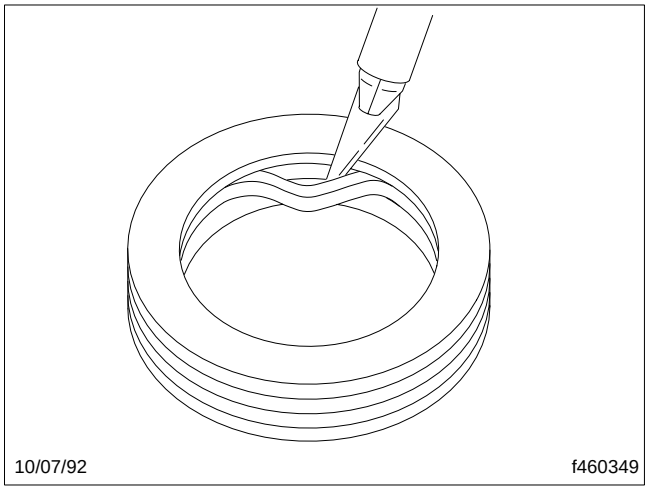


Fig. 19, Remove the Seal Ring

13.5 Remove the thin washer, thrust bearing, input shaft, rotary valve, and worm shaft assembly from the valve housing. See **Fig. 20**.

IMPORTANT: Do not disassemble the input shaft or worm shaft assembly any further. These are not serviceable.

13.6 Remove the roller thrust bearing assembly and the thick thrustwasher from the valve housing. See **Fig. 21**.

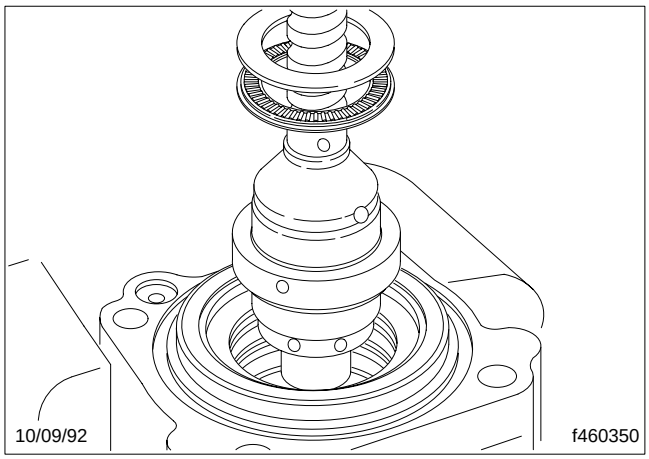


Fig. 20, Remove the Washer, Thrust Bearing, Input Shaft, Rotary Valve, and Worm Shaft Assembly

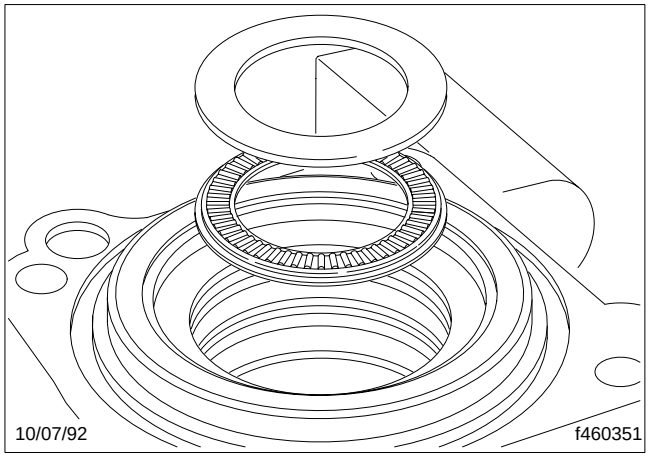


Fig. 21, Remove the Roller Thrust Bearing Assembly

13.7 Using a small knife, a probe, or a pick, remove and discard the seal rings and O-rings from the valve housing. See **Fig. 22**.

⚠ CAUTION

In the next step, be careful when removing the retaining ring and seal from the valve housing, or you may damage the seal bore. If this happens, you will have to replace the gear housing.

13.8 Turn the valve housing over, and remove the retaining ring. See **Fig. 23**.

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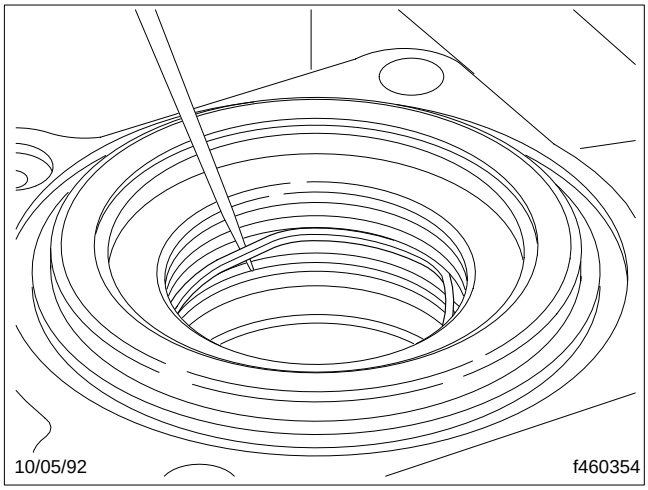


Fig. 22, Remove the Seal Rings and O-Rings

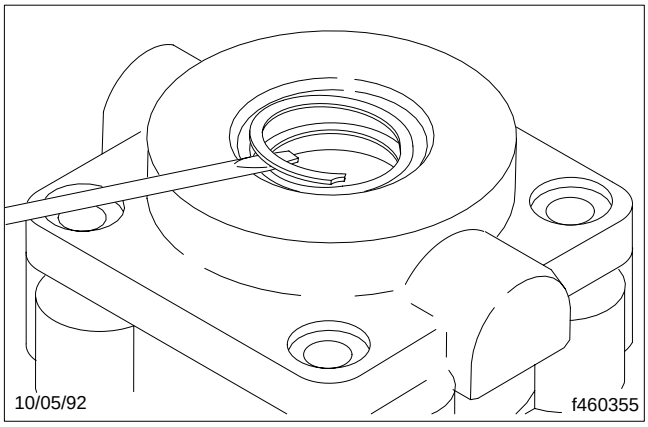


Fig. 23, Remove the Retaining Ring

13.9 Using a 1-1/8 inch socket, tap out the seal from the valve housing. See **Fig. 24**. Discard the seal.

13.10 If replacing either of the auxiliary port plugs, remove them. Be sure to remove and discard the O-rings.

14. Disassemble the housing.

NOTE: The steering gear is equipped with either a poppet fixed stopscrew, or an adjusting screw and sealing nut. See **Fig. 25**.

14.1 If the poppet fixed stopscrew needs replacement, remove it.

14.2 If the adjusting screw and sealing nut need replacing, remove them.

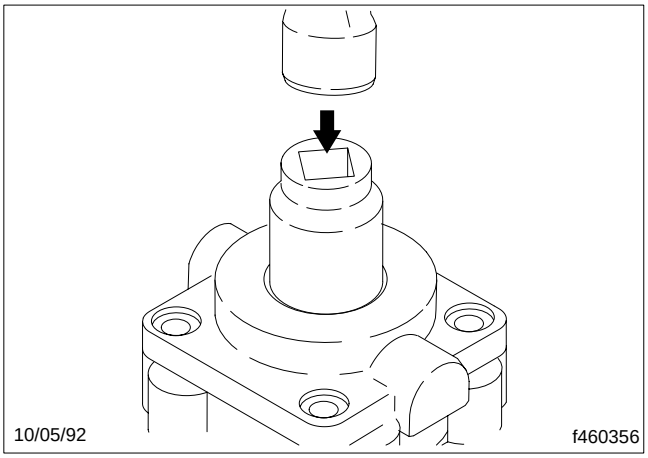
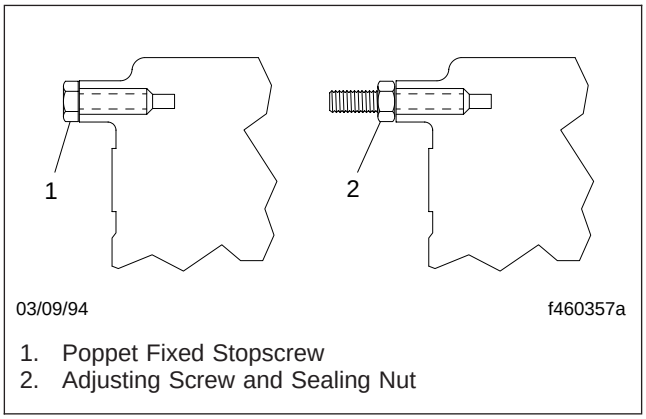


Fig. 24, Tap Out the Seal



1. Poppet Fixed Stopscrew
2. Adjusting Screw and Sealing Nut

Fig. 25, Steering Gear Adjusting Screws

14.3 Remove the retaining ring from the output end of the housing trunnion. See **Fig. 26**.

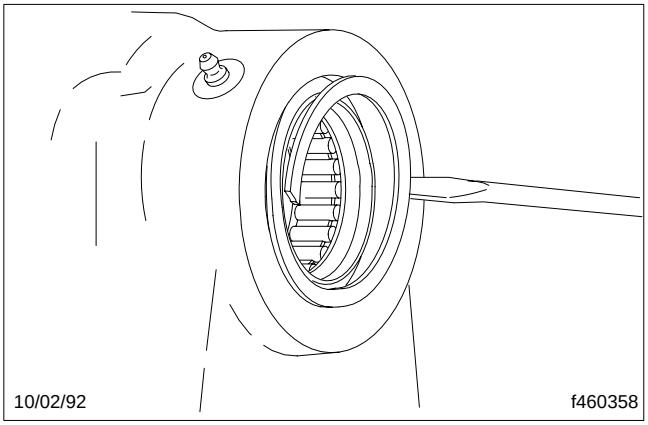


Fig. 26, Remove the Retaining Ring

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

14.4 Remove and discard the dirt seal. See **Fig. 27**.

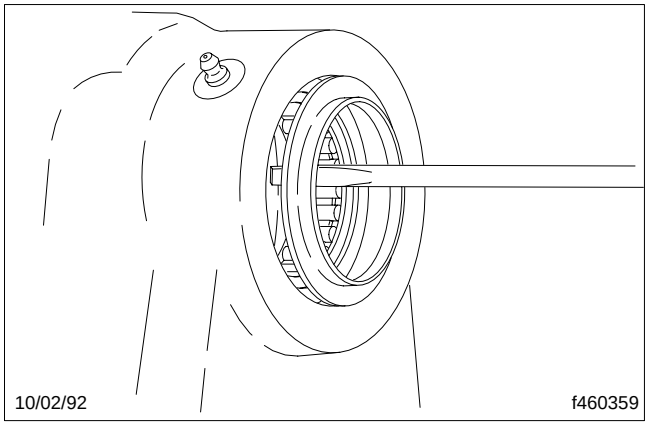


Fig. 27, Remove the Dirt Seal

14.5 Insert a screwdriver into the gear housing, and carefully push the seal and the spacer washer out of the other end of the bearing bore. See **Fig. 28**. Be careful not to damage the sealing area of the bore. Discard the seal.

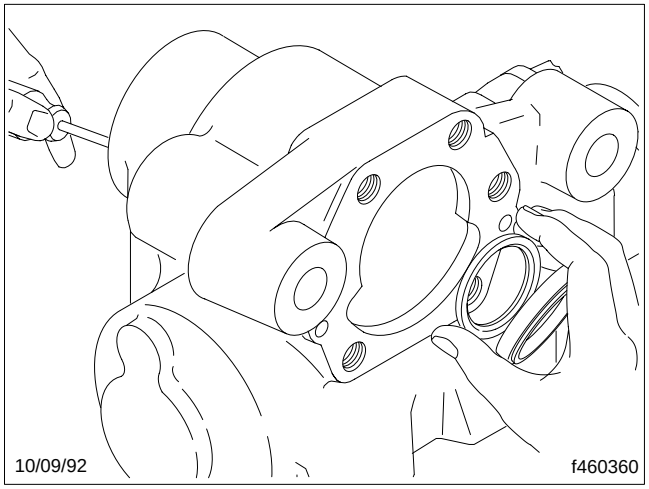


Fig. 28, Remove the Seal and Spacer Washer

14.6 If replacing the roller bearing in the housing, remove it, using special tool J37705 (TAS40), or J37071 (TAS55/65). Press the roller bearing out of the trunnion end of the housing, from the side of the bore where the side cover was attached. See **Fig. 29**.

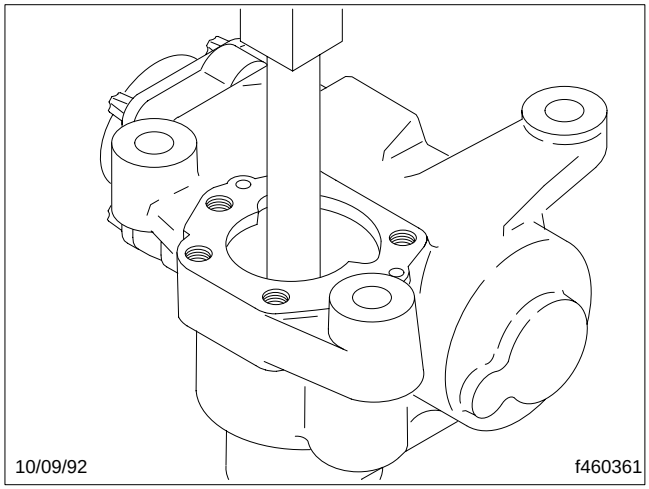


Fig. 29, Press the Roller Bearing Out of the Housing

⚠ CAUTION

Be sure the retaining ring is not damaged when the roller bearing is pressed out.

14.7 If replacing the retaining ring, remove it through the trunnion end, opposite the end where the side cover was attached. See **Fig. 30**. Be careful not to damage the pressure seal bore area.

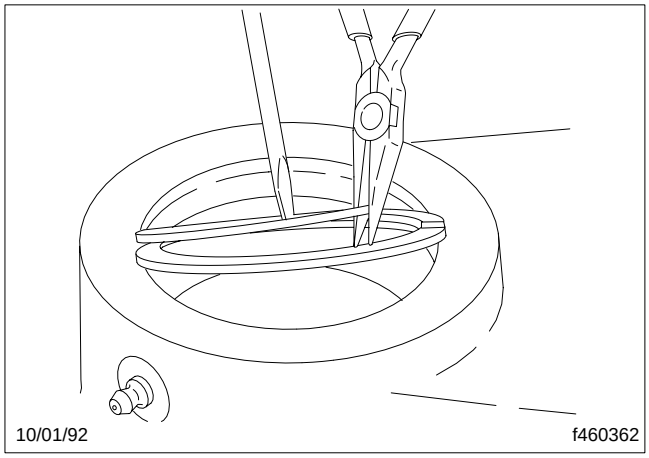


Fig. 30, Remove the Retaining Ring

Inspection

All sealing surfaces and seal cavities must be free of nicks and corrosion. If any part is nicked or corroded

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

where sealing occurs, the part must be replaced to ensure proper sealing.

Wash all parts in a clean petroleum-based solvent. Blow-dry them with air.

1. Inspect the rack piston teeth for cracks and wear. If a step can be detected by running your fingernail horizontally across the teeth surfaces, the rack piston, the sector shaft, and the set of steel balls must be replaced.
2. Inspect the rack piston internal ball-track grooves for brinelling (dents) or spalling (flaking). See **Fig. 31**. If either condition exists, replace the rack piston, the valve/worm shaft assembly, and the set of 29 (TAS40), 31 (TAS55), or 32 (TAS65) steel balls.

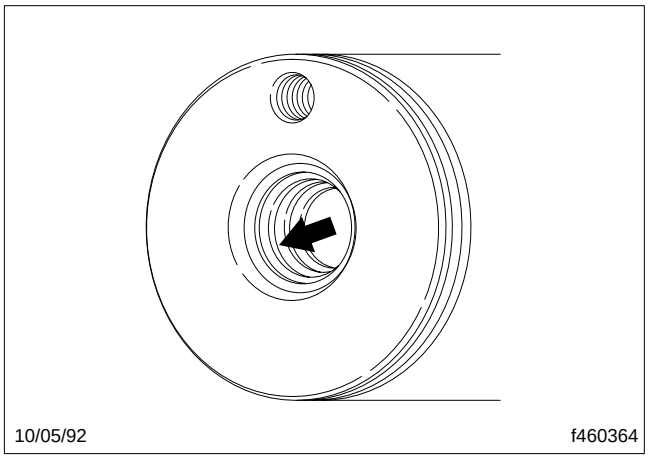


Fig. 31, Inspect the Rack Piston

3. Inspect the worm shaft ball-track grooves for brinelling or spalling. See **Fig. 32**. If either condition exists, replace the worm/input shaft assembly, the rack piston, and the set of steel balls. Inspect the upper shaft seal area, near the input shaft serrations, for nicks. Run your fingernail across the sealing surface to detect steps. See **Fig. 33**.
4. Inspect the housing cylinder bore. Minor scoring marks running lengthwise through the bore are normal, and should not be compared to the scoring that might be found in the cylinder bores of an internal combustion engine. Replace the housing only if it has been tested for internal leakage, and it is determined that the scoring is the cause of internal leakage greater than 1 gpm (3.8 L/min). For the power steering system troubleshooting procedures, see **Section 46.08, Subject 300**.

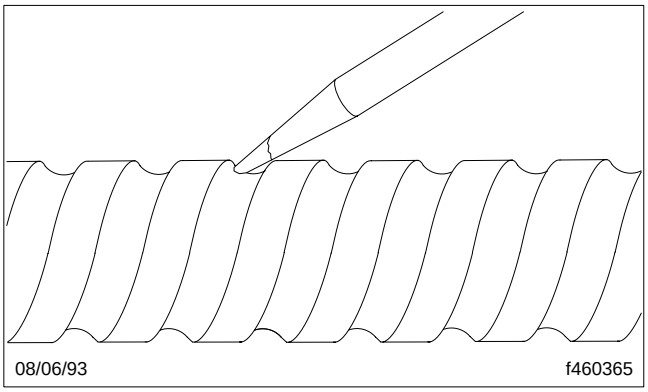


Fig. 32, Inspect the Worm Shaft

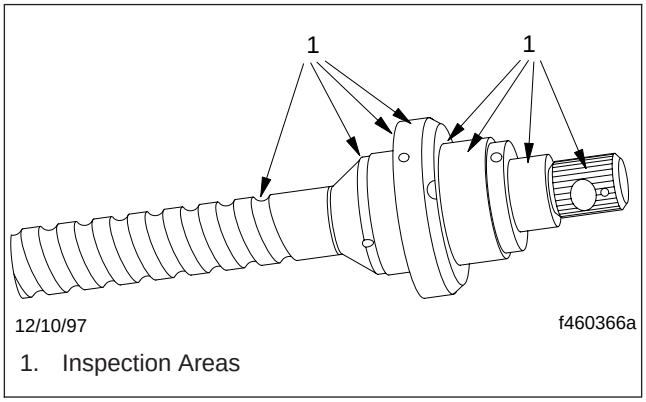


Fig. 33, Inspection Areas on the Upper Worm Shaft

NOTE: In evaluating this test, make sure that internal leakage of more than 1 gpm (3.8 L/min) can be attributed only to the housing, and not to the seals in the worm shaft, rack piston, and valve assembly.

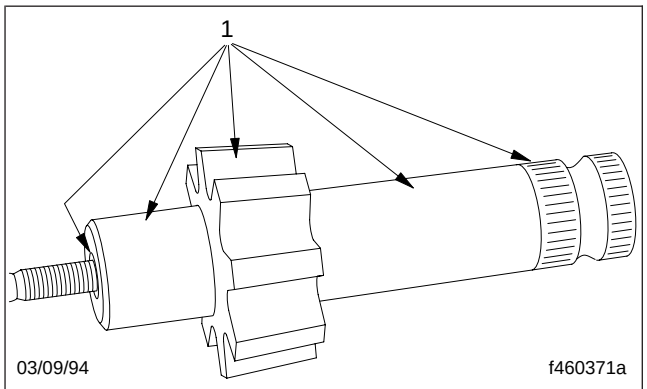
5. Inspect the housing faces for nicks that would prevent proper sealing. Replace the gear housing if these nicks cannot be easily removed with a fine-toothed flat file, without changing the dimensional characteristics.
6. Inspect the housing roller bearing for brinelling or spalling. If either condition exists, replace the housing bearing.

   Inspect the side cover bushing. If the clearance between the bushing and the sector shaft is more than 0.008 inch (0.20 mm), replace the side cover and bushing assembly.

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

7. Inspect the sector shaft bearing sealing areas for brinelling or spalling. See **Fig. 34**. Run your fingernail across these areas to detect steps. Also, inspect for cracks. If any of these conditions exist, replace the sector shaft.



1. Inspection Areas

Fig. 34, Inspect the Sector Shaft Bearing Sealing Areas

8. Check the sector shaft assembly for damaged adjusting screw threads. Make sure the adjusting screw retainer is locked in place and has no cracks. The adjusting screw must turn by hand with no end play (lash). If the adjusting screw is damaged, replace it and its retainer.
9. Inspect the thrust bearing rollers for any deterioration. Inspect the thrustwashers for brinelling, spalling, or cracks. Replace any part if these conditions are detected.

Assembly

IMPORTANT: Be sure that required tools are available before beginning the service procedures described here. See the special tools table in **Specifications 400**. The special tools required for disassembly and assembly of the steering gear parts are available from SPX Kent-Moore or an affiliated dealer.

After inspection, clean all parts again in a clean petroleum-based solvent, and blow-dry them with air.

All seals, seal rings, and gaskets must be replaced with new ones each time the gear is disassembled. Individual seals, seal rings, and gaskets, as well as complete seal kits, are available from Acterra parts distributors.

1. If required, install a new sector shaft roller bearing; otherwise, go on to the next step.
   1.1 Put the gear housing on its side, with the trunnion end of the bore facing up, as shown in **Fig. 35**.

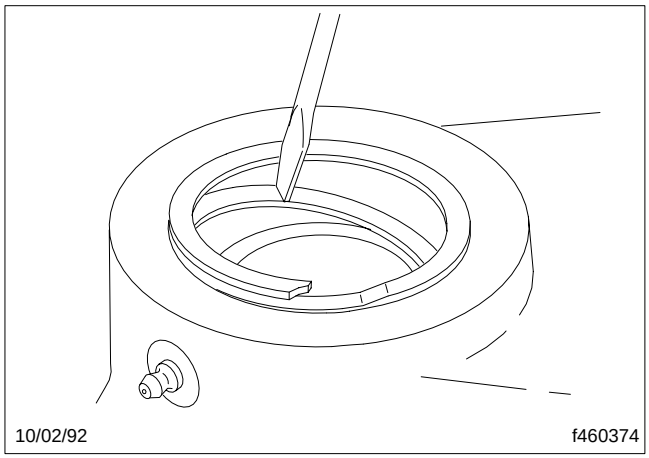


Fig. 35, Install the Retaining Ring

   1.2 Install the retaining ring in the groove closest to the side cover end of the bore. Lubricate the bore.
   1.3 Place the new roller bearing on the housing bore, with the lettered side of the bearing shell facing up.

CAUTION

When using special tool J37705 (TAS40) or J37071 (TAS55/65) to install the roller bearing, be sure to use the installation side of the tool, or you may damage the new roller bearing.

   1.4 Using the installation end of the special tool, press the roller bearing into the housing, until it seats against the retaining ring. See **Fig. 36**.
2. Install the sector shaft seals.
   2.1 Put the gear housing on its side, with the side cover end of the bore facing up, as shown in **Fig. 37**.
   2.2 Install the washer in the bore, with the small diameter end of it facing the roller bearing retaining ring. See **Fig. 37**.

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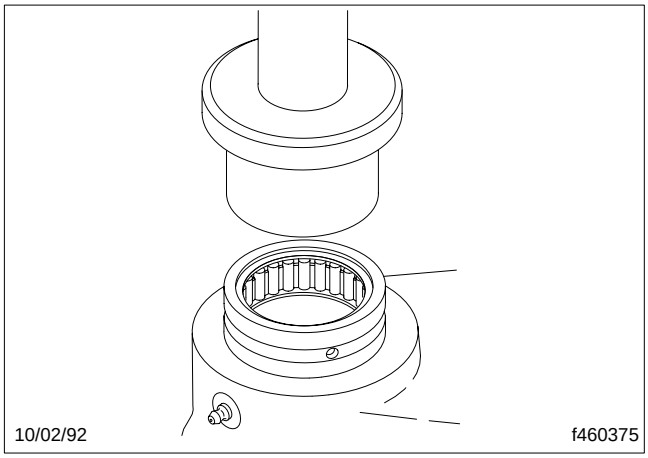


Fig. 36, Press the Roller Bearing into the Housing

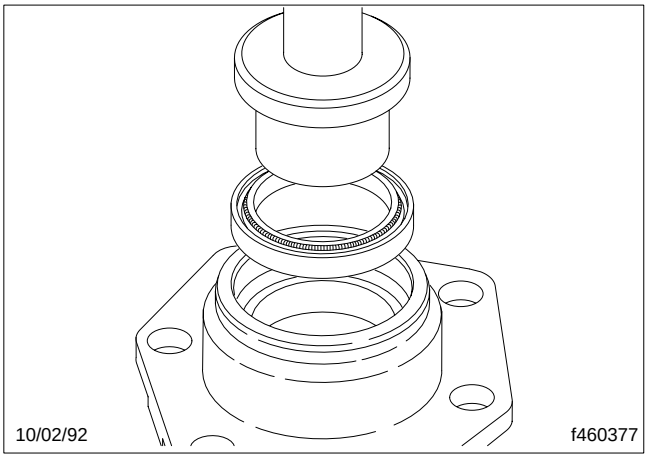


Fig. 38, Attach the New Seal to the Tool

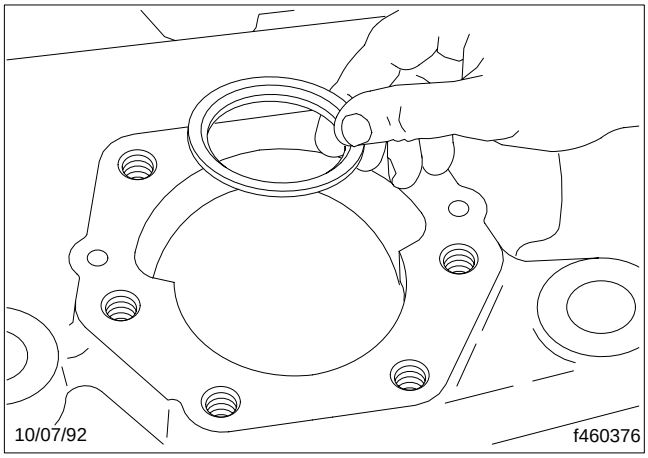


Fig. 37, Install the Washer in the Bore

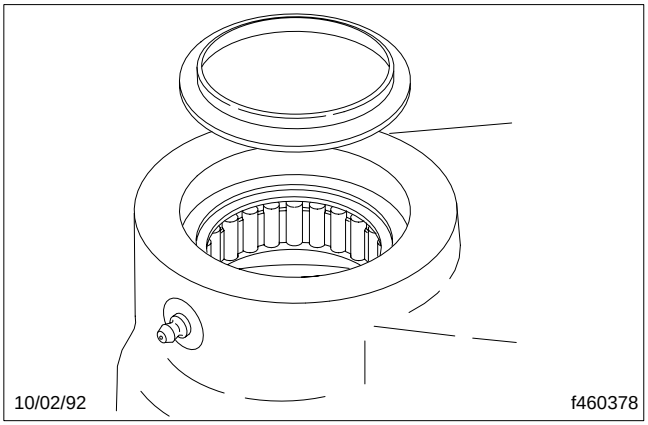


Fig. 39, Install the New Seal

2.3 Put the new seal on special tool J37705 (TAS40) or J37071 (TAS55/65) so that the lip of the seal with the garter spring is toward the shoulder of the tool. See **Fig. 38**.

2.4 From the side cover end of the bore, press the new seal onto the washer (and the roller bearing below it) with a force of 100 to 800 lb (45 to 363 kg).

2.5 Turn the gear housing over so that the trunnion end of the bore is up. Install the new dirt seal against the roller bearing, with the lip facing up. See **Fig. 39**.

2.6 Install the second retaining ring, seating it firmly into the groove in the bore. See **Fig. 40**.

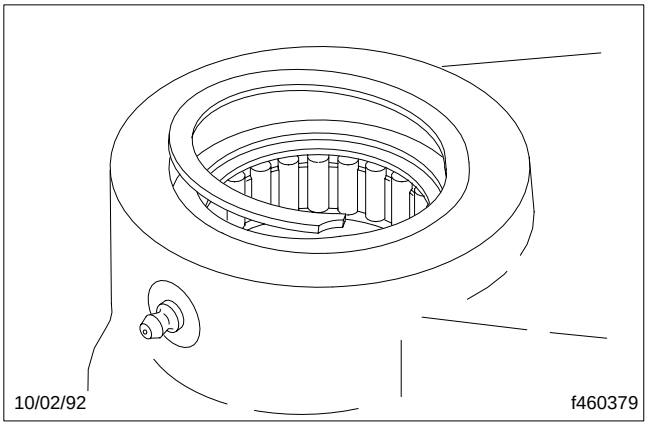


Fig. 40, Install the Second Retaining Ring

2.7 Pack the area between the dirt seal and the pressure seal (including the roller

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bearing) with Mobil Temp® 1 grease, or equivalent. See **Fig. 41**.

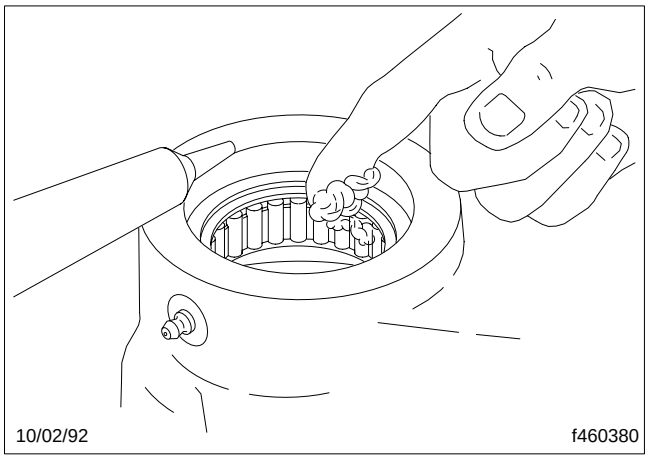


Fig. 41, Lubricate the Area Between the Seals

3. Assemble the valve housing.

CAUTION

In the next step, when putting the valve housing in a vise, be careful not to clamp against the threaded port hole or the relief-valve hole sealing faces. To do so may damage these surfaces, which would require the replacement of the valve housing.

3.1 Put the valve housing in a vise so the input/worm shaft can be installed with the worm shaft up.

3.2 Lubricate and install a new O-ring in the valve housing.

3.3 Lubricate a new large diameter O-ring and a new seal ring, then install them in the valve housing. See **Fig. 42**.

3.4 Install the roller thrust bearing and the thick thrustwasher on the input shaft thrust face. See **Fig. 43**.

3.5 Install a new seal ring onto the input shaft, and against the thick thrustwasher.

3.6 Lubricate, then install the input shaft/valve/worm assembly in the valve housing, seating it firmly. See **Fig. 44**.

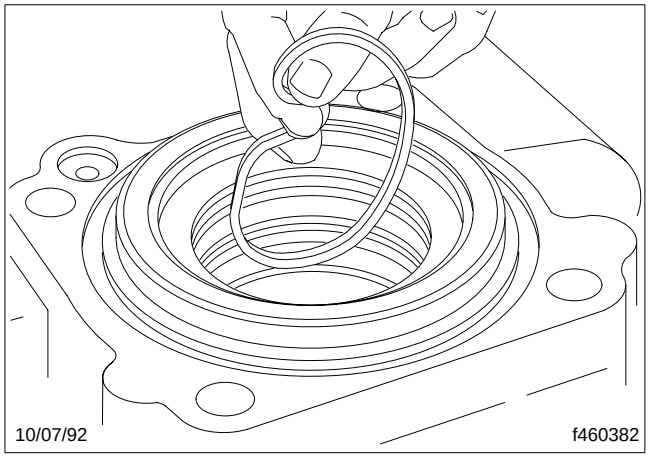


Fig. 42, Installing a New O-Ring

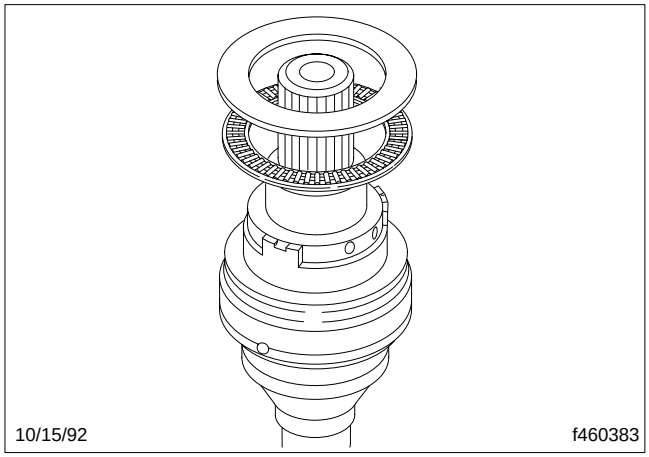


Fig. 43, Installing the Roller Thrust Bearing and Thrustwasher

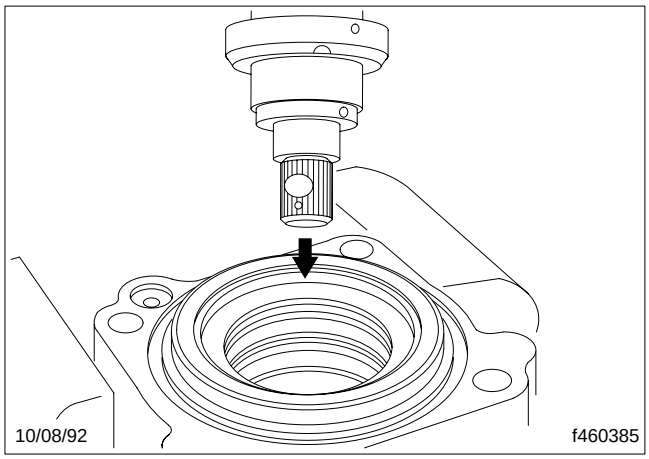


Fig. 44, Install the Input Shaft/Valve/Worm Assembly

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3.7 Lubricate, then install a second thrust bearing and thin washer over the worm shaft. See **Fig. 45**.

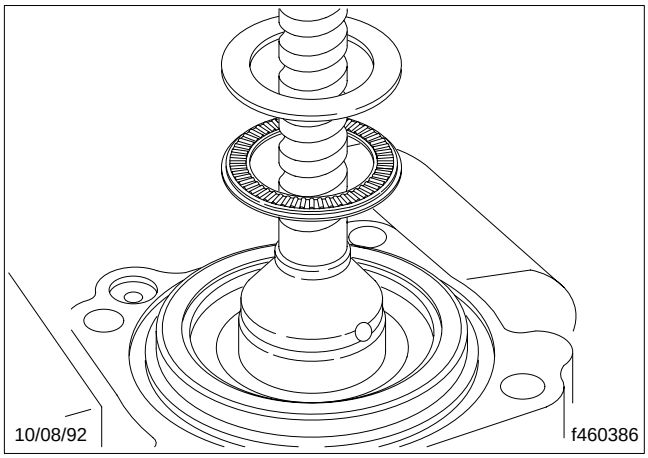


Fig. 45, Installing a Second Thrust Bearing

3.8 Lubricate the new O-ring and seal ring. Install the O-ring, then the seal ring in the groove of the bearing adjuster. See **Fig. 46**.

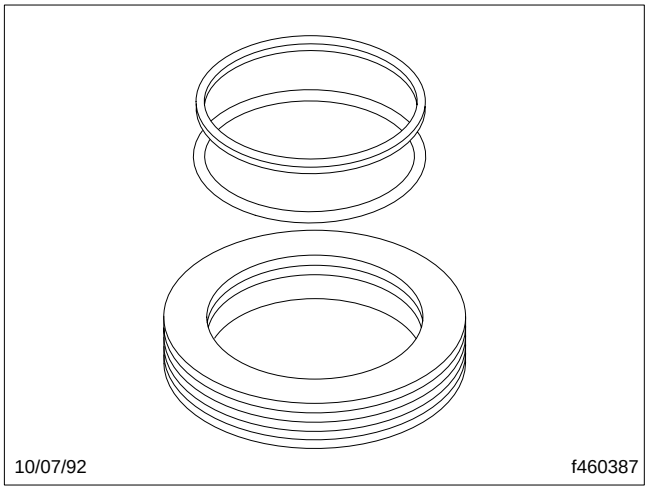


Fig. 46, Installing the O-Ring and Seal Ring

3.9 Making sure the bearing adjuster threads are clean and free of any stake burrs, lubricate and then install the bearing adjuster over the worm shaft, and into the valve housing.

3.10 Using a torque wrench and bearing adjuster tool J37070, tighten the valve adjuster 11 to 15 lbf·ft (15 to 20 N·m), then back it off 1/4 to 1/2 turn. See **Fig. 47**.

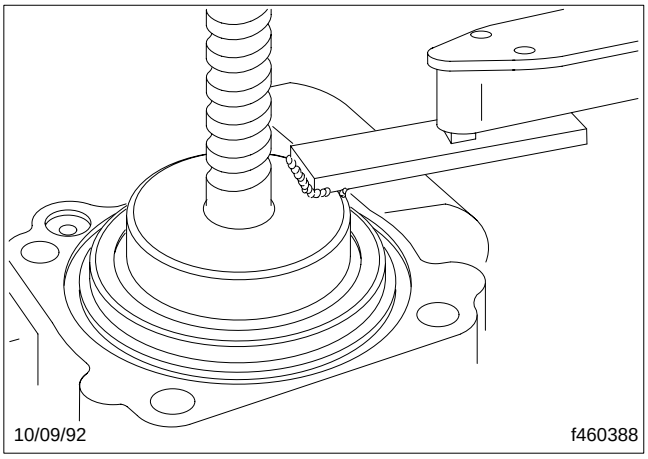


Fig. 47, Tighten the Valve Adjuster

3.11 Turn the valve housing over in the vise so that the worm shaft is facing down.

3.12 Using an inch-pound torque wrench, check the torque needed to turn the input shaft slowly 360 degrees clockwise and counterclockwise. Tighten the bearing adjuster until the torque needed to turn the input shaft increases by 5 to 10 lbf·in (60 to 120 N·cm). See **Fig. 48**.

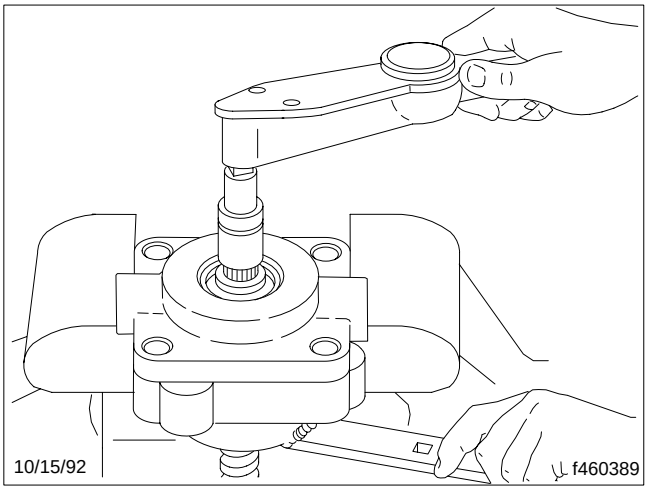


Fig. 48, Checking the Torque

3.13 Turn the valve housing over in the vise again so that the worm shaft is facing up.

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3.14 Oil and install the locknut on the bearing adjuster, and using special tools J37070 and J37464, tighten the locknut 101 to 122 lbf·ft (137 to 165 N·m), while holding the bearing adjuster. See **Fig. 49**.

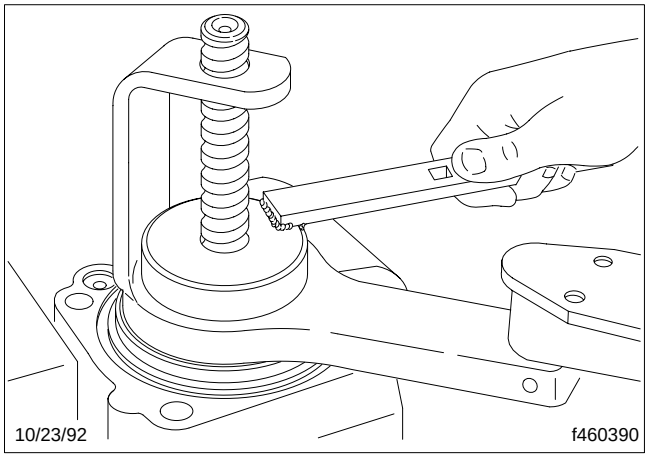


Fig. 49, Installing the Locknut on the Bearing Adjuster

3.15 Check the torque needed to turn the input shaft again. If the torque has not increased 5 to 10 lbf·in (60 to 120 N·cm), remove the locknut from the bearing adjuster, and repeat the steps above beginning with tightening the valve adjuster, then backing it off.

3.16 Using a punch, stake the locknut to the valve housing at two opposite slots in the locknut. Stake each slot in the most clockwise corner, as shown in **Fig. 50**.

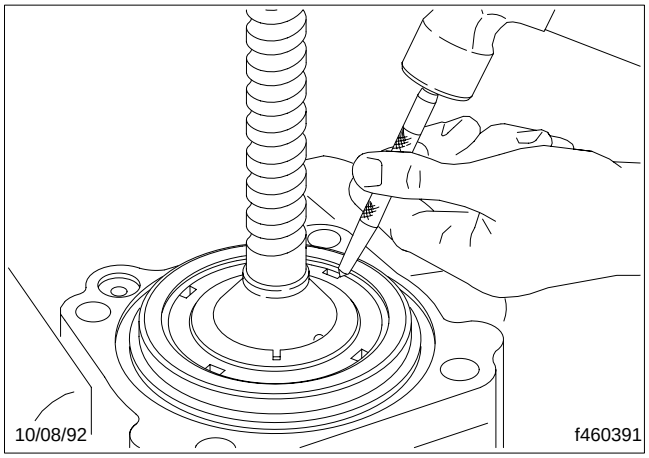


Fig. 50, Stake Each Slot

3.17 Stake the locknut to the bearing adjuster at two places 180 degrees apart. See **Fig. 50**. Do not use a spot that was staked before.

3.18 Check the torque needed to turn the input shaft. If the torque is not greater than 5 to 10 lbf·in (60 to 120 N·cm) the torque previously noted, unstake the locknut from the bearing adjuster, and repeat the steps above beginning with tightening the valve adjuster, then backing it off.

NOTE: The torque needed to turn the input shaft must not be more than 22 lbf·in (240 N·cm).

3.19 Oil the new seal rings, and install them in the valve housing. See **Fig. 51**.

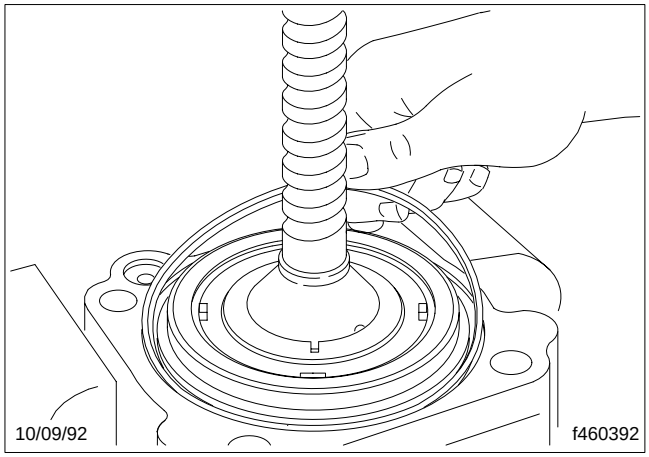


Fig. 51, Installing New Seal Rings

4. Reset the automatic poppet valves.

IMPORTANT: Make sure the poppet adjuster seat and sleeve assemblies and the threaded holes in the rack piston are free of Loctite®. Use 7/16-20 thread chasers to remove the Loctite®.

4.1 Turn the poppet adjuster seat and sleeve assembly so that it is in the **opposite** direction in which it was installed, and loosely screw it into the threaded hole in the rack piston. See **Fig. 52**.

4.2 Press the adjuster seat into the adjuster sleeve with a force of 500 to 2500 lb (227

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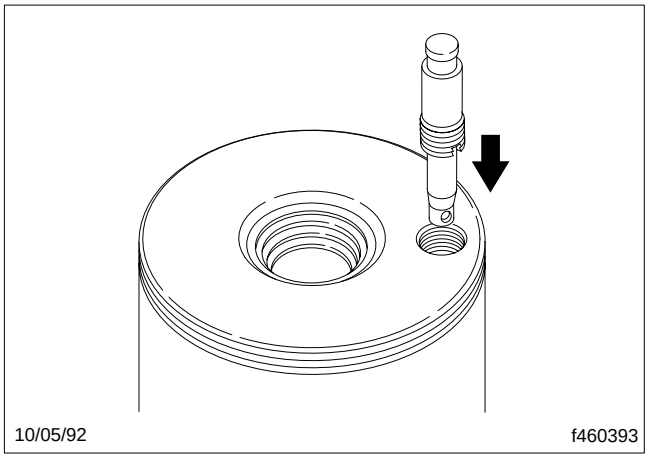


Fig. 52, Installing the Poppet Adjuster Seat and Sleeve Assembly in the Rack Piston

to 1134 kg), until the shoulder on the seat bottoms on the sleeve. See **Fig. 53** and **Fig. 54**.

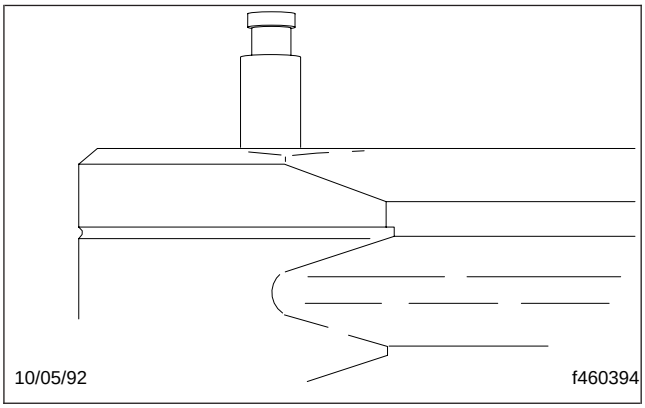


Fig. 53, The Adjuster Seat in the Adjuster Sleeve

4.3 Remove the adjuster seat and sleeve assembly from the rack piston.

4.4 Repeat the previous steps for the other poppet adjuster seat and sleeve assembly.

5. Install the rack piston seal: install a new backup O-ring and new Teflon® seal ring on the rack piston. See **Fig. 55**. Do not stretch them more than necessary when installing them.

6. Install the automatic poppets.

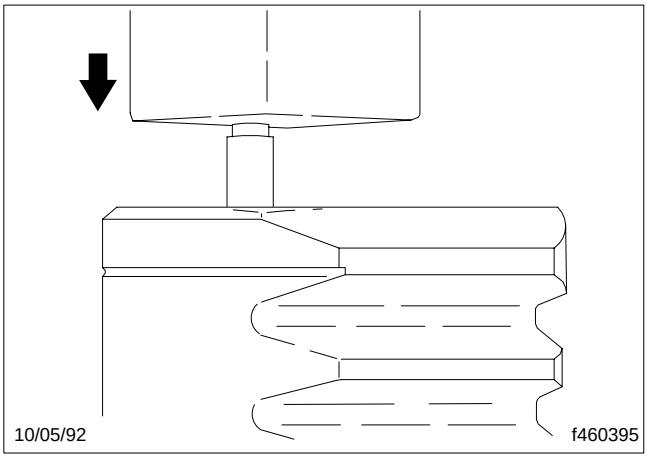


Fig. 54, Installing the Adjuster Seat into the Adjuster Sleeve

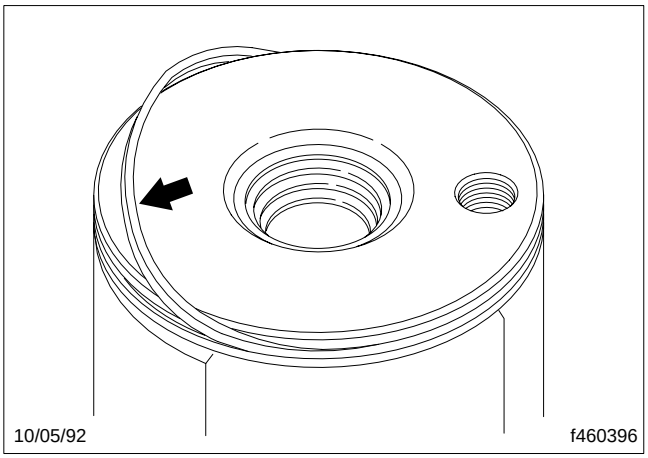


Fig. 55, Installing the Rack Piston Seal

⚠ CAUTION

When doing the next step, be careful not to get any Loctite® or Locquic on the adjuster seat itself. If this happens, the automatic poppets will not adjust correctly.

NOTE: If you are installing new poppet adjuster seat and sleeve assemblies, they may already have Dri-Loc® 200 on them; if so, more Loctite® is not needed.

6.1 Apply Locquic primer T to the threaded poppet holes in the rack piston, and to the threads on the poppet adjuster seat and sleeve assemblies. Let dry for ten min-

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utes, then apply Loctite® RC680 to the same threads. See **Fig. 56**.

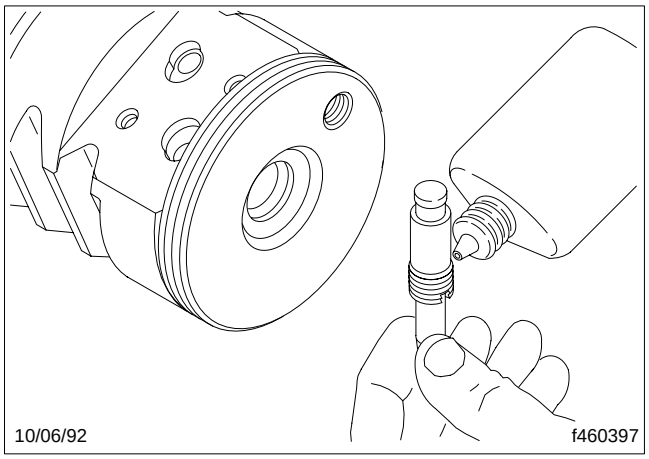


Fig. 56, Apply Primer to the Threaded Poppet Holes

6.2 Place the rack piston in a padded vise, and install a poppet adjuster seat and sleeve assembly, slotted end out, into the threaded hole at one end of the rack piston. See **Fig. 57**.

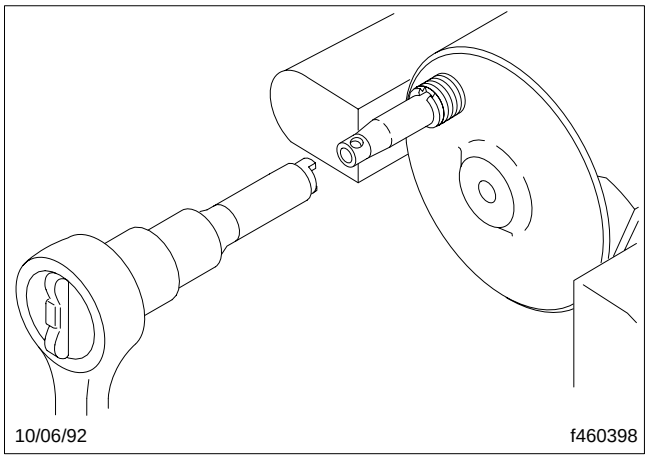


Fig. 57, Installing the Poppet Adjuster Seat and Sleeve Assembly into the Rack Piston

⚠ WARNING

Wear eye protection while assembling the poppets. The poppets are spring-loaded, and could be ejected, which could result in serious eye injury.

6.3 In the other end of the hole, install the poppet assembly parts in the following order: one poppet, the poppet spring, the nylon spacer rod, the push tube, the other poppet, and the other poppet adjuster seat and sleeve assembly.

6.4 Using special tool J36452 or J38713 (preferred), tighten both poppet adjuster seat and sleeve assemblies 10 lbf·ft (14 N·m). See **Fig. 58**.

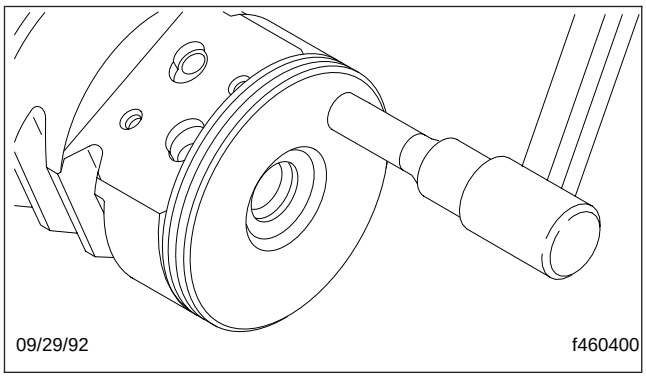


Fig. 58, Tighten the Poppet Adjuster Seat and Sleeve Assemblies

7. Install the worm shaft and valve housing assembly into the rack piston.

7.1 Put the rack piston on a clean, cloth-covered bench, with the worm end of the piston near the edge of the bench, and the ball guide holes facing up.

NOTE: When made to the correct dimensions to raise and support the piston, a wooden V-block will make the following steps easier.

7.2 Insert the worm shaft and input shaft assembly into the worm end of the rack piston, close to the maximum depth, without the valve housing contacting the upper poppet.

7.3 Line up the grooves in the worm shaft with the ball guide holes in the rack piston. Make sure the valve housing extends over the edge of the bench, or the rack piston is put on a V-block so that the valve housing and worm shaft can turn freely.

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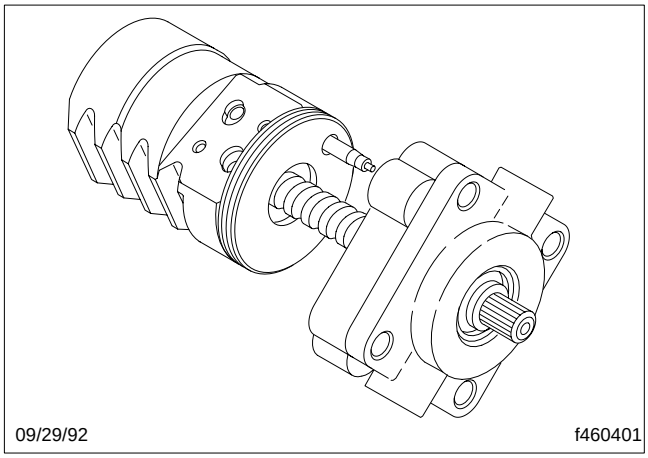


Fig. 59, Inserting the Worm Shaft and Input Shaft Assembly into the Rack Piston

⚠ WARNING

In the next step, do not seat the ball return guides with a hammer. This could damage them and cause steering gear lockup or loss of steering, resulting in an accident causing personal injury or property damage.

8. Install the steel balls.

   8.1 Install new ball return guide halves in the rack piston. See **Fig. 60**. Make sure they are correctly seated.

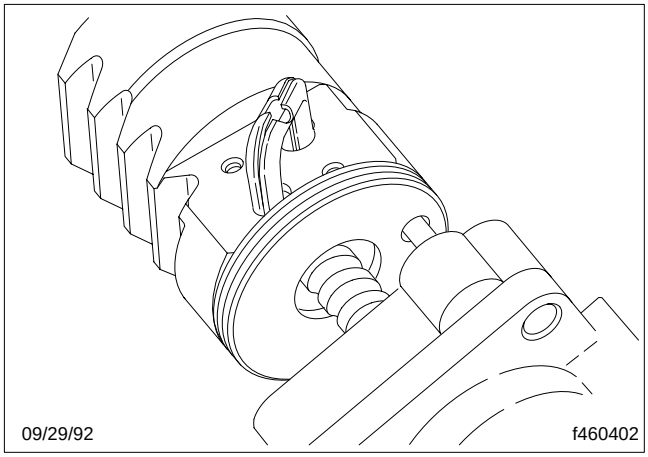


Fig. 60, Installing the New Ball Return Guide Halves

⚠ CAUTION

If you are installing a new rack piston or a new input shaft/valve/worm assembly, do not install the existing steel balls. Use a new set of steel balls, or damage to the steering gear may result.

NOTE: The worm gear may have to be rotated slightly to seat guide halves. Left-hand ball return guide halves are copper-plated; right-hand return guide halves are not. Make sure the correct new ball return guide halves are installed by comparing them with the old one, then discard the old ones.

8.2 Insert the 29 (TAS40), 31 (TAS55), or 32 (TAS65) steel balls in the ball return guide hole, as shown in **Fig. 61**. As the balls are dropped into the guide, turn the worm shaft so that the balls are pulled down into the grooves.

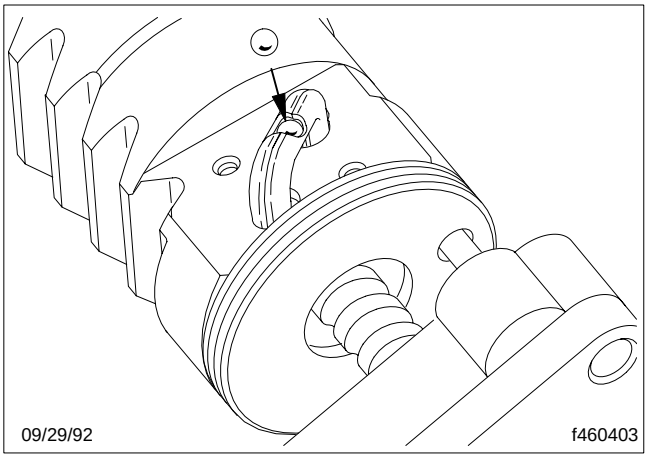


Fig. 61, Inserting the Steel Balls in the Return Guide Hole

⚠ WARNING

Make sure the ball return guide halves stay down and in place while you are inserting the steel balls or turning the input shaft. Failure to hold the ball guide halves down may result in a ball being trapped outside the closed ball-track loop. A trapped ball could cause a steering lockup, which could result in an accident and personal injury or property damage.

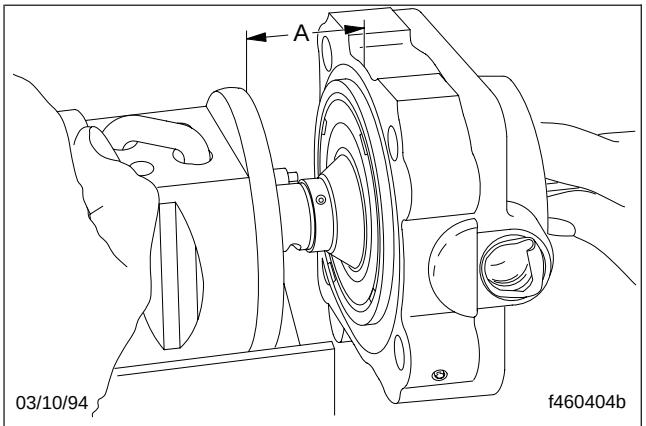
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8.3 If the ball guide halves rise up at any time during or after the installation of the steel balls, remove all of the balls, and the input shaft/valve/worm assembly from the rack piston. Repeat the previous steps beginning with inserting the worm shaft and input shaft assembly into the worm end of the rack piston.

IMPORTANT: Do not let the valve housing pilot face touch the poppet adjuster, or move more than 2.7 inches (69 mm) from the upper end of the rack piston. See **Fig. 62**. If this happens, the poppet adjuster could be incorrectly preset or the worm could be backed out beyond the closed ball loop.

8.4 Lubricate the new seal for the ball return guide cap, and install it in the groove in the cap.



A. 2.7 Inches (69 mm)

Fig. 62, Maximum Distance Between the Valve Housing Pilot Face and the Upper End of the Rack Piston

8.5 Using a 5/32 inch Allen socket and two new 5/32 inch Allen head screws (or a T-30 Torx socket and two new Torx head screws), install the ball return guide cap on the rack piston. Make sure the seal makes full contact with the rack piston surface. Tighten the fasteners alternately once or twice, to a final torque of 14 to 22 lbf·ft (19 to 30 N·m).

8.6 To ensure that the steel balls have been correctly installed, turn the worm shaft from one end of travel to the other, without allowing the valve housing to contact the poppet adjuster, and without moving the valve housing pilot face more than 2.7 inches (69 mm) from the input end (upper end) of the rack piston. See **Fig. 62**.

8.7 If the worm shaft does not turn, remove all of the steel balls, and install them again.

9. Install the poppet stopscrew. If the poppet stopscrew is being replaced, install the new one and its washer in the gear housing. See **Fig. 63**. Tighten it 38 to 42 lbf·ft (52 to 57 N·m).

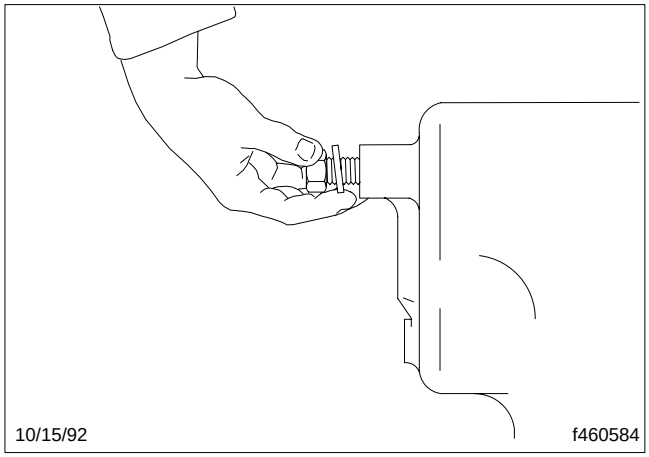


Fig. 63, Installing the Poppet Stopscrew

10. Preset the poppet adjusting screw, if equipped.

10.1 If the service poppet adjusting screw and the service sealing jam nut are being used for automatic poppet adjustment, turn the adjusting screw into the jam nut until 1.03 to 1.09 inches (26 to 28 mm) protrudes from the bottom of the jam nut. See **Fig. 64**.

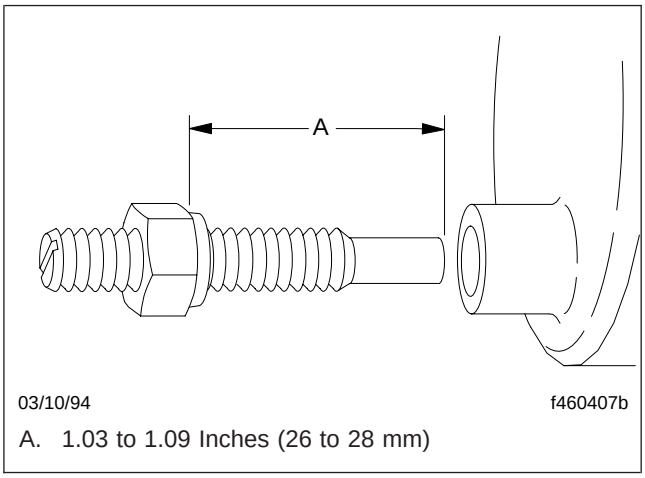
10.2 Install the assembly into the gear housing. Tighten the jam nut 33 to 37 lbf·ft (45 to 50 N·m).

11. Install the rack piston/valve housing assembly into the gear housing.

11.1 Put clean oil on the rack piston Teflon® seal ring and into the bore of the gear housing. Position the rack piston on the worm gear with a gap of 10 to 13 mm (3/8 to 1/2 inch) between the valve housing and the upper poppet adjuster seat and sleeve assembly.

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments



A. 1.03 to 1.09 Inches (26 to 28 mm)

Fig. 64, Turn the Adjusting Screw into the Jam Nut

CAUTION

When installing the rack piston in the steering gear housing, be careful not to damage the seal ring on the rack piston, as this could seriously affect the operation of the steering gear.

Do not let the poppet adjuster seat and sleeve assemblies on the rack piston bottom out when installing the rack piston in the gear housing.

IMPORTANT: This gap is to ensure that the poppets do not make contact with anything while the steering gear is being assembled.

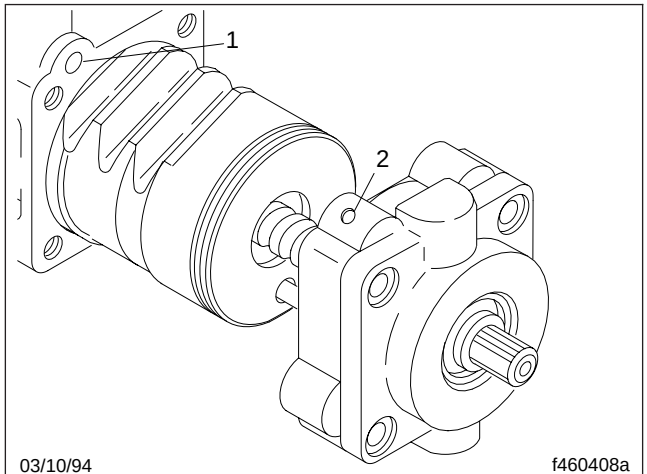
11.2 Install the rack piston and worm shaft assembly in the gear housing, being careful not to damage the seal ring on the rack piston. Do not let the poppet adjuster sleeve assemblies bottom out inside the gear housing. Install the piston with the rack teeth toward the sector shaft hole in the housing. See **Fig. 65**. Be sure the valve housing cylinder feed hole lines up with the gear housing feed hole.

11.3 Using an E-16 Torx socket wrench, install and tighten the four valve housing bolts 75 to 85 lbf·ft (102 to 115 N·m).

12. Install the relief valve components, if equipped.

12.1 Assemble a new O-ring on the relief valve cap.

12.2 Assemble the small end of tapered spring onto the pin on the other part of the relief valve and insert the assembly, tapered spring end first, into the relief valve cap cavity. See **Fig. 66**.



1. Gear Housing Feed Hole
2. Valve Housing Cylinder Feed Hole Boss

Fig. 65, Installing the Rack Piston and Worm Shaft Assembly in the Gear Housing

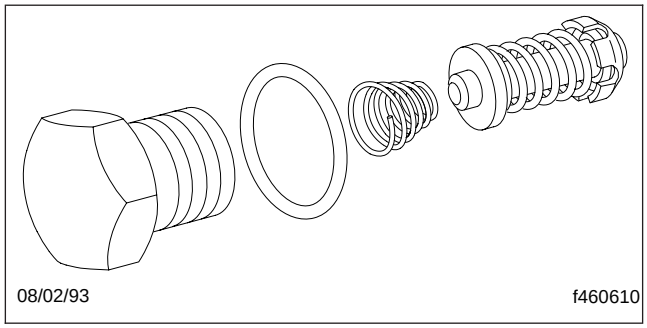


Fig. 66, Assemble the Spring and Pin into the Relief Valve Cap

12.3 Turn the relief valve cap as assembled into the valve housing and torque it to 30 lbf·ft (41 N·m). See **Fig. 67**.

13. If the sector shaft adjusting screw is being replaced, do the following; otherwise go to the next step and install the sector shaft/side cover components.

13.1 Coat the end of the new adjusting screw with wheel bearing grease, and with the sector shaft in a padded vise, insert the

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

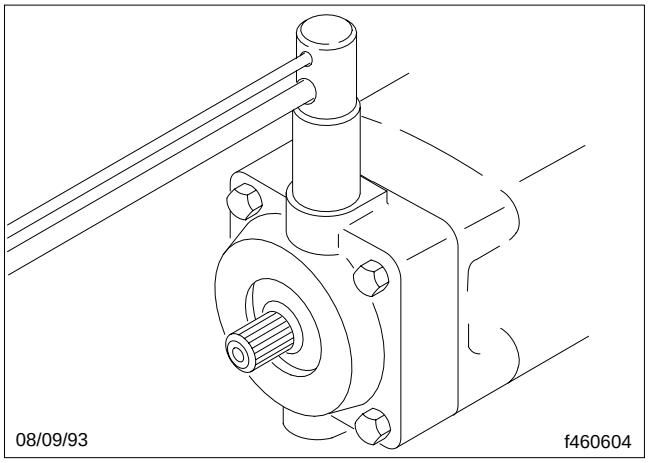


Fig. 67, Turn the Relief Valve Cap into the Valve Housing

new adjusting screw into the recess in the sector shaft end.

13.2 Install a new sector shaft screw retainer in the sector shaft. Adjust the retainer so that the sector shaft adjusting screw can be turned freely by hand. It should have a maximum end play of 0.002 inch (0.05 mm).

⚠ WARNING

Be careful when staking the sector-shaft screw retainer. If the retainer is broken or cracked, the sector shaft could come loose, resulting in loss of manual and power steering control. This could cause an accident resulting in personal injury or property damage. Replace a broken or cracked sector-shaft screw retainer.

13.3 Stake the sector shaft screw retainer to the slots in the sector shaft. See **Fig. 68**. Check the adjusting screw again for free movement and end play.

14. Install the sector shaft/side cover components.

14.1 Lightly oil the side cover DU bushing. Do not grease it. See **Fig. 69**.

14.2 Put a new seal on special tool J37705 (TAS40) or J37071 (TAS55/65) so that the garter spring is against the shoulder of the tool. See **Fig. 70**. Press the new seal into the side cover with a force of 100 to 800

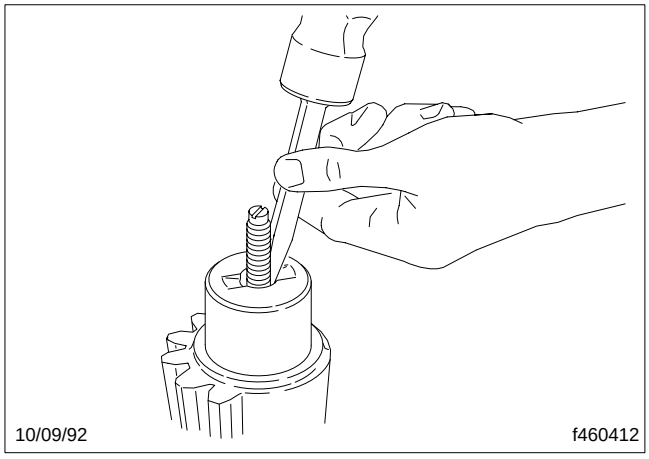


Fig. 68, Stake the Sector Shaft Screw Retainer to the Sector Shaft

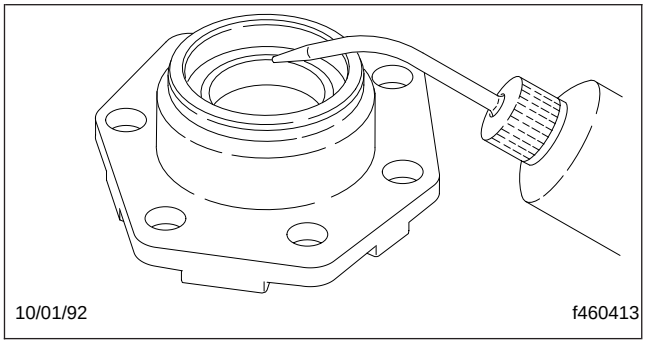


Fig. 69, Oil the Side Cover DU Bushing

lb (45 to 363 kg). Make sure the seal is seated against the bottom of the counterbore.

14.3 Lightly oil the short bearing end of the sector shaft.

Insert the sector shaft into the side cover. Screw the sector shaft adjusting screw counterclockwise into the side cover, until the screw seats. Rotate the adjusting screw clockwise one turn, so that the side cover rotates freely on the sector shaft.

14.4 Install the sector shaft adjusting screw jam nut onto the sector shaft adjusting screw a few threads. Final adjustment will be made later.

14.5 Press a new rubber plug into the hole provided in the side cover, until the plug is flush.

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

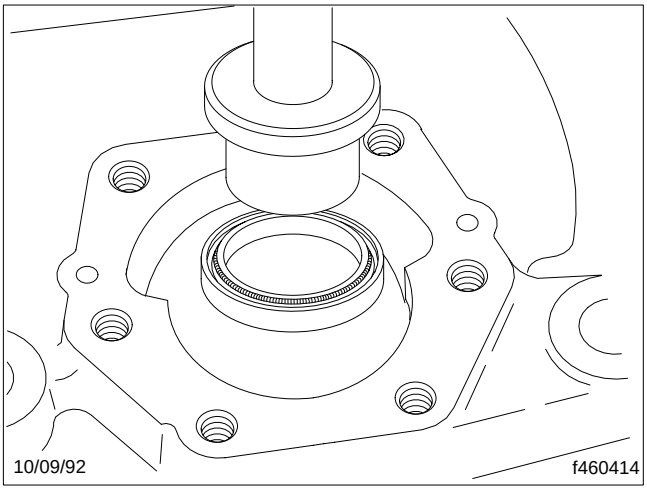


Fig. 70, Put a New Seal on the Tool

⚠ WARNING

Do not weld or plug this hole permanently. This is a safety vent which functions only if the side cover output shaft seal does not work. If the seal does not work and the plug cannot vent, the steering gear can lock up or otherwise malfunction. This could result in a loss of steering control, which could cause personal injury or property damage.

15. Install the sector shaft/side cover assembly.

    15.1 Apply clean grease to a new side cover gasket, and install it on the side cover. Apply enough grease to hold the gasket in place.

    15.2 There are four teeth on the rack piston. Turn the input shaft as needed to position the rack piston so that the tooth space between the second and the third tooth is in the center of the sector shaft opening. See **Fig. 71** and **Fig. 72**. This will center the rack piston in the opening.

    15.3 Remove all tape from the sector shaft splines. Retape the splines and the bolt groove with **one layer** of masking tape.

⚠ CAUTION

If the splines on the sector shaft are not taped correctly, the spline will damage the housing seal during assembly, causing the seal to leak.

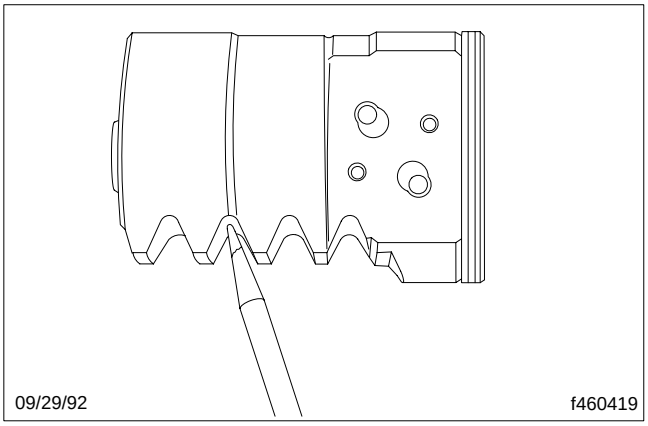


Fig. 71, Positioning the Rack Piston

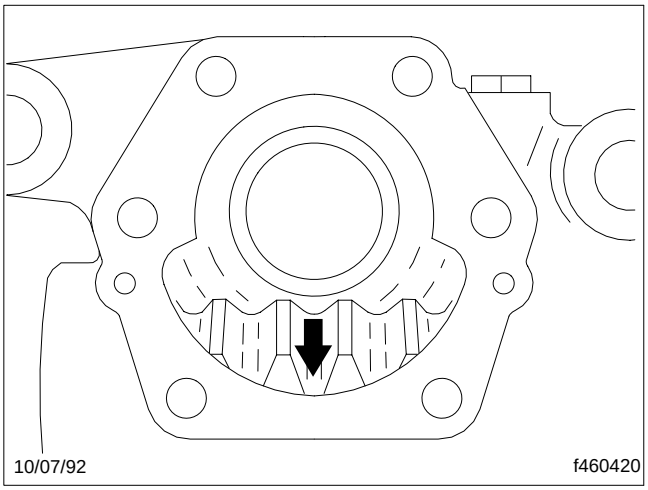


Fig. 72, Positioning the Rack Piston

    15.4 Install the sector shaft and side cover, as an assembly, in the gear housing. Make sure the center tooth of the sector engages the center space (between the second and third teeth) of the rack piston.

    15.5 Install the special side cover bolts in the side cover. Using the torque pattern shown in **Fig. 73** or **Fig. 74**, tighten:

    - TAS40 dry bolts 160 lbf·ft (217 N·m); lubricated bolts 118 lbf·ft (160 N·m);
    - TAS55/65 dry bolts 230 lbf·ft (312 N·m); lubricated bolts 170 lbf·ft (230 N·m). See **Fig. 75**.

16. Install the sector shaft seal.

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

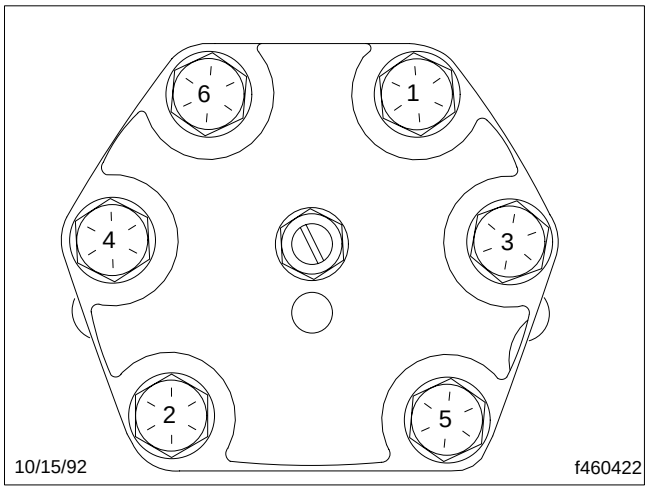


Fig. 73, Tightening Sequence

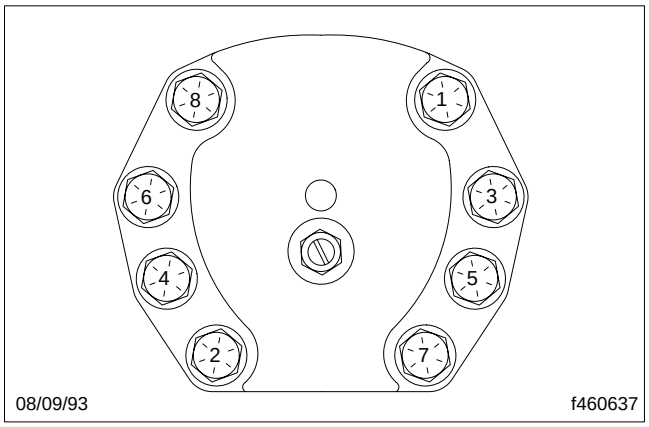


Fig. 74, Tightening Sequence

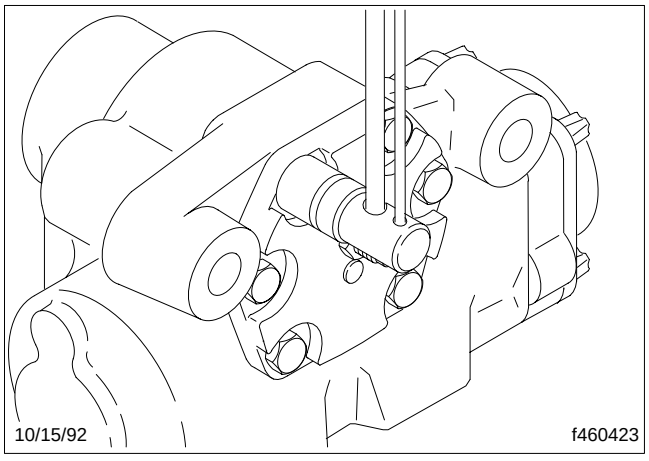


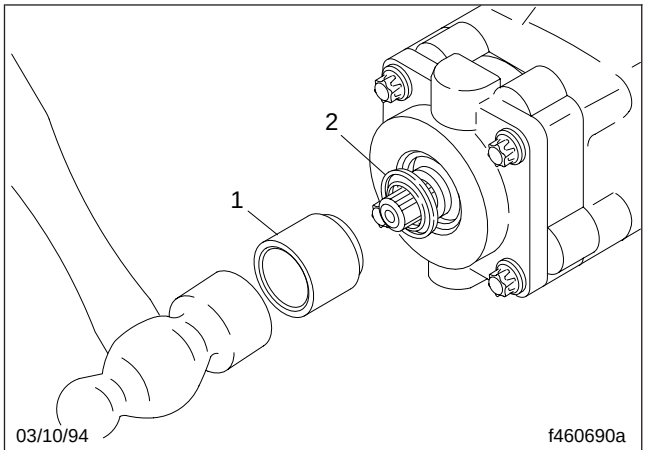
Fig. 75, Install the Bolts in the Side Cover

Remove the tape from the sector shaft, and pack the end of the housing trunnion area at the sector shaft with Mobil Temp 1 or 2 grease, or equivalent. Put grease on the new trunnion dirt seal, and install it over the sector shaft and into the trunnion bore.

17. Install the input shaft seals and retaining ring.

    IMPORTANT: Make sure the input shaft seal is installed squarely in the seal bore.

    17.1 Apply clean grease to the new input shaft seal. Place it, garter spring side first, over the input shaft. Using special tool J37073 and a mallet, tap the seal installer tool until the tool shoulder is square against the valve housing. See **Fig. 76**. Remove any seal material that may have sheared off in the retaining groove.



1. Tool J37073
2. Seal

Fig. 76, Tap the Seal Installing Tool Against the Valve Housing

    17.2 Install a new retaining ring into the groove in the valve housing. See **Fig. 77**.

    17.3 Pack the end of the valve housing bore (around the input shaft) with Mobil Temp 1 or 2 grease, or equivalent. Apply grease to the new dirt and water seal, and install it over the input shaft. Seat the dirt and water seal in the groove behind the serrations of the input shaft, and against the valve housing. See **Fig. 78**.

18. Install the grease fitting and auxiliary port plug.

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

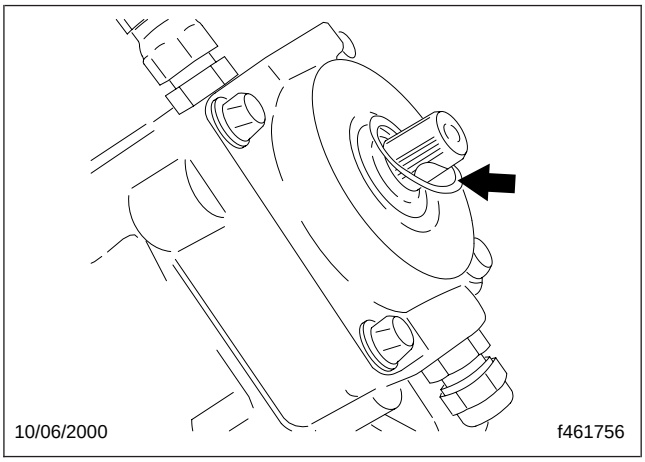


Fig. 77, Install a New Retaining Ring

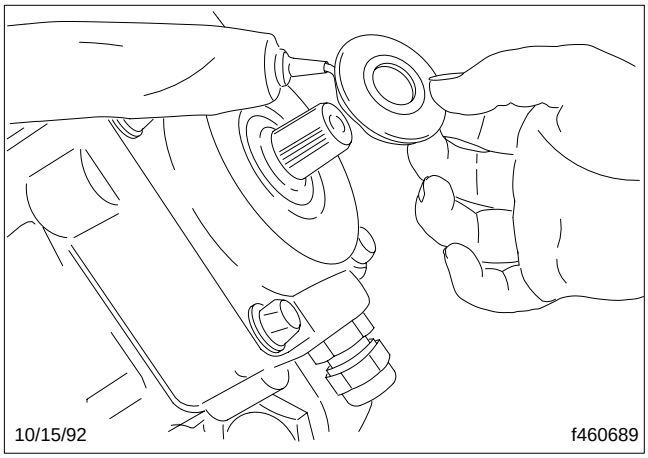


Fig. 78, Install the Dirt and Water Seal

18.1 If the grease fitting is being replaced, install a new one in the gear housing, using a piece of metal tubing over the head of the new fitting, as shown in **Fig. 79**. Tap the new grease fitting in place.

18.2 If the auxiliary port plugs were removed, install new O-rings on them, and install the plugs in the gear housing. Tighten them 25 to 35 lbf·ft (34 to 47 N·m).

Final Adjustments

Before installing the steering gear on the vehicle, make these adjustments:

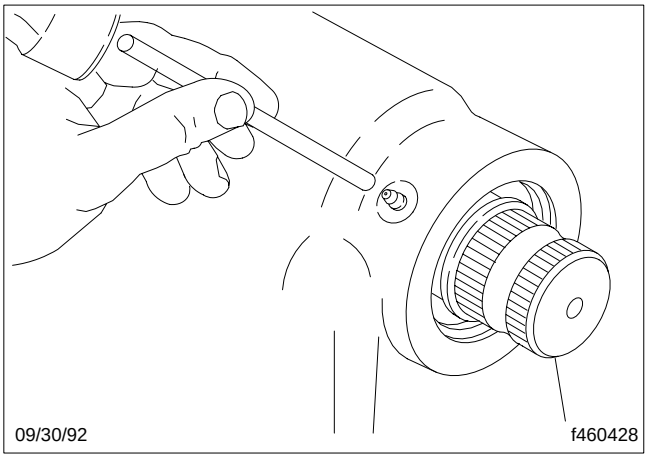


Fig. 79, Tap the Grease Fitting in Place

NOTE: Worm shaft preload adjustment was done when the input shaft was installed in the valve housing during the assembly procedure.

1. Adjust the sector shaft preload.

⚠ CAUTION

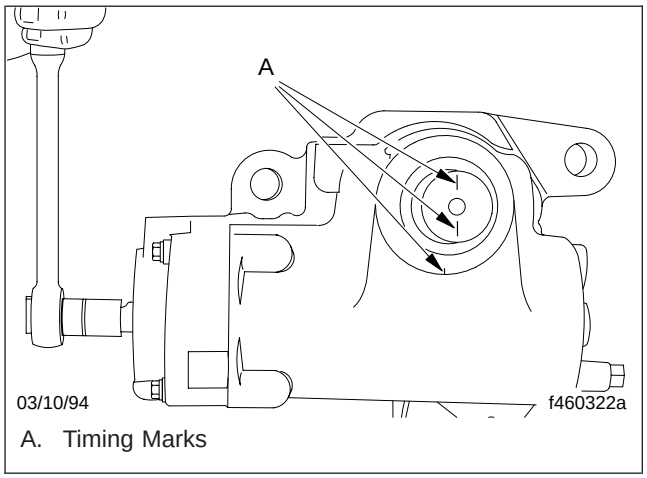
When the steering gear is not connected to the steering system, do not turn the input shaft more than 1-1/2 turns from the center position, or the automatic poppets could become inoperative when the steering gear is installed on the vehicle. This would require either disassembling the gear to position the poppet seat and sleeve assemblies for automatic adjustment, or using the special poppet adjusting screw kit 021407-X1 for manual poppet adjustment.

1.1 Center the steering gear by turning the input shaft until the timing mark on the end of the sector shaft is in line with the timing mark on the end of the housing trunnion. See **Fig. 80**. Use a 12-point, 11/16-inch, or 3/4-inch socket wrench to turn the input shaft. If the input shaft is turned more than 1-1/2 turns from the center position, you will have to either disassemble the gear to adjust the poppets again, or install the special poppet adjusting screw kit 021407-X1.

NOTE: If new or reset poppets are in the gear, they will be moved when the input shaft is turned less than one rotation in ei-

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Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments



A. Timing Marks

Fig. 80, Line Up the Timing Marks

ther direction from the center position. This will not affect the function of the poppets.

1.2 With the adjusting screw nut loose, adjust the sector shaft adjusting screw while turning the input shaft 180 degrees each side of center, until the input shaft reaches a torque of 45 to 50 lbf·in (500 to 560 N·cm). See **Fig. 81**. Use a 12-point socket and an inch-pound torque wrench to turn the input shaft.

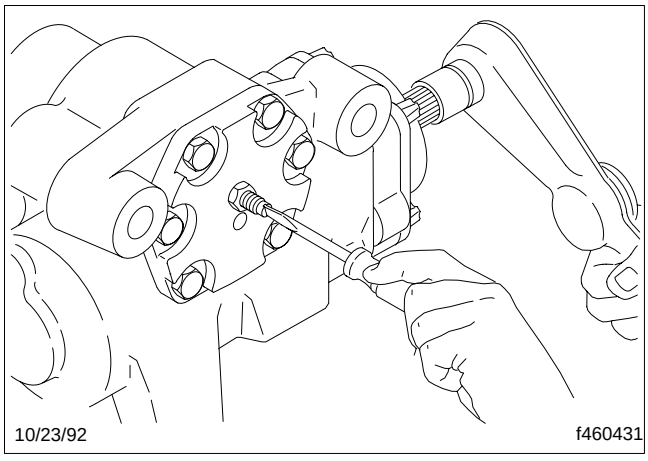


Fig. 81, Adjust the Sector Shaft Adjusting Screw

1.3 Back out the sector shaft adjusting screw one-half turn. Note the torque needed to turn the input shaft through 180 degrees each side of center.

1.4 Tighten the sector shaft adjusting screw so that the torque noted in the above substep is increased by 6 to 8 lbf·in (60 to 100 N·cm). Then, while holding the adjusting screw in place, tighten the sector shaft adjusting screw jam nut 40 to 45 lbf·ft (54 to 61 N·m).

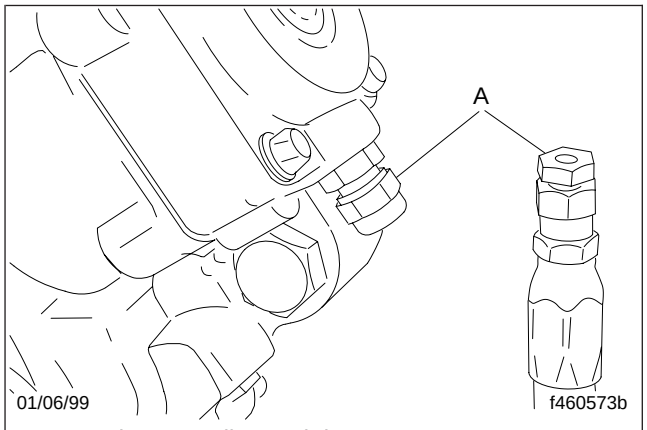
2. Check the torque needed to turn the input shaft. If it is more than 40 lbf·in (452 N·cm), readjust the input shaft.

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Input Shaft Seal Removal and Installation

Removal

1. Disconnect the return line from the steering gear and plug the line. Cap the return port of the gear with a high pressure fitting. See **Fig. 1**.



A. Cap the return line and the return port.

Fig. 1, Disconnect the Return Line

2. Disconnect the steering driveline from the steering gear input shaft as follows:

   2.1 Remove the pinch bolt nut and pinch bolt from the steering driveline lower end yoke. Discard the nut.

CAUTION

Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

   2.2 Remove the lower end yoke from the input shaft. Do not turn the steering gear input shaft when removing the lower end yoke. Push the driveline shaft into the driveline tube, as you remove the lower end yoke.

3. Remove the dirt and water seal from the steering gear. See **Fig. 2**.
4. Wipe out the grease and then remove the spiral retaining ring. See **Fig. 3**. Use a screwdriver inserted into the notch formed in the end of the ring.
5. Slip the input yoke back onto the input shaft with the pinch bolt installed but not tightened. See **Fig. 4**.

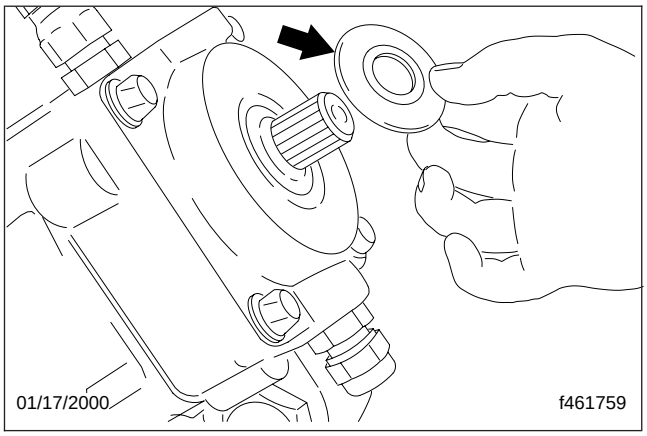


Fig. 2, Remove the Dirt and Water Seal

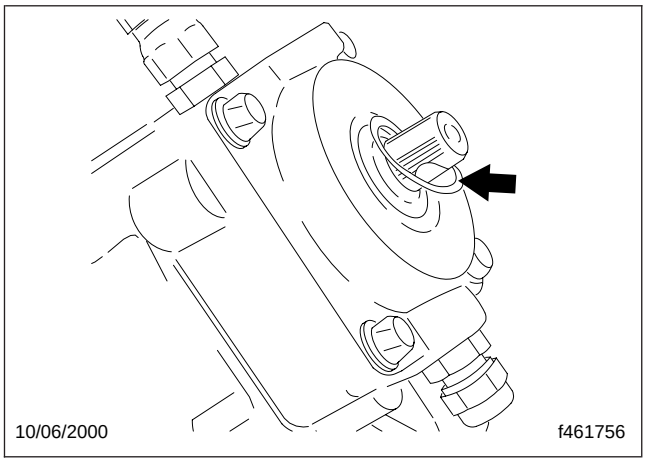
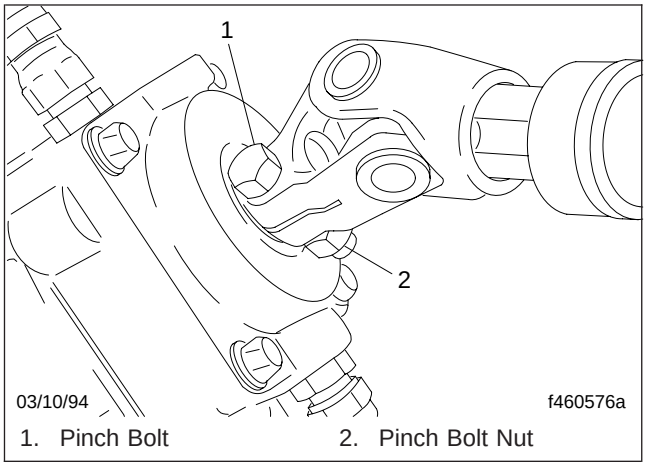


Fig. 3, Remove the Retaining Ring



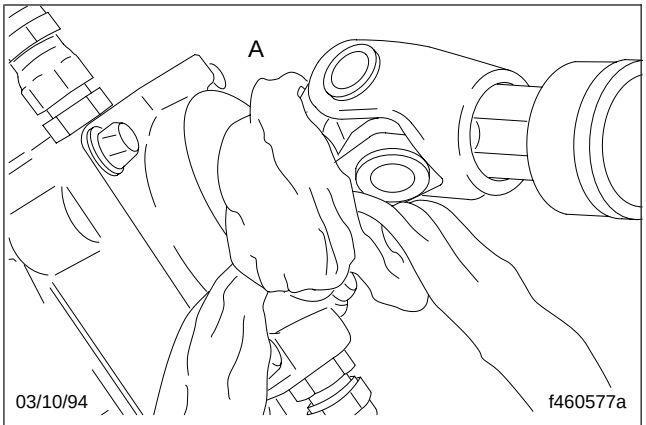
1. Pinch Bolt
2. Pinch Bolt Nut

Fig. 4, Install the Pinch Bolt

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Input Shaft Seal Removal and Installation

6. Tie or wrap a shop towel around the input shaft area and place a drip pan under the vehicle to catch the oil. See **Fig. 5**.



A. Cover the input shaft area.

Fig. 5, Shop Towel Covering the Input Shaft

7. Add the power steering fluid specified in **Specifications 400** as necessary to the fill line on the dipstick.
8. With the vehicle in neutral, momentarily turn the starter; quickly turn off the engine if it starts.
9. Remove the shop towel, pinch bolt, and input yoke.
10. Remove the seal. See **Fig. 6**.

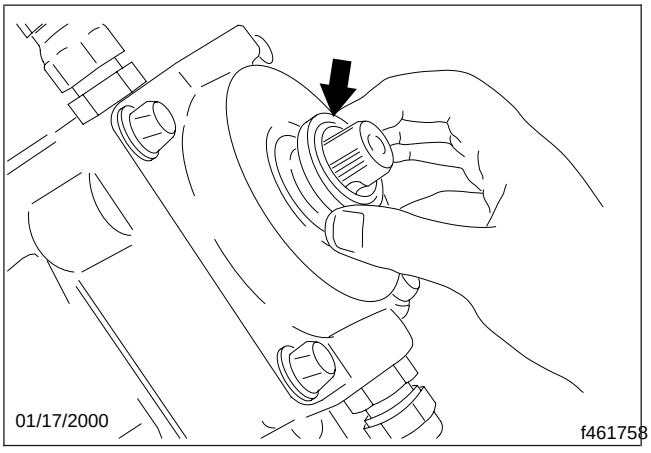


Fig. 6, Remove the Input Shaft Seal

11. Check the seal area of the valve housing for any seal fragments. Remove any that are found.
12. Check the seal for heat damage. If the seal is stiff and brittle, and not pliable like the new seal, it is probably heat damaged. You need to determine and fix the cause of excessive heat in the vehicle. See **Section 46.08, Subject 300**.

Installation

1. Put clean grease on the new input shaft seal and place it over the input shaft, garter spring side first. Place seal installer tool J37073 over the input shaft and against the seal, small diameter end first. See **Fig. 7**. Tap the seal installer tool until the tool shoulder is square against the valve housing. Remove any seal material that may have sheared off in the seal bore or retaining ring groove.

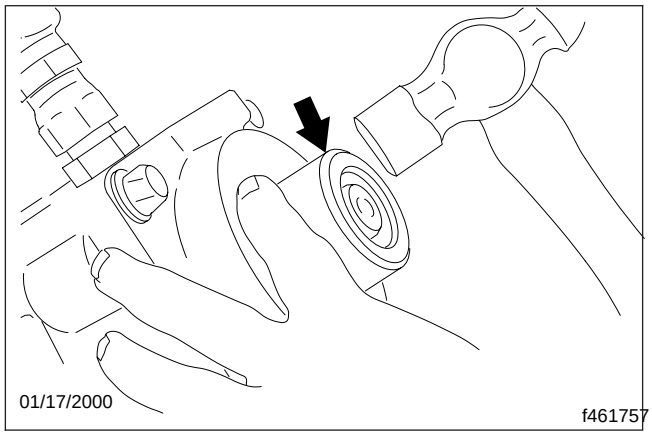
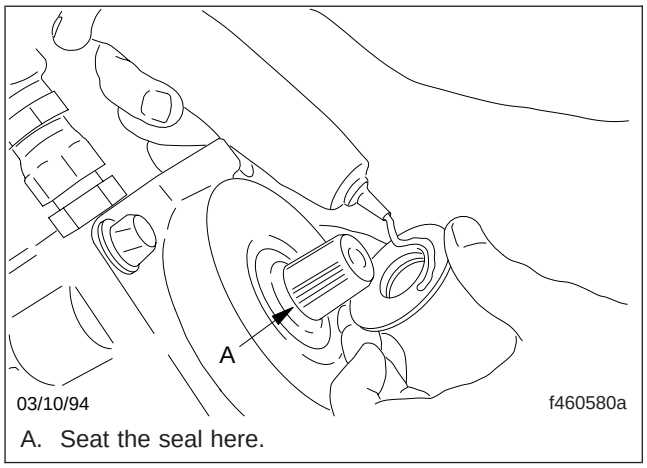


Fig. 7, Position the Seal Installer Tool

2. Insert the new retaining ring into the groove.
3. Pack the end of the valve housing bore around the input shaft with clean high temperature industrial grease (Mobil Temp 1 or 2 or equivalent). Apply more of the grease to a new dirt and water seal and install it over the input shaft. See **Fig. 8**. Seat it in the groove behind the serrations and against the valve housing.
4. Connect the steering driveline to the steering gear input shaft.
   - 4.1 Clean the input shaft and the inside of the driveline yoke.
   - 4.2 Apply a thin film of grease to the yoke splines. Use lithium-based grease, NLGI grade 2.

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A. Seat the seal here.

Fig. 8, Install the Dirt and Water Seal

4.3 Slide the yoke onto the input shaft, and install the new yoke pinch bolt. Before installing the pinch bolt nut, make sure the pinch bolt is centered in the steering column shaft notch. The pinch bolt is centered if it can slip in and out of the end yoke with ease. Install a **new** pinch bolt nut, and tighten it 55 to 65 lbf·ft (75 to 88 N·m).

4.4 Apply white Torque Seal OGP F900WHITE to the exposed pinch bolt threads and the locknut.

5. Connect the return line to the steering gear return port.

6. Fill and bleed the steering system.

IMPORTANT: Do not turn the steering wheel in the following steps until instructed. Doing so can cause air to enter the system, which can make it more difficult and time-consuming to bleed air from the system.

6.1 Fill the power steering reservoir with the steering fluid specified in **Specifications 400** until nearly full.

Crank the engine for 10 seconds without allowing it to start. If the engine does start, shut it down immediately. Check and fill the reservoir as needed.

Repeat this procedure three times, each time checking and filling the reservoir.

6.2 Start the engine and let it idle for two minutes. Shut down the engine, and check the fluid level in the reservoir.

6.3 Start the engine again. Steer the vehicle from full left to full right, several times. As needed, add fluid to the full line on the reservoir dipstick.

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Checks

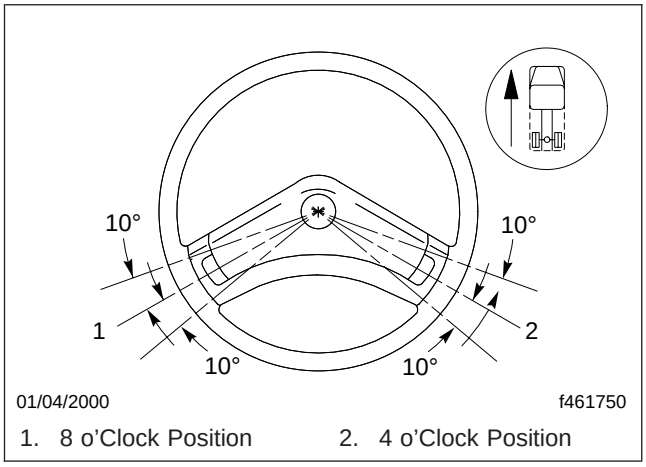
After power steering components have been worked on, and before the vehicle is placed into service, make the following checks.

⚠ WARNING

Failure to make the following checks could result in damage to the power steering system. This could cause a loss of hydraulic assist, which could cause personal injury or property damage.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. With the engine turned off and warm, check the power steering reservoir fluid level.
3. Check for air in the system.
   - 3.1 Place a thermometer in the power steering reservoir. Then warm the hydraulic system to normal operating temperature of 125 to 135°F (51 to 57°C) by operating the engine at low idle while turning the steering wheel through several full-left and full-right turns.
   - 3.2 With the engine running and the power steering system at operating temperature, turn the steering wheel slowly from stop to stop while checking the power steering reservoir for frothing or a change in the fluid level (a sign that air is trapped in the system). If air is present, inspect the system for leaking hoses or loose fittings. Replace the hoses or tighten the fittings as needed. Bleed the air from the system.
4. At full-left and full-right wheel cuts, be sure the axle stops (on the rear-side of the spindle) are set so there is at least 1/2-inch (13-mm) clearance between the tires and any fixed components that are attached to the vehicle. Clearance between moving components should be 3/4 inch (19 mm). If clearance is less than this, reset the axle stops.
5. Check that the automatic poppets or the manual poppet adjusting screw (if equipped) are set correctly. If needed, adjust them. For instructions, see **Subject 100**.
6. If there are still problems with the power steering system, see **Section 46.08, Subject 300** and do the steering system tests as instructed. Otherwise, go to the next step.
7. Remove the chocks from the tires.
8. Test drive the vehicle or take a ride with the driver.

   Check the steering wheel spoke position. With the front tires pointing straight ahead, check the position of the steering wheel spokes. They must be pointing within ±10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 1**. If not, remove the steering wheel and install it in the correct position. For instructions, refer to the applicable section in this group.



1. 8 o'Clock Position 2. 4 o'Clock Position

Fig. 1, Steering Wheel Centered

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See **Fig. 1** for a steering system plumbing diagram.

Special Tools, SPX Kent-Moore, Warren, MI 48092, 1-800-328-6657		
Part Number		Tool
TAS40	TAS55/65	
J37070	J37070	Adjuster Tool
J37464	J37464	Adjuster Locknut Tool
J37705	J37071	Bearing and Seal Tool
J37073	J37073	Input Seal Installer
J38713	J38713	Poppet Adjuster Seat Tool, Heavy-Duty (preferred)
J36452	J36452	Poppet Adjuster Seat Tool
J37130	J37130	Relief Valve Plug
J8092	J8092	Tool Handle

Table 1, Special Tools, SPX Kent-Moore, Warren, MI 48092, 1-800-328-6657

⚠ WARNING

Fill only with approved clean automatic transmission fluid. Any mixture or any unapproved fluid could lead to seal deterioration and leaks. Any fluid leak could eventually cause loss of power steering assist.

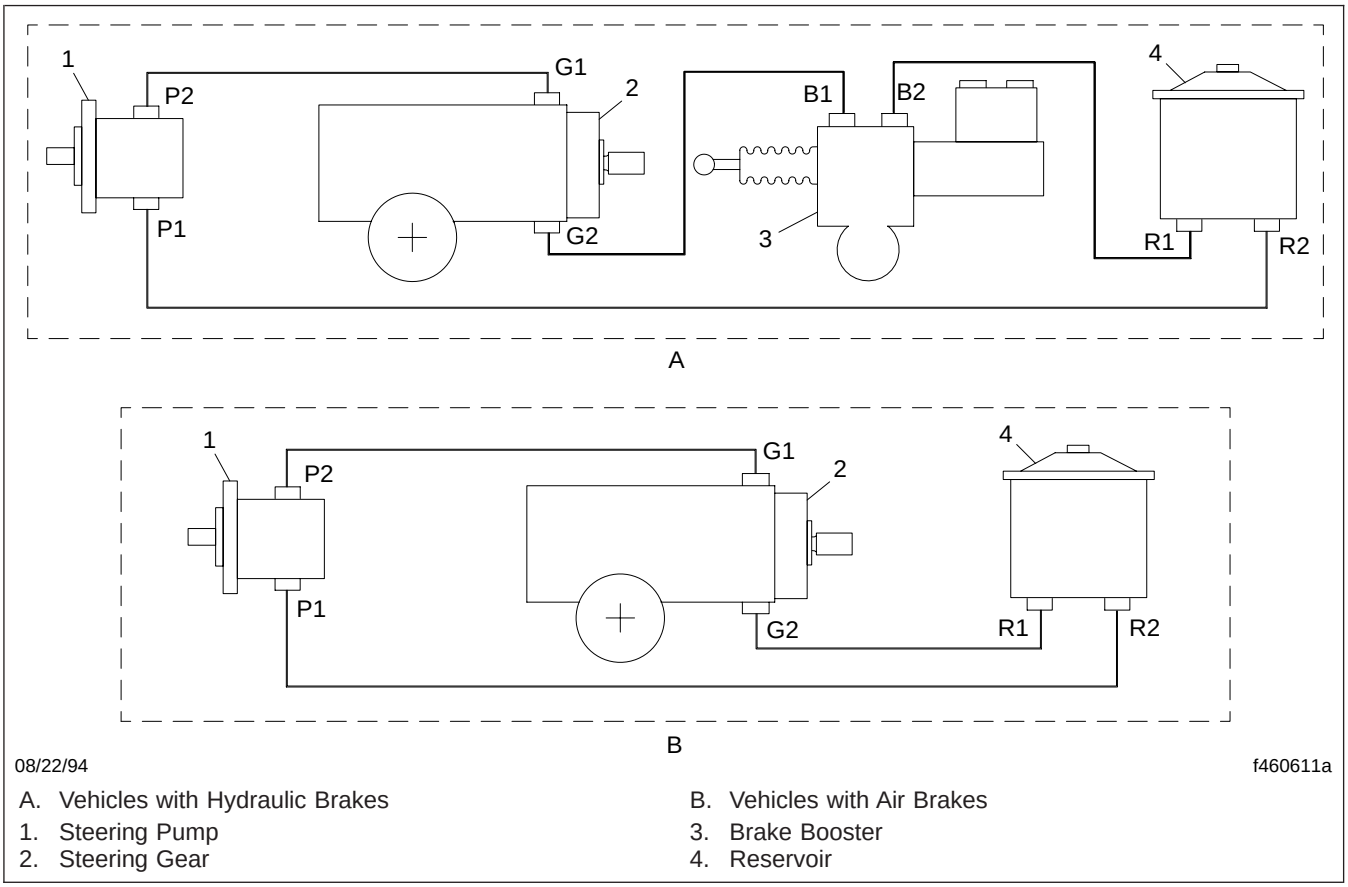
Power Steering Fluid	
Steering Gear and Lubricant Type	Recommended Lubricant
Power Steering Gears With Automatic Transmission Fluid Installed*	Dexron® III
	Type E
	Type F
	Mobil 210

* Do not mix engine oil with automatic transmission fluid (ATF). Use the same lubricant for parts as is in the power steering system.

Table 2, Power Steering Fluid

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Specifications



A. Vehicles with Hydraulic Brakes
1. Steering Pump
2. Steering Gear
B. Vehicles with Air Brakes
3. Brake Booster
4. Reservoir

Fig. 1, Steering System Plumbing Diagram

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General Information

The TRW PS Series power steering pump supplies power steering fluid for the operation of the power steering gear. The main parts of the power steering pump are the housing, input shaft, cam ring, rotor, vanes, control valve, and cover assembly.

The input shaft, powered by the adaptor gear in the engine gear case or by the crankshaft pulley, turns the rotor, which is inside the cam ring. As the rotor turns, centrifugal force pushes the vanes out toward the surface of the cam ring. As fluid enters the cam ring through the inlet port, the rotor vanes force it out through the outlet port and into the system. The fluid operates the steering gear. Eventually the fluid returns to the power steering reservoir, and then back to the power steering pump.

If the system pressure gets too high, a relief valve inside the control valve is forced off its seat, shunting fluid into a relief passage connected to the inlet port. The fluid then recirculates inside the pump instead of going to the outlet port. When the system pressure drops to the correct level, the relief valve seats, closing off the relief passage to the inlet port. The fluid flow returns to normal, flowing from the inlet port to the outlet port and then into the power steering system.

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Removal

1. Turn off the engine, apply the parking brakes, and chock the rear tires.
2. Open the hood.
3. Clean all dirt from around the fittings and hose connections.
4. Place a drain pan under the pump, then disconnect the hoses from the fittings on the pump. Plug the hoses and cap the fittings to keep out dirt and to prevent fluid from leaking.
5. Remove the power steering pump.
   - 5.1 Remove the capscrews and washers that attach the pump to the engine accessory drive mounting flange.
   - 5.2 Pull the pump straight out from the engine. Keep it level to avoid spilling fluid.
6. Turn the pump upside down over the drain pan and let the fluid drain out.
7. Discard the gasket, washers, and capscrews from the pump mounting flange.

Installation

1. Using engine oil, lightly lubricate a new gasket and the pump shaft.
2. Install the power steering pump.
   - 2.1 Install a new gasket on the pump mounting flange. Place the pump on the engine accessory drive mounting.
   - 2.2 Install new washers and new capscrews. Torque the capscrews 27 to 32 lbf·ft (37 to 43 N·m).
3. Connect the inlet hose, from the power steering reservoir, to the inlet port. Torque the hose 26 lbf·ft (35 N·m).
4. Connect the outlet hose, from the power steering gear, to the outlet port.
5. Bleed the power steering system.
   - 5.1 Check the fluid level in the power steering reservoir and if needed, fill it to the correct level with Dexron® III automatic transmission fluid (ATF).
   - 5.2 Start the engine and let it idle for several minutes.
   - 5.3 Turn the wheels to a full-left and full-right turn. Repeat about three times.
   - 5.4 Check the fluid level in the power steering reservoir. Add fluid as necessary to the full line on the reservoir or dipstick.
   - 5.5 Shut down the engine.
6. Close the hood.
7. Remove the chocks from the tires.

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Steering Pump Disassembly, Inspection, and Assembly

⚠ CAUTION

Be careful when working on the pump housing; it is aluminum, and can be easily damaged. When putting the pump in a vise, pad the vise jaws and clamp only the cover. Tighten the vise just enough to hold the pump.

Disassembly

⚠ WARNING

Wear safety goggles or glasses when disassembling the power steering pump. Some of the parts are held in place by springs or snap rings, which can release with considerable force, possibly causing injury.

NOTE: Prepare for fluid drainage before disassembling the pump.

1. Remove the power steering pump from the engine. For instruction, see **Subject 100**.
2. Carefully remove the end plug from the pump housing. Remove the spring if it did not come out with the end plug. See **Fig. 1**.
3. Remove and discard the O-ring from the plug.

IMPORTANT: TRW does not recommend disassembly of the control valve spool assembly.

4. Remove the control valve spool assembly by hand, or by pushing it with a small rod. Do not push on the small screen in the relief valve seat assembly.
5. Using a solvent-proof marker, make a mark across the housing and the cover. See **Fig. 2**. Remove the capscrews and washers that hold the housing and the cover together. Using a twisting motion, separate the housing from the cover.
6. Remove the spring.
7. Using a solvent-proof marker, draw a line across the top plate and the bottom plate. See **Fig. 3**.
8. Holding the cam ring in place, remove the top plate. Remove and discard the O-ring and backup O-ring.
9. Holding the bottom plate in place, remove the cam ring. Note and record whether the dots near the locating pin holes on the cam ring are up or down. See **Fig. 4**.
10. Look for wear on the outside edge of the vanes. Note and record the direction of the wear for assembly. Carefully remove the rotor and vanes, as the vanes will slip from their slots in the rotor.
11. Remove the locating pins. Make marks on the outside of the cover (not on the sealing surface) to note from which holes the locating pins were removed.
12. Remove the bottom plate.
13. Turn the cover over and remove the large retaining ring.
14. Press out the input shaft and ball bearing assembly.
15. Remove the spacer from the cover.
16. Using care not to damage the bore, remove the shaft seal.

Inspection

1. Clean all the parts, using a solvent compatible with the power steering fluid. Then, using filtered compressed air, dry all the parts.

NOTE: Replace any parts that are damaged or worn.

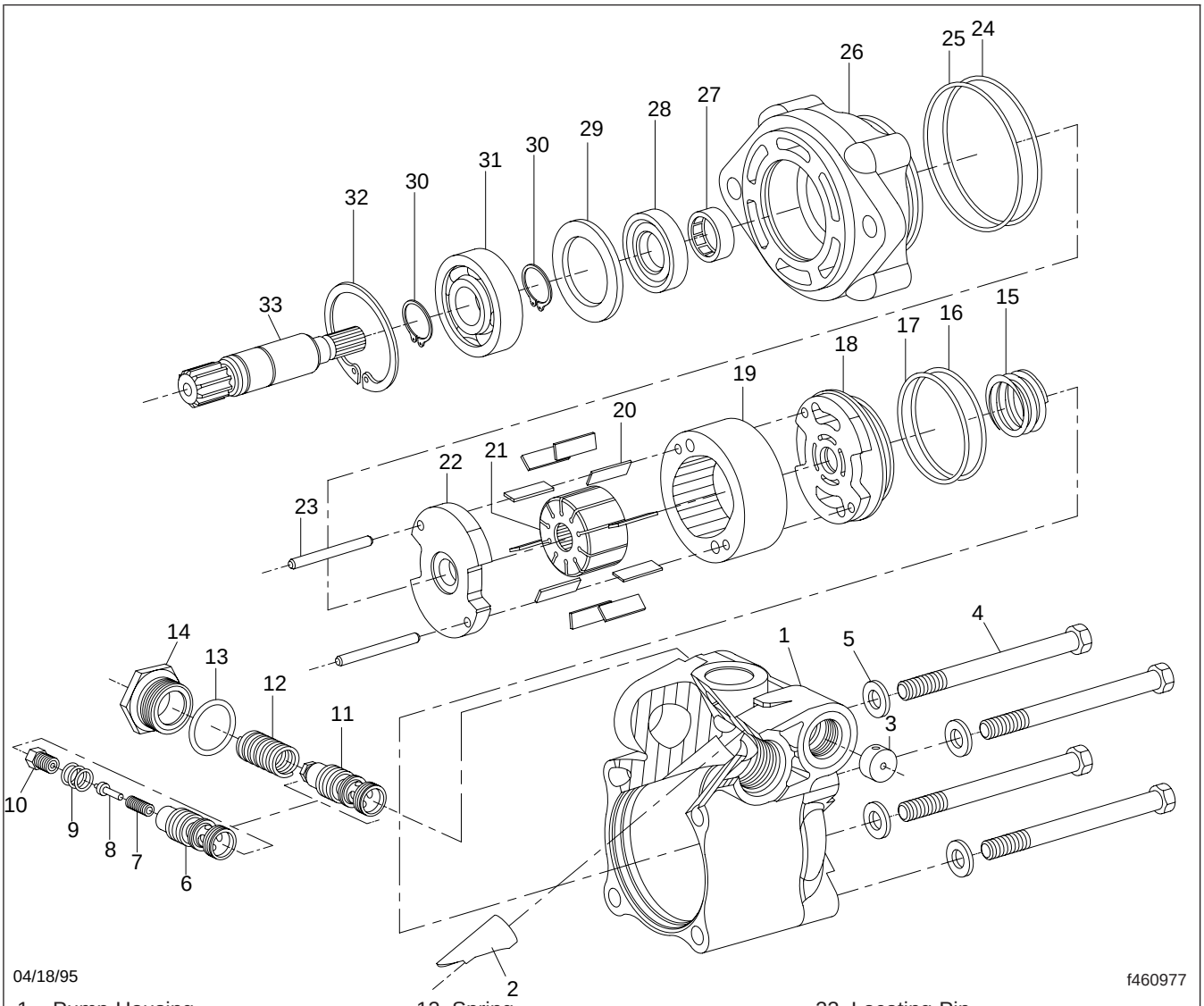
2. Inspect the housing for cracks, stripped threads, a damaged valve bore, and damaged sealing areas. See **Fig. 5**.
3. Inspect the cover for nicks in the O-ring seal grooves. Make sure that the seal drain hole is open, and that the seal bore is free of nicks and other damage. See **Fig. 6**.

   Make sure that the surface on which the bottom plate rests is flat and free of nicks and other damage.
4. Check that the needles roll freely in the needle bearing. If needed, replace the needle bearing as follows.

   4.1 Place the cover in a press with the flange side down. Using an 11/16-inch socket, press the needle bearing out of the cover.

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Steering Pump Disassembly, Inspection, and Assembly



1. Pump Housing
2. Boost Tube
3. Orifice
4. Mounting Capscrew
5. Washer
6. Spool
7. Spring
8. Poppet
9. Shims
10. Relief Valve Seat Assembly
11. Control Valve Spool Assembly
12. Spring
13. O-Ring
14. End Plug
15. Spring
16. O-Ring
17. Backup O-Ring
18. Top Plate
19. Cam Ring
20. Vane
21. Rotor
22. Bottom Plate
23. Locating Pin
24. Small O-Ring
25. Large O-Ring
26. Cover
27. Needle Bearing
28. Shaft Seal
29. Spacer
30. Small Retaining Ring
31. Ball Bearing
32. Large Retaining Ring
33. Input Shaft

Fig. 1, Power Steering Pump

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Steering Pump Disassembly, Inspection, and Assembly

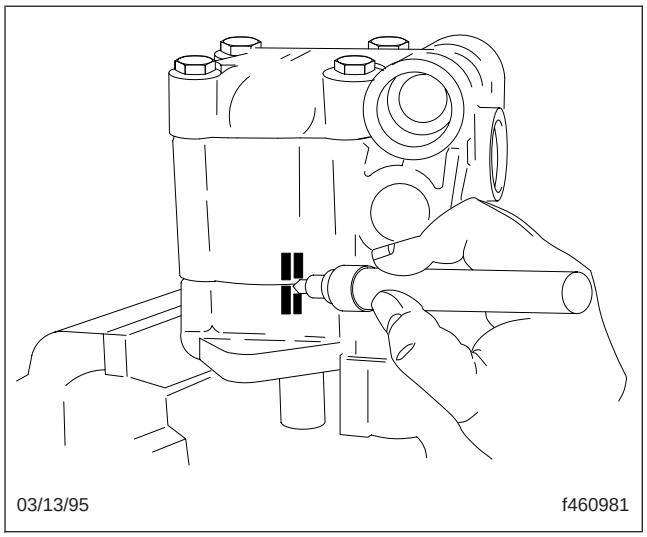


Fig. 2, Marking the Housing and the Cover

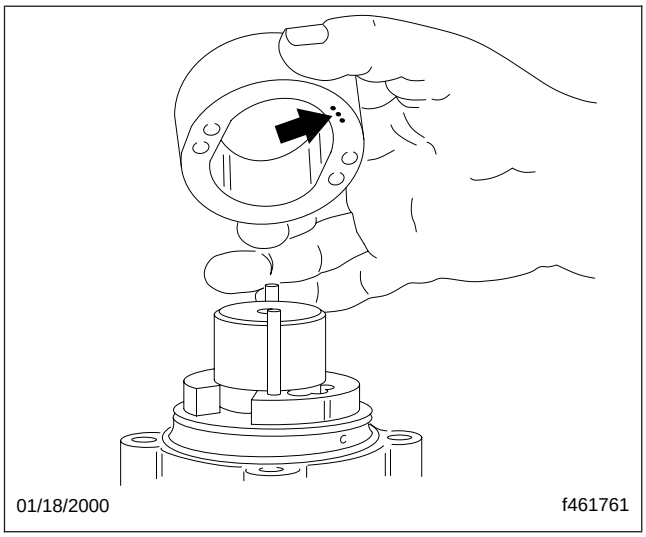


Fig. 4, Cam Ring Dots

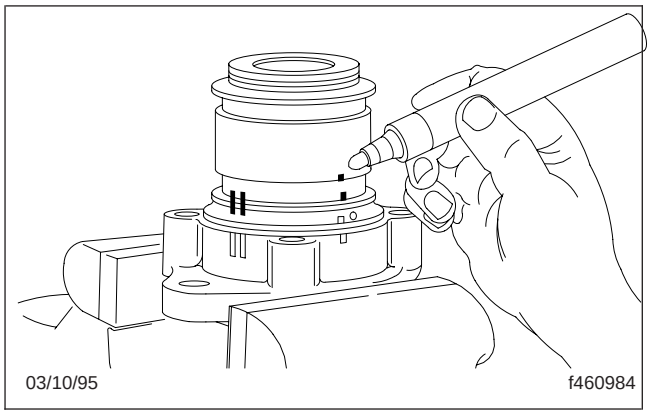
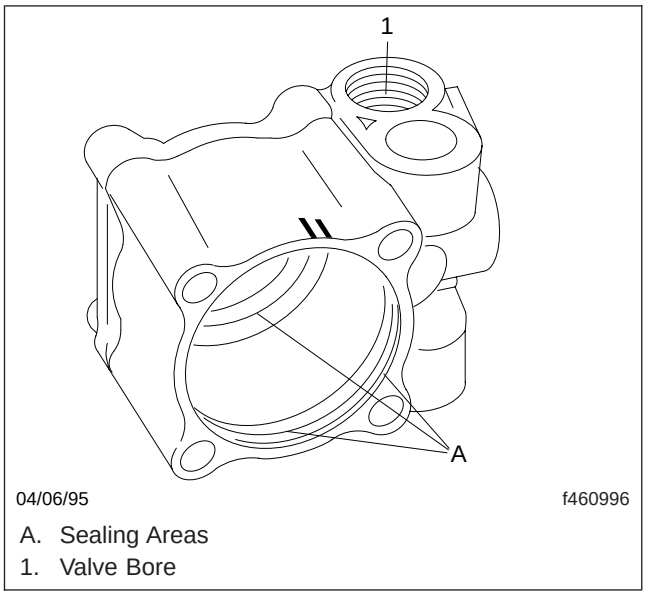


Fig. 3, Marking the Top Plate and the Bottom Plate



A. Sealing Areas
1. Valve Bore

Fig. 5, Inspect the Housing

CAUTION

Make sure that the press is clean and free of debris. Debris could damage the face of the cover, which will affect pump operation.

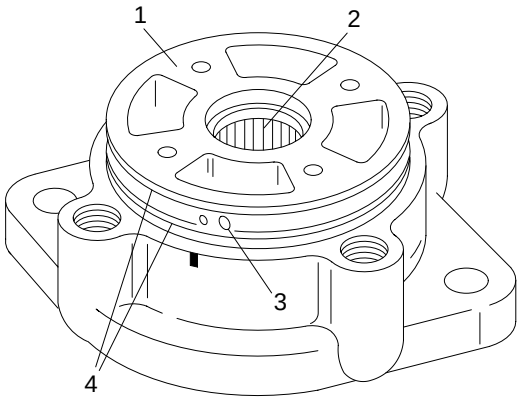
4.2 Put the cover in a clean press with the flange side up. Make sure that the lettered side of the needle bearing is facing toward the press.

4.3 Using a 7/8-inch deep socket, press the new needle bearing into the cover until it is flush with the inside surface of the cover.

5. Inspect the top plate for seal area nicks, and abnormal wear or erosion. A polished pattern from the rotor and vanes is normal. Grooves you can feel with your fingernail are not normal.
6. Look for abnormal wear, erosion, or surface damage on the inside of the cam ring.
7. Check the vanes on the rotor for damage or too much play in the rotor slots. If you can move the

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Steering Pump Disassembly, Inspection, and Assembly



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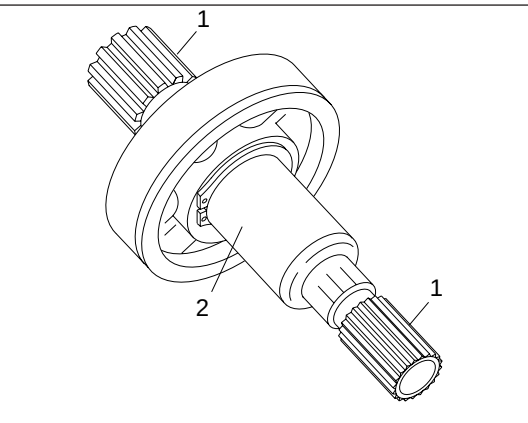
1. Bottom Plate Surface
2. Needle Bearing
3. Seal Drain Hole
4. Seal Grooves

Fig. 6, Inspect the Cover

vanes from side to side in the slots, replace the whole rotor assembly.

NOTE: If the vanes are removed, make sure they are installed with the rounded edge out.

8. Check the bottom plate for abnormal wear patterns.
9. Check the input shaft for damaged splines and abnormal wear grooves around the seal area. See **Fig. 7**. Replace the input shaft as follows if there are grooves that can be detected with your fingernail.



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1. Spline
2. Shaft Seal Area

Fig. 7, Check the Input Shaft

9.1 Remove the retaining ring (engine drive end) from the shaft.

Remove the Woodruff key, if equipped.

9.2 Applying pressure to the engine drive end of the input shaft, press the input shaft from the ball bearing.

9.3 Press the new input shaft, from the small splined end, into the ball bearing until the shaft bottoms out on the retaining ring.

9.4 Install the retaining ring on the input shaft with the sheared edge pointing away from the bearing. Make sure that the retaining ring is properly seated.

IMPORTANT: TRW does not recommend disassembly of the control valve spool assembly.

10. Check the control valve spool assembly for wear or chipping. If needed, back flush with air and solvent. Check the assembly for nicks or burrs.

Assembly

CAUTION

Make sure that the press is clean and free of debris. Debris could damage the face of the cover, which will affect pump operation.

1. Coat the outside surface of the shaft seal with a petroleum-based chassis grease. With the lettered side facing toward the needle bearing, press the seal into the cover. The installed seal should be flush with, or just below, the sealing surface on the cover.
2. Grease the inside surface of the shaft seal using a petroleum-based chassis grease.
3. Install the spacer. Make sure that it lies flat.

CAUTION

Do not allow the splines to contact the shaft seal. The splines could damage the shaft seal.

4. Insert the input shaft, small splined end first, into the cover. Do not allow the splines to contact the shaft seal. Insert the shaft into the seal by hand until the ball bearing contacts the cover.

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Using a 7/8-inch socket, press the shaft and bearing into the cover.

CAUTION

When placing the cover in a padded vise, do not use excessive clamping force. This could damage the cover.

5. Place the cover in a padded vise and install the large retaining ring with the sheared edge out.

   Turn the cover assembly over.

6. Install the new large and small O-rings in the cover. Make sure that they are seated properly.

7. Using the marks made during disassembly as a guide, install the locating pins.

IMPORTANT: In one of the four cutouts in the cover there is a bar. When installed, the bottom plate must cover this bar.

8. Install the bottom plate with the pockets facing up. See **Fig. 8**. Make sure that the marks made during disassembly are aligned.

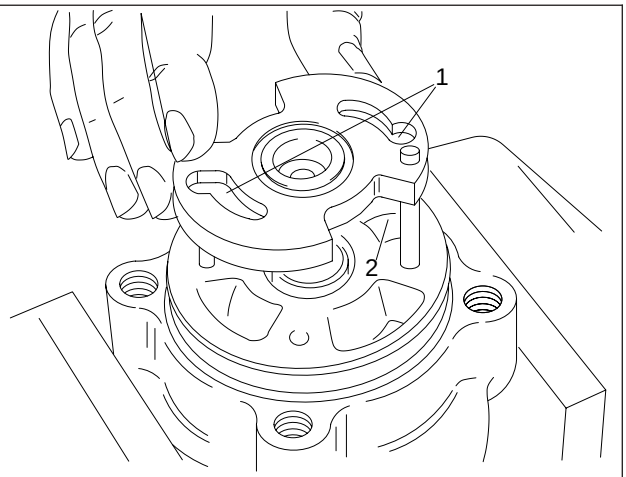


Fig. 8, Installing the Bottom Plate

9. Install the cam ring with the dots facing up or down as noted during disassembly. Make sure that the cam ring is flush with the bottom plate's large outside diameter, and that the marks made during disassembly are aligned. See **Fig. 9**.

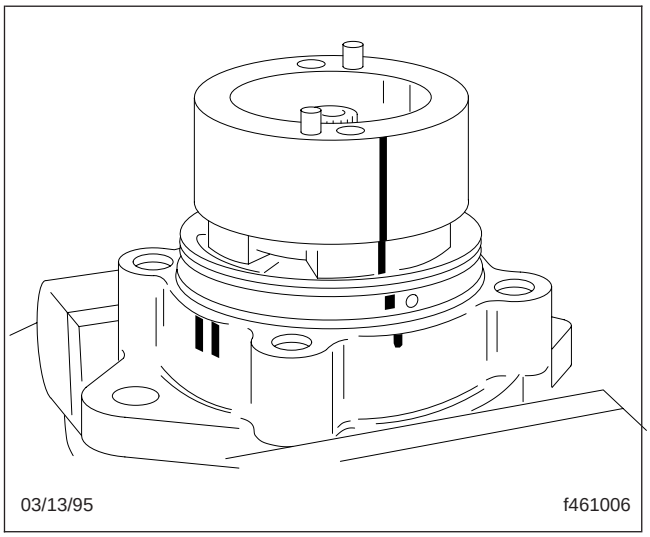


Fig. 9, Installing the Cam Ring

10. Install the rotor and vanes. Make sure that the squared edge on each vane points toward the center of the rotor.

11. Install the top plate with the pin holes down. Make sure that the locating pins are engaged in the pin holes, not the pockets.

    Make sure that the top plate is flush with the cam, and that the marks made during disassembly are aligned.

NOTE: The backup O-ring will fit tighter on the top plate after loosely wrapping (no twisting) it around two fingers, then allowing it to unwrap.

12. Install the backup O-ring on the top plate. Seat the O-ring at the bottom of the groove.

13. Install a new O-ring, without allowing it to roll, on the top plate. Seat the O-ring at the top of the groove.

14. Grease both the O-ring and the backup O-ring.

CAUTION

The housing may have sharp edges. Use care to not cut your finger when applying grease to the housing.

15. Grease the sealing areas of the housing. See **Fig. 10**.

16. Place the spring on the top plate.

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Steering Pump Disassembly, Inspection, and Assembly

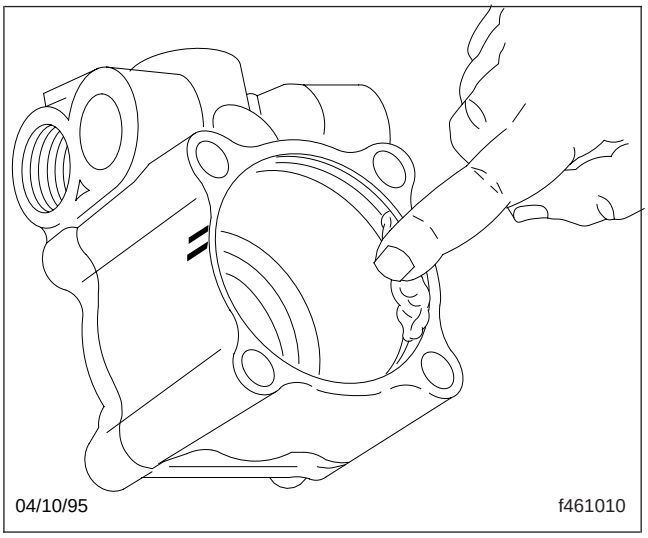


Fig. 10, Greasing the Sealing Areas

17. Place the housing over the cover assembly. Make sure that the marks made during disassembly are aligned.

CAUTION

Evenly thread the capscrews into the cover. If not evenly threaded into the cover, damage could occur to the seals, top plate, or housing.

18. Install the mounting capscrews and washers. Evenly thread all four capscrews into the cover. Alternately tighten the capscrews 30 lbf·ft (41 N·m).
19. Screw the relief valve seat assembly into the control valve spool assembly. Tighten the assembly 87 lbf·in (983 N·cm).

NOTE: Placing the spool assembly in a collet will assist the tightening procedure.

20. Insert the valve spool assembly, screen end last, into the housing. Make sure that the spool slides freely in the housing.
21. Install the spring in the housing.
22. Install a new O-ring on the end plug.
23. Lightly grease the O-ring and the end plug threads. Install the end plug and tighten 30 lbf·ft (41 N·m).
24. Install the Woodruff key into the new input shaft (if removed during the input shaft replacement).
25. Turn the pump by hand and make sure that it turns freely.
26. Install the power steering pump on the engine. For instructions, see **Subject 100**.

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Specifications

Dexron® III automatic transmission fluid is the only hydraulic fluid approved for use in the power steering system.

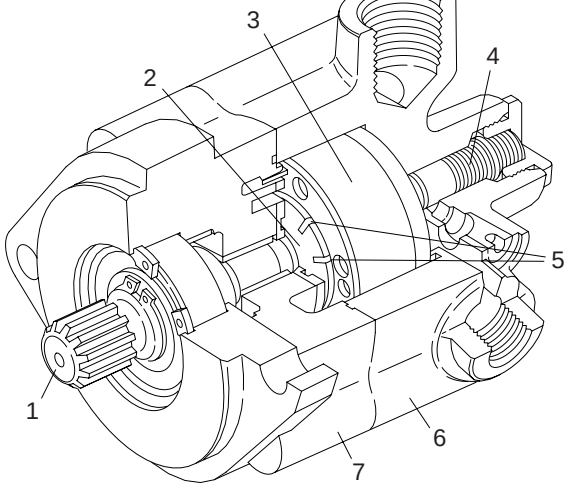
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General Information

The LuK Automotive Hydraulics LF 73 power steering pump supplies power steering fluid for the operation of the power steering gear.

The pump (used on Cummins ISB and ISC series engines) is mounted on the left side of the engine at the rear of the gear case, or on the air compressor. It is powered by an adaptor gear in the engine.

The main parts of the power steering pump are the housing, drive shaft, cam ring, rotor, vanes, and control valve. See **Fig. 1**.



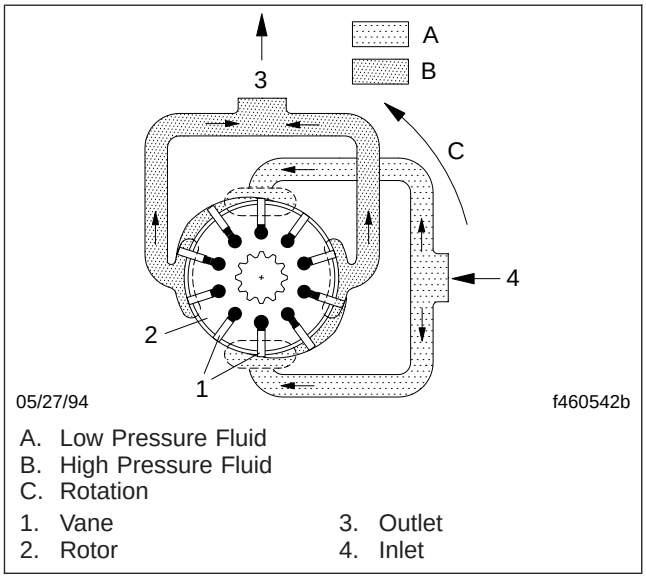
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1. Drive Shaft
2. Rotor
3. Cam Ring
4. Control Valve
5. Vane
6. Housing
7. Flange Assembly

Fig. 1, Pump Components

The drive shaft, powered by the adaptor gear in the engine gear case, turns the rotor, which is inside the cam ring. As the rotor turns, centrifugal force pushes the vanes out toward the surface of the cam ring. As fluid enters the cam ring through the inlet port, the rotor vanes force it out through the outlet port and into the system. The fluid operates the steering gear. Eventually the fluid returns to the power steering reservoir, and then back to the power steering pump. See **Fig. 2**.

If the system pressure gets too high, a poppet inside the control valve is forced off its seat, shunting fluid



05/27/94 f460542b

A. Low Pressure Fluid
B. High Pressure Fluid
C. Rotation
1. Vane
2. Rotor
3. Outlet
4. Inlet

Fig. 2, Pump Fluid Flow Diagram

into a relief passage connected to the inlet port. The fluid then recirculates inside the pump instead of going to the outlet port. When the system pressure drops to the correct level, the poppet seats, closing off the relief passage to the inlet port. The fluid flow returns to normal, flowing from the inlet port to the outlet port and then into the power steering system.

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Removal

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Clean all dirt from around the fittings and hose connections.
4. Place a drain pan under the power steering pump, then disconnect the hoses from the pump. Plug the hoses and cap the fittings to keep out dirt and to prevent fluid from leaking.
5. Remove and discard the capscrews and washers that attach the pump to the engine accessory drive mounting flange. Slide the pump out of the shaft sleeve, and remove the pump from the engine.
6. Remove and discard the gasket.

Installation

1. Using engine oil, lightly lubricate a new gasket and the pump shaft.
2. Install the power steering pump.
   - 2.1 Install the gasket on the pump mounting flange, then place the pump on the engine accessory drive mounting. Turn the pump or shaft as needed to mesh the shaft with the shaft sleeve. Seat the pilot of the pump mounting flange in the accessory drive mounting without applying unnecessary force.
   - 2.2 Install new washers and capscrews. Torque the capscrews 27 to 32 lbf·ft (37 to 43 N·m).
3. Connect the hoses to the pump.
4. Check the fluid level of the power steering reservoir and add Dexron® III automatic transmission fluid (ATF) if necessary. Start the engine and let it idle for two minutes. Do not turn the steering wheel. Doing so can cause air to enter the system.

   Turn off the engine, and check the fluid level in the reservoir.
5. Start the engine again. To remove air from the system, steer the vehicle from full left to full right several times.

   Add fluid as necessary to the full line on the dipstick or reservoir.
6. If the steering gear does not have a manual bleed screw, turn the steering wheel from full lock to full lock two or three times with the engine running at idle. Repeat this step, and add fluid as necessary until there are no bubbles in the reservoir.

   If the steering gear is equipped with a manual bleed screw, turn the steering wheel from full lock to full lock two or three times with the engine running at idle. Loosen the manual bleed screw about one turn and look for clear fluid or fluid mixed with bubbles at the threaded area of the bleed screw. Repeat this step and add fluid as necessary until only clear fluid shows. Tighten the manual bleed screw 27 to 33 lbf·in (305 to 373 N·cm). Refill the reservoir if necessary to the full line on the dipstick or reservoir.
7. Turn off the engine.
8. Lower the hood.
9. Remove the chocks from the tires.

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Replacement

⚠ WARNING

Wear safety goggles or glasses when disassembling the power steering pump. Some of the parts are held in place by springs or snap rings, which can release with considerable force, possibly causing injury.

NOTE: The shaft seal kit contains a replacement seal for LF and VT series pumps. The seal for the LF series pump is smaller.

1. Turn off the engine, apply the parking brakes, and chock the tires.

⚠ CAUTION

Be careful when working on the pump housing; it is aluminum, and can be easily damaged. When putting it in a vise, pad the vise jaws; tighten the vise just enough to hold the pump.

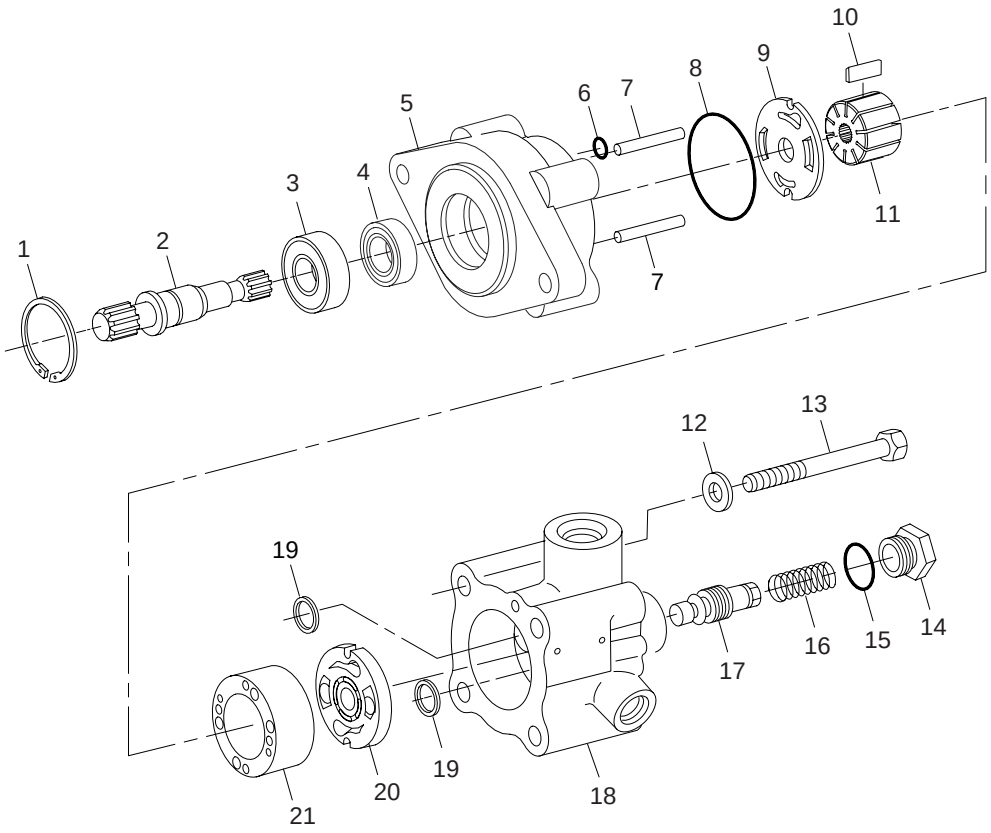
2. Remove the power steering pump from the engine, following the instructions in **Subject 100**.
3. Carefully remove the end plug (there is a spring underneath it) from the pump body. Remove the spring. Slide out the control valve. Be careful not to scratch the control valve. See **Fig. 1**.
4. Remove and discard the O-ring from the plug.
5. Put the pump housing in a padded vise. Remove the capscrews that hold the housing and the flange assembly together.
6. Remove and discard the combination O-ring/backup rings from the pump housing.
7. Remove the pressure plate, guide pins, cam ring, rotor, vanes, and wear plate as a unit and set aside.
8. Remove and discard the small and large O-rings from the flange assembly. See **Fig. 2**.
9. Remove the snap ring holding the shaft seal in place. Discard the snap ring.
10. Put the flange assembly in a vise with the inner end of the shaft pointing up. Carefully tap out the driveshaft.
11. Remove and discard the shaft seal.
12. Using a solvent compatible with the power steering fluid, clean all of the parts. Using filtered compressed air, dry all the parts.
13. Coat all the parts with Dexron® III automatic transmission fluid (ATF).
14. Place the spacer over the outer (drive) end of the shaft with the cupped side of the spacer facing the inner end of the shaft.
15. Using ATF, lubricate the new shaft seal. Carefully place the seal over the outer (drive) end of the shaft, up against the spacer. The lettered side of the seal should be visible.

NOTE: To correctly install the driveshaft seal, it is necessary to make a suitable driver from tubular stock. See **Fig. 3** for the applicable dimensions.

16. Using a suitable driver, install the shaft seal into the bore in the flange assembly. Make sure the spring side of the seal faces the flange. See **Fig. 4**. Seat the seal firmly against the shoulder in the bore.
17. Install the small snap ring in its groove on the driveshaft, with the sharp edge facing toward the bushing.
18. Put the flange assembly in a padded vise with the drive end of the shaft pointing up. Install a new large O-ring in the flange assembly.
19. Install a new small O-ring in the flange assembly.
20. Install the pressure plate, guide pins, cam ring, rotor, vanes, and wear plate as a unit. Make sure that the two guide pins are seated in the flange assembly.
21. Using ATF, lubricate the new combination O-ring/backup rings. Install the rings in the pump housing with the black side facing the housing, and the white plastic side exposed.
22. Install the pump housing over the flange assembly, lining up the mounting holes.
23. Install the capscrews and washers in the pump housing. Tighten them in a cross pattern 29 to 37 lbf·ft (39 to 50 N·m).
24. Install the control valve in the pump housing.

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Shaft Seal Replacement



10/16/95 f461063

1. Snap Ring
2. Driveshaft
3. Driveshaft Bushing
4. Shaft Seal
5. Flange Assembly
6. Small O-Ring
7. Guide Pin
8. Large O-Ring
9. Wear Plate
10. Vane
11. Rotor
12. Washer
13. Capscrew
14. End Plug
15. End Plug O-Ring
16. Spring
17. Control Valve
18. Pump Housing
19. Combination O-Ring/Backup Ring
20. Pressure Plate
21. Cam Ring

Fig. 1, Steering Pump Assembly

CAUTION

Make sure you install the control valve correctly in its bore. If it is installed backwards, the power steering pump will not work and will quickly overheat, which could cause severe damage to the pump.

24.1 Lubricate the control valve with ATF. Install the control valve, with the hexplug end up, into the bore in the pump housing. See **Fig. 5**.

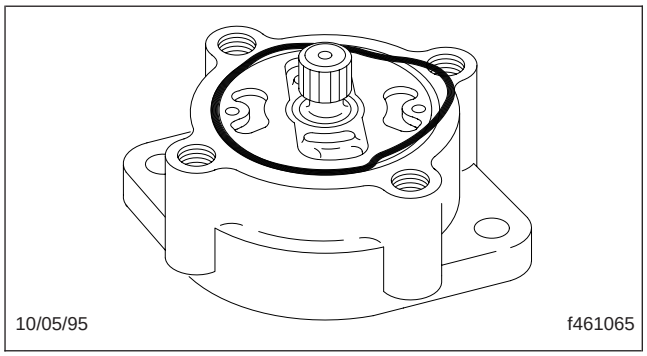
24.2 Install the spring over the hexplug end of the control valve.

24.3 Install a new O-ring on the end plug. Install the end plug. Tighten it 33 to 40 lbf·ft (45 to 54 N·m).

25. Turn the shaft by hand. It should turn smoothly and without binding.

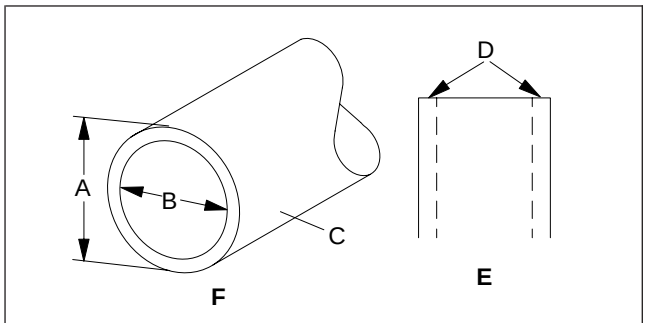
26. Install the power steering pump on the engine. For instructions, see **Subject 100**.

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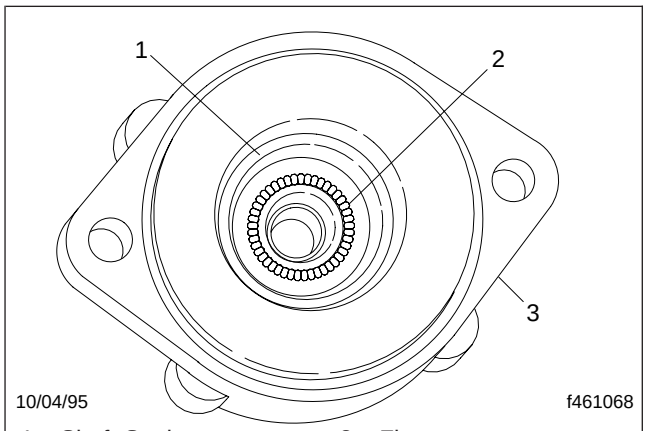
Fig. 2, Remove the Large O-Ring



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A. Slightly smaller than the o.d. of the shaft seal.
B. Slightly larger than the o.d. of the driveshaft.
C. To be made of tubular stock.
D. The ends must be square.
E. Side View
F. Front View

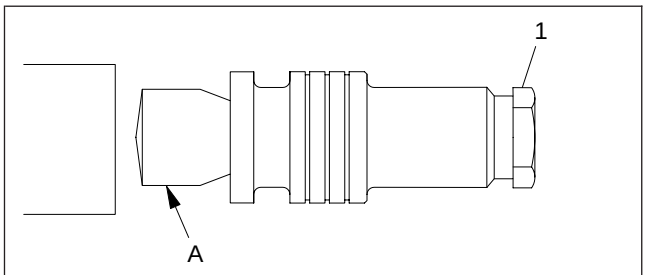
Fig. 3, Shaft Seal Installation Tool



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1. Shaft Seal
2. Garter Spring
3. Flange

Fig. 4, Install the Shaft Seal



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A. Insert this end first.
1. Hexplug

Fig. 5, Install the Control Valve

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Specifications

The approved hydraulic fluid for the power steering system is Dexron® III automatic transmission fluid (ATF).

Model Code Description*										
LF73V	21	16	163	L	P	U	D	02	11	GE11
Flange Type	Displacement (cubic cm/rev)	Control Flow (L/min)	Pressure Limit (bar)	Direction of Rotation	Inlet Port Connection	Pressure Port Connection	Pressure Port View from Cover End	Shaft	Design Number	With Gear and Locknut

* Model codes contain specifications in metric units.

Table 1, Model Code Description

Pump Specifications			
LuK Model Code	**Pump Displacement cubic inch/rev (cubic cm/rev)**	**Control Flow gpm (L/min)**	**Maximum Pressure psi (bar)**
LF73V-21-16-163-L-P-U-D-02-11-GE11	1.28 (21)	4.2 (16)	2396 (165)

Table 2, Pump Specifications

Pump Specifications			
LuK Model Code	**Pump Displacement: cubic inch/rev (cubic cm/rev)**	**Control Flow: gpm (L/min)**	**Maximum Pressure: psi (bar)**
LF73V-21-16-163-L-P-U-D-02-11-GE11	1.28 (21)	4.2 (16)	2396 (165)

Table 3, Pump Specifications

Pump Port Specifications			
Code	**Size**	**Shaft Minor Diameter Inches (mm)**	**O-Ring Chamfer**
Inlet Port			
M	M26 x 1.5	0.63 (16)	—
P	1-1/16–12	0.79 (20)	SAE J514
U	1-5/16–12		
Outlet Port			
M	M16 x 1.5	0.55 (14)	—
N	M18 x 1.5		—
U	3/4–16		SAE J514

Table 4, Pump Port Specifications

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Specifications

Pressure Settings	
Code	**Pressure in psi (kPa)**
80	1116.5–1261.5 (7700–8700)
100	1406.5–1551.5 (9700–10 700)
110	1551.5–1696.5 (10 700–11 700)
115	1624–1769 (11 200–12 200)
120	1696.5–1841.5 (11 700–12 700)
130	1841.5–1986.5 (12 700–13 700)
135	1914–2059 (13 200–14 200)
140	1986.5–2131.5 (13 700–14 700)
145	2059–2204 (14 200–15 200)
150	2131.5–2276.5 (14 700–15 700)
155	2204–2349 (15 200–16 200)
163	2320–2465 (16 000–17 000)
000	—

Table 5, Pressure Settings

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General Information[1]

NOTE: Procedures contained in this section have been slightly modified from the original component manufacturer's service manual. If you are not clear on how to perform an operation, consult the component manufacturer's service literature before continuing a specific procedure.

The TRW THP 45 and 60 series power steering gears are integral hydraulic power steering gears. Integral hydraulic power steering gears contain a manual steering mechanism, a hydraulic control valve, and a hydraulic power cylinder.

The rotary control valve controls the flow of hydraulic fluid through the steering gear. The speed at which the driver can turn the steering wheel with power assist is dependent on the pump flow directed to a cylinder cavity.

The pressure required for the steering gear to steer the vehicle is created by the power steering pump to overcome resistance at the steered wheels. The control valve senses these requirements and directs fluid to the appropriate cylinder cavity in the steering gear (and in the auxiliary cylinder if it is a dual steering system) at the proper flow rate and pressure.

The higher pressure a steering gear can withstand, the more work it can perform. The maximum operating pressure for all THP gears is 2685 psi (18 512 kPa). The maximum flow rate for all THP gears is 8 gpm (30.3 L/min).

The THP series gears can steer a vehicle within its front axle weight rating through a turn at low speed and engine idle. As the steering wheel is turned faster or slower, more or less fluid will be required by the gear.

The THP 45 power steering gear is used for front axle capacities up to 9000 lb (4100 kg). The THP 60 power steering gear is used for front axle capacities up to 14,300 lb (6500 kg).

The recommended minimum flow at 1.5 steering wheel turns per second is 2.2 gpm (8.3 L/min) for the THP 45 steering gear and 2.6 gpm (9.8 L/min) for the THP 60 steering gear.

If the rotary control valve is controlling an auxiliary cylinder, increased minimum flow is required (generally at least 75 percent) based on the size of the auxiliary cylinder and the steering geometry of the vehicle.

Maximum internal leakage for all THP gears is 1.2 gpm (4.5 L/min).

Principles of Operation

When the steering wheel is turned, force is transmitted from the steering wheel to the steering gear input shaft. A torsion bar, pinned at one end to the input shaft and at the other end to the worm shaft, turns with the input shaft and exerts a rotational force on the worm shaft. In response, the worm shaft, acting through the recirculating ball mechanism, tries to move the rack piston on or along the axis through the gear housing cylinder bore.

The axial movement of the rack piston is resisted by its engagement to the sector shaft, which is connected by linkage to the steered wheels. Because of this resistance, the torsion bar is twisted by the input shaft, thereby actuating the control valve. Pressurized fluid, directed by the control valve, assists in moving the rack piston on or along the axis through the cylinder bore. The rack piston then turns the sector shaft to steer the vehicle.

If the steered wheels receive a shock load, the shock forces are transmitted through the sector shaft to the rack piston and on to the worm shaft. The internal construction of the steering gear causes the control valve to send high-pressure fluid to the correct cylinder cavity to resist the shock forces. By absorbing the shock forces hydraulically, the steering gear prevents kickback at the steering wheel.

Most THP steering gears are equipped with two poppet (unloading) valves, one at each end of the rack piston. One valve or the other, depending on the direction of the turn, will trip as the steered wheels approach the axle stops, which must be set to the manufacturer's specifications. The tripped valve reduces pressure in the gear and helps to reduce heat generated by the pump. At the same time, the valves also reduce forces on the steering linkage. These valves are automatically set to axle stops after installation in the vehicle at first full right and first full left turns.

Some THP steering gears with or without poppets are supplied with a relief valve. The relief valve limits

[1] The illustrations in this section are provided by TRW Commercial Steering Systems and are used with permission.

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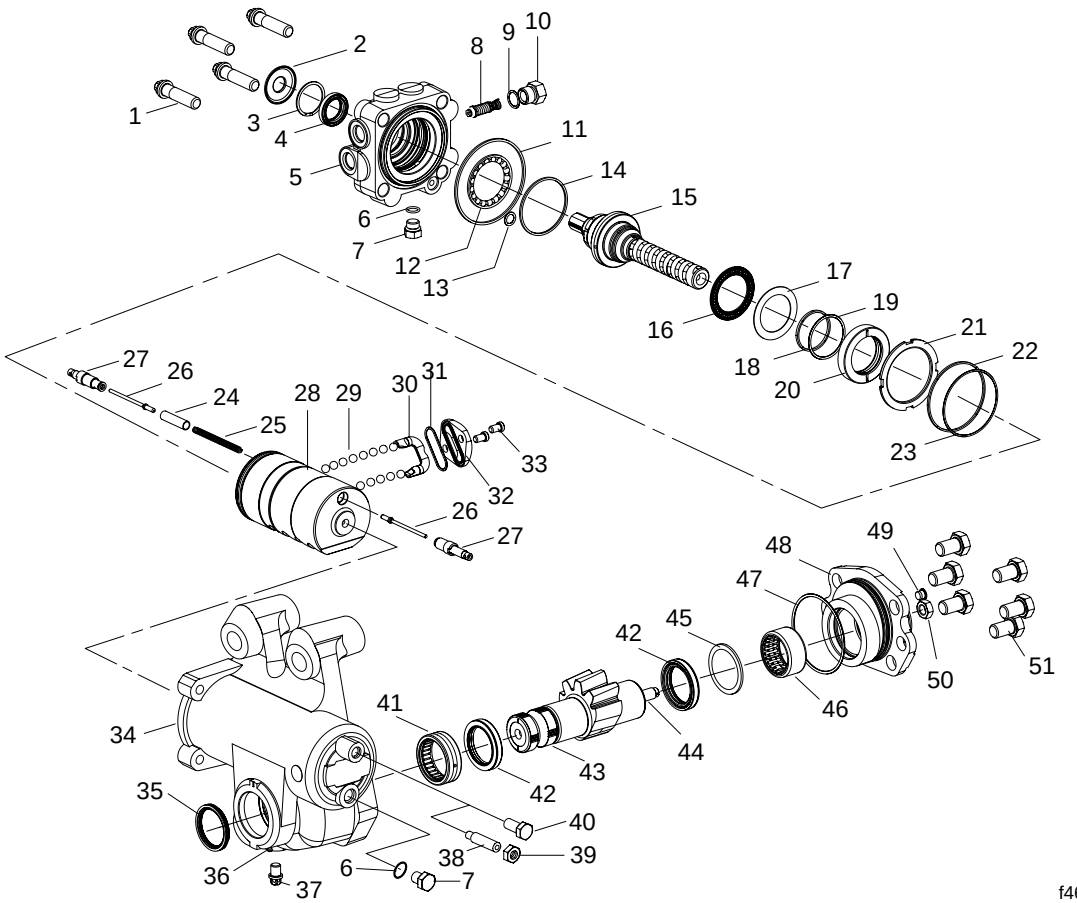
General Information

maximum supply pressure to protect the power steering gear, but it does not reduce pressure as the steered wheels approach the axle stops.

Some THP steering gears that are mounted with the output shaft above the rack piston bore are equipped with either an automatic bleed system or a manual bleed screw. Most Acterra vehicles have an automatic bleed system.

See **Fig. 1** for an exploded view of the THP steering gear.

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1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
6. Auxiliary Port O-Ring (2)
7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
13. O-Ring
14. Seal Ring
15. Input Shaft Assembly
16. Thrust Bearing
17. Thrust Washer
18. Seal Ring
19. O-Ring
20. Bearing Adjuster
21. Adjuster Locknut
22. O-Ring
23. Seal Ring
24. Push Tube
25. Poppet Spring
26. Poppet
27. Poppet Seat and Sleeve Assembly
28. Rack Piston
29. Ball
30. Ball Return Guide
31. Cap Seal
32. Ball Return Guide Cap
33. Torx® Capscrew
34. Gear Housing
35. Dirt and Water Seal
36. Grease Fitting
37. Automatic Bleed Plug
38. Poppet Adjusting Screw
39. Poppet Adjusting Screw Nut
40. Poppet Fixed Stop Screw
41. Roller Bearing
42. Output Seal
43. Sector Shaft Assembly
44. Sector Shaft Adjusting Screw
45. Washer
46. Roller Bearing
47. Side Cover O-Ring
48. Side Cover Assembly
49. Vent Plug, Side Cover
50. Adjusting Screw Jam Nut
51. Capscrew

Fig. 1, THP Steering Gear

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Replacement

1. Verify that the axle stops are adjusted to the specifications in **Section 33.00**, Subject 110. Ensuring correct axle stop adjustment now will eliminate the possibility of resetting the steering gear poppets after the steering gear is replaced.
2. Place the front tires in the straight-ahead position. If possible, drive the vehicle in a straight line for a short distance stopping at the spot where the work is to be done.
3. Turn off the engine, apply the parking brakes, chock the tires, disconnect the batteries, and open the hood.
4. Clean all the fittings and hose connections on the steering gear until they are free of dirt.
5. Drain the hydraulic fluid from the power steering system. Disconnect the hydraulic lines from the steering gear, marking the lines for later reference. Plug the lines and the fittings to keep out dirt.
6. Remove the bolts, nuts, and washers that attach the power steering reservoir to the mounting bracket. Remove the power steering reservoir.

CAUTION

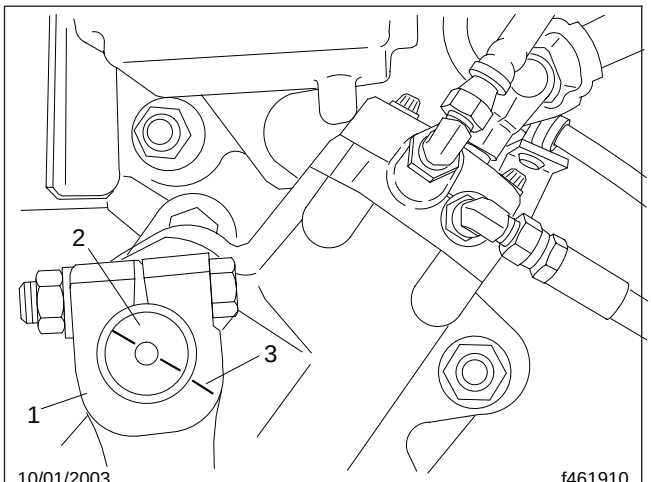
Do not pound the U-joint or lower end yoke on or off the steering gear input shaft. Internal damage to the steering gear can result.

7. Remove and discard the pinch bolt and nut that attach the steering driveline to the steering gear. Remove the lower end yoke from the steering gear.

CAUTION

Do not turn the steering wheel or the steering shaft more than one-half turn (except for alignment purposes) during the removal and installation procedures. Doing so may damage the clockspring.

8. Remove and discard the pinch bolt and nut that attach the pitman arm to the steering gear. Remove the pitman arm from the steering gear. See **Fig. 1**.



1. Pitman Arm
2. Sector Shaft
3. Timing Mark

Fig. 1, Pitman Arm Timing Mark

WARNING

The steering gear is heavy. Use caution when removing, lifting, or carrying the steering gear. Failure to do so could cause personal injury.

9. Remove the bolts, nuts, and washers that attach the steering gear to the mounting bracket. Remove the steering gear.
10. Using bolts, nuts, and washers, attach the steering gear to the mounting bracket. Torque the bolts 342 to 434 lbf·ft (464 to 588 N·m).
11. Match the mark on the pitman arm to the timing mark on the steering gear sector shaft and attach the pitman arm to the steering gear. Using a new pinch bolt and nut, attach the pitman arm to the steering gear. Tighten the nut to one of the following torque specs:
    - 130 to 155 lbf·ft (176 to 210 N·m) for a 5/8–18 pinch bolt and nut
    - 200 to 230 lbf·ft (271 to 312 N·m) for a 3/4–16 pinch bolt and nut
12. Using a new pinch bolt and nut, attach the lower end yoke to the input shaft. Tighten the nut to one of the following torque specs:
    - 55 to 65 lbf·ft (75 to 88 N·m) for a 7/16 pinch bolt and nut

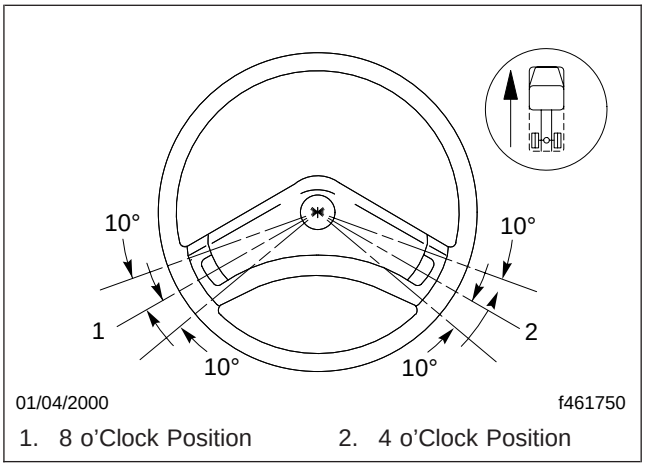
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Power Steering Gear Replacement

- 30 to 35 lbf·ft (41 to 47 N·m) for an M10 pinch bolt and nut

13. Unplug the hydraulic lines and fittings and connect the lines.
14. Using bolts, nuts, and washers, attach the power steering reservoir to the mounting bracket.
15. Connect the batteries.
16. Fill the power steering reservoir with hydraulic fluid until nearly full. For approved hydraulic fluids, see **Specifications 400**.
17. Bleed the power steering system. For instructions, see **Subject 110**.
18. Check the hydraulic lines for leaks.
19. Remove the chocks from the tires and close the hood.
20. Test drive the vehicle.

    With the front tires pointing straight ahead, check the position of the steering wheel spokes. The spokes on a two-spoke steering wheel should be within ±10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 2**. If the steering wheel is not in the correct position, remove the steering wheel and install it in the correct position. For instructions, refer to the applicable section in this group.



1. 8 o'Clock Position 2. 4 o'Clock Position

Fig. 2, Two-Spoke Steering Wheel Centered

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Filling and Air Bleeding the System

IMPORTANT: Make sure the poppets are set correctly before beginning this procedure. If the poppets are not set correctly, see **Subject 160**.

1. Fill the power steering reservoir with hydraulic fluid until nearly full. Do not steer.
2. Start the engine and run it for 10 seconds, then shut it off. Check and fill the reservoir with hydraulic fluid. Repeat this step at least three times checking the fluid level in the reservoir each time.

IMPORTANT: Do not let the hydraulic fluid level drop significantly or allow the reservoir to empty. Doing so may introduce air into the system.

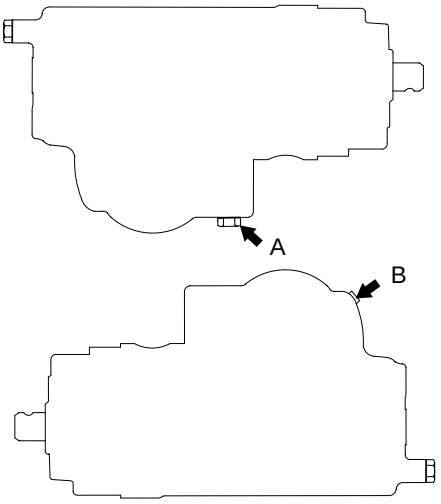
3. Start the engine and let it idle for two minutes. Do not steer. Shut off the engine and check the hydraulic fluid level in the reservoir. If needed, add more fluid.
4. Start the engine again. Turn the steering wheel from full left to full right several times. If needed, add hydraulic fluid to the reservoir.

   Automatic bleed systems should now be free of trapped air. If the vehicle has a manual bleed system, proceed to the next step. See **Fig. 1**.

IMPORTANT: Do not turn the steering wheel while the bleed screw is loosened.

5. With the engine idling, turn the steering wheel from full left to full right several times. Stop steering and loosen the manual bleed screw about one turn. Allow air and aerated hydraulic fluid to bleed out until only clear fluid is seen. Close the bleed screw and add fluid to the reservoir if needed.

   Repeat this step until all the air is out of the system. Torque the bleed screw 40 to 50 lbf·in (450 to 560 N·cm).



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A. Steering gear with automatic bleed plug. Do not remove the bleed plug.
B. Steering gear with manual bleed plug.

Fig. 1, Steering Gears With Bleed Systems

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Replacement

The power steering pump is used in this procedure to force out the input shaft seal. To use this procedure, the power steering pump should have a minimum of 1500 psi (10 342 kPa) available.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the return line from the steering gear and plug the line. Cap the return port of the gear with a high-pressure fitting.
3. Remove the steering driveline from the steering gear input shaft.
4. Remove the dirt and water seal from the steering gear, see **Fig. 1**. Save the seal to determine the correct size of the new seal.
5. Wipe out the grease, then remove the spiral retaining ring using a screwdriver inserted into the notch formed in the end of the ring. Do not scratch the bore with the screwdriver.
6. Slip the input yoke back on the input shaft, then insert but do not tighten the pinch bolt.
7. Tie or wrap a shop towel around the input shaft area and place a drip pan under the vehicle to catch the oil.

WARNING

Fill the power steering reservoir with approved, clean fluid only. Do not mix automatic transmission fluid types. If you are changing fluid types, completely flush the steering system with the fluid type being added. Any mixture or any unapproved fluid could lead to seal deterioration and leaks. Any fluid leak could eventually cause loss of power steering assist, which could cause personal injury and property damage.

8. Fill the power steering reservoir to the full line on the reservoir dipstick. For approved hydraulic fluids, see **Specifications 400**.
9. With the vehicle in neutral, briefly turn the starter without allowing the engine to start. If the engine starts, shut it down immediately. This should force out the input shaft seal.
10. Remove the shop towel, pinch bolt, and input yoke. Remove the input shaft seal, item 4 in **Fig. 1**.
11. Inspect the seal area of the valve housing for seal fragments. Remove all seal fragments.
12. Check the seal for heat damage. If the seal is stiff and brittle, and not pliable like the new seal, it is probably heat damaged. Determine and fix the cause of any excessive heat in the vehicle. Discard the old seal.

WARNING

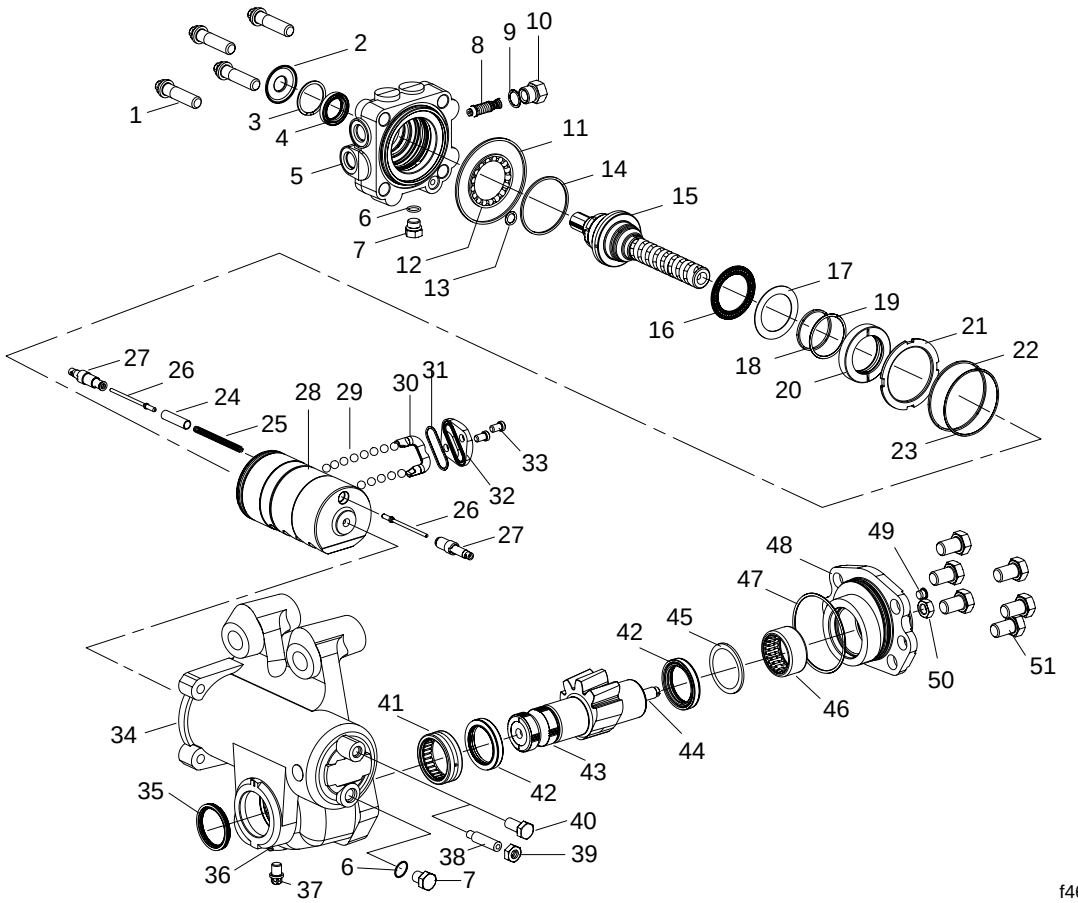
Do not use a socket to install the input shaft seal. You will not be able to control the seal installation depth with a socket and this could lead to leaks. Leaks could result in loss of steering assist which could result in serious personal injury or death.

13. Install a new input shaft seal.
    - 13.1 Put clean grease on the inside diameter of the new input shaft seal and install it on the input shaft.
    - 13.2 Place seal installer tool J37073 over the input shaft and against the seal, small diameter end first. Tap the seal installer tool with a hammer until the tool shoulder is square against the valve housing. Remove any seal material that may have sheared off in the seal bore or retaining ring groove.
14. Install a new retaining ring in the groove.
15. Pack the end of the valve housing bore and around the input shaft with clean grease.
16. Install a new dirt and water seal.
    - 16.1 Choose the correct size dirt and water seal by comparing the replacement seals to the old seal, or by measuring the major diameter of the input shaft serrations. See **Table 1** for the major serration diameter and the corresponding seal part number.
    - 16.2 Apply clean grease to the new dirt and water seal and install it on the input shaft. Seat it in the groove behind the serrations and against the valve housing.

      Wipe any excess grease from the valve housing bore and input shaft once the seal has been installed.

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Input Shaft Seal Replacement



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1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
6. Auxiliary Port O-Ring (2)
7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
13. O-Ring
14. Seal Ring
15. Input Shaft Assembly
16. Thrust Bearing
17. Thrust Washer
18. Seal Ring
19. O-Ring
20. Bearing Adjuster
21. Adjuster Locknut
22. O-Ring
23. Seal Ring
24. Push Tube
25. Poppet Spring
26. Poppet
27. Poppet Seat and Sleeve Assembly
28. Rack Piston
29. Ball
30. Ball Return Guide
31. Cap Seal
32. Ball Return Guide Cap
33. Torx® Capscrew
34. Gear Housing
35. Dirt and Water Seal
36. Grease Fitting
37. Automatic Bleed Plug
38. Poppet Adjusting Screw
39. Poppet Adjusting Screw Nut
40. Poppet Fixed Stop Screw
41. Roller Bearing
42. Output Seal
43. Sector Shaft
44. Sector Shaft Adjusting Screw
45. Washer
46. Roller Bearing
47. Side Cover O-Ring
48. Side Cover
49. Vent Plug, Side Cover
50. Adjusting Screw Jam Nut
51. Capscrew

Fig. 1, THP Steering Gear

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Major Serration Diameters and Corresponding Seal Part Numbers		
Major Serration Diameter: inch (mm)	**Serration Size**	**Part Number**
0.807/0.799 (20)	13/16 inch (21 mm) x 36	478044
0.866/0.857 (22)	7/8 inch (22 mm) x 36	478060
0.987/0.977 (25)	1 inch (25 mm) x 36	478050
1.008/1.000 (25)	1 inch (25 mm) x 79	478050

Table 1, Major Serration Diameters and Corresponding Seal Part Numbers

17. Using a new pinch bolt and nut, attach the steering driveline to the input shaft. Tighten the nut 30 to 35 lbf·ft (41 to 47 N·m).
18. Apply torque seal, OGP F900WHITE, to the exposed bolt threads and the nut.
19. Connect the return line to the steering gear return port.
20. Fill and air bleed the steering system. For instructions, see **Subject 110**.

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Sector Shaft Adjustment

The sector shaft adjustment can only be completed if the adjusting screw jam nut is accessible when the steering gear is attached to the frame rail. The jam nut is located on the side cover. If the jam nut is not accessible, the adjustment can be made by removing the steering gear and placing it in a vise. See **Subject 100** for removal instructions.

1. Apply the parking brakes and chock the rear tires.
2. With the engine on, turn the steering wheel until the timing mark on the sector shaft lines up with the timing mark on the housing. The line on the sector shaft should be at a 90-degree angle from the input shaft. The sector shaft is now on its center of travel. Turn the engine off.
3. Remove the cotter pin and castle nut that attach the drag link to the pitman arm. Remove the drag link from the pitman arm.

IMPORTANT: To avoid resetting the poppets, do not turn the input shaft more than 1-1/2 turns from the center-of-travel position while the drag link is disconnected.

4. From the center-of-travel position, grasp the pitman arm at the lower end of the arm and gently try to move the arm back and forth. If the pitman arm is loose or lash (free play) is detected, the sector shaft is out of adjustment.
5. Loosen the adjusting screw jam nut.

NOTE: If the steering gear is removed from the frame rail to correct the lash, leave the pitman arm attached to the steering gear and follow the instructions under the "Final Adjustments" heading in **Subject 150**.

6. If no lash is detected, use a screwdriver to turn the shaft adjusting screw counterclockwise until you feel lash at the sector shaft.
7. Slowly turn the shaft adjusting screw clockwise until you feel no lash at the sector shaft without using more than 10 lbf·ft (14 N·m) of torque. See **Fig. 1**. From this position, turn the screw clockwise 1/8 to 3/16 of a turn more. Hold the adjusting screw in place and tighten the jam nut 43 lbf·ft (58 N·m).

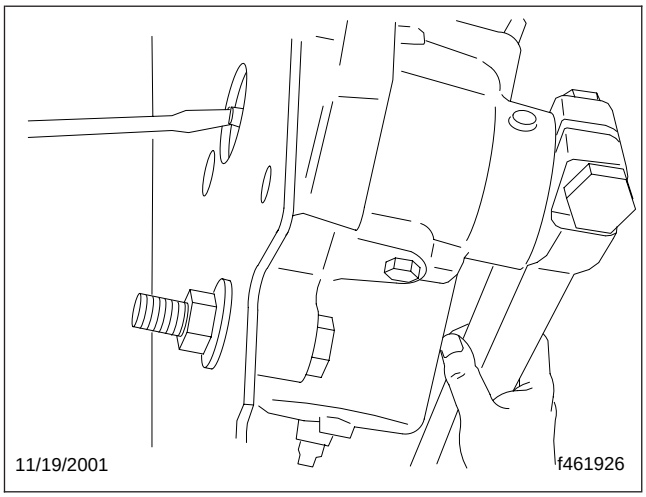


Fig. 1, Adjusting the Sector Shaft

8. Turn the steering wheel one-quarter turn each side of center then back to center and check the pitman arm for lash. There should be no lash. If lash is detected, loosen the jam nut and repeat the previous step as well as this step.
9. If the steering gear was removed from the frame rail, install the steering gear on the frame rail. For instructions, see **Subject 100**.
10. Using a castle nut, attach the drag link to the pitman arm. Torque the castle nut using the appropriate torque value.
    - 3/4–16: 90 to 170 lbf·ft (122 to 230 N·m)
    - 7/8–14: 160 to 300 lbf·ft (217 to 407 N·m)
11. If required, continue to tighten the castle nut until a slot on the nut aligns with the hole in the ball stud. Do **not** back off the nut when locating the cotter pin hole. Install a new cotter pin in the ball stud and nut, then lock the cotter pin in place.

⚠ WARNING

Failure to install and lock a new cotter pin in the ball stud and nut could result in disengagement of the parts and loss of steering control.

⚠ CAUTION

Do not use a power grease gun to add grease to the sector shaft bearing. Doing so could damage

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Sector Shaft Adjustment

the high pressure seal and contaminate the hydraulic fluid.

12. Using only a hand-operated grease gun, add grease to the sector shaft bearing through the grease fitting in the housing until grease begins to extrude past the dirt and water seal.
13. Remove the chocks from the tires.

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Poppet Adjustment

The poppet adjustment will work in most cases with at least 1-3/4 turns of the steering wheel from each side of center. If a large reduction in wheel cut is being made and this procedure does not work, you may have to replace or reset the poppets using the "Poppet Component Replacement" procedure in **Subject 160**.

1. Check that the axle stops are adjusted to the specifications in **Section 33.00**, Subject 110.
2. Start the engine and allow the vehicle to idle for five to 10 minutes to warm the hydraulic fluid.
3. Shut down the engine, apply the parking brakes, and chock the rear tires.
4. If a new poppet adjusting screw and nut, items 38 and 39 in **Fig. 1**, are being used, turn the screw into the nonsealing end of the nut until the drive end of the screw is flush with the nut.

NOTE: The steering gear will have either a poppet fixed stop screw or a poppet adjusting screw. See **Fig. 1**. If the adjusting screw is already part of the steering gear, back the nut off of the adjusting screw until it is flush with the end of the adjusting screw.

5. Make sure that the engine is off and the wheels are in the straight-ahead position.
6. If equipped with a poppet fixed stop screw and washer, remove and discard both items from the lower end of the housing.

   If equipped with a poppet adjusting screw and nut that need to be replaced, remove and discard both items.
7. Using a 7/32-inch Allen wrench (THP 60) or a 6-mm Allen wrench (THP 45), turn the adjusting screw and nut assembly (without turning the nut on the screw) into the housing until the nut is firmly against the housing. Tighten the nut against the housing.

CAUTION

Make sure the drive end of the adjusting screw is not below the face of the nut. If the drive end of the adjusting screw is below the face of the nut, the poppet seat flange will break when the upper poppet is prepared for setting.

WARNING

Fill the power steering reservoir with approved, clean fluid only. Do not mix automatic transmission fluid types. If you are changing fluid types, completely flush the steering system with the fluid type being added. Any mixture or any unapproved fluid could lead to seal deterioration and leaks. Any fluid leak could eventually cause loss of power steering assist, which could cause personal injury and property damage.

8. Fill the power steering reservoir with hydraulic fluid until nearly full. For approved hydraulic fluids, see **Specifications 400**.
9. Place a jack under the center of the front axle and jack up the front of the vehicle so the steer axle tires are off the ground.

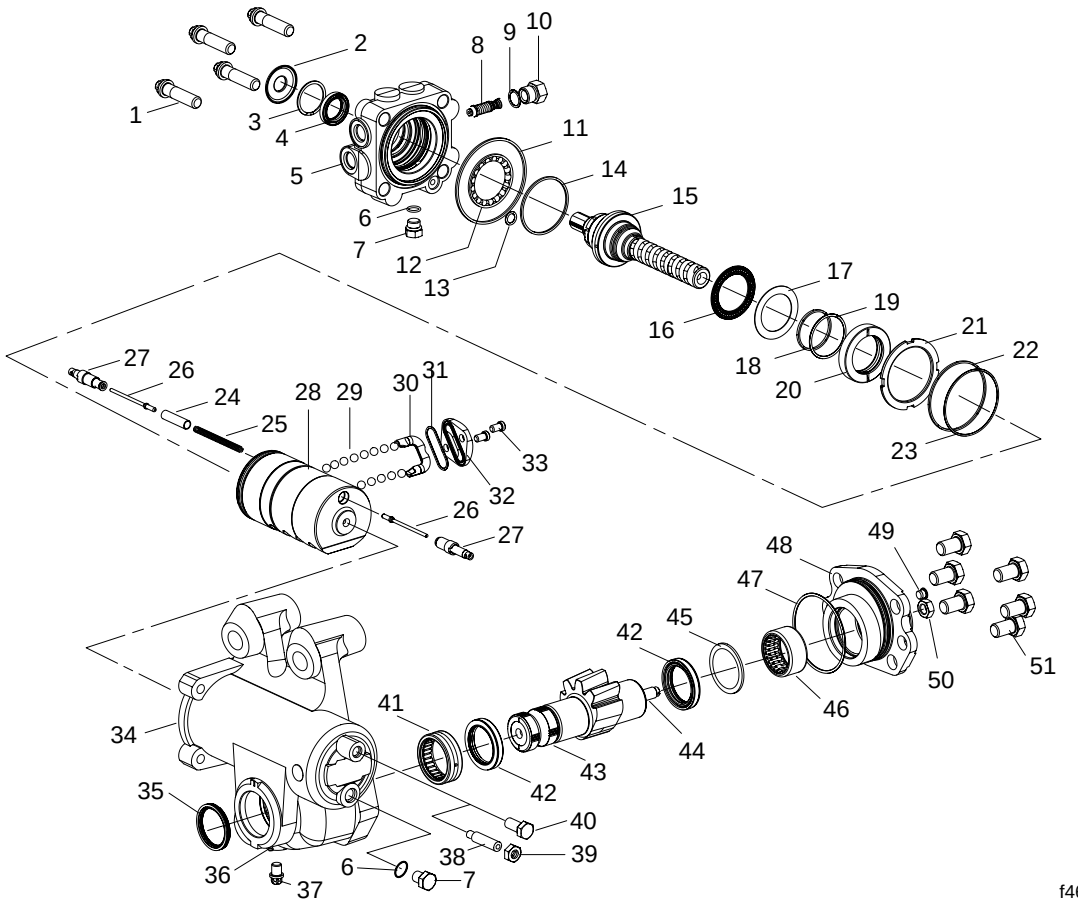
CAUTION

Do not hold the steering wheel at full turn for more than 10 seconds at a time. The heat buildup at pump relief pressure may damage components.

10. Push the upper poppet out to prepare it for setting.
    - 10.1 Start the engine and let it run at idle speed.
    - 10.2 Note which sector shaft timing mark is nearest the housing piston bore.
    - 10.3 Turn the steering wheel in the direction that makes this timing mark move toward the adjusting screw just installed. Turn the steering wheel in this direction until axle stop contact is made.
    - 10.4 Pull hard on the steering wheel. Put up to 40 lbf (178 N) pull on a 20-inch diameter steering wheel after the axle stop is contacted.
11. Set the upper poppet.
    - 11.1 Turn the steering wheel in the opposite direction (the end of the timing mark away from the adjusting screw) until the other axle stop is contacted.

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Poppet Adjustment on a Single Gear



1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
6. Auxiliary Port O-Ring (2)
7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
13. O-Ring
14. Seal Ring
15. Input Shaft Assembly
16. Thrust Bearing
17. Thrust Washer
18. Seal Ring
19. O-Ring
20. Bearing Adjuster
21. Adjuster Locknut
22. O-Ring
23. Seal Ring
24. Push Tube
25. Poppet Spring
26. Poppet
27. Poppet Seat and Sleeve Assembly
28. Rack Piston
29. Ball
30. Ball Return Guide
31. Cap Seal
32. Ball Return Guide Cap
33. Torx® Capscrew
34. Gear Housing
35. Dirt and Water Seal
36. Grease Fitting
37. Automatic Bleed Plug
38. Poppet Adjusting Screw
39. Poppet Adjusting Screw Nut
40. Poppet Fixed Stop Screw
41. Roller Bearing
42. Output Seal
43. Sector Shaft Assembly
44. Sector Shaft Adjusting Screw
45. Washer
46. Roller Bearing
47. Side Cover O-Ring
48. Side Cover Assembly
49. Vent Plug, Side Cover
50. Adjusting Screw Jam Nut
51. Capscrew

Fig. 1, THP Steering Gear

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11.2 Pull hard on the steering wheel. Put up to 40 lbf (178 N) pull on a 20-inch diameter steering wheel.

11.3 Release the steering wheel and shut off the engine.

12. Loosen the nut and back out the adjusting screw until the adjusting screw is one inch (2.5 cm) past the nut. Tighten the nut against the housing.

⚠ CAUTION

Do not hold the steering wheel at full turn for more than 10 seconds at a time. The heat buildup at pump relief pressure may damage components.

13. Set the lower poppet.

13.1 Start the engine and let it idle.

13.2 Turn the steering wheel in the original direction (the end of the timing mark is toward the adjusting screw) until axle stop contact is made.

13.3 Hold the steering wheel in this position with up to 40 lbf (178 N) pull for 10 seconds, then release. Repeat this hold-and-release process as many times as necessary while completing the next step.

14. Position the adjusting screw.

14.1 With the steering wheel held tightly at full turn, loosen the nut and hold it in place with a wrench.

14.2 Using an Allen wrench and finger pressure only, turn the adjusting screw clockwise until the Allen wrench stops. Do not attempt to turn the adjusting screw in any farther. Pause the turning-in process each time the driver releases the steering wheel. Continue turning only while the steering wheel is held at full turn.

IMPORTANT: The length of the adjusting screw beyond the nut must not be more than 1-1/16 inch (27 mm) for proper thread engagement.

NOTE: The length of the adjusting screw beyond the nut may be different for each vehicle.

14.3 Back off the adjusting screw 3-1/4 turns and tighten the nut 35 lbf·ft (47 N·m).

15. The poppets have now been completely reset. Check the power steering reservoir and fill if necessary.

16. Lower the vehicle and remove the chocks from the tires.

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Disassembly, Inspection, Assembly, and Final Adjustments

Disassembly

NOTE: Replace all seals, seal rings, and gaskets each time the gear is disassembled.

1. Place the front tires in the straight ahead position. If possible, drive the vehicle in a straight line for a short distance stopping at the spot where the work is to be done. Apply the parking brakes, chock the tires, disconnect the batteries, and open the hood.
2. Remove all dirt from around the fittings and hose connections before removing the steering gear.

IMPORTANT: To avoid resetting the poppets, do not turn the input shaft more than 1-1/2 turns from the center-of-travel position while the drag link is disconnected.

3. Remove the power steering gear. For instructions, see **Subject 100**.

⚠ CAUTION

Never steam clean or high-pressure wash hydraulic steering components. Do not force or abuse closely fitted parts. Use care that the bearing and sealing surfaces are not damaged by the disassembly and assembly procedures. Failure to follow these precautions could result in damage to the components.

4. Clean and dry the steering gear before beginning to disassemble it.
5. As you disassemble the gear, clean all parts in clean, OSHA-approved solvent and use only air to blow dry the parts.
6. With the input shaft horizontal and the side cover and valve housing accessible, put the steering gear in a vise with the clamps firmly against the housing mounting flange or boss.

IMPORTANT: Do not clamp against the body of the housing. If the mounting boss or flange is not accessible, fabricate and attach a mounting plate to the housing mounting bosses.

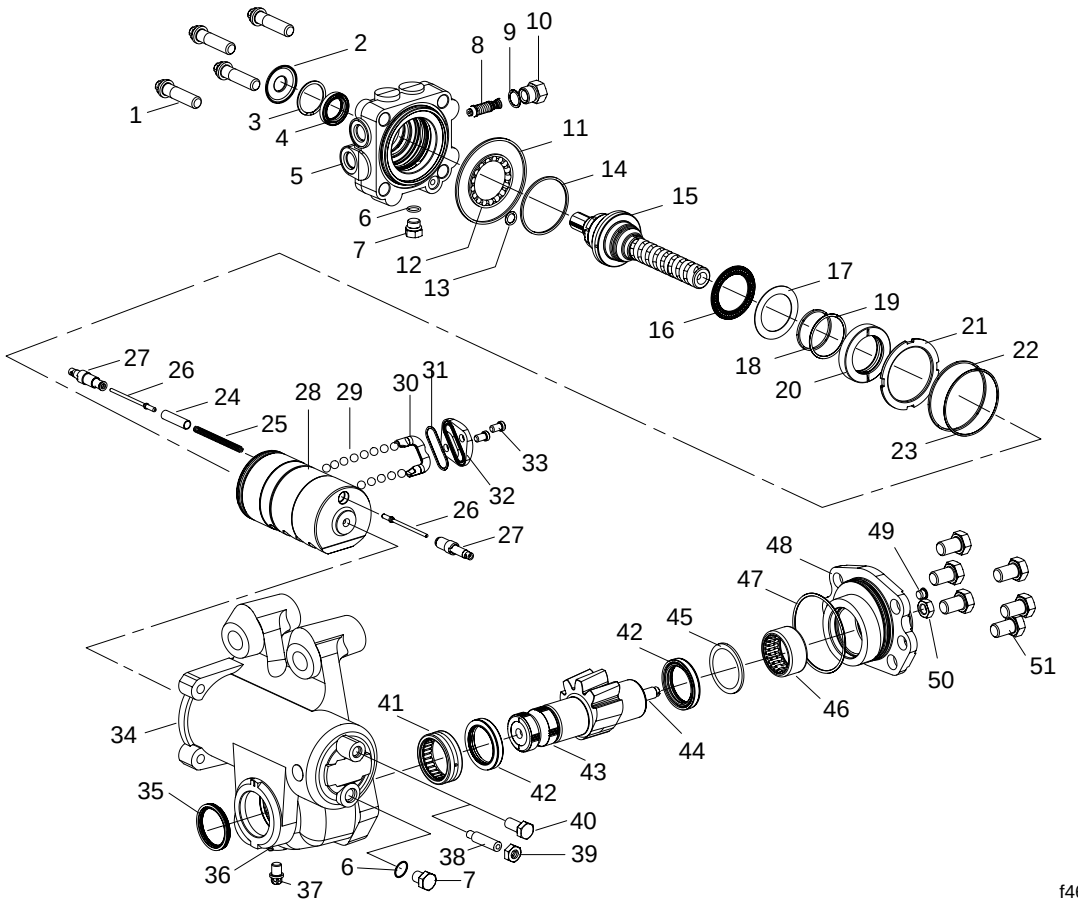
7. Place a drain pan under the gear and remove the plugs from the hydraulic ports.
8. Rotate the input shaft until the timing mark on the end of the sector shaft is in line with the timing mark on the end of the housing. The sector shaft is now positioned for removal.
9. Remove any paint or corrosion from the exposed area of the sector shaft.
10. Tape the serrations and bolt groove of the sector shaft with one layer of masking tape. The tape should not extend on to the sector shaft bearing diameter.
11. Remove the adjusting screw jam nut, item 50 in **Fig. 1**.
12. Remove the capscrews that attach the side cover to the housing.
13. Remove the side cover and sector shaft assembly from the gear. Start the cover and sector shaft assembly removal by lightly tapping the end of the shaft with a soft mallet.
14. Remove and discard the vent plug, item 49 in **Fig. 1**.
15. Remove and discard the side cover O-ring, item 47 in **Fig. 1**.
16. Turn the sector shaft adjusting screw, item 44 in **Fig. 1**, clockwise through the side cover and pull the sector shaft out of the side cover.

IMPORTANT: Take care not to damage the bore or bearing when removing the output seal.

17. Clamp the side cover in a vise. Place a 3/8-inch drive socket in the center of the side cover. Using the socket for support, pry out the output seal with a rolling head pry bar. Discard the seal and remove the socket. Remove the washer.
18. Inspect the sector shaft assembly for damaged adjusting screw threads. The retainer must be securely staked in place. The adjusting screw must rotate by hand with no perceptible end play.
19. If equipped with a relief valve, remove the relief valve cap, the O-ring, and the relief valve from the valve housing. Discard the O-ring.
20. Remove the dirt and water seal, item 2 in **Fig. 1**, from the input shaft assembly. Save this seal to determine the correct size of the new seal.
21. Clean any paint or corrosion from the exposed area of the input shaft

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Disassembly, Inspection, Assembly, and Final Adjustments



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1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
6. Auxiliary Port O-Ring (2)
7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
13. O-Ring
14. Seal Ring
15. Input Shaft Assembly
16. Thrust Bearing
17. Thrust Washer
18. Seal Ring
19. O-Ring
20. Bearing Adjuster
21. Adjuster Locknut
22. O-Ring
23. Seal Ring
24. Push Tube
25. Poppet Spring
26. Poppet
27. Poppet Seat and Sleeve Assembly
28. Rack Piston
29. Ball
30. Ball Return Guide
31. Cap Seal
32. Ball Return Guide Cap
33. Torx® Capscrew
34. Gear Housing
35. Dirt and Water Seal
36. Grease Fitting
37. Automatic Bleed Plug
38. Poppet Adjusting Screw
39. Poppet Adjusting Screw Nut
40. Poppet Fixed Stop Screw
41. Roller Bearing
42. Output Seal
43. Sector Shaft
44. Sector Shaft Adjusting Screw
45. Washer
46. Roller Bearing
47. Side Cover O-Ring
48. Side Cover
49. Vent Plug, Side Cover
50. Adjusting Screw Jam Nut
51. Capscrew

Fig. 1, THP Steering Gear

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22. Remove the four valve housing capscrews and remove the rack piston. Place the rack piston on a clean cloth.

IMPORTANT: The set position of the poppet seat and sleeve assembly must not be disturbed if the poppets are not going to be replaced or reset during disassembly.

23. Remove and discard the O-ring and the valve housing O-ring, items 13 and 11 in **Fig. 1**.

CAUTION

Do not remove the input shaft assembly or the balls from the rack piston until the ball return guides are removed. If this precaution is not followed, the ball return guides will be damaged.

24. Remove and discard the two Torx® capscrews, item 33 in **Fig. 1**. Remove the ball return guide cap and the cap seal. Discard the cap seal.

25. Remove the ball return guide by carefully inserting a screwdriver between the rack piston and guide.

NOTE: Left-hand ball return guide halves are plated with copper or zinc chromate for identification. Right-hand guide halves are not plated.

26. Remove the balls from the rack piston by rotating the input shaft assembly until the balls fall out. Place the balls and return guide in a container. Count the balls and make sure all have been removed. There are 29 balls in the THP 45 model and 31 balls in the THP 60 model.

IMPORTANT: The balls are a matched set. If any are lost, the set must be replaced.

27. Remove the valve housing and input shaft assembly from the rack piston.

28. Cut and remove the seal ring and O-ring, items 23 and 22 in **Fig. 1**, from the rack piston.

29. Inspect the poppet seat and sleeve assembly.

    29.1 Push on the poppet stem; it should spring back.

    29.2 Push on the poppet seat; it should not move by hand.

    29.3 If the components are bent or broken, if the poppet stems do not spring back, or if the poppet seat moves by hand, replace the poppet seat and sleeve assembly. For instructions, see **Subject 160**.

NOTE: TRW recommends that the poppet seat and sleeve assemblies not be removed unless replacement of the poppet is required.

30. Inspect the valve housing and input shaft assembly for heat damage or bearing roughness. If these conditions are present, if there is excessive internal leakage, or if preload adjustment is required, see the instructions in **Subject 170**.

31. Remove and discard the dirt and water seal, item 35 in **Fig. 1**.

32. Insert a screwdriver through the trunnion opening and carefully push the output seal out without damaging the sealing area of the bore. Discard the output seal.

NOTE: A special hook groove has been machined into the bore to hold the seal in position. Clean out the rubber from the groove prior to installing a new seal.

33. Inspect the roller bearing for brinelling or spalling. If the roller bearing needs to be replaced, see the instructions in **Subject 180**.

34. Inspect the following components for damage. If they are damaged, see the instructions in **Subject 190**.

    - poppet fixed stop screw
    - poppet adjusting screw and nut
    - automatic bleed plug
    - manual bleed screw
    - auxiliary port plug and O-ring

Inspection

WARNING

If one of the conditions in Table1 is found in one component of the steering gear, inspect all components carefully for signs of impact damage. Replace the components if you suspect impact damage. Failure to replace all damaged components could result in a serious vehicle accident.

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Disassembly, Inspection, Assembly, and Final Adjustments

Conditions in the Steering Gear That Indicate Impact Damage	
Condition	**Area**
Brinelling	Ball track grooves of rack piston
	Ball track grooves of worm screw
	Bearing area of sector shaft
	Thrust washer and bearing in valve housing
	Ball cup and bearing in valve housing
Cracks or Breaks	Bearing area of sector shaft
	Sector shaft teeth
	Rack piston teeth
	Housing
	Thrust washer and bearing in valve housing
	Worm screw
	Ball cup and bearing in valve housing
Twisted Serrations	Output shaft serrations

Table 1, Conditions in the Steering Gear That Indicate Impact Damage

1. Make sure all sealing surfaces and seal cavities are free of nicks and corrosion. Any nicked or corroded surface requires part replacement to ensure proper sealing.
2. Inspect the rack piston teeth for cracks or damage. If teeth are damaged, replace the rack piston, the sector shaft, and the set of balls.
3. Inspect the rack piston ball track grooves for brinelling or spalling. If either condition exists, replace the input shaft assembly, the valve housing, the rack piston, and the balls.
4. Inspect the sealing area of the input shaft assembly for nicks and damage. Inspect for discoloration from excess heat. Inspect the input shaft ball track grooves for brinelling or spalling. If any of these conditions exist, replace the:
   - input shaft
   - worm/valve assembly
   - valve housing
   - balls
   - rack piston
5. Inspect the gear housing cylinder bore. Some scoring marks are normal. If there was internal leakage greater than 1.2 gpm (4.5 L/min), make sure there are no damaged seals before replacing the housing.
6. Inspect the valve housing mating surface for nicks that would prevent proper sealing. Replace the gear housing if these nicks are present and cannot be easily removed with a fine-tooth flat file without changing the dimensional characteristics.
7. Inspect the roller bearing in the side cover assembly for brinelling or spalling. If either condition exists, replace the side cover assembly.
8. Inspect the sector shaft bearing and sealing areas and sector teeth contact surfaces for brinelling, spalling, or cracks. Run the end of your fingernail across these areas to detect steps. Remove the masking tape from the shaft and inspect the shaft for twisted or damaged serrations. If any of these conditions exist, replace the sector shaft.

NOTE: A replacement sector shaft comes with the adjusting screw and retainer.

Assembly

NOTE: Use the bearing and seal tool (J37705 for THP 45, J37071 for THP 60) in the following two steps.

1. Install a new output seal on the short end of the bearing and seal tool so that the lip with the garter spring is toward the shoulder of the tool. Working from the side cover side of the housing, pilot the bearing and seal tool into the washer and bearing, then press with 100 to 800 lb (445 to 3560 N) until the seal is seated firmly.
2. Using the long end of the bearing and seal tool, install the dirt and water seal, item 35 in **Fig. 1**, making sure it is not distorted or twisted.

IMPORTANT: Press the seal only until it seats against the bearing; do not press it in farther.

3. Pack the roller bearing seal, the output seal, and the dirt and water seal liberally with clean, high-temperature industrial grease, Exxon Polyrex® EP2 grease (045422).

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4. Lightly oil the valve housing O-ring, item 11 in **Fig. 1**, and install the O-ring in the mounting face groove of the valve housing.
5. Lightly oil a new seal ring, item 14 in **Fig. 1**, and install the seal ring in the valve housing mounting face groove.
6. Install a new O-ring, item 22 in **Fig. 1**, and then a seal ring, item 23, on the rack piston. Do not overstretch the rings as they are being installed. Do not allow the seal ring to become twisted.
7. Apply clean oil to the gear housing cylinder bore. Place the rack piston in the housing with the ball return guide holes up.
8. Install the input shaft assembly in the rack piston close to maximum depth without the valve housing making contact with the poppet stem. Insert two 14 mm x 2.0 mm All Threads through the lower valve housing mounting holes and tighten them to support the worm and valve assembly. Line up the rack piston ball guide holes with the worm ball track grooves by rotating the input shaft.
9. Install the ball return guide in the rack piston until seated. Rotate the input shaft slightly if necessary.

⚠ WARNING

Do not seat the ball return guide with a hammer. Damage to the guide can result in subsequent lockup or loss of steering, resulting in personal injury or property damage.

IMPORTANT: If a new rack piston, input shaft, or input shaft assembly is being installed, the balls must be replaced. The balls in a service ball kit are sized to function in the ball track guide path as altered by component replacement.

When using a service ball kit, use the correct quantity of balls, 29 balls for the THP 45 model and 31 balls for the THP 60 model.

NOTE: Hold the ball return guide firmly in place while performing the following step.

10. Insert as many balls as you can through the hole in the top of the ball return guide. Rotate the input shaft to pull the balls down and around the ball track guide path. Continue until the correct number of balls is in the ball track guide path.

    If the ball guide becomes unseated (raised) at any time, start the procedure again beginning with the previous step.

⚠ WARNING

Hold down the ball return guide until the ball return guide cap is installed. Failure to hold the guide will result in a trapped ball or balls, which could cause a vehicle accident resulting in personal injury or property damage.

⚠ CAUTION

Do not allow the valve housing to contact the poppet stem or move more than 2.5 inches (64 mm) from the upper end of the rack piston during these procedures. This could incorrectly reset the poppet or back out the input shaft assembly beyond the closed ball loop, trapping the balls.

⚠ CAUTION

Remove any fluid present in the two screw holes. Fluid in these holes could cause improper clamp load when torquing the ball return guide cap.

11. Install a new cap seal in the groove of the ball return guide cap. Make sure the seal makes full contact with the rack piston surface. Install two new Torx capscrews and torque each capscrew alternately until a final torque of 18 lbf·ft (24 N·m) is reached.

IMPORTANT: The cap seal is greased to hold the seal in the groove while it is assembled. Be sure not to trap the seal outside of the groove during assembly.

12. Rotate the input shaft from one end of travel to the other without contacting the poppet stem to the valve housing and without moving the valve housing face more than 2.5 inches (64 mm) from the input end (upper end) of the rack piston. If you cannot rotate the input shaft, remove the balls and install them again.

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Disassembly, Inspection, Assembly, and Final Adjustments

WARNING

If a gear is installed on a vehicle when the input shaft is not able to be rotated, the gear will not function correctly. Steering and gear failure may result, possibly causing personal injury or property damage.

13. Apply clean oil to the seal ring, item 23 in **Fig. 1**, on the rack piston. Make sure there is a space of 3/8 to 1/2 inch (10 to 13 mm) between the valve housing and the poppet stem to prevent poppet contact at either end. Remove the All Threads and push the rack piston into the housing with the rack piston teeth toward the sector shaft cavity. Line up the valve housing cylinder feed hole with the gear housing feed hole. Make sure both O-rings in the valve housing remain in position.

IMPORTANT: Do not damage the seal ring while installing the rack piston in the housing.

IMPORTANT: The poppet seat and sleeve assembly must not bottom against the internal poppet stops in the steering gear until the gear is installed on the vehicle and the poppet adjustment procedures are performed.

14. Lubricate and install the four valve housing capscrews in the housing. Torque the capscrews 118 to 138 lbf·ft (160 to 187 N·m).
15. If the gear is equipped with a relief valve, install a new O-ring on the relief valve cap. Install the small end of the tapered spring on the pin on the relief valve cartridge and install the relief valve with the large end of the tapered spring end first in the relief valve cap cavity. Turn the relief valve cap into the valve housing and torque 30 lbf·ft (41 N·m).

CAUTION

The caged bearing assembly is sealed and will not receive lubrication from the hydraulic fluid in the gear. Failure to use the proper grease could result in premature bearing wear.

16. Apply a generous amount of Exxon Polyrex EP2 grease (045422), and **only** this type of grease, to the caged bearing assembly in the side cover. Then install the washer, item 45 in **Fig. 1**, on top of the bearing.

NOTE: Use bearing and seal tool J37705 on a THP 45 steering gear. Use bearing and seal tool J37071 on a THP 60 steering gear.

17. Grease and install a new output seal on the installation tool so that the side with the garter spring is against the shoulder of the tool. Pilot the tool into the side cover with a force of 100 to 800 lb (445 to 3560 N) until it is seated against the bearing or bushing.

IMPORTANT: Make sure the outside diameter of the seal and the inside diameter of the bore are free from grease and dust for proper engagement of the seal.

18. Apply a generous amount of Exxon Polyrex EP2 grease (045422) to the short bearing area of the sector shaft.
19. Install the sector shaft in the side cover and turn the sector shaft adjusting screw counterclockwise until the screw reaches solid height.

    Rotate the adjusting screw clockwise one-half turn so that the side cover will rotate freely on the sector shaft.
20. Install the sector shaft adjusting screw jam nut, item 50 in **Fig. 1**, on the sector shaft adjusting screw a few threads. Final adjustment will be made later.
21. Press the new vent plug into the hole provided in the side cover until the plug has bottomed.

WARNING

Do not weld or otherwise plug this hole in a permanent manner. This is a safety vent that functions only if the side cover fails. If the seal fails and the plug cannot vent, the steering gear may lockup or malfunction possibly resulting in personal injury or property damage.

22. Apply clean oil to the new side cover O-ring, item 47 in **Fig. 1**, and install it on the side cover.

WARNING

If the rack piston is not centered when the sector shaft is installed, gear travel will be severely limited in one direction. This could cause an accident possibly resulting in personal injury or property damage.

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23. There are four teeth on the rack piston. Rotate the input shaft to position the rack piston so that the space between the second and third tooth is in the center of the sector shaft opening. This will center the rack piston for installation of the sector shaft.

⚠ CAUTION

If the serrations are not properly taped, they will damage the output seal in the housing and cause the seal to leak.

24. Remove all tape on the serrations. Apply one layer of masking tape on the serrations and bolt groove of the sector shaft. Install the sector shaft in the housing. The center tooth of the sector shaft must engage the center space (between the second and third tooth) of the rack piston. Lightly tap on the side cover with a rubber mallet to seat the cover against the housing face.
25. Install the capscrews in positions 3 and 4 on the side cover by hand. Then install the remaining capscrews in the side cover and tighten them in the sequence shown in **Fig. 2**. Lubricate the capscrews and torque 180 to 220 lbf·ft (244 to 298 N·m).

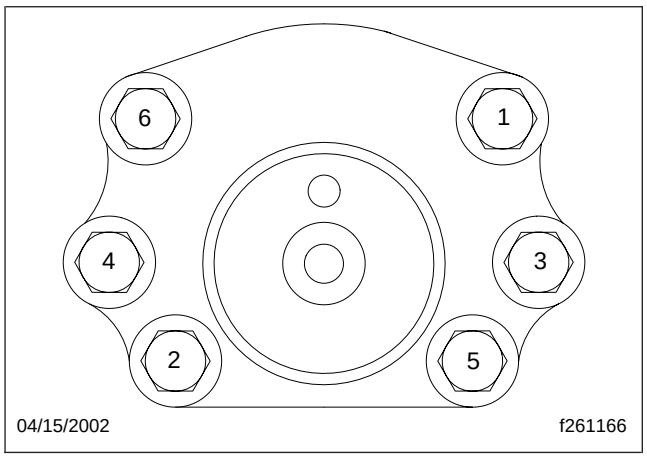


Fig. 2, Capscrew Tightening Sequence

IMPORTANT: If the capscrews must be replaced, use capscrews of the same design, type, and length as those removed.

26. Remove the tape from the sector shaft.
27. Pack the end of the valve housing bore with Exxon Polyrex EP2 grease (045422). Apply more grease to the inside of a new dirt and water seal and install it on the input shaft. Seat the seal in the groove behind the serrations and against the valve housing.

NOTE: This step may have already been completed if the valve housing and input shaft assembly were disassembled for repair.

Final Adjustments

Before installing the steering gear on the vehicle, make the following adjustments.

NOTE: Worm shaft preload adjustment was done when the input shaft was installed in the valve housing during the assembly procedure.

IMPORTANT: When the steering gear is not connected to the steering system, do not turn the input shaft more than 1-1/2 turns from the center position or the automatic poppets could become inoperative when the steering gear is installed on the vehicle. This would require disassembling the gear to position the poppet seat and sleeve assemblies.

1. Using a 3/4- or 11/16-inch socket or box end wrench, center the steering gear by rotating the input shaft until the timing mark on the end of the sector shaft is in line with the timing mark on the end of the housing trunnion.

NOTE: If new or reset poppets are in the gear, they will be moved when the input shaft is turned less than one rotation in either direction from the center position. This will not affect the function of the poppets.

2. With the adjusting screw jam nut loose, turn the sector shaft adjusting screw clockwise to provide 45 to 50 lbf·in (508 to 565 N·cm) of torque to rotate the input shaft through one-half turn each side of center.

NOTE: This step will properly mesh and seat the rack piston and sector shaft for final adjustments.

3. Turn the sector shaft adjusting screw counterclockwise one-half turn and note the maximum

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Disassembly, Inspection, Assembly, and Final Adjustments

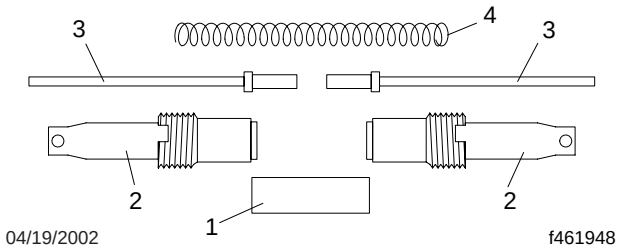
torque required to rotate the input shaft through one-half turn each side of center.

4. Turn the sector shaft adjusting screw clockwise to increase the maximum torque noted in the previous step by 7 lbf·in (79 N·cm). Tighten the jam nut firmly against the side cover while holding the adjusting screw in position.
5. Torque the jam nut 43 lbf·ft (58 N·m) and check the input shaft torque again. Adjust the sector shaft adjusting screw if the input shaft torque exceeds 40 lbf·in (452 N·cm).
6. Install the steering gear on the vehicle. For instructions, see **Subject 100**.
7. Remove the chocks from the tires.

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Replacement

1. Remove the rack piston from the steering gear. For instructions, see **Subject 150**.
2. Place the rack piston in a soft-jawed vise.
3. Place special tool, J36452-A, over the seat of the poppet seat and sleeve assembly and engage the special tool in the slots of the threaded sleeve. Hit the end of the tool firmly four or five times with a two-pound sledge hammer to loosen the Loctite®.
4. Place a ratchet on the special tool and remove the seat and sleeve assembly from the rack piston. If the ratchet does not turn easily, strike the special tool again with a hammer. If the engaging tangs will not stay in place while torquing, it may be necessary to hold the tool in place with an arbor press while applying loosening torque.
5. Discard the poppet seat and sleeve assembly. See **Fig. 1**.



1. Push Tube
2. Poppet Seat and Sleeve Assembly
3. Poppet
4. Spring

Fig. 1, Poppets Components

6. Remove the two poppets, the spring, and the push tube. See **Fig. 1**.
7. If necessary, remove and discard the second poppet seat and valve assembly.

NOTE: It is possible to reset one poppet seat and sleeve assembly for automatic poppet adjustment while it is in the rack piston if one poppet seat and sleeve assembly and the poppets, spring, spacer rod, and push tube are removed.

8. To reset the automatic poppet adjustment when one poppet seat and sleeve assembly has been left in the rack piston, insert a 3/8-inch (9.5-mm) diameter x 6-inch (152-mm) drill rod down through the poppet seat hole at the opposite end of the rack piston and against the adjuster seat to press the seat in until it bottoms against the adjuster sleeve.

CAUTION

Do not allow Loctite or Locquic to get on the adjuster seat component of the poppet seat and sleeve assembly. Failure to follow this precaution will prevent the poppets from functioning properly.

9. Carefully apply Locquic® T primer to the threads in the poppet holes and to the threads on the new seat and sleeve assemblies. Allow the primer to dry for ten minutes, then carefully apply Loctite RC680 to the same threads.

WARNING

Wear eye protection when assembling the poppets since the spring-loaded poppets could eject and cause personal injury.

10. Place the rack piston in a soft-jawed vise. If the second poppet seat and valve assembly was removed, install a new poppet seat and sleeve assembly, with the slotted end out, into the poppet hole in one end of the rack piston.
11. From the other end of the poppet hole in the rack piston, install one poppet, the poppet spring, push tube, the other poppet, and a new poppet seat and valve assembly. The new components will stack up as shown in **Fig. 2**.

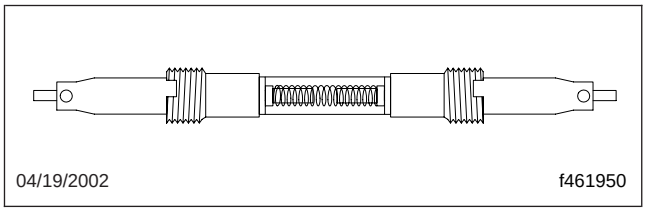


Fig. 2, Poppet Components Assembled

12. Torque the poppet seat and valve assemblies 18 lbf·ft (24 N·m).
13. Install the rack piston in the steering gear. For instructions, see **Subject 150**.

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Valve Housing/Input Shaft Disassembly, Inspection, and Assembly

Disassembly

1. Remove the valve housing and the input shaft assembly from the steering gear. For instructions, see **Subject 150**.
2. Place the valve housing, with the input shaft in the upright position, in a soft-jawed vise.
3. Unstake the valve housing where the material was moved into the adjuster locknut slot.
4. Using a roll pin punch and hammer, unstake the adjuster locknut from the bearing adjuster. See **Fig. 1**.
5. Using the adjuster locknut tool (J37464), remove the adjuster locknut from the valve housing.
6. Using the bearing adjuster tool (J37070), remove the bearing adjuster from the valve housing.
7. Remove and discard the seal ring and O-ring, items 18 and 19 in **Fig. 1**, from the bearing adjuster.
8. Remove the input shaft from the valve housing.
9. Remove the thrust washer and thrust bearing, items 17 and 16 in **Fig. 1**, from the input shaft.

CAUTION

The input shaft assembly must not be disassembled any further. The components are a select fit at assembly and are available only as part of this subassembly. If disassembled further, the subassembly must be replaced.

10. Remove the bearing assembly, item 12 in **Fig. 1**, from the valve housing.

IMPORTANT: Do not remove the ball cup that the bearing assembly rides on. Do not remove the special spacer seal behind the ball cup.

11. Remove and discard the seal ring, item 14 in **Fig. 1**, from the valve housing.
12. Remove the valve housing from the vise. Turn the valve housing over and remove the retaining ring, item 3 in **Fig. 1**.

CAUTION

Be careful when removing the input shaft seal to prevent damage to the valve housing seal bore.

13. Using a 1-1/8-inch socket and hammer, remove the input shaft seal, item 4 in **Fig. 1**, from the valve housing. Discard the input shaft seal.

NOTE: The valve housing also utilizes a ball plug for manufacturing purposes that must not be removed.

Inspection

1. Inspect the sealing areas of the input shaft and valve housing for nicks. Run the edge of your fingernail over the sealing surfaces to detect steps. Inspect for discoloration from excess heat. Inspect the input shaft ball track grooves for brinelling or spalling. If any of these conditions exist, the input shaft assembly, valve housing, and balls must be replaced. Replace the rack piston if brinelling or spalling is found.
2. Inspect the rollers in the thrust bearing and the bearing assembly for deterioration. Inspect the thrust washer and ball bearing race in the valve housing for brinelling, spalling, or cracks. Replace all parts that exhibit these conditions.

Assembly

IMPORTANT: Do not clamp the valve housing against the threaded port hole or relief valve hole sealing faces when placing the valve in the vise.

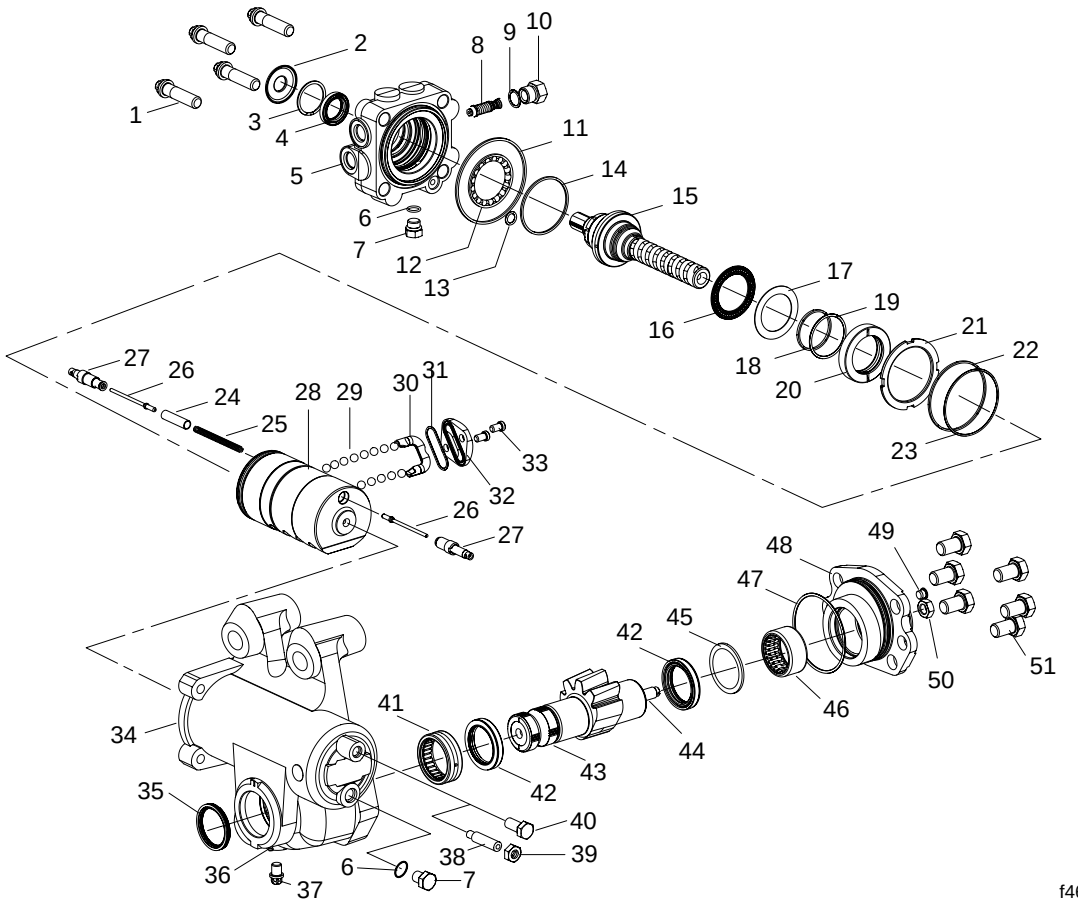
1. Place the valve housing in a vise so the input shaft can be assembled with the worm screw up.
2. Lightly oil a new seal ring and install the seal ring in the large diameter groove in the valve housing. It may be necessary to bend and work the seal ring into the groove. Smooth out the seal ring.

IMPORTANT: The seal ring must be smoothed out to prevent it from damage when the worm screw is installed.

3. Install the bearing assembly in the valve housing. See **Fig. 2** for correct orientation of the bearing assembly.
4. Dip the input end of the input shaft assembly in oil up to the worm lead. Install the input shaft

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Valve Housing/Input Shaft Disassembly, Inspection, and Assembly



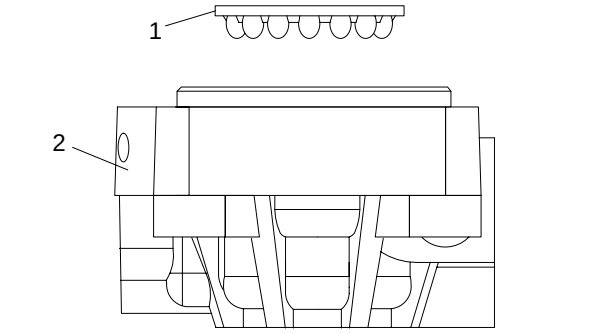
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1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
6. Auxiliary Port O-Ring (2)
7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
13. O-Ring
14. Seal Ring
15. Input Shaft Assembly
16. Thrust Bearing
17. Thrust Washer
18. Seal Ring
19. O-Ring
20. Bearing Adjuster
21. Adjuster Locknut
22. O-Ring
23. Seal Ring
24. Push Tube
25. Poppet Spring
26. Poppet
27. Poppet Seat and Sleeve Assembly
28. Rack Piston
29. Ball
30. Ball Return Guide
31. Cap Seal
32. Ball Return Guide Cap
33. Torx® Capscrew
34. Gear Housing
35. Dirt and Water Seal
36. Grease Fitting
37. Automatic Bleed Plug
38. Poppet Adjusting Screw
39. Poppet Adjusting Screw Nut
40. Poppet Fixed Stop Screw
41. Roller Bearing
42. Output Seal
43. Sector Shaft Assembly
44. Sector Shaft Adjusting Screw
45. Washer
46. Roller Bearing
47. Side Cover O-Ring
48. Side Cover Assembly
49. Vent Plug, Side Cover
50. Adjusting Screw Jam Nut
51. Capscrew

Fig. 1, THP Steering Gear

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Valve Housing/Input Shaft Disassembly, Inspection, and Assembly



1. Bearing Assembly 2. Valve Housing

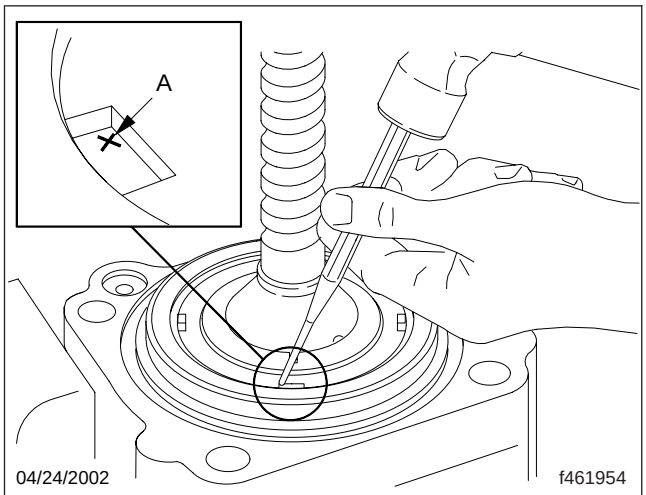
Fig. 2, Correct Orientation of Bearing Assembly

end of the assembly in the valve housing until it is firmly seated.

5. Apply oil to the thrust bearing and thrust washer, then install the bearing and washer over the ball groove end of the worm screw and seat them against the shoulder of the input shaft assembly.
6. Lightly oil a new O-ring and install it in the bearing adjuster seal groove. Lightly oil a new seal ring and install it in the same bearing adjuster seal groove. Smooth out the seal ring.

NOTE: Be sure the valve housing, the adjuster locknut, and the bearing adjuster threads are clean and free of any staking burrs that would impede the locknut from turning freely in the valve housing.

7. Lightly oil a new bearing adjuster and install it in the valve housing. Using a torque wrench inserted in the bearing adjuster tool (J37070), torque the bearing adjuster 13 lbf·ft (18 N·m). This will seat the components. Back off the adjuster one-quarter to one-half of a turn.
8. Lightly oil a new adjuster locknut and install it on the bearing adjuster with the slightly rounded side down. Tighten slightly to keep the bearing adjuster in place.
9. Reverse the valve housing in the vise so that the worm screw is down. With a pound-force-per-inch torque wrench on the input shaft, note the torque required to rotate the input shaft 360 degrees in each direction. Tighten the bearing adjuster to increase the maximum torque at the input shaft 5 to 10 lbf·in (56 to 113 N·cm) over that which was previously noted.
10. Reverse the valve housing in the vise so that the worm screw is up. Torque the adjuster locknut while holding the bearing adjuster in the position established in the previous step with the adjuster locknut tool (J37464). When using a torque wrench in the adjuster locknut tool, the torque wrench reading should be 112 lbf·ft (152 N·m).
11. Check the input shaft torque. It should match the torque measured previously. If the torque readings do not match, repeat the previous two steps.
12. Stake the valve housing in the clockwise-most corner of two opposing slots in the adjuster locknut. See **Fig. 3**. Stake the locknut into the bearing adjuster in two places, 180 degrees apart, at the threaded area. Choose areas that have not been previously staked.



A. Stake the valve housing in the clockwise-most corner of the slot in the adjuster locknut.

Fig. 3, Stake the Valve Housing

13. After staking, the torque required to rotate the input shaft must be between 5 to 10 lbf·in (56 to 113 N·cm) greater than the torque noted previously. The torque value must not exceed 22 lbf·in (249 N·cm). If necessary, unstake and readjust.
14. Place the valve housing/worm screw assembly in the vise so that the worm screw is down.

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Valve Housing/Input Shaft Disassembly, Inspection, and Assembly

IMPORTANT: Remove any seal material that may have sheared off and is in the seal bore and retaining groove ring.

15. Apply Exxon Polyrex® EP2 grease (045422) to the outside and inside diameters (fill cavity between the lips) of the new input shaft seal and install it, garter spring side first, on the input shaft. Align the seal in the valve housing seal bore.

IMPORTANT: The input shaft seal must be square in the seal bore and installed to the correct depth.

16. Place the seal driver tool (J37073) with the smaller end first, on the input shaft and against the seal. Tap the seal installer tool until the tool shoulder is squarely against the valve housing. This will correctly position the seal in the housing bore just beyond the retaining ring groove.
17. Insert the new retaining ring, item 3 in **Fig. 1**, into the retaining ring groove in the valve housing.
18. Pack the end of the valve housing bore around the input shaft with Exxon Polyrex EP2 grease (045422). Apply more of the grease to the inside of a new dirt and water seal and install it on the input shaft. Seat the seal in the groove behind the serrations and against the valve housing.
19. Install the valve housing/input shaft assembly in the steering gear. For instructions, see **Subject 150**.

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Replacement

1. Remove the roller bearing, item 41 in **Fig. 1**, from the gear housing. For instructions, see **Subject 150**.
2. Place the long end of the bearing and seal tool (J37705 for THP 45, J37071–A for THP 60) against the trunnion end of the bearing and press it out of the side-cover end of the bearing bore. Discard the roller bearing.

⚠ CAUTION

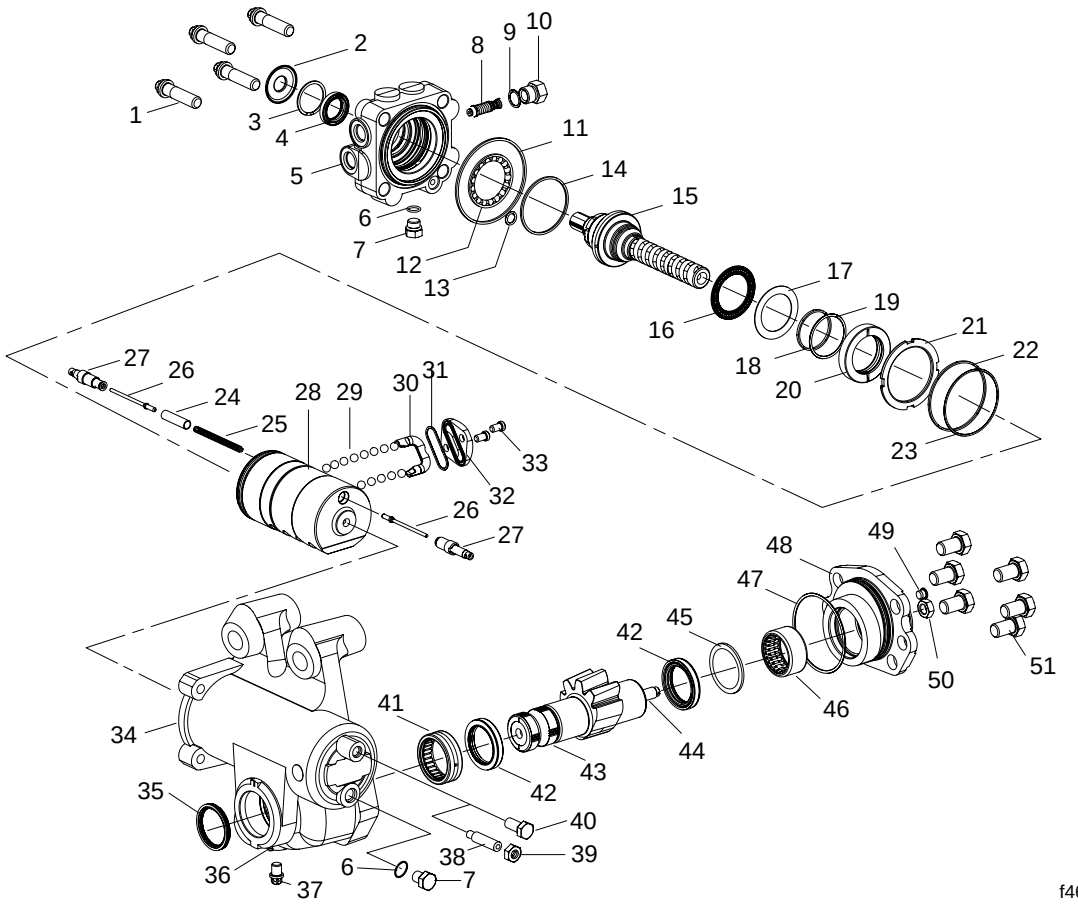
Use the short end of the bearing and seal tool to press in the roller bearing. If the long end of the bearing and seal tool is used to press in the bearing, the cage on the roller bearing may be damaged.

NOTE: If the unmachined trunnion face is not square, use shims to square it before pressing in the bearing.

3. Using the short end of the bearing and seal tool, press the new roller bearing into the gear housing from the side-cover end of the bearing bore until it is seated against the step bore. Be sure the housing is square with the press base and the bearing is not cocked.
4. Install the side cover on the gear housing. For instructions, see **Subject 150**.

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Roller Bearing Replacement



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1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
6. Auxiliary Port O-Ring (2)
7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
13. O-Ring
14. Seal Ring
15. Input Shaft Assembly
16. Thrust Bearing
17. Thrust Washer
18. Seal Ring
19. O-Ring
20. Bearing Adjuster
21. Adjuster Locknut
22. O-Ring
23. Seal Ring
24. Push Tube
25. Poppet Spring
26. Poppet
27. Poppet Seat and Sleeve Assembly
28. Rack Piston
29. Ball
30. Ball Return Guide
31. Cap Seal
32. Ball Return Guide Cap
33. Torx® Capscrew
34. Gear Housing
35. Dirt and Water Seal
36. Grease Fitting
37. Automatic Bleed Plug
38. Poppet Adjusting Screw
39. Poppet Adjusting Screw Nut
40. Poppet Fixed Stop Screw
41. Roller Bearing
42. Output Seal
43. Sector Shaft Assembly
44. Sector Shaft Adjusting Screw
45. Washer
46. Roller Bearing
47. Side Cover O-Ring
48. Side Cover Assembly
49. Vent Plug, Side Cover
50. Adjusting Screw Jam Nut
51. Capscrew

Fig. 1, THP Steering Gear

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Poppet Fixed Stop Screw Replacement

1. If damaged, remove the poppet fixed stop screw, item 40 in **Fig. 1**, and the washer. Discard the washer.
2. Install a new poppet fixed stop screw and torque 48 lbf·ft (65 N·m).

Poppet Adjusting Screw Replacement

1. If damaged, remove the poppet adjusting screw and poppet adjusting screw nut, items 38 and 39 in **1**, without allowing the nut to change its position on the screw.
2. Install a new nut on the new poppet adjusting screw matching its position to the nut and screw removed. Torque the nut 35 lbf·ft (48 N·m).

Automatic Bleed Plug and Auxiliary Port Plug Replacement

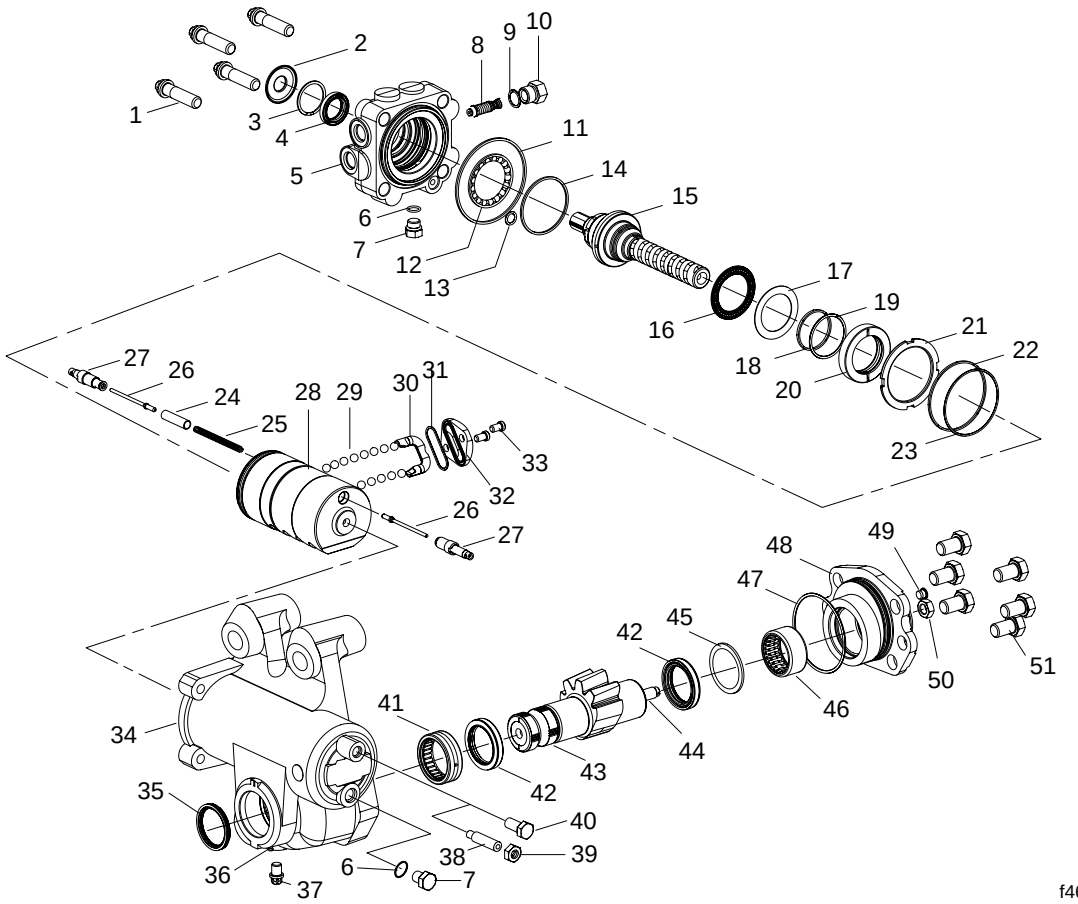
1. If damaged, remove the automatic bleed plug, item 37 in **Fig. 1**.
2. Install a new automatic bleed plug and torque the plug 48 lbf·ft (65 N·m).
3. If damaged, remove the auxiliary port plug and the auxiliary port O-ring, items 7 and 6 in **Fig. 1**.
4. Install a new auxiliary port plug and auxiliary port O-ring in the gear housing or valve housing and torque the plug 30 lbf·ft (41 N·m).

Manual Bleed Screw Replacement

1. If damaged, remove the manual bleed screw. For possible manual bleed screw locations, see **Fig. 2**.
2. Install a new manual bleed screw and torque the screw 45 lbf·in (508 N·cm).

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Housing Port Plugs, Screws, and Fittings Replacement



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1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
6. Auxiliary Port O-Ring (2)
7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
13. O-Ring
14. Seal Ring
15. Input Shaft Assembly
16. Thrust Bearing
17. Thrust Washer
18. Seal Ring
19. O-Ring
20. Bearing Adjuster
21. Adjuster Locknut
22. O-Ring
23. Seal Ring
24. Push Tube
25. Poppet Spring
26. Poppet
27. Poppet Seat and Sleeve Assembly
28. Rack Piston
29. Ball
30. Ball Return Guide
31. Cap Seal
32. Ball Return Guide Cap
33. Torx® Capscrew
34. Gear Housing
35. Dirt and Water Seal
36. Grease Fitting
37. Automatic Bleed Plug
38. Poppet Adjusting Screw
39. Poppet Adjusting Screw Nut
40. Poppet Fixed Stop Screw
41. Roller Bearing
42. Output Seal
43. Sector Shaft Assembly
44. Sector Shaft Adjusting Screw
45. Washer
46. Roller Bearing
47. Side Cover O-Ring
48. Side Cover Assembly
49. Vent Plug, Side Cover
50. Adjusting Screw Jam Nut
51. Capscrew

Fig. 1, THP Steering Gear

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Housing Port Plugs, Screws, and Fittings Replacement

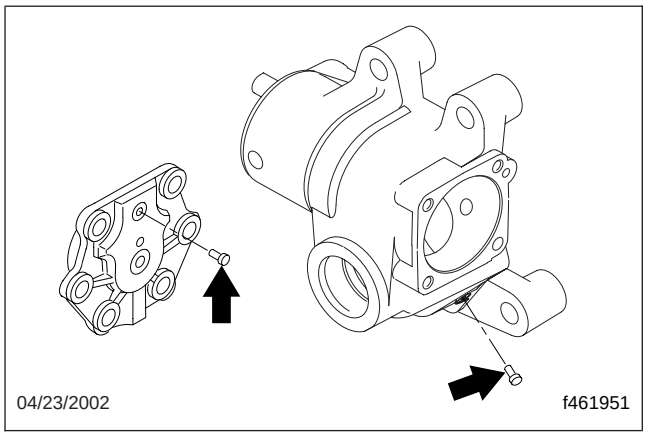


Fig. 2, Possible Manual Bleed Screw Locations

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Post-Service Checks |

After power steering components have been worked on and before the vehicle is placed into service, the following items must be checked.

⚠ WARNING

Failure to check the following items could result in damage to the power steering system. This could cause a loss of hydraulic assist, which could cause personal injury or property damage.

1. Operate the engine at low idle while turning the steering wheel through several full left and right turns. With the engine running and the power steering system at operating temperature, turn the steering wheel slowly from stop to stop while checking the power steering reservoir for frothing or a change in the fluid level, a sign that air is trapped in the system. If air is present, inspect the system for leaking hoses or loose fittings. Replace the hoses or tighten the fittings as necessary. Bleed the air from the system.
2. With the engine turned off and warm, check the power steering reservoir fluid level using the instructions in **Group 46** of the *Acterra Maintenance Manual*.
3. At full-left and full-right wheel cuts, be sure the axle stops on the rear-side of the spindle are set so there is at least 1/2-inch (13-mm) clearance between the tires and any fixed components that are attached to the vehicle. Clearance between moving components should be 3/4 inch (19 mm). If clearance is less than the above, reset the axle stops.
4. Check that the poppets are set correctly. If needed, adjust them. For instructions refer to **Subject 140**.
5. If there are still problems with the power steering system, see **Section 46.08, Subject 300** and perform the troubleshooting procedures. Otherwise, go to the next step.
6. Test drive the vehicle or take a ride with the driver. Check the steering wheel spoke position. If during straight-ahead driving on a level road the steering wheel spokes on a four-spoke steering wheel are not within ±10 degrees of the 9 o'clock and 3 o'clock positions or within ±10 degrees of the 8 o'clock and 4 o'clock positions on a two-spoke steering wheel, remove the steering wheel and reposition it.

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Specifications

⚠ WARNING

Fill the power steering reservoir only with approved clean fluid. Do not mix automatic transmission fluid with engine oil; use one or the other. If you are changing from one fluid type to the other, completely flush the steering system with the fluid type being added. Any mixture or any unapproved fluid could lead to seal deterioration and leaks. Any fluid leak could eventually cause loss of power steering assist.

The following hydraulic fluids are approved for use in the steering system:

- Automatic Transmission Fluid (ATF), Dexron® II
- Automatic Transmission Fluid (ATF), Dexron® III

The following type of grease is approved for use on the steering gear components:

- Exxon Polyrex® EP2 (045422)

Special tools can be ordered from:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092
1-800-328-6657

Special Tools		
Part Number		Description
THP 45	THP 60	
J37705	J37071 and J37071–A	Bearing and Seal Tool
J36452–A		Special Tool
J37070		Bearing Adjuster Tool
J37073		Seal Driver Tool
J37464		Adjuster Locknut Tool

Table 1, Special Tools

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General Information

A *Checklist for Troubleshooting Power Steering Problems*, form STI-492, has been developed to accompany the procedures below. Form STI-492 can be downloaded or printed **here** after logging into **www.AccessFreightliner.com**.

Each step and substep in these troubleshooting procedures corresponds to a step or substep on form STI-492. Use **Table 1** to determine which steps should be completed, based on the customer's complaint. It is very important that the information provided by the driver is communicated accurately to prevent wasting of diagnostic time. For example, if complaints include "Pulling to one side" and "Noisy steering," steps 1, 3, 4, 5, and 6 will be the tests for the most likely failure modes.

Start with the lowest test number and work up to the highest. For example, when completing steps 1, 3, and 6 to determine the cause of a vehicle pulling to one side, start with step 1 and finish with step 6.

Troubleshooting Steps

NOTE: Some of these inspections and procedures can be found in the Pretrip and Post-Trip Inspections and Maintenance chapter in the vehicle driver's/operator's manual.

Steps 1 through 4 may have been performed by the customer. Verify the vehicle service history with the customer to prevent redundant testing.

All measurements and readings must be recorded on STI-492.

Refer to the applicable section in this manual to repair or replace steering system components.

1. Check the tire pressure and load.

   1.1 Check the tires for damage.

   1.2 Check that the front tires are inflated to the correct pressure, and the tire pressure is equal on both sides. Correct the pressure if needed.

   Low pressure causes increased steering effort due to friction with the road surface. Unequal tire pressure causes unequal friction between the tire and the road. This can cause pulling to one side.

Steering Complaint and Troubleshooting Steps Checklist												
LH	RH	Both	Complaint	Troubleshooting Steps								
				1	2	3	4	5	6	7	8	9
			Hard or heavy steering	•	•		•	•	•	•	•	•
			Low assist									
			Binding									
			Locking									
			Occasional loss of assist									
			Reduced wheel cut								•	
			Pulling to one side*	•		•			•			
			Darting/oversteering	•	•	•	•		•			
			Wandering									
			Noisy steering				•	•	•			
			External seals leaking					•	•			•
			Excessive heat									

* If there is consistent pull to one side, a braking issue could feel like a steering assist problem. Refer to **Group 42** in this manual to ensure the brake system is functioning properly.

Table 1, Steering Complaint and Troubleshooting Steps Checklist

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Troubleshooting Procedures

1.3 Check that the rear tires are inflated to the correct pressure, and the tire pressure is equal on both sides. Correct the pressure if needed.

1.4 Check that the tire sizes are correctly matched, and whether duplex or oversized tires (that were not originally specified for the vehicle) have been installed.

Extra tire width causes increased steering effort due to extra friction with the road surface. If the axle stops were turned out to reduce wheel cut due to a change in tires, the power steering gear poppets may need to be adjusted.

1.5 Communicate with the driver or operator to determine whether the vehicle is operated at or over the rated load.

Increased load causes greater steering effort. Make sure the vehicle is being operated within rated capacities.

2. Check fifth wheel lubrication and condition.

A dry fifth wheel plate makes it difficult to change direction. Check the plate surface for burrs, gouges, and irregularities.

3. Check vehicle alignment and wheel bearing adjustment.

3.1 Check the vehicle service history for the last known alignment, and inspect tire wear for indications that an alignment needs to be completed.

3.2 Check front axle caster and camber measurements.

3.3 Ensure wheel bearings and rear axle are in good condition, and that toe is set correctly.

3.4 Ensure the rear axle is properly aligned.

4. Check for loose and binding components. Check whether any steering components need maintenance or adjustment.

4.1 Check for proper lubrication of the drag link, tie rods, and knuckle pins. Apply lubrication as needed.

4.2 Check the COE steering column, if equipped. Chock the rearmost tires. With the engine shut down, turn the steering wheel and check for looseness or binding. Make sure all components are free to move, but are not excessively loose.

4.3 Check the steering driveline U-joints for looseness or binding. Lubricate them if needed.

4.4 Check the sector shaft adjustment.

- With the vehicle on the ground, the engine idling, and the front tires pointed straight ahead, turn the steering wheel until slight motion is observed at the front wheels.
- Align a reference mark on the steering wheel to a rule, then, with the engine running, slowly turn the steering wheel in the opposite direction until motion is again detected at the wheels.
- Measure the lash (free play) at the rim of the steering wheel.

Excessive lash exists if steering wheel movement exceeds 2-1/2 inches (64 mm) with a 20-inch (508-mm) steering wheel, or 2-1/4 inches (57 mm) with an 18-inch (457-mm) steering wheel.

4.5 Check that the front wheels self-return without binding.

- With the engine off, chock the rearmost tires and place the front tires on radius plates (turntables).
- Disconnect the drag link from the steering arm.
- By hand, pull one tire to the axle stop and release. The tire should self-return to almost straight ahead.
- Repeat with the opposite tire.

If a tire does not return to near straight ahead, check for binding or lack of lubrication in the steering axle kingpin bushings or tie rod linkage.

- Connect the drag link and tighten the castle nut, then install a new cotter pin.

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4.6 Inspect all suspension fasteners and components for wear or looseness.

5. Check the steering system for leaks and restrictions, and test the system back pressure.

5.1 Inspect hoses, fittings, and seals for damage or leaks.

- With the engine idling, inspect for kinked or collapsed hoses. Repair or replace any collapsed or kinked hoses. If collapsed hoses are found, ensure the steering system is filled with the correct automatic transmission fluid.
- Inspect fittings for leaks. Repair leaking fittings; replace parts as needed.
- Inspect all external seals. Replace leaking seals.

  Inspect the seal bores and sealing surfaces for scrapes or burrs. Make sure the seals are installed correctly using the recommended tools.
- If you replaced the steering gear input shaft seal and found it to be excessively hard, test the system operating temperature in step 6.

5.2 Inspect the steering gear for external leakage.

- Clean the area around the input shaft and inspect the input shaft for signs of leakage after operating the vehicle under normal conditions through steering maneuvers.
- Inspect the sector shaft for signs of leakage. A well greased or heavily used steering gear may weep oil from the grease seal, but a confirmed leak will be evidenced by fluid collecting while the vehicle is being operated under normal conditions.
- Inspect the vent plug in the trunnion housing for signs of leakage. Any fluid in or around the rubber vent plug indicates leakage from an internal steering gear seal.

NOTICE

Do not turn the steering wheel or allow system pressure to exceed the rating of the gauge during the following test. Damage to the gauge could occur.

5.3 Check total steering system back pressure.

- Install a low pressure gauge—300 psi (2068 kPa) maximum—between the steering pump and the steering gear.
- Check for correct fluid level. If necessary, add fluid. If bubbles or foam appear in the reservoir, check hose fittings for looseness or leaks.
- With the engine idling, read the total system back pressure on the pressure gauge.
- If the total system back pressure is greater than 100 psi (689 kPa), or 140 psi (965 kPa) for a vehicle with hydraulic brakes, replace the steering fluid filter and re-test the system. If the system back pressure is still excessive, go to the next substep.

  If the total system back pressure is less than 100 psi (689 kPa), or 140 psi (965 kPa) for a vehicle with hydraulic brakes, restriction is not a problem—go to step 6.

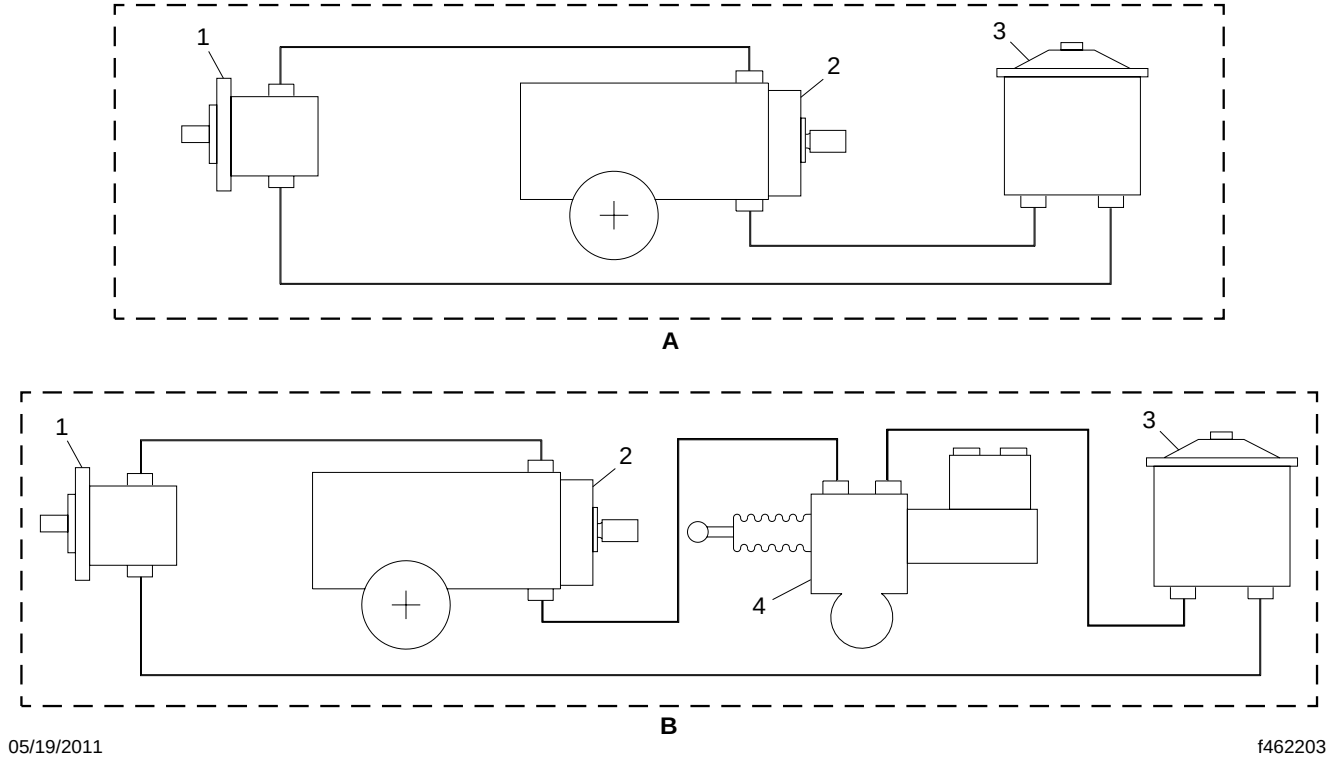
5.4 Leave the low pressure gauge in place and check individual steering system components for excessive restriction. See **Fig. 1** for a plumbing diagram.

- Bypass the steering gear by disconnecting the steering gear input and output lines from the gear and coupling them together. See **Fig. 2** for an example.

  If the drop in system pressure from the value found in substep 5.3 is greater than 55 psi (379 kPa), the steering gear has excessive restriction. If the drop in pressure is less than 55 psi (379 kPa), reconnect the

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Troubleshooting Procedures



A. Vehicles With Air Brakes
1. Steering Pump
2. Steering Gear

B. Vehicles With Hydraulic Brakes
3. Reservoir
4. Brake Booster

Fig. 1, Plumbing Diagrams

gear input and output lines to the gear and continue with this substep.

- If the vehicle is equipped with hydraulic brakes, bypass the brake booster by disconnecting the booster input and output lines and coupling them together.

  If the drop in system pressure from the value found in substep 5.3 is greater than 40 psi (276 kPa), the brake booster has excessive restriction. If the drop in pressure is less than 40 psi (276 kPa), reconnect the booster input and output lines and continue with this substep.

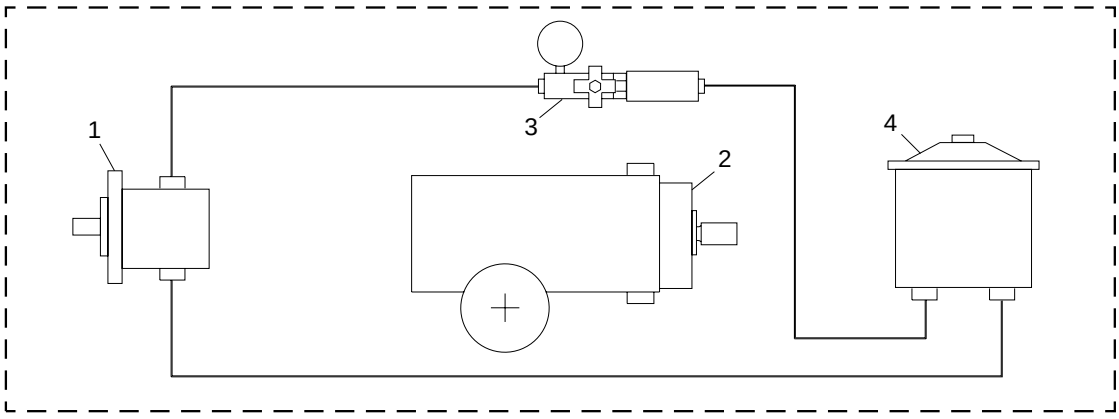
- Test each hydraulic line in the power steering system individually by bypassing them one at a time, as was done with the steering gear and brake booster, if equipped.

  If the drop in system pressure from the value found in substep 5.3 is greater than 12 psi (83 kPa) for any one line, replace the line and test total system back pressure again.

6. Check steering pump performance. Power steering fluid temperature should be approximately 180°F (82°C) to best replicate fluid temperatures under normal driving conditions.

   If the system fails the tests in the following substeps, replace the pressure relief valve (PRV) and complete the tests in the substeps below again. If the system fails again, replace the pump.

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1. Steering Pump
2. Steering Gear
3. Low Pressure Gauge
4. Reservoir

Fig. 2, Testing Steering Gear Restriction

Install the PSSA between the steering pump and the gear for the following substeps. See the following heading, **Power Steering System Analyzer Setup**, for instructions on PSSA installation.

NOTICE

Do not leave the load valve closed for longer than five seconds during the following test. Doing so could damage the power steering system.

6.1 Check for erratic pump response.

- Slowly close the load valve and watch the pressure and flow readings as the valve closes, then open the valve immediately.
- If the pressure rises rapidly or appears uncontrolled, open the load valve immediately.
- If the response was erratic, replace the PRV or pump, as required. If the response was smooth and controlled, go to the next substep.

6.2 Check the pump relief pressure.

- Slowly close the load valve. When the valve is completely closed, read the pressure gauge, then open the valve.
- If the pump relief pressure does not exceed the relief pressure in **Table 2** or **Table 3**, refer to the pump manufacturer's service literature to verify the exact relief pressure for the pump.
- If the pump relief pressure does not exceed the relief pressure in **Table 2**, **Table 3**, or the pump manufacturer's specifications, replace the PRV or pump, as required.
- If the pump relief pressure exceeds the relief pressure in **Table 2** or **Table 3**, it is acceptable. Go to the next substep.

6.3 Test the pump relief valve reaction at idle.

- Run the engine at idle and note the flow rate with the load valve open.

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Troubleshooting Procedures

Minimum Measured Pump Flow and Relief Pressure at Engine Idle				
Power Steering Gear	**Flow at 1500 rpm, No Load: gpm (L/min)**	**Flow at 1000 psi (6900 kPa): gpm (L/min)**	**Flow at 1800 psi (12 400 kPa): gpm (L/min)**	**Typical Relief Pressure: psi (kPa)**
Sheppard M100	3.7 (14.0)	2.8 (10.6)	2.3 (8.7)	2175 ± 100 (15 000 ± 700)*
TRW TAS40	3.7 (14.0)	2.1 (7.9)†	1.6 (6.1)	
TRW TAS55		2.4 (9.1)†	1.9 (7.2)	
TRW TAS65		2.8 (10.6)†	2.3 (8.7)	
TRW TAS85		3.3 (12.5)	2.8 (10.6)	
TRW TAS65 With C28 or C32 Linear Cylinder	5.8 (22.0)	4.9 (18.5)	4.4 (16.7)	
TRW TAS65 With RCS65				
TRW TAS85 With C28 or C32 Linear Cylinder		5.4 (20.4)†	4.9 (18.5)	
TRW TAS85 With RCS65				
ThyssenKrupp LZS5 Rack and Pinion	3.7 (14.0)	3.3 (12.5)	2.8 (10.6)	2300 ± 116 (15 500 ± 800)

* On vehicles with TRW TAS steering gears and hydraulic brakes, typical relief pressure is 2375 ± 100 psi (16 375 ± 690 kPa).

† Approximate value based on flow at 1800 psi (12 400 kPa).

Table 2, Minimum Measured Pump Flow and Relief Pressure at Engine Idle

Minimum Measured Pump Flow and Relief Pressure for High-Pressure Gears at Engine Idle				
Power Steering Gear	**Flow at 1500 rpm, No Load: gpm (L/min)**	**Flow at 1000 psi (6900 kPa): gpm (L/min)**	**Flow at 2300 psi (15 860 kPa): gpm (L/min)**	**Typical Relief Pressure: psi (kPa)**
Sheppard HD94	3.7 (14.0)	2.6 (9.8)	1.8 (6.8)	2683 ± 100 (18 500 ± 700)
TRW THP45		2.2 (8.3)	1.4 (5.3)	
TRW THP60 or PCF60		2.6 (9.8)	1.8 (6.8)	
TRW THP60 With Linear Cylinder	5.8 (22.0)	4.1 (15.5)	3.3 (12.5)	
TRW THP60 With RCH45				

Table 3, Minimum Measured Pump Flow and Relief Pressure for High-Pressure Gears at Engine Idle

- Close the load valve until the pump relief pressure is reached. Smoothly and quickly open the load valve and note the flow rate. Repeat this action three times. The flow rate should return to the flow rate first noted with the load valve open.
- If the flow rate does not return smoothly and quickly, the pump relief valve is not working correctly. Replace the replace the PRV or pump, as required.
- If the flow rate returns smoothly and quickly, the pump relief valve is acceptable. Go to the next substep.

6.4 Test the pump relief valve reaction at 1500 rpm.

- Run the engine at 1500 rpm and note the flow rate with the load valve open.
- Close the load valve until the pump relief pressure is reached. Smoothly and quickly open the load valve and note the flow rate. Repeat this ac-

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tion three times. The flow rate should return to the flow rate first noted with the load valve open.

- If the flow rate does not return smoothly and quickly, replace the PRV or pump, as required.
- If the flow rate returns smoothly and quickly, the pump relief valve is acceptable. Go to the next substep.

6.5 Test the flow of the pump at idle with a load applied.

For vehicles with low-pressure steering gears, run the engine at idle and slowly close the load valve until the pressure gauge reads 1000 psi (6900 kPa). Read the flow rate on the gauge, then set the pressure to 1800 psi (12 400 kPa). Read the flow gauge, then open the load valve. Compare the values to those in **Table 2**.

For vehicles with high-pressure steering gears, use 1000 psi (6900 kPa) and 2300 psi (15 860 kPa) as the test load pressures. See **Table 3** for minimum flow rate.

6.6 Test the maximum flow of the pump with no load applied.

- Run the engine at 1500 rpm, make sure the load valve is completely open, and read the flow gauge.
- If the flow rate is below the minimum indicated in **Table 2** or **Table 3**, replace the PRV or pump, as required.
- If the flow rate is above 5.5 gpm (20.8 L/min) on a vehicle with a single steering gear, or 7.7 gpm (28.8 L/min) on a vehicle with an assist cylinder installed, replace the pump.

7. Test the steering gear internal leakage.

Select TRW integral steering gears and all ThyssenKrupp rack and pinion steering gears are equipped with an internal PRV that significantly limits maximum supply pressure to protect the steering gear. These gears, unlike gears on vehicles fitted with hydraulic brake boosters, cannot be tested for internal leakage by plugging the internal PRV in the gear. The pump output must be limited to prevent excessive pressure from damaging the gear, and the internal PRV passage must be blocked to direct oil flow through the gear.

Use PartsPro® for the specific VIN to determine if the steering gear is equipped with an internal PRV, which will be listed as a serviceable part under module 536.

If a TRW steering gear has an internal PRV but no hydraulic brake booster, see the following heading, **Internal Leakage Test Setup, TRW Steering Gears With an Internal PRV**, for instructions on setting up the necessary test components before proceeding with the following substeps.

ThyssenKrupp rack and pinion steering gears are also equipped with an internal PRV, but cannot be tested for internal leakage.

IMPORTANT: Make sure the fluid temperature is approximately 180°F (82°C) and the vehicle is stationary with the front wheels pointing forward.

7.1 Run the engine at idle with the load valve open.

⚠ WARNING

Keep fingers clear of the stop bolt and spacer block during the following test. Make sure that the spacer block contacts the axle stop squarely. Contact that is not square could break the stop bolts or eject the spacer block, which could cause serious personal injury.

7.2 Place an unhardened steel spacer, 1-inch (25-mm) thick, between the axle and the stop bolt on one side of the axle.

The spacer should have an extension or handle long enough to keep fingers clear of the axle stop area. A brazing rod or welding rod works well for this purpose.

NOTICE

While running the following test, do not hold the steering wheel in the full-turn position for more than five seconds. Doing so could damage the pump.

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Troubleshooting Procedures

7.3 Have someone turn the steering wheel, applying enough force to completely close the rotary valve.

Complete closure of the rotary valve requires approximately 20 lbf (27 N) pull on the steering wheel, and will be indicated by a pressure reading nearly equal to the system relief pressure (tested in substep 6.2).

7.4 Hold the steering wheel in the full-turn position. Note the steering gear internal leakage on the PSSA.

7.5 Repeat the previous substeps for the opposite turn.

The maximum permissible internal leakage for a single gear is 1.0 gpm (3.8 L/min). If leakage is greater in either turning direction, replace the steering gear components as needed.

For systems with two or more steering gears and/or linear cylinders, the total acceptable internal leakage is 1.0 gpm (3.8 L/min) for each steering gear/ram in the system. Maximum internal leakage on a dual-gear system is 2.0 gpm (7.6 L/min). If the leakage is more than 2.0 gpm (7.6 L/min) on a dual-gear system, isolate the auxiliary cylinder from the system using the substeps that follow.

7.6 Disconnect the auxiliary cylinder hydraulic lines at the main gear auxiliary ports.

7.7 Plug the main steering gear ports with suitable steel or high-pressure plugs or caps.

7.8 Repeat the internal leakage test.

If the internal leakage is less than 1 gpm (3.8 L/min), repair or replace the auxiliary gear or linear cylinder. If the internal leakage is greater than 1 gpm (3.8 L/min), repair or replace the main gear.

8. Check the steering gear poppet relief valve and stop bolt adjustment.

NOTE: Poppets limit the steering assist when the front wheels approach the stop bolts. Improper adjustment can apply excessive force to the steering linkage, or cause loss of assist, as the steering wheel approaches either full-left or full-right turn.

8.1 Check the steering system for stop bolt adjustment.

Make sure the stop bolt settings limit the steering travel so there is ½-inch (13-mm) clearance from all stationary components, and 3/4-inch (19-mm) clearance from all moving components.

8.2 Make sure the pitman arm is situated on the steering gear sector shaft correctly. Check that the pitman arm and sector shaft timing marks are aligned.

NOTICE

If power steering pump relief pressure is reached while the steering wheel is at full lock, release the steering wheel from this position. Do not allow the pump relief pressure to be maintained for longer than five seconds or damage to the pump may result.

8.3 Check the poppet relief pressure.

- Install the PSSA between the steering pump and the steering gear. See the following heading, **Power Steering System Analyzer Setup**, for instructions on PSSA installation.
- Run the engine at idle with the load valve open. Turn the steering wheel to either full-lock position. Note the pressure gauge reading, then repeat for the opposite turn.
- The pressure should drop slightly before the stop bolts are contacted. If the pressure increases (from contact with the stop bolts), the poppets must be manually reset.

  If the pressure is relieved and assist is lost when the wheel is too far from the axle stop bolts, refer to the applicable section in this manual for gear-specific information.
- After poppet replacement or adjustment, test again for correct poppet relief function and record the new pressure.

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8.4 Check for normal hissing sound at full turn.

NOTE: Noise from the power steering system does not necessarily mean there is a problem. Some noises are normal and are the result of proper operation.

See **Table 4** for possible causes and remedies for common noises associated with the power steering system and power steering pump.

8.5 Check for abnormal power steering noise.

Listen for a hissing sound at less than full turn. If a hissing sound is heard, check the steering gear poppet and the axle stop adjustment.

NOTICE

If the temperature exceeds 250°F (121°C), damage to hoses, seals, and other components may result if the vehicle continues to operate at excessive steering system temperatures. If this temperature is exceeded, stop the test and record the last noted temperature on STI-492.

9. Test the system operating temperature.

- Run the engine at governed speed.
- Observe the power steering fluid temperature until it stabilizes.
- Record the power steering fluid temperature in 10-minute intervals until 40 minutes have passed.
- If the temperature does not exceed 250°F (121°C) during the test, excessive heat due to system components is probably not the cause of the complaint. The system may still experience overheating due to driving and load conditions.

  If the temperature exceeds 250°F (121°C), excessive steering system back pressure or excessive pump flow may be the cause of the high temperature problem. If system back pressure or restriction values found in substeps 5.3 and 5.4 above were close to the maximum allowable, complete step 5 again. If steering pump flow and relief pressures found in step 6 above were close to the maximum allowable, complete step 6 again.
- If excessive heat continues to be a problem, a cooler may need to be added to the system.

Power Steering System Noise	
Noise	**Remedy**
Growling or other abnormal steering noise	Check the fluid level. Check for air bubbles and foam. Check for hose and fitting leaks. If there is air in the fluid, check for inlet tube and hose leaks. Correct all leaks.
A change from the usual pump sound	Check the steering fluid reservoir for air bubbles and foam. If there is air in the fluid, check for inlet tube and hose leaks. Correct all leaks.
Clicking noise during a turn	Check for loose steering components. Tighten any loose steering components. Check the front suspension for insufficient spring pin shims. Add front spring pin shims if needed.
Hissing when the steering wheel is at or near full turn	This is normal; no action is needed.
Steering Pump intake line is plugged	Drain the system. Clear the intake line if needed. Fill the system.
Air leak at the pump or reservoir connections, fittings, or shaft seal	Check all the connections by pouring power steering fluid over them, and listening for a reduction in sound. Tighten all connections as needed.
Pump input shaft is misaligned	Replace the pump.

Table 4, Power Steering System Noise

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Troubleshooting Procedures

Power Steering System Analyzer Setup

The hydraulic power steering system is tested with a Power Steering System Analyzer (PSSA), and with the hydraulic fluid at operating temperature. The PSSA and adaptor kit are available from SPX Kent-Moore.

A PSSA is a combination of a flow meter, a shutoff valve, and a high-pressure gauge. See **Fig. 3**. The PSSA will allow you to measure flow and pressure, and provide a load on the pump in the hydraulic lines of the steering system.

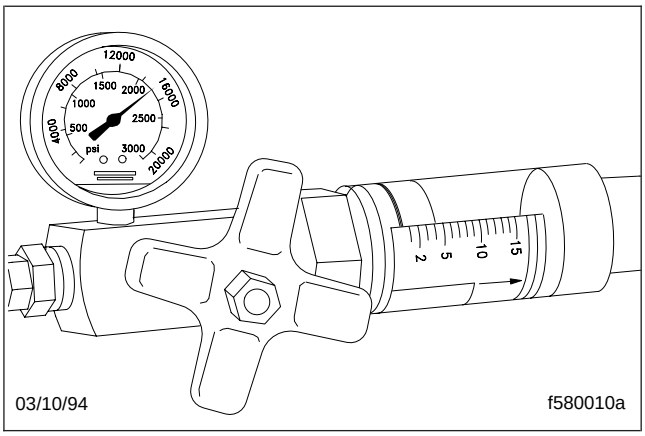


Fig. 3, Power Steering System Analyzer

1. Install a PSSA between the pump high-pressure line and the steering gear.
2. Fill and bleed the steering system as needed.

NOTICE

Do not leave the load valve fully closed for longer than five seconds. Doing so could damage the power steering system.

3. Run the engine at idle.
4. Partially close the load valve on the PSSA until the pressure gauge reads 1000 psi (6895 kPa).
5. Open the valve when the fluid temperature reaches about 180°F (82°C).

Internal Leakage Test Setup, TRW Steering Gears With an Internal PRV

Select TRW steering gears are equipped with an internal PRV that limits maximum supply pressure to protect the steering gear. These gears cannot be tested for internal leakage using the standard procedure. The pump output must be limited to prevent excessive pressure from damaging the gear, and the internal PRV passage must be blocked to direct oil flow through the gear.

Use PartsPro® to determine if a specific TRW steering gear is equipped with an internal PRV, which will be listed as a serviceable part under module 536.

If your TRW steering gear has an internal PRV, complete the following steps to set up the necessary internal leakage test components. See **Table 5** for a list of required leakage test components. The plumbing fittings and hose part numbers are recommended, but may be replaced with identical parts from other suppliers, if necessary.

The ThyssenKrupp rack and pinion steering gear is also equipped with an internal PRV, but cannot currently be tested for internal leakage.

IMPORTANT: The front wheels must be raised or on turnplates during this procedure.

1. Turn the engine off. Remove the relief valve cap, O-ring, and relief valve from the steering gear. See **Fig. 4**.
2. Install the relief valve plug, J-37130, in the internal PRV hole. Install the relief valve cap and O-ring over the plug.
3. Assemble the relief valve cartridge body, relief valve, and tee fittings as shown in **Fig. 4**.
4. Install the PSSA and other test components as shown in **Fig. 4**.
5. Open the external relief valve (**Fig. 4**, Item 15) on the relief valve cartridge. Ensure the PSSA shutoff valve is fully open.
6. Raise the front wheels off the ground and turn the steering wheel to the right and left full-lock positions five times to bleed air from the system.
7. Start the engine and bleed the remaining air out of the system by continuing to turn the wheel from side to side.

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NOTICE

Do not leave the PSSA shutoff valve fully closed for longer than five seconds. Doing so could damage the power steering system.

8. With the engine on, close the shutoff valve on the PSSA.
9. Set the system relief pressure by closing the external relief valve (**Fig. 4**, Item 15) until the gauge on the PSSA reaches 2,000 psi (13 790 kPa), then fully open the shutoff valve on the PSSA.
10. Continue with the steering gear internal leakage test (step 9 of the **Troubleshooting Steps** heading above).

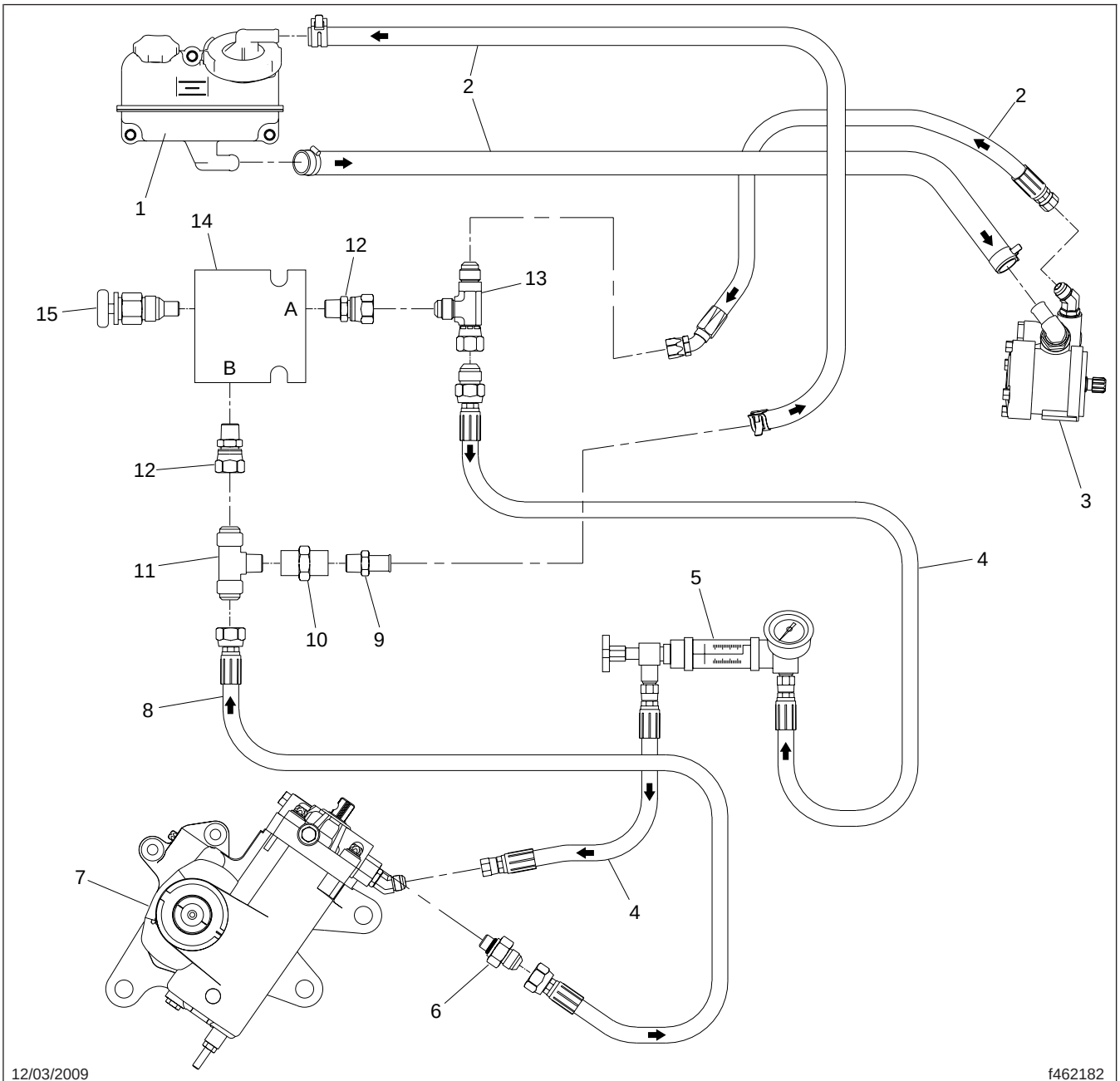
Internal Leakage Test Components			
Part	**Available From**	**Part Number (Vendor P/N)**	**Item #, Fig. 4**
Power Steering System Analyzer (PSSA)	SPX Kent-Moore	J-26487	5
PSSA Adaptor Kit	SPX Kent-Moore	J-28593	—
Relief Valve Plug	SPX Kent-Moore	J-37130	—
Connector, Straight Thread with O-Ring	Daimler Trucks PDC	23-11470-088	6
Power Steering Hose, 42"	Daimler Trucks PDC	14-12694-042	8
Connector, 3/8" Male NPT to 5/8" Beaded Hose Barb	Daimler Trucks PDC	23-11321-001	9
Pipe Coupling, 3/8" NPT	Parker Hannifin	PH 3/8 GG S (3/8 GG-S)	10
Tee, Male JIC with Male NPT Branch*	Parker Hannifin	PH 8STXS (8 STX-S)	11
Swivel Adaptor, 3/8" Male NPT to Female 37 degree JIC (qty 2)	Weatherhead	WH 9100X8X6 (9100x8x6)	12
Swivel Nut Run Tee	Parker Hannifin	PH 8 R6X S (8 R6X-S)	13
3/8" Female NPT Aluminum Relief Valve Threaded Cartridge Body	Parker Hannifin	B10-2-A6P (PH B102A6P)	14
Aluminum Hydraulic Threaded Cartridge Relief Valve with Knob	Parker Hannifin	PH RAH101K30 (RAH101K30)	15

* Use steel 37 degree JIC fittings only.

Table 5, Internal Leakage Test Components

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Troubleshooting Procedures



A. High-Pressure Input Port
B. Low-Pressure Output Port

1. Power Steering Fluid Reservoir
2. Existing Power Steering Fluid Lines (Qty 3)
3. Power Steering Pump
4. PSSA Fluid Lines (Qty 2)
5. PSSA
6. Connector, Straight Thread with O-Ring
7. Power Steering Gear (TAS85 shown)
8. Power Steering Hose, 42"
9. Connector, Male NPT to Beaded Hose Barb
10. Pipe Coupling
11. Tee, Male JIC with Male NPT Branch
12. Swivel Adaptor (Qty 2)
13. Swivel Nut Run Tee
14. Relief Valve Threaded Cartridge Body
15. External Relief Valve, Threaded Cartridge Type

Fig. 4, Internal Leakage Test Component Installation

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General Description

NOTE: Procedures in this section have been slightly modified from the original component manufacturer's service manual. See manufacturer's service literature for additional information.

The TRW TAS85 power steering gear uses pressurized hydraulic fluid to help the driver turn the front wheels. It is an integral hydraulic power steering gear that contains a manual steering mechanism, a hydraulic control valve, and a hydraulic power cylinder.

The pressure required for the steering gear to steer the vehicle is created by the power steering pump to overcome resistance at the steered wheels. The control valve senses these requirements and directs fluid to the appropriate cylinder cavity in the steering gear at the proper flow rate and pressure.

The maximum operating pressure for the TAS85 gear is 2175 psi (14 966 kPa). The maximum flow rate is 8 gpm (30.3 L/min). The recommended minimum flow at 1.5 steering wheel turns per second is 3.9 gpm (14.8 L/min). The TAS85 power steering gear is used for front axle capacities up to 18,000 pounds (8200 kg).

Maximum internal leakage for the TAS85 gear is 1 gpm (3.8 L/min).

Principles of Operation

When the driver turns the steering wheel, that force travels from the steering wheel to the steering gear input shaft. A torsion bar, pinned at one end to the input shaft and at the other end to the worm shaft, turns with the input shaft and exerts a rotational force on the worm shaft. In response to the rotational force exerted by the torsion bar, the worm shaft moves the rack piston forward or backward in the gear housing by means of a series of recirculating balls in the spiral channels of the worm shaft. Grooves in the rack piston mesh with teeth in the sector shaft and, as the piston slides back and forth, it turns the sector shaft. The sector shaft swings the pitman arm. The pitman arm pulls or pushes the drag link, and the drag link moves the axle steering arm, steering the vehicle.

The rack piston's axial movement is resisted by its engagement to the sector shaft, which is linked to the steered wheels. Because of this resistance, the torsion bar activates the control valve, which directs pressurized fluid to the upper or lower cylinder cavity (depending on the direction of turn). The pressurized fluid provides the extra force needed to overcome the resistance from the steered wheels and allows the worm shaft to slide the rack piston in the gear housing.

Most TAS steering gears are equipped with two poppet (unloading) valves, one at each end of the rack piston. As the front wheels reach the axle stop—the farthest the wheels can turn in either direction—one poppet or the other, depending on the direction of the turn, will trip to prevent steering gear damage. The tripped poppet reduces pressure in the gear, heat generated by the power steering fluid pump, and outside forces acting on the steering linkage.

Some TAS steering gears are supplied with a relief valve. The relief valve limits maximum supply pressure to protect the power steering gear, but it does not reduce pressure as the steered wheels approach the axle stops.

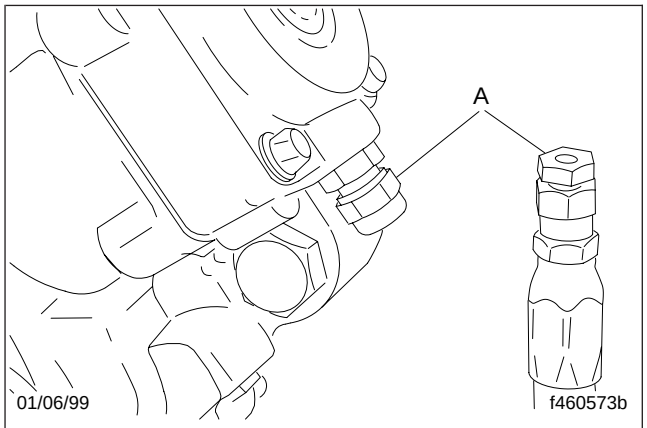
TAS steering gears that are mounted with the sector shaft above the rack piston bore are equipped with an automatic bleed system or a manual bleed screw.

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Input Shaft Seal Replacement

The power steering pump is used in this procedure to force out the input shaft seal. To use this procedure, ensure the power steering pump has a minimum of 1500 psi (10 342 kPa) available.

1. Apply the parking brakes and chock the tires.
2. Disconnect the return line from the steering gear and plug the line. See **Fig. 1**. Cap the return port of the gear with a high-pressure fitting.



A. Cap the return line and the return port.

Fig. 1, Disconnected Return Line

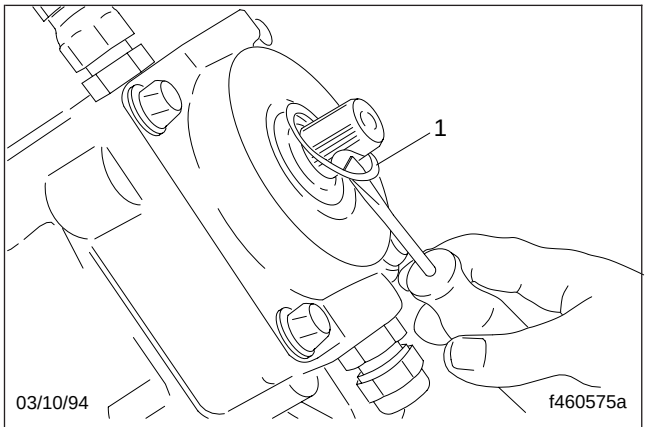
3. Disconnect the steering driveline from the steering gear input shaft as follows.

   3.1 Remove and discard the pinch bolt and nut from the steering driveline lower end yoke.

   Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

   3.2 Remove the lower end yoke from the input shaft. Do not turn the steering gear input shaft when removing the lower end yoke. Push the driveline shaft into the driveline tube as you remove the lower end yoke.

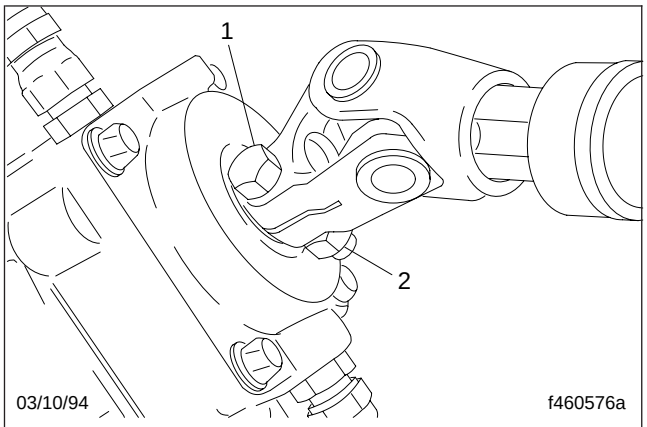
4. Remove the dirt and water seal from the steering gear. Save this seal to determine the correct size of the new seal.
5. Wipe out the grease, then remove the spiral retaining ring using a screwdriver inserted into the notch formed in the end of the ring. See **Fig. 2**. Do not scratch the bore with the screwdriver.



1. Retaining Ring

Fig. 2, Retaining Ring Removal

6. Slip the input yoke back on the input shaft, then insert but do not tighten the pinch bolt. See **Fig. 3**.



1. Pinch Bolt 2. Pinch Bolt Nut

Fig. 3, Pinch Bolt Installation

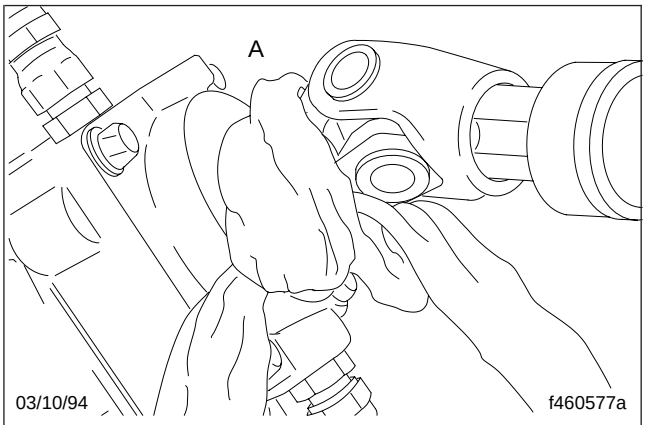
7. Tie or wrap a shop towel around the input shaft area and place a drip pan under the vehicle to catch the oil. See **Fig. 4**.

WARNING

Fill the power steering reservoir with approved, clean fluid only. Do not mix automatic transmission fluid types. If you are changing fluid types,

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On-Vehicle Adjustments

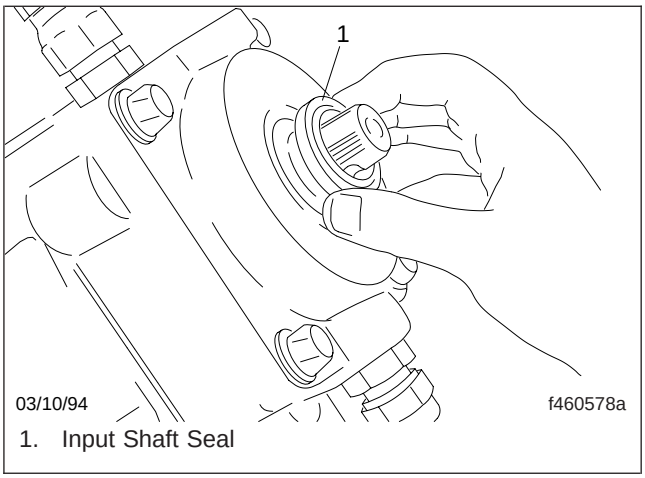


A. Cover the input shaft area.

Fig. 4, Shop Towel Covering the Input Shaft

completely flush the steering system with the fluid type being added. Any mixture or any unapproved fluid could lead to seal deterioration and leaks. Any fluid leak could eventually cause loss of power steering assist, which could cause personal injury and property damage.

8. Fill the power steering reservoir to the full line on the reservoir dipstick. For approved hydraulic fluids, see **Specifications 400**.
9. With the vehicle in neutral, briefly turn the starter without allowing the engine to start. If the engine starts, shut it down immediately. This should force out the input shaft seal.
10. Remove the shop towel, pinch bolt, and input yoke. Remove the input shaft seal. See **Fig. 5**.

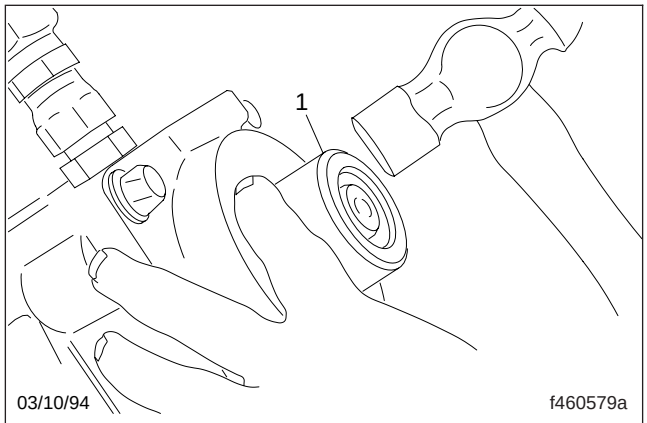


1. Input Shaft Seal

Fig. 5, Input Shaft Seal Removal

11. Inspect the seal area of the valve housing for seal fragments. Remove any seal fragments.

    Check the seal for heat damage. If the seal is stiff and brittle, and not pliable like the new seal, it is probably heat damaged. Determine and fix the cause of any excessive heat in the vehicle. Discard the old seal.
12. Put clean grease on the new input shaft seal, then place the seal over the input shaft, garter spring side first.
13. Place seal installer tool J37073 over the input shaft and against the seal, small diameter end first. See **Fig. 6**. Tap the seal installer tool with a hammer until the tool shoulder is square against the valve housing. Remove any seal material that may have sheared off in the seal bore or retaining ring groove.



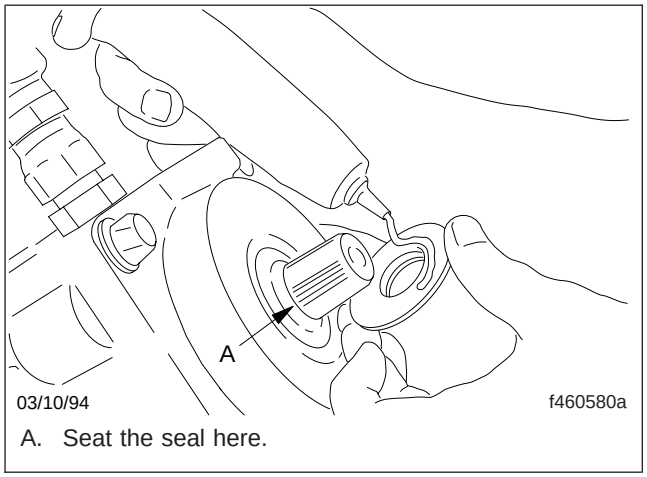
1. Seal Installer Tool

Fig. 6, Seal Installer Tool Position

14. Install the new retaining ring into the groove.
15. Pack the end of the valve housing bore and around the input shaft with clean grease. Apply more of the grease to a new dirt and water seal and install the seal over the input shaft. See **Fig. 7**. Seat it in the groove behind the serrations and against the valve housing.

    Wipe any excess grease from the valve housing bore and input shaft once the seal has been installed.
16. Connect the steering driveline to the steering gear input shaft, as follows.

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A. Seat the seal here.

Fig. 7, Dirt and Water Seal Installation

16.1 Clean the input shaft and the inside of the driveline yoke.

16.2 Apply a thin film of grease to the yoke splines.

16.3 Slide the yoke on the input shaft and install a new pinch bolt and nut. Tighten the nut 30 to 35 lbf·ft (41 to 47 N·m).

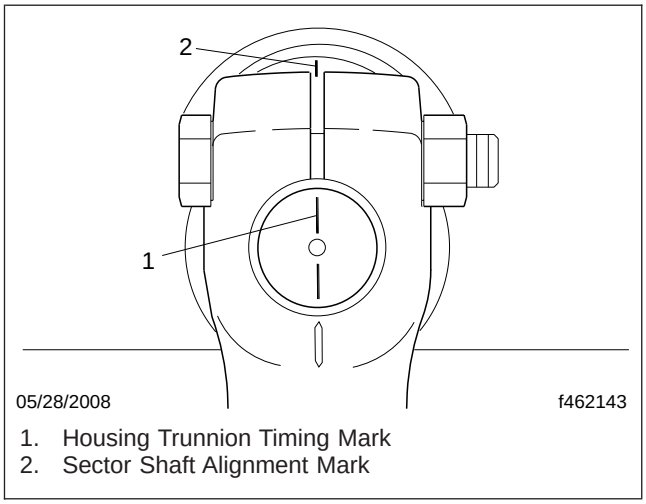
16.4 Apply Torque Seal to the exposed bolt threads and to the nut.

17. Connect the return line to the steering gear return port.
18. Fill and air bleed the steering system. For instructions, see **Subject 120**.
19. Perform the post-service checks in **Subject 130**.

Sector Shaft Adjustment

The sector shaft adjustment can only be completed if the adjusting screw jam nut is accessible when the steering gear is attached to the frame rail, otherwise the steering gear must be removed. The jam nut is located on the side cover.

1. Apply the parking brakes and chock the tires.
2. With the engine on, turn the steering wheel until the timing mark on the sector shaft lines up with the timing mark on the end of the housing trunnion. The line on the sector shaft should be at a 90-degree angle to the input shaft centerline. See **Fig. 8**.



1. Housing Trunnion Timing Mark
2. Sector Shaft Alignment Mark

Fig. 8, Timing Mark Placement

3. Turn the engine off.
4. Remove the cotter pin and castle nut that attach the drag link to the pitman arm. Remove the drag link from the pitman arm.

IMPORTANT: To avoid resetting the poppets, do not turn the input shaft more than 1-1/2 turns from the center-of-travel position while the drag link is disconnected.

5. With the sector shaft in the center position, grasp the pitman arm and gently try to move it back and forth. Finger pressure is adequate to detect lash (free play) of a loose sector shaft. See **Fig. 9**. If the pitman arm is loose, or lash is detected, the sector shaft is out of adjustment.
6. Loosen the sector shaft adjusting screw jam nut. If no lash was detected, turn the shaft adjusting screw counterclockwise until lash is detected. See **Fig. 10**, Item 52.
7. Slowly turn the adjusting screw clockwise until no lash is felt at the pitman arm. Use no more than 10 lbf·ft (14 N·m) of torque.

   From this position, slowly turn the adjusting screw clockwise 1/8 to 3/16 of a turn more. Hold the adjusting screw in place and tighten the jam nut 43 lbf·ft (58 N·m).
8. Turn the steering wheel 1/4 of a turn to each side of center and recheck the pitman arm for lash. You should detect no lash. If lash exists, adjust the sector shaft again.

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On-Vehicle Adjustments

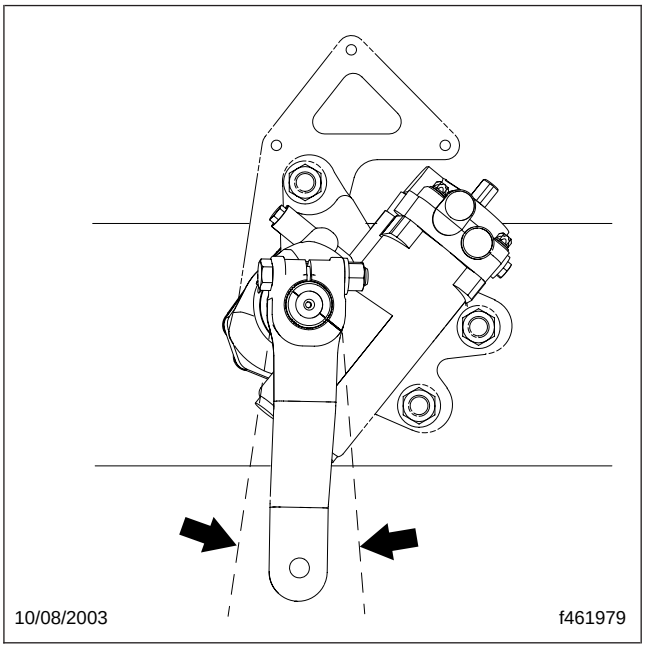


Fig. 9, Lash Check

9. Connect the drag link to the pitman arm.
10. Perform the post-service checks in **Subject 130**.

Poppet Adjustment

The TAS85 steering gear has automatic poppet valves that reset themselves if the axle stops are reset for increased steering travel. However, if the axle stops are reset for **decreased** steering travel, the poppet valves must be reset manually using a special service poppet adjusting screw and sealing jam nut kit.

Use the following procedure to manually reset the poppet valves.

1. Verify that the axle stops are adjusted to the specifications in **Group 33**.

IMPORTANT: The axle stops must be set so that there are at least 1-3/4 steering wheel turns from a straight-ahead position to both a full-left and a full-right turn; otherwise the poppet valves will not work.

2. Start the engine and allow the vehicle to idle to warm the hydraulic fluid.
3. Shut down the engine, apply the parking brakes, and chock the tires.
4. If a new poppet adjusting screw and nut are being used, turn the screw into the nonsealing end of the nut until the drive end of the screw is flush with the nut.

NOTE: The steering gear will have either a poppet fixed stop screw or a poppet adjusting screw. If the adjusting screw is already part of the steering gear, back the nut off of the adjusting screw until it is flush with the end of the adjusting screw.

5. Make sure that the engine is off and the wheels are in the straight-ahead position.
6. Remove the fixed stop screw and washer, or the poppet adjusting screw and sealing nut, and discard both items.

NOTICE

Make sure the drive end of the adjusting screw is not below the face of the nut. If the drive end of the adjusting screw is below the face of the nut, the poppet seat flange will break when the upper poppet is prepared for setting.

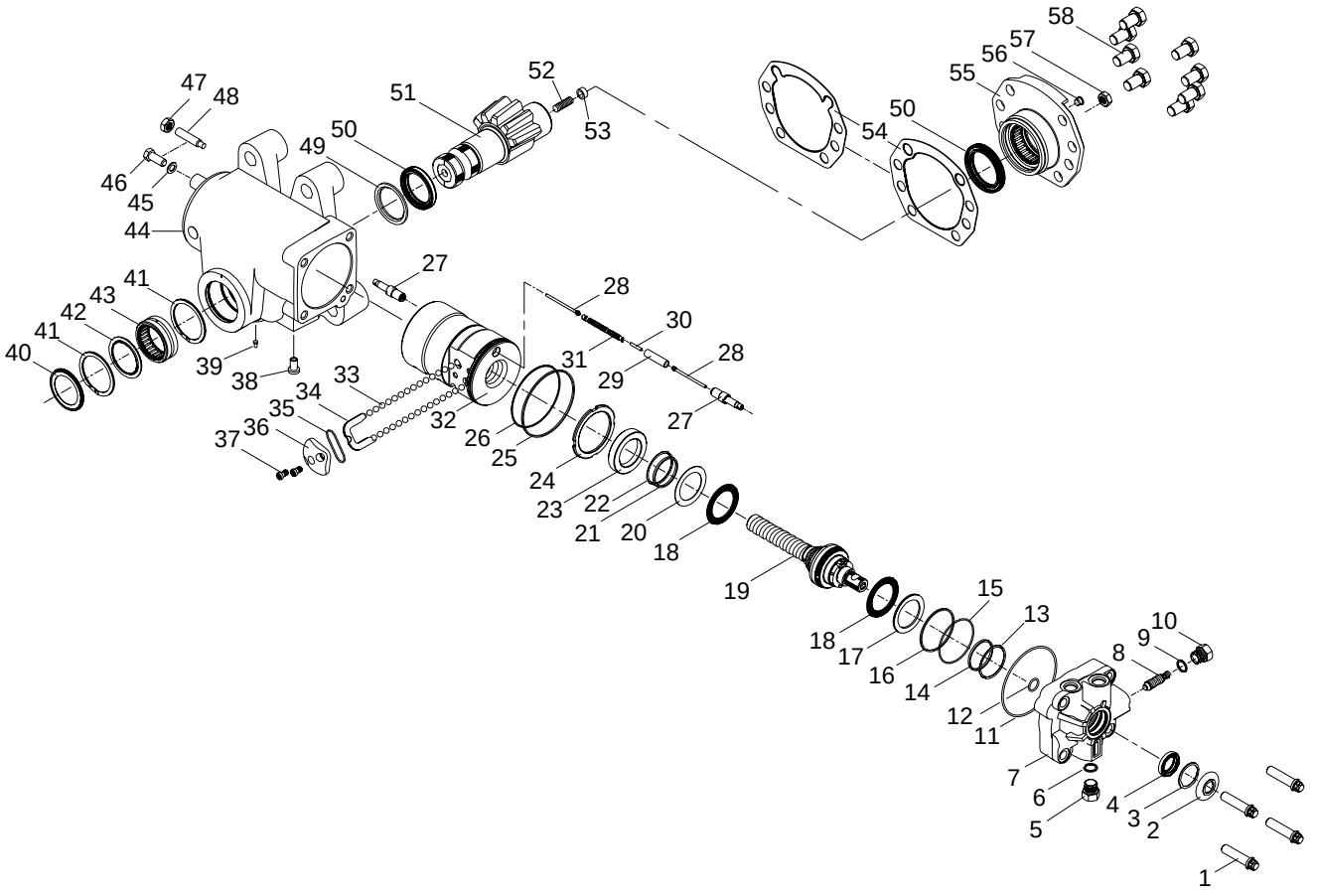
7. Using a wrench, turn the adjusting screw and nut assembly (without turning the nut on the screw) into the housing until the nut is firmly against the housing. Tighten the nut against the housing. See **Fig. 11**.

WARNING

Fill the power steering reservoir with approved, clean fluid only. Do not mix automatic transmission fluid types. If you are changing fluid types, completely flush the steering system with the fluid type being added. Any mixture or any unapproved fluid could lead to seal deterioration and leaks. Any fluid leak could eventually cause loss of power steering assist, which could cause personal injury and property damage.

8. Fill the power steering reservoir to the full line on the reservoir dipstick. For approved hydraulic fluids, see **Specifications 400**.
9. Place a jack under the center of the front axle and jack up the front of the vehicle so the steer axle tires are off the ground.

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1. Bolts, Valve Housing
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Auxiliary Port Plug
6. O-Ring, Auxiliary Port Plug
7. Valve Housing
8. Relief Valve
9. O-Ring, Relief Valve
10. Relief Valve Cap
11. Seal Ring, Large
12. Seal Ring, Small
13. Seal Ring
14. O-Ring
15. Seal Ring
16. O-Ring, Valve Housing
17. Thrust Washer, Thick
18. Roller Thrust Bearing
19. Input Shaft/Valve/Worm Assembly
20. Thrust Washer, Thin
21. Seal Ring
22. O-Ring
23. Bearing Adjuster
24. Adjuster Locknut
25. Seal Ring, Rack Piston
26. O-Ring, Backup
27. Poppet Adjuster Seat and Sleeve Assembly
28. Poppet
29. Push Tube
30. Spacer Rod
31. Poppet Spring
32. Rack Piston
33. Steel Balls
34. Ball Return Guide Halves
35. Seal, Ball Return Guide Cap
36. Ball Return Guide Cap
37. Torx® Screws
38. Plug, Auto-Bleed
39. Grease Fitting
40. Dirt and Water Seal, Trunnion
41. Retaining Ring
42. Dirt Seal
43. Roller Bearing
44. Gear Housing
45. Washer, Stopscrew
46. Fixed Stop Screw, Poppet
47. Service Sealing Jam Nut
48. Service Poppet Adjusting Screw
49. Washer, Spacer
50. Output Seal
51. Sector Shaft
52. Adjusting Screw, Shaft
53. Retainer, Adjusting Screw
54. Gasket, Side Cover
55. Side Cover and Bushing/Bearing Assembly
56. Vent Plug, Side Cover
57. Jam Nut
58. Special Bolts, Side Cover

Fig. 10, TRW TAS85 Power Steering Gear Components

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On-Vehicle Adjustments

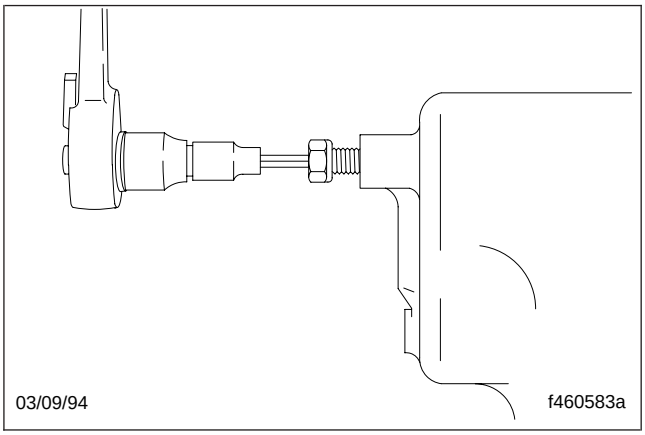


Fig. 11, Adjusting Screw and Nut Assembly

NOTICE

Do not hold the steering wheel at full turn for more than ten seconds at a time. The heat buildup at pump relief pressure may damage components.

10. Push the upper poppet out to prepare it for setting, as follows.
    - 10.1 Start the engine and let it idle.
    - 10.2 Note which sector shaft timing mark is nearest the housing piston bore.
    - 10.3 Turn the steering wheel in the direction that makes the timing mark move toward the adjusting screw just installed. Turn the steering wheel in this direction until contact is made with the axle stop.
    - 10.4 Pull hard on the steering wheel. Put up to 40 lbf (178 N) pull on a 20-inch diameter steering wheel after contacting the axle stop.
11. Set the upper poppet, as follows.
    - 11.1 Turn the steering wheel in the opposite direction (the timing mark should move away from the adjusting screw) until the other axle stop is contacted.
    - 11.2 Pull hard on the steering wheel. Put up to 40 lbf (178 N) pull on a 20-inch diameter steering wheel.
    - 11.3 Release the steering wheel and shut off the engine.
12. Loosen the sealing nut and back out the adjusting screw until the adjusting screw is 1 in (2.5 cm) past the nut; see **Fig. 12**. Tighten the nut against the housing.

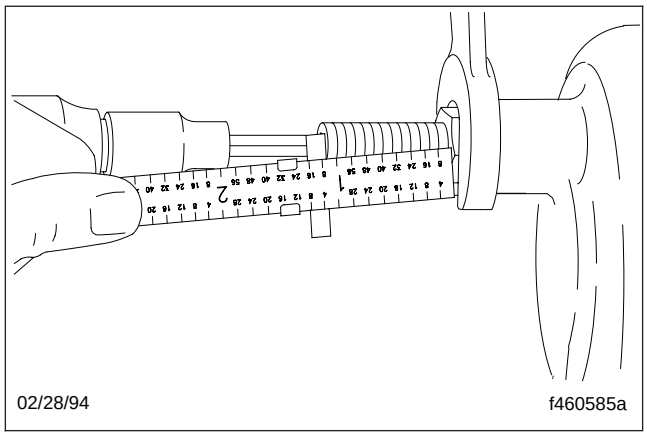


Fig. 12, Adjusting Screw Position

13. Set the lower poppet, as follows.
    - 13.1 Start the engine and let it idle.
    - 13.2 Turn the steering wheel in the original direction (the end of the timing mark will move toward the adjusting screw) until contact is made with the axle stop.
    - 13.3 Hold the steering wheel in this position with up to 40 lbf (178 N) pull for ten seconds, then release. Repeat this hold-and-release process as many times as necessary while completing the next step.
14. Position the adjusting screw, as follows.
    - 14.1 With the steering wheel held tightly at full turn, loosen the nut and hold it in place with a wrench.
    - 14.2 Using a wrench and finger pressure only, turn the adjusting screw clockwise until the wrench stops. Do not attempt to turn the adjusting screw any farther. Pause the turning-in process each time the driver releases the steering wheel. Continue turning only while the steering wheel is held at full turn.
    - 14.3 Back off the adjusting screw 3-1/4 turns and tighten the nut 35 lbf·ft (47 N·m).

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⚠ WARNING

If the adjusting screw protrudes more than 1-1/16 inches (27 mm) from the sealing nut, the screw could fall out of the steering gear, resulting in loss of power steering. This could cause an accident resulting in serious personal injury or property damage.

NOTE: The length of the adjusting screw beyond the nut must not exceed 1-1/16 inches (27 mm).

15. Check the power steering reservoir and fill if necessary.
16. Lower the vehicle.
17. Perform the post-service checks in **Subject 130**.

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Removal

1. Park the vehicle with the steer tires in the straight-ahead position. Shut down the engine.
2. Apply the parking brakes, chock the tires, and disconnect the batteries.
3. Clean all outside dirt from around the fittings and hose connections.
4. Drain the fluid from the power steering system. Disconnect all hydraulic lines from the gear, marking the lines for later installation reference. Seal the lines and the fittings to keep out dirt.
5. Disconnect the pitman arm from the steering gear sector shaft, as follows.
   - 5.1 Remove and discard the pinch bolt, washer, and nut from the pitman arm.
   - 5.2 Remove the pitman arm using a suitable puller, then swing the pitman arm and drag link out of the way.
6. Disconnect the steering driveline from the steering gear input shaft, as follows.
   - 6.1 Remove and discard the pinch bolt and nut from the steering driveline lower end yoke.

NOTICE

Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

- 6.2 Remove the lower end yoke from the input shaft.

⚠ WARNING

The steering gear is heavy. Use caution when removing, lifting, or carrying the steering gear. Failure to do so could cause personal injury.

7. Remove the fasteners that attach the steering gear to the frame rail. Remove the steering gear.

Installation

1. Verify correct axle stop adjustment. For instructions, refer to **Group 33**. Ensuring correct axle stop adjustment now will eliminate the need to reset the steering gear poppet valves after the gear is installed.
2. Install the steering gear and fasteners as shown in **Fig. 1**. Tighten the fasteners 427 lbf·ft (579 N·m).

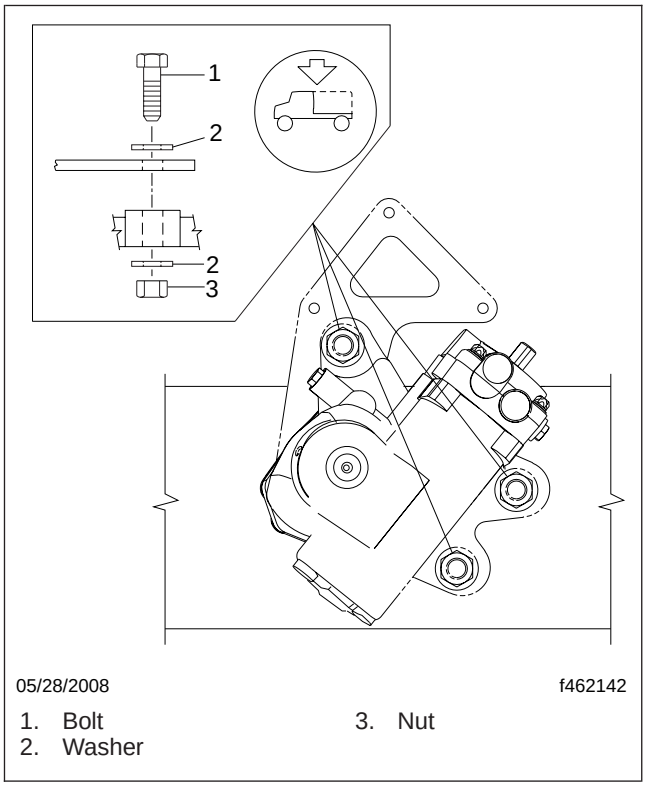


Fig. 1, Steering Gear Installation

3. If not previously done, center the steering gear. The sector shaft alignment mark must be at a right angle to the steering gear input shaft centerline. Make sure the steering gear remains centered as work continues.
4. Connect the steering driveline to the steering gear input shaft, as follows.
   - 4.1 Clean the steering gear input shaft and the inside of the driveline yoke.
   - 4.2 Apply a thin film of grease to the yoke spline.
   - 4.3 Slide the yoke on the input shaft and install a new pinch bolt and nut. Tighten the nut 30 to 35 lbf·ft (41 to 47 N·m).

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Removal and Installation

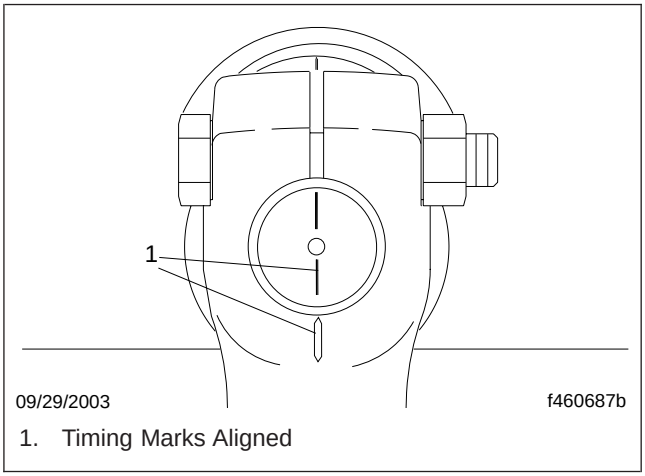
4.4 Apply Torque Seal to the exposed bolt threads and to the nut.

⚠ WARNING

Never leave a chisel wedged in the pitman arm slot. When using a chisel to spread the slot in the pitman arm, maintain a firm grip on the chisel at all times. Otherwise the chisel may fly loose, which could cause an injury.

5. Install the pitman arm, as follows.

   5.1 Position the pitman arm on the steering gear, aligning the timing mark as shown in **Fig. 2**.



1. Timing Marks Aligned

Fig. 2, Typical Pitman Arm and Timing Marks

NOTE: The pitman arm may not fit over the splines on the sector shaft without spreading the slot in the arm. Use a ball-peen hammer to drive a chisel into the slot. Hold the chisel in place. Install the pitman arm on the sector shaft. Remove the chisel from the slot.

   5.2 Install a new pinch bolt, washer, and nut. Tighten the nut 200 to 230 lbf·ft (272 to 313 N·m).

   5.3 Apply Torque Seal to the exposed bolt threads and to the nut.

6. If they were removed, attach the hydraulic line fittings to the steering gear. Tighten the fittings 38 lbf·ft (52 N·m). Tighten the pressure line fitting jam nut 41 lbf·ft (56 N·m).
7. Remove the plugs from the hydraulic lines. Connect the lines to the steering gear as previously marked. Tighten the nut on each fitting finger tight. Then, use a wrench to tighten the nut until there is firm resistance. Tighten one-sixth turn more.
8. Connect the batteries.
9. Fill and bleed the steering system. For instructions, see **Subject 120**.
10. Perform the post-service checks in **Subject 130**.

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Filling and Air Bleeding the System

1. Verify that the poppets are adjusted correctly.

⚠ WARNING

Fill the power steering reservoir with approved, clean fluid only. Do not mix automatic transmission fluid types. If you are changing fluid types, completely flush the steering system with the fluid type being added. Any mixture or any unapproved fluid could lead to seal deterioration and leaks. Any fluid leak could eventually cause loss of power steering assist, which could cause personal injury and property damage.

2. Fill the power steering reservoir with the steering fluid specified in **Specifications 400** until nearly full.

   Start and run the engine for ten seconds, then shut it off. Check and, if necessary, refill the reservoir.

3. Start the engine and let it idle for two minutes. Shut down the engine, then check and, if necessary, refill the reservoir.

4. Start the engine again. Steer the vehicle from full left to full right several times. Check and, if necessary, refill the reservoir.

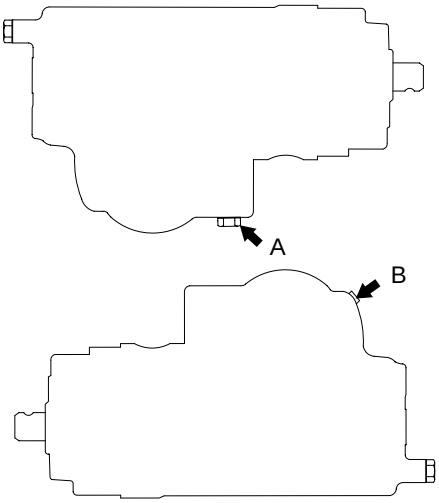
   Automatic bleed systems should now be free from trapped air. Proceed with the next step for manual bleed systems, see **Fig. 1**

IMPORTANT: Do not turn the steering wheel with the manual bleed screw loosened. Doing so can cause air to enter the system, which can make it more difficult and time-consuming to bleed air from the system.

5. Allow the engine to idle. Loosen the manual bleed screw one turn. Allow air and aerated fluid to bleed out until only clear fluid is seen. Tighten the manual bleed screw.

   Check and, if necessary, refill the reservoir. Repeat this step three or four times, each time checking and filling the reservoir, until the air is discharged.

6. Tighten the manual bleed screw 45 lbf·in (500 N·cm).



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A. Steering gear with automatic bleed plug. Do not remove the bleed plug.
B. Steering gear with manual bleed plug.

Fig. 1, Steering Gears With Bleed Systems

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Post-Service Checks

After power steering components have been worked on and before the vehicle is placed into service, the following items must be checked.

⚠ WARNING

Failure to make the following checks could result in damage to the power steering system. This could cause a loss of hydraulic assist, which could cause personal injury or property damage.

1. With the engine turned off and warm, check the power steering reservoir fluid level.
2. Check for air in the system, as follows.
   - 2.1 Place a thermometer in the power steering reservoir. Then warm the hydraulic system to normal operating temperature of 125 to 135°F (51 to 57°C) by operating the engine at low idle while turning the steering wheel through several full left and right turns.
   - 2.2 With the engine running and the power steering system at operating temperature, turn the steering wheel slowly from stop to stop while checking the power steering reservoir for frothing or a change in the fluid level (a sign that air is trapped in the system). If air is present, inspect the system for leaking hoses or loose fittings. Replace the hoses or tighten the fittings as needed. Bleed the air from the system.
3. At full-left and full-right wheel cuts, be sure the axle stops (on the rear-side of the spindle) are set so there is at least 1/2-inch (13-mm) clearance between the tires and any fixed components that are attached to the vehicle. Clearance between moving components should be 3/4-inch (19 mm). If clearance is less than this, reset the axle stops.
4. Check that the poppets are set correctly. If necessary, adjust them. For instructions, see **Subject 100**.
5. Test drive the vehicle and check the steering wheel spoke position.

   With the front tires pointing straight ahead, check the position of the steering wheel spokes. The spokes on a two-spoke steering wheel should be within ±10 degrees of the 8o'clock and 4o'clock positions. If not, remove the steering wheel and install it in the correct position. See **Fig. 1**.

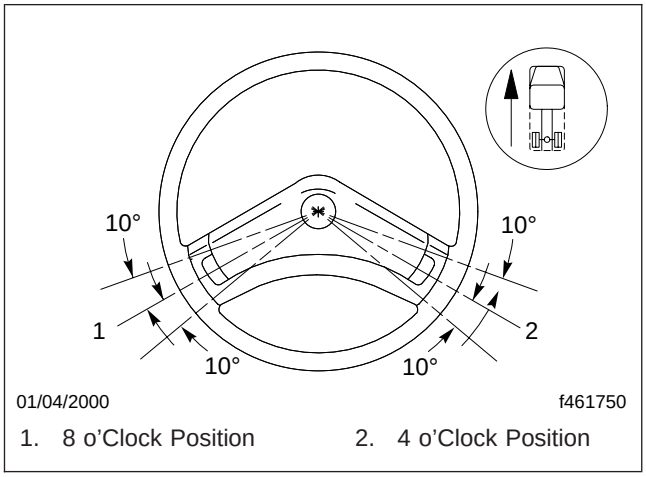


Fig. 1, Two-Spoke Steering Wheel Centered

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Exxon Polyrex® EP2 Grease (045422) is approved for use on steering gear components.

⚠ WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. A fluid leak could eventually cause loss of power steering assist.

TRW TAS85 power steering gears use ATF fluid that meets Dexron III or TES-389 specifications.

Special tools can be ordered from:

SPX Kent-Moore
28635 Mount Road
Warren, Michigan 48092-3499
1-800-328-6657

SPX Kent-Moore Tools	
Tool	**Part Number**
Bearing Adjuster Tool	J37070
Poppet Adjuster Seat Tool	J36452
Seal Installer Tool	J37073

Table 1, SPX Kent-Moore Tools

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General Information

The fuel system delivers fuel from the fuel tanks to the engine. It consists of the engine fuel system components, the fuel tank(s) and tank mounting components, and the fuel lines and (if so equipped) shut-off valve.

The engine fuel system components include fuel filters, injectors, fuel transfer pumps, and a fuel governor. For service and maintenance procedures, refer to the applicable engine manufacturer's service and maintenance manuals.

The fuel tanks are held in place by metal straps and brackets that transfer the load to the vehicle frame. On some installations, cab-access and chassis-access step assemblies attach to the fuel tanks and tank brackets.

Fuel suction and return lines made of reinforced braided-fabric or reinforced nylon tubing bring fuel from the tank to the engine and return surplus fuel from the engine to the tank.

The EquiFlo® inboard fuel system is standard equipment. See **Fig. 1**. This system consists of inboard-routed fuel lines, with the suction and return lines installed in a common opening of the fuel tank(s), a quarter-turn, non-vented fuel cap, and shut-off valves (when so equipped) located on top of the transmission. The fuel tank vent and line are located on the top of the tank.

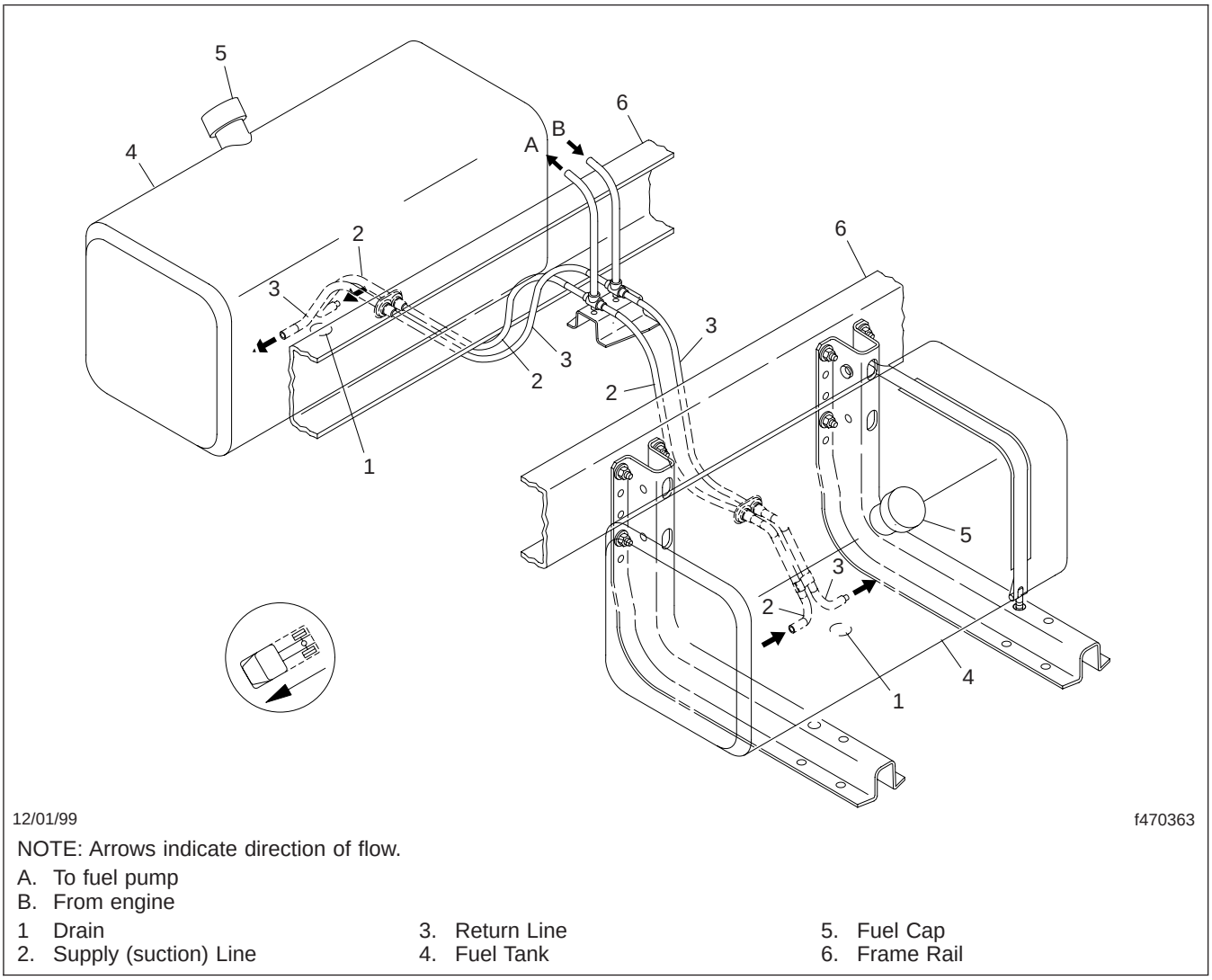
The fuel lines are routed inboard of the frame rails and upward to a point on the transmission where the shut-off valves (if so equipped) are located.

Fuel is drawn equally from, and returned to, each tank, so that their levels stay equal. The suction and return fuel lines, although entering the fuel tank via the same opening, are designed to direct the fuel flow to the bottom of the tank. This ensures thorough mixing of the fuel before it is drawn up by the suction line, so that vapor can disperse, and (on electronic engines only) warm fuel is not recirculated.

Standard equipment includes a fuel level gauge sender in the primary tank, with an electric fuel level gauge mounted in the cab instrument panel.

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General Information



NOTE: Arrows indicate direction of flow.

A. To fuel pump
B. From engine

1 Drain
2. Supply (suction) Line
3. Return Line
4. Fuel Tank
5. Fuel Cap
6. Frame Rail

Fig. 1, EquiFlo Inboard Fuel System

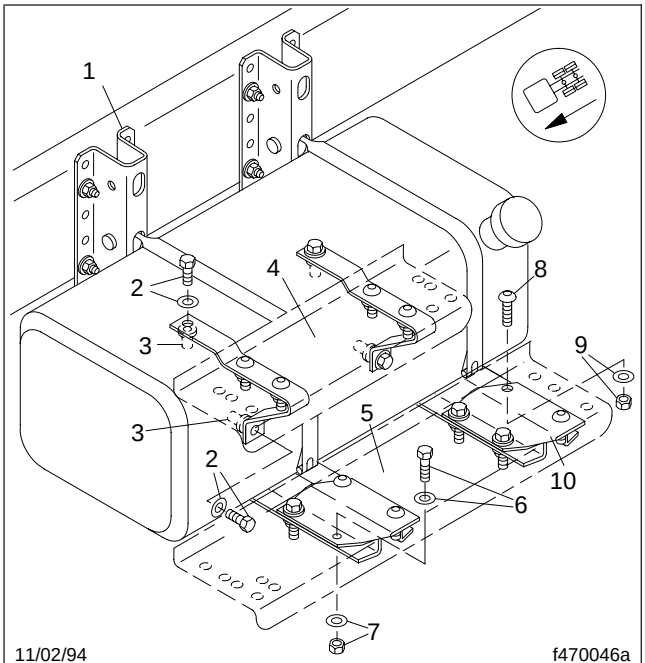
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Tank-Mounted Step Assembly Removal and Installation

Removal

Cab-Access Step

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. To remove a *single-level* step, or the *lower step* of a *dual-level* installation, remove the locknuts, bearing washers, and capscrews that attach the bottom of the step brackets to the fuel tank brackets. Remove the step. See **Fig. 1**.



NOTE: Left-side 30-gallon fuel tank shown.

1. Fuel Tank Bracket
2. 3/8-16 Capscrew and Bearing Washer
3. 3/8-16 Sealed Weldnut
4. Upper Step Assembly
5. Lower Step Assembly
6. 3/8-16 Capscrew and Bearing Washer
7. Bearing Washer and 3/8-16 Locknut
8. Inboard Button-Head Capscrew
9. Bearing Washer and 1/4-20 Locknut
10. Outboard Button-Head Capscrew, Bearing Washer and Locknut

Fig. 1, Tank-Mounted Cab-Access Step Installation (dual-level steps shown)

3. To remove the lower step from a 45-gallon *long* fuel tank, remove the *inboard* button-head capscrews, bearing washers, and locknuts that attach the step and step brackets to the fuel tank brackets. Do not remove the outboard fasteners that attach the step to the step brackets. Remove the step.
4. To remove the *upper step* of a *dual-level* installation, remove the capscrews and bearing washers that attach the step brackets to the sealed weldnuts on the fuel tank. Remove the step.

Chassis-Access Step

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the capscrews and bearing washers that attach the step clamps to the top of the fuel tank. See **Fig. 2**.
3. Remove the step. Remove the step clamps and fasteners from the step.

Installation

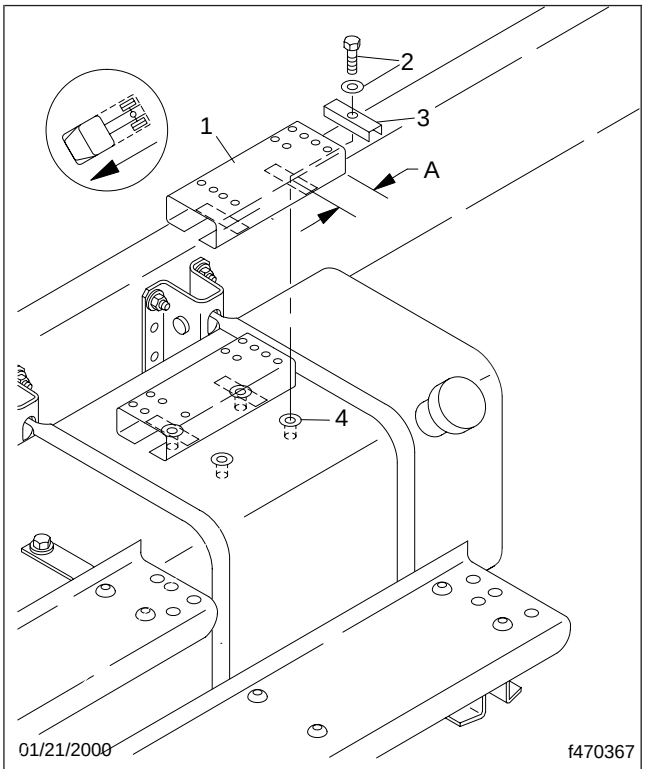
Cab-Access Step

NOTE: The procedures below are for step *assemblies*; if the step and its brackets have been disassembled, use the procedures below to install the brackets. See **Fig. 3** or **Fig. 4** to position the step on the brackets.

1. To install a *single-level* step, or the *lower step* of a *dual-level* installation, on the right-side of the vehicle, position the step brackets against the rear flanges of the outboard ends of the fuel tank brackets; on the left-side of the vehicle, position the step brackets against the front flanges of the fuel tank brackets.
2. Install the capscrews, bearing washers and locknuts that attach the step brackets to the tank brackets. Tighten the locknuts 28 lbf·ft (38 N·m).
3. For a lower step on a 45-gallon long fuel tank, install the inboard button-head capscrews, bearing washers and locknuts. Tighten the locknuts 7 lbf·ft (10 N·m).
4. To install the *upper step* of a *dual-level* installation, align the fastener holes of the upper step

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Tank-Mounted Step Assembly Removal and Installation



NOTE: Used on left-side 45-gallon long and left-side 75-gallon fuel tanks only. 75-gallon tank shown.

A. 2-23/32 ± 3/16 inches (69 ± 5 mm)

1. Chassis-Access Step
2. 3/8–16 Capscrew and Bearing Washer
3. Step Clamp
4. 3/8–16 Sealed Weldnut

Fig. 2, Tank-Mounted Chassis-Access Step Installation

brackets with the sealed weldnuts on the top and outboard side of the fuel tank.

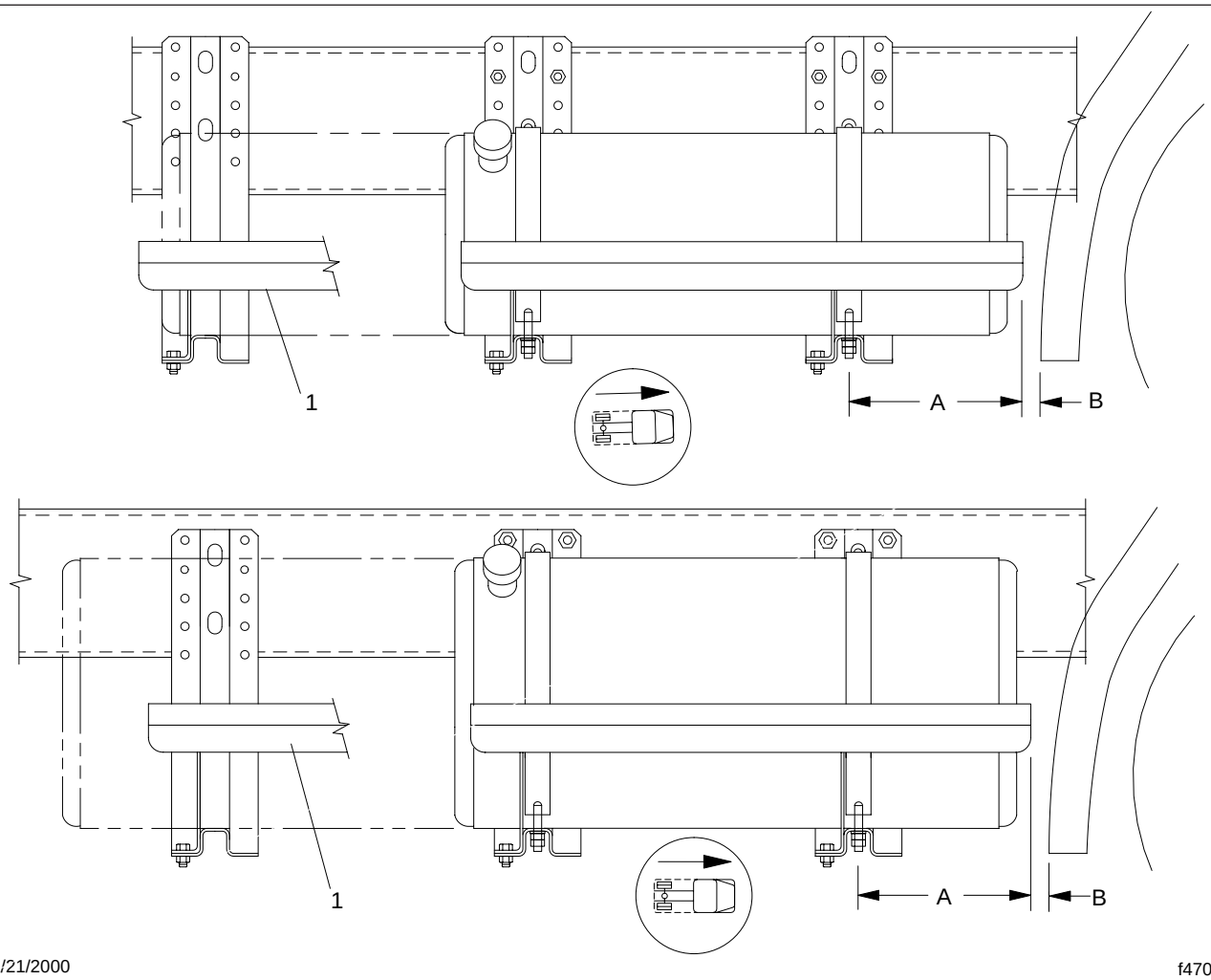
5. Install the capscrews and bearing washers that attach the step brackets to the fuel tank. Tighten the capscrews 26 lbf·ft (35 N·m).
6. Remove the chocks from the rear tires.

Chassis-Access Step

1. Install the step clamps, capscrews, and bearing washers on the fuel tank; leave the fasteners loose. Turn the step clamps so they point to the front and rear of the truck (parallel to the frame rail). See **Fig. 2**.
2. Install the step on the fuel tank so the distance from the rear of the step to the center of the step clamp is 2-23/32 ± 3/16 inches (69 ± 5 mm).
3. Turn the step clamps so they point from side to side, and the ends are positioned over both bottom flanges of the step.
4. Tighten the step clamp capscrews 26 lbf·ft (35 N·m).
5. Remove the chocks from the rear tires.

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Tank-Mounted Step Assembly Removal and Installation



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NOTE: Right-side fuel tanks and steps shown; left-side fuel tanks and steps are opposite.

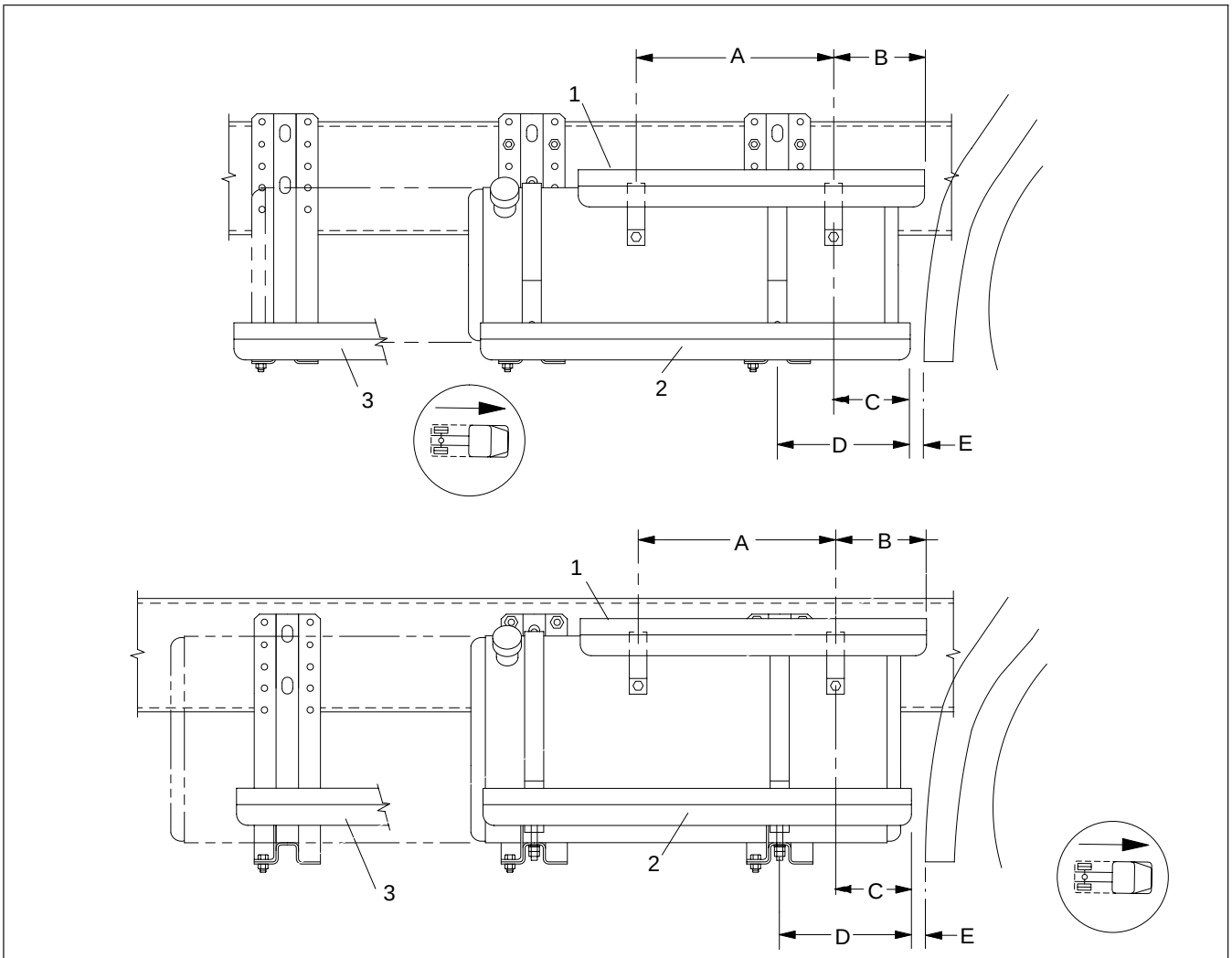
A. 11-13/32 inches (290 mm)
B. 29/32 inches (23 mm)

1. Left-Side Only

Fig. 3, Single-Level Cab-Access Step Positioning

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Tank-Mounted Step Assembly Removal and Installation



01/21/2000 f470365

NOTE: Right-side fuel tanks and steps shown; left-side fuel tanks and steps are opposite.

A. 16-1/4 inches (412.5 mm)
B. 7-3/4 inches (197.2 mm)
C. 6-57/64 inches (175 mm)
D. 11-7/16 inches (290.5 mm)
E. 59/64 inches (23.5 mm)

1. Upper Step
2. Lower Step
3. Left-Side Only

Fig. 4, Dual-Level Cab-Access Step Positioning

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Fuel Tank Removal and Installation

Removal

WARNING

Damaged fuel tanks must be replaced. A repaired fuel tank will not meet the strength, leakage, and venting standards required by U.S. federal regulations for original and replacement fuel tanks. A repaired fuel tank may be more likely to spill fuel or be ruptured in a vehicle accident, which could lead to personal injury or property damage.

If a damaged tank is found, use the following procedure (see **Fig. 1**):

1. Park the vehicle on level ground. Apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the cab-access step(s). For instructions, see **Subject 100**.

WARNING

Do not drain fuel near, or expose fuel vapor to, open flame or intense heat. To do so is a dangerous practice, which would create a hazardous work area. This could lead to personal injury or property damage.

3. Place a suitable container under the fuel tank and remove the drain plug.

   If the fuel is to be re-used, store it in a clean container to protect it from contaminants.
4. Disconnect the fuel return and suction lines from the tank. Cap the lines to prevent fuel spillage.
5. If removing a single or primary tank, disconnect the electrical connector from the fuel level gauge sender.
6. Remove the tank straps and isolators. See **Fig. 2**.
   - 6.1 Remove the nuts and washers from the tank strap T-bolts at the outboard end of the tank brackets.
   - 6.2 Remove the cotter pins and clevis pins from the inboard end of the tank straps. Remove the tank straps and isolators.
7. Using a fork lift, remove the fuel tank.
8. Inspect the tank straps, isolators, and brackets for wear and damage. Replace worn or damaged parts with new parts.

WARNING

Failure to replace worn or damaged parts could result in loss of a fuel tank and spilling of fuel, which could cause property damage or personal injury.

9. When replacing a fuel tank, remove all parts necessary to install the new fuel tank. Inspect the parts and replace them as needed. Install all necessary components on the new fuel tank before installation.
   - 9.1 Remove and clean all pipe plugs, fittings and lines. Transfer the components to the new fuel tank. Coat all tapered pipe plug and fitting threads with Loctite® 592, or an equivalent sealer.
   - 9.2 Inspect the vent line. Transfer it to the new fuel tank.
   - 9.3 Transfer the chassis-access steps to the new tank, if so equipped. For instructions, see **Subject 100**.
   - 9.4 If a single or primary fuel tank is being replaced, transfer the fuel level gauge sender and gasket to the new fuel tank. Use a star pattern to distribute the torque evenly around the sender unit. See **Fig. 3**.

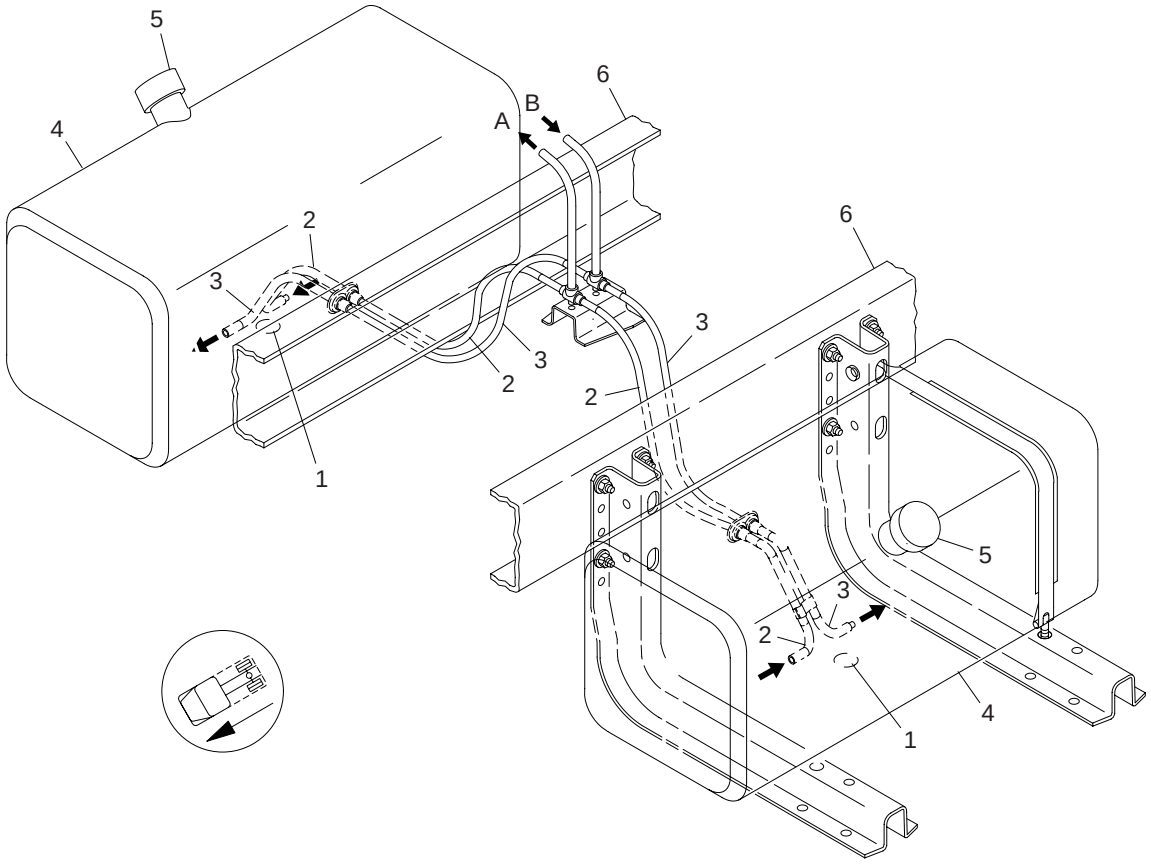
Installation (See Fig. 4)

1. Using a fork lift or other approved lifting device, place the fuel tank in its approximate installed position. Make sure the fuel filler neck is outboard.

   Move the tank fore or aft until the distance from the front of the tank to the centerline of the forward tank bracket is 10-13/16 ± 3/16 inches (275 ± 5 mm).
2. Install the isolators and tank straps. See **Fig. 2**.
   - 2.1 Install the clevis pins through the inboard end of the tank brackets and tank straps. Install and lock new cotter pins in the clevis pins.

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Fuel Tank Removal and Installation



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NOTE: Arrows indicate direction of flow.

A. To fuel pump
B. From engine

1 Drain
2. Supply (suction) Line
3. Return Line
4. Fuel Tank
5. Fuel Cap
6. Frame Rail

Fig. 1, EquiFlo® Inboard Fuel System

⚠ CAUTION

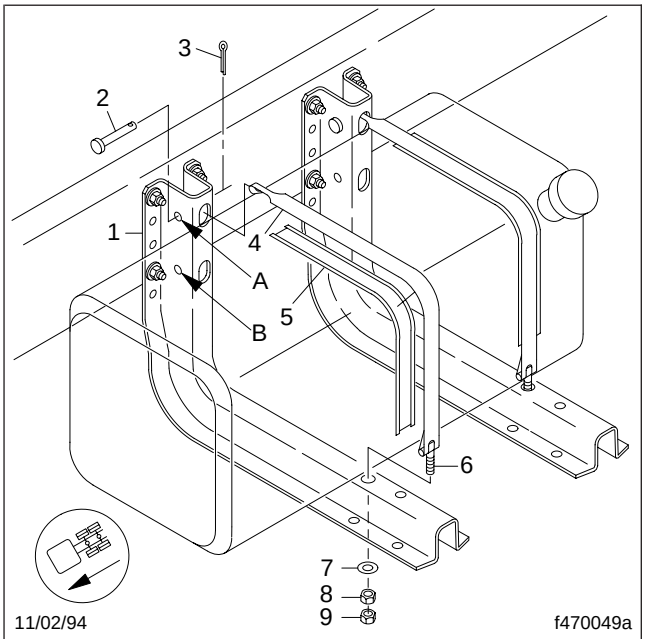
Do not overtighten the fuel tank straps. To do so could damage the fuel tanks.

2.2 Install a bearing washer and two nuts on each tank strap T-bolt. Tighten the first nuts 15 lbf·ft (20 N·m).

2.3 While holding the first nut stationary with a wrench, tighten each jam nut 30 lbf·ft (41 N·m).

3. Attach the electrical connector to the fuel level gauge sender.
4. Make certain the fuel lines are clean. Install them on the fittings on the fuel tank. See **Subject 150** for general guidelines. Coat all tapered pipe plug and fitting threads with Loctite 592 or an equivalent sealer. Install pipe plugs in any remaining open threaded holes.
5. Install the cab-access step(s). For instructions, see **Subject 100**.
6. Add clean fuel to the fuel tank.

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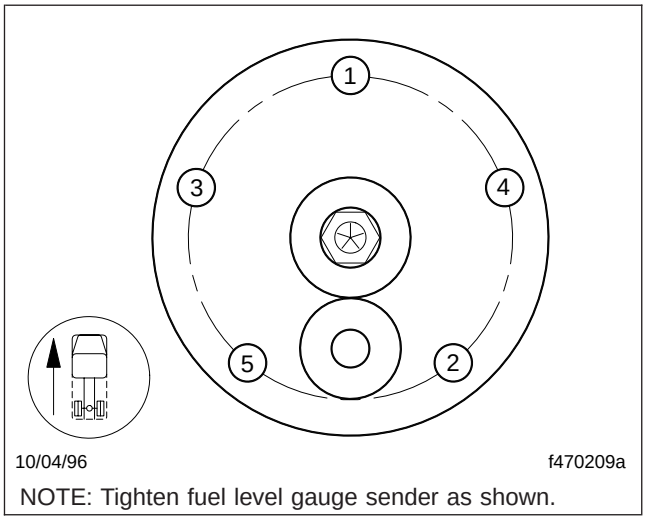


A. Use for 45-gallon short tank (shown) or 75-gallon tank.
B. Use for 45-gallon long tank or 30-gallon tank.

1. Fuel Tank Bracket
2. Tank Strap Clevis Pin
3. Clevis Pin, Cotter Pin
4. Fuel Tank Strap
5. Tank Strap Isolator
6. Tank Strap T-Bolt
7. Bearing Washer
8. 1/2–13 Hexnut
9. 1/2–13 Jam Nut

Fig. 2, Fuel Tank Brackets and Straps

7. Prime the engine fuel pump. For instructions, see **Subject 160**.
8. Remove the chocks from the rear tires.

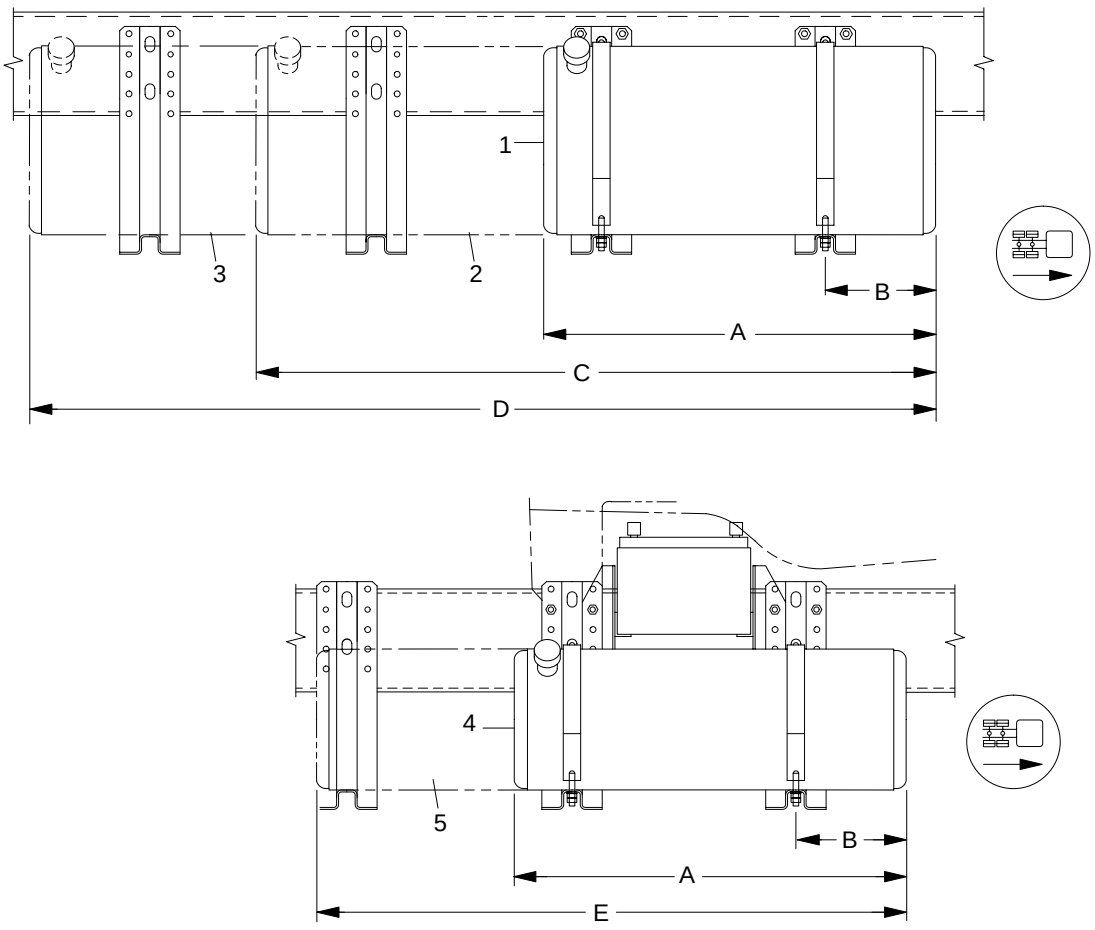


NOTE: Tighten fuel level gauge sender as shown.

Fig. 3, Electric Fuel Level Gauge Sender Tightening Sequence

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Fuel Tank Removal and Installation



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A. 38 inches (965 mm)
B. 10-13/16 ± 3/16 inches (275 ± 5 mm)
C. 64 inches (1626 mm)
D. 85 inches (2166 mm)
E. 57 inches (1448 mm)

1. 45-Gallon Short Tank
2. 75-Gallon Tank
3. 100-Gallon Tank
4. 30-Gallon
5. 45-Gallon Long Tank

Fig. 4, Fuel Tank Positioning

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Replacement (See Fig. 1)

1. Park the vehicle on a level surface and apply the vehicle parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the cab-access step(s). For instructions, see **Subject 100**.
3. Remove the fuel tank strap and isolator.
   - 3.1 Remove the nuts and washer from the tank strap T-bolt at the outboard end of the tank bracket.
   - 3.2 Remove the cotter pin and clevis pin from the tank strap eye at the inboard end of the tank bracket.
4. Inspect the isolator and clevis pin for wear or damage and replace, if needed.

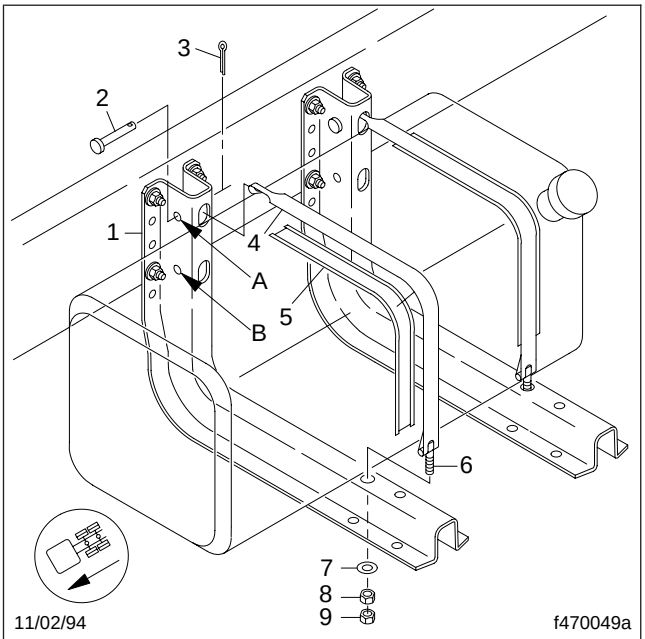
WARNING

Failure to replace worn or damaged parts could result in loss of a fuel tank and spilling of fuel, which could cause property damage or personal injury.

5. Install the isolator and the new tank strap on the tank.
   - 5.1 Install the clevis pin through the inboard end of the tank bracket and tank strap. Install and lock a new cotter pin in the clevis pin.

   IMPORTANT: Fuel tanks can be damaged by overtightening the fuel tank straps.

   - 5.2 Install a bearing washer and two nuts on the tank strap T-bolt. Tighten the first nut 15 lbf·ft (20 N·m).
   - 5.3 While holding the first nut stationary with a wrench, tighten the jam nut 30 lbf·ft (41 N·m).
6. Install the cab-access step(s). For instructions, see **Subject 100**.
7. Remove the chocks from the rear tires.



A. Use for 45-gallon short tank (shown) or 75-gallon tank.
B. Use for 45-gallon long tank or 30-gallon tank.

1. Fuel Tank Bracket
2. Tank Strap Clevis Pin
3. Clevis Pin Cotter Pin
4. Fuel Tank Strap
5. Tank Strap Isolator
6. Tank Strap T-Bolt
7. Bearing Washer
8. 1/2–13 Hexnut
9. 1/2–13 Jam Nut

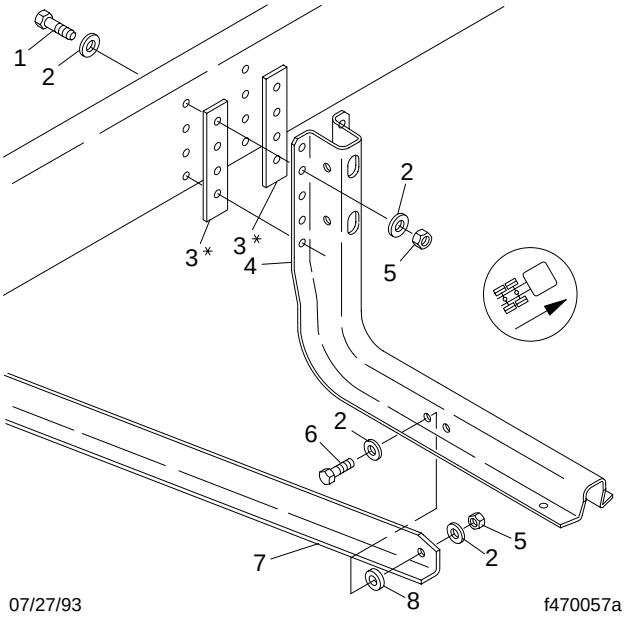
Fig. 1, Strap Installation

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Fuel Tank Bracket Replacement

Replacement (See Fig. 1)

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the fuel tank. For instructions, see **Subject 110**.
3. If the fuel tank bracket has a compression brace attached, remove the locknut, washers, spacer and capscrew that attach the brace to the bracket.
4. Remove the locknuts, hardened washers and capscrews that attach the fuel tank bracket to the frame rail. Remove the bracket, and if so equipped, the fuel tank bracket spacers.
5. From inside the frame rail, install the two upper capscrews and hardened washers. If so equipped, install the fuel tank bracket spacers onto the outboard ends of the capscrews. Position the new tank bracket on the capscrews. Install the two upper hardened washers and locknuts, finger-tight.
6. Install the two lower sets of fasteners. Tighten all of the locknuts 68 lbf·ft (92 N·m).
7. If a compression brace was attached to the bracket, install the capscrew, hardened washers, spacer, compression brace and locknut. See **Fig. 1**. Tighten the locknut 68 lbf·ft (92 N·m).
8. Install the fuel tank. For instructions, see **Subject 110**.
9. Remove the chocks from the rear tires.



1. 1/2–13 Capscrew
2. Bearing Washer
3. Fuel Tank Bracket Spacer (used with 14,000- and 16,000-lb front suspension without frame reinforcement)
4. Fuel Tank Bracket
5. 1/2–13 Locknut
6. 1/2–13 Capscrew
7. Compression Brace
8. Compression Brace Spacer

Fig. 1, Bracket Installation

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Replacement

1. Park the vehicle on a level surface and apply the vehicle parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the fasteners and clamps that attach the fuel crossover line to the compression brace.
3. Remove the locknuts, bearing washers, spacers and capscrews that attach the compression brace to the fuel tank brackets. Remove the compression brace.
4. Position the new compression brace. Install the capscrews, bearing washers, spacers and locknuts in the indicated mounting holes.
5. Tighten the locknuts 68 lbf·ft (92 N·m).
6. Install the clamps and fasteners that attach the fuel crossover line to the compression brace. Tighten the fasteners snugly.
7. Remove the chocks from the rear tires.

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General Guidelines

If diesel fuel lines are worn, damaged, or deteriorated, replace them. Use the following guidelines for installing and routing them.

- Fuel lines must be free of droops, sharp bends and kinks in the lines.
- Fuel lines must not extend more than 2 inches (5 cm) below the fuel tank unless they are completely enclosed in a protective housing.
- Fuel lines must be routed in a continuous upward slope from the fuel tank to prevent high and low spots in the hoses.
- Fuel lines must be routed at least 6 inches (15 cm) from exhaust pipes
- Heat shields and/or hose insulation must be used to protect any section of fuel line that is less than 6 inches (15 cm) from a heat source.
- Fuel lines must be routed to allow routinely serviceable components such as dipsticks, filters and water separators to be readily accessed without the need to disconnect the fuel lines.
- Fuel lines must be secured to prevent chafing, kinking or other damage.
- Fuel lines must be long enough to allow movement of the parts to which they are attached.
- Coat all pipe threads (tapered threads) with Loctite® 592 or an equivalent.
- Finger-tighten pipe fittings; then tighten one and one-half turns. Tighten more if necessary to seal.
- Fuel lines and fittings must be free of leaks, to prevent fuel loss or entry of air into the line, which may result in a loss of prime by the engine fuel system.
- Drains or other bottom fittings must not extend more than 3/4 inch (19 mm) below the lowest part of the fuel tank or sump.

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Priming

Before priming the system, make sure there is enough fuel in the tank(s). Do not fill them to more than 95 percent of capacity.

⚠ WARNING

Federal regulations prohibit filling a fuel tank to more than 95 percent of its capacity. A tank with air space is much less likely to rupture in an accident than one that has little or no air space. Fuel tank rupture could result in fuel spillage and a hazardous condition.

⚠ CAUTION

Do not crank the starter more than 30 seconds at a time during any of the following procedures; wait 2 minutes after each try to allow the starter to cool or starter damage may occur.

1. Park the vehicle on a level surface and apply the parking brakes. Chock the rear tires.
2. If the engine or fuel/water separator is equipped with a priming pump, use it to prime the fuel transfer pump.
   - 2.1 Operate the priming pump plunger until there is resistance.
   - 2.2 Push the plunger in and tighten it by hand.
   - 2.3 Start the engine; if it does not start, more priming is needed. Once the engine has started, it may run rough; if so, run the engine at low idle until it runs smoothly.
3. If the engine or fuel/water separator is not equipped with a priming pump, pressurize the fuel in the fuel tank to prime the fuel transfer pump.
   - 3.1 Remove the fuel tank cap from the primary tank.
   - 3.2 Loosen the fuel supply line at the fuel transfer pump.
   - 3.3 While an assistant looks for a constant fuel flow at the loosened fuel supply line, partially block the fuel tank opening with a clean rag and use an air hose to apply no more than 5 psi (35 kPa) air pressure to the fuel tank.
   - 3.4 When the fuel flow is constant, remove the air hose and rag and tighten the fuel supply line.

   IMPORTANT: To prevent fuel loss or entry of air into a fuel line, make sure that all fuel line connections are tight.

   - 3.5 Start the engine. Once the engine has started, it may run rough. If this occurs, run the engine at low idle until it runs smoothly.
4. Remove the chocks from the rear tires.

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Specifications

See **Fig. 1** for fuel tank positioning.

See **Fig. 2** for single-level cab-access step positioning.

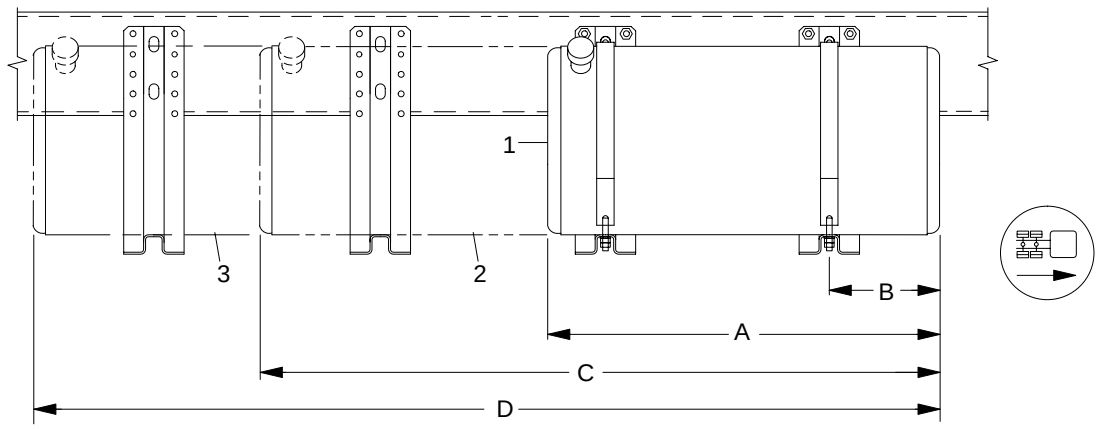
See **Fig. 3** for dual-level cab-access step positioning.

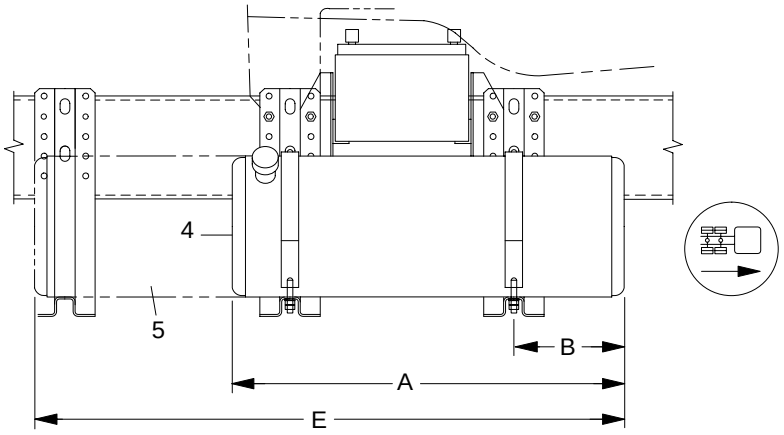
Fastener Torques			
Description	**Size**	**Grade**	**Torque lbf·ft (N·m)**
Cab-Access Step Bracket-to-Fuel Tank Bracket Locknut	3/8–16	C	28 (38)
Cab-Access Step Bracket-to-Fuel Tank Weldnut Capscrew	3/8–16	5	26 (35)
Cab-Access Step-to-Step Bracket Locknut	1/4–20	B	7 (10)
Chassis-Access Step Clamp Capscrew	3/8–16	5	26 (35)
Fuel Tank Strap T-Bolt:			
Hexnut	1/2–13	B	15 (20)
Jam Nut	1/2–13	B	30 (41)
Fuel Tank Bracket Mounting Locknut	1/2–13	C	68 (92)
Compression Brace Mounting Locknut	1/2–13	C	68 (92)

Table 1, Fastener Torques

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Specifications





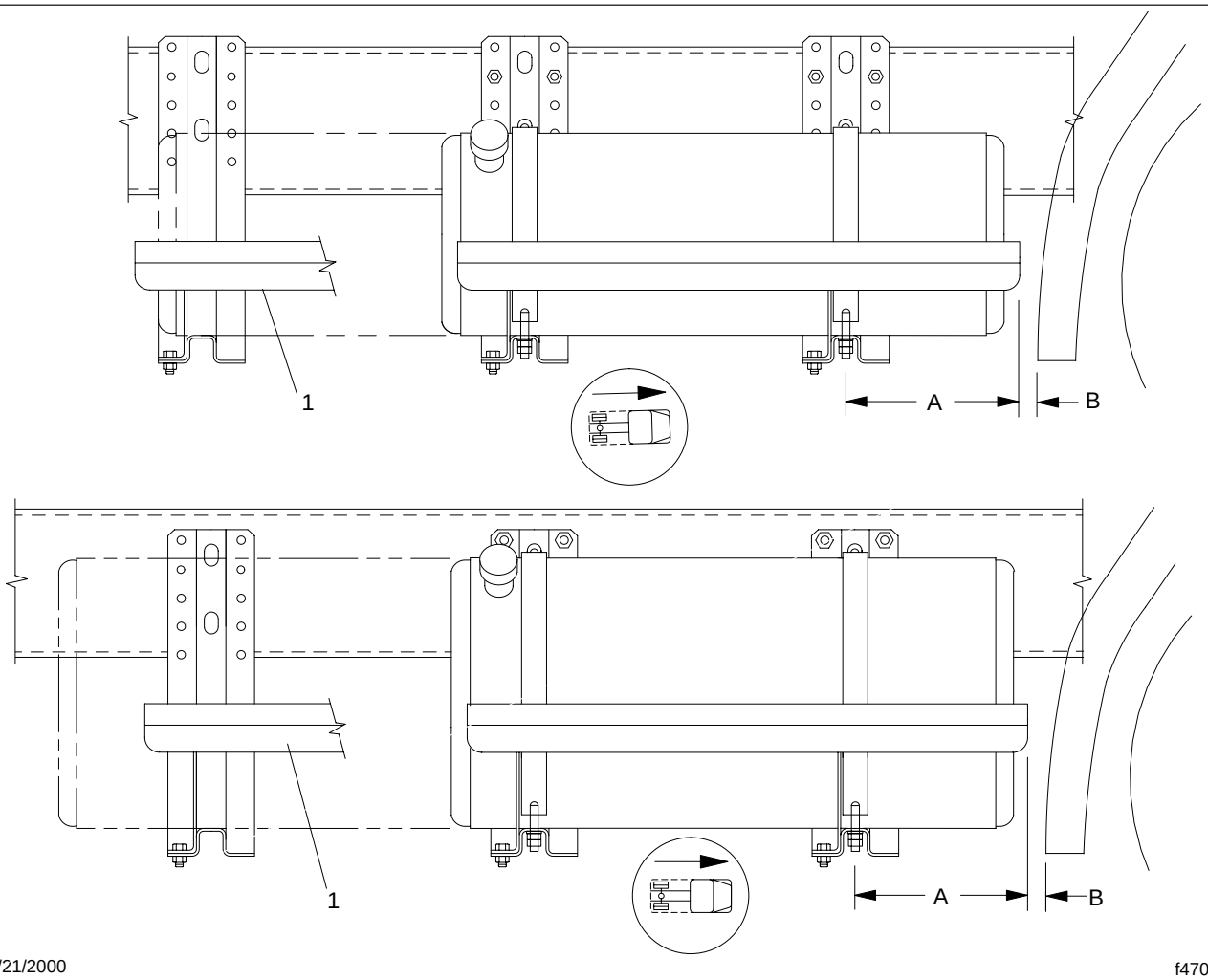
11/19/96 f470050b

A. 38 inches (965 mm)
B. 10-13/16 ± 3/16 inches (275 ± 5 mm)
C. 64 inches (1626 mm)
D. 85 inches (2166 mm)
E. 57 inches (1448 mm)

1. 45-Gallon Short Tank
2. 75-Gallon Tank
3. 100-Gallon Tank
4. 30-Gallon
5. 45-Gallon Long Tank

Fig. 1, Fuel Tank Positioning

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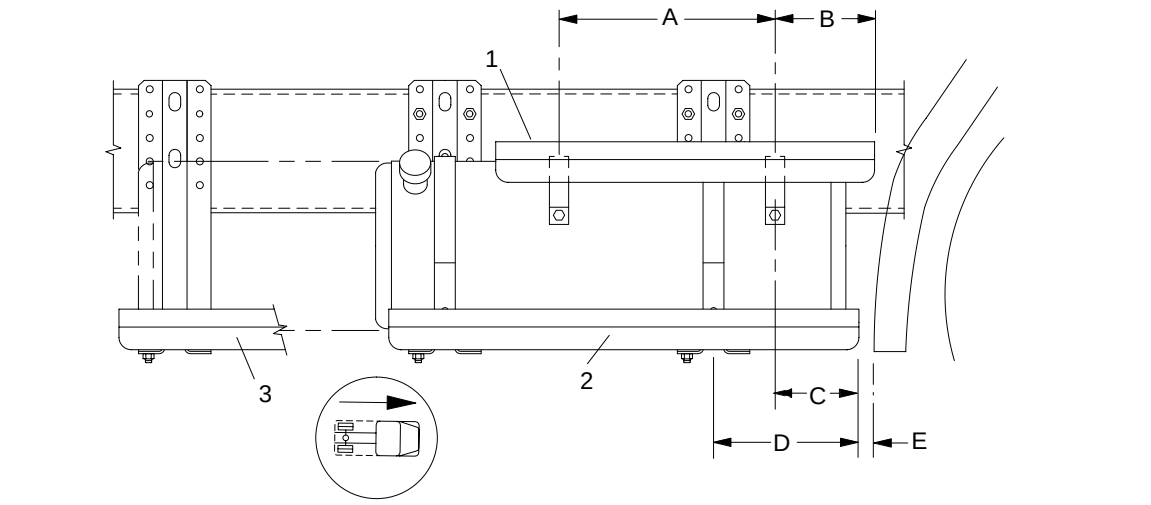
NOTE: Right-side fuel tanks and steps shown; left-side fuel tanks and steps are opposite.

A. 11-13/32 inches (290 mm)
B. 29/32 inches (23 mm)
1. Left-Side Only

Fig. 2, Single-Level Cab-Access Step Positioning

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Specifications



01/21/2000 f470365

NOTE: Right-side fuel tanks and steps shown; left-side fuel tanks and steps are opposite.

A. 16-1/4 inches (412.5 mm)
B. 7-3/4 inches (197.2 mm)
C. 6-57/64 inches (175 mm)
D. 11-7/16 inches (290.5 mm)
E. 59/64 inches (23.5 mm)

1. Upper Step
2. Lower Step
3. Left-Side Only

Fig. 3, Dual-Level Cab-Access Step Positioning

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General Description

The fuel/water separator is mounted on the frame rail, between the fuel tank and the fuel pump. Fuel drawn to the engine travels through the fuel/water separator, which removes water and solid contaminants. The fuel/water separator includes a spin-on filter element and a sight bowl. See **Fig. 1**. The fuel/water separator may also be equipped with the following optional components:

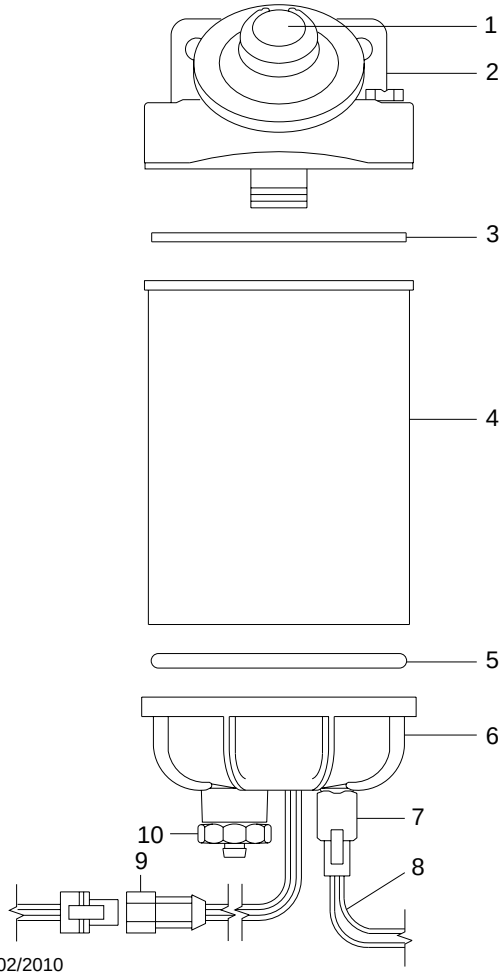
- Ignition-controlled heater to melt ice and wax in the fuel
- Water sensor probe to alert the operator to drain the sight bowl
- Manual priming pump to easily prime the fuel/water separator

Principles of Operation

Diesel fuel enters at the top of the separator and flows down past the heater element, if equipped, to the top of the filter element. As the fuel flows down the sides of the element, the heavier contaminants fall directly to the collection bowl. The filter element itself contains a resin that repels water and forces it to bead and fall to the collection bowl.

Filtered fuel is drawn out through the top of the separator, and the water and solid contaminants remain in the collection bowl. As water collects, it completes the circuit between the two prongs of the water sensor probe, if equipped, and a warning light on the dash alerts the operator to drain the bowl.

The heater is operated by turning on the ignition switch for 5 minutes before starting the engine.



1. Priming Pump
2. Mounting Head
3. Gasket
4. Filter Element
5. O-Ring
6. Sight Bowl
7. Water Sensor Probe
8. Water Sensor Probe Wiring Harness
9. Heater Wiring Harness
10. Drain Plug

Fig. 1, Fuel/Water Separator Assembly

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Removal

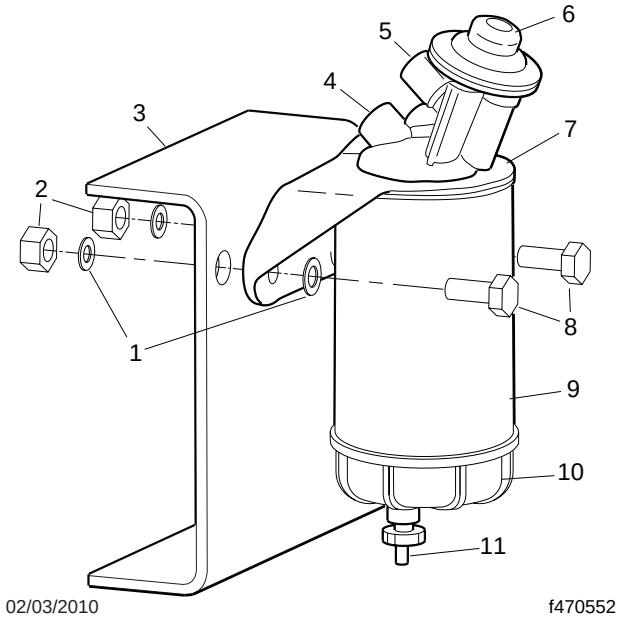
1. Shut down the engine, apply the parking brake, and chock the tires.

   Open the hood.

2. Place a suitable container under the fuel/water separator.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

3. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump. See **Fig. 1**.



1. Washers (qty 2)
2. Nuts (qty 2)
3. Frame Rail
4. Fuel Outlet Port
5. Fuel Inlet Port
6. Priming Pump
7. Mounting Head
8. Mounting Bolts (qty 2)
9. Filter Element
10. Sight Bowl
11. Drain Plug

Fig. 1, Fuel/Water Separator Assembly and Installation

4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

⚠ WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

5. Disconnect the fuel lines from the fuel/water separator.
6. If equipped, disconnect the wiring harnesses from the water sensor probe and the heater element.
7. Remove the fuel/water separator mounting bolts, and remove the fuel/water separator from its mounting bracket.

Installation

1. Mount the fuel/water separator on the frame rail mounting bracket, and install the mounting bolts. Tighten the bolts 40 lbf·ft (55 N·m).
2. Remove the sight bowl and the filter element as a unit from the new fuel/water separator.
3. Using clean motor oil or diesel fuel, lubricate the gasket in the top of the filter element.
4. Make sure the drain in the sight bowl is closed, then fill the filter element and bowl assembly with clean fuel.
5. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
6. If equipped, connect the wiring harnesses to the water sensor probe and the heater.
7. Connect the fuel lines to the fuel/water separator. Tighten all fittings finger-tight plus 1/4 turn.
8. Prime the fuel/water separator.

   If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

   If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.
9. Start the engine and check for leaks.
10. Shut down the engine and repair any leaks.

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Replacement

1. Shut down the engine, apply the parking brakes, and chock the tires.

   Open the hood.

2. Place a suitable container under the fuel/water separator.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

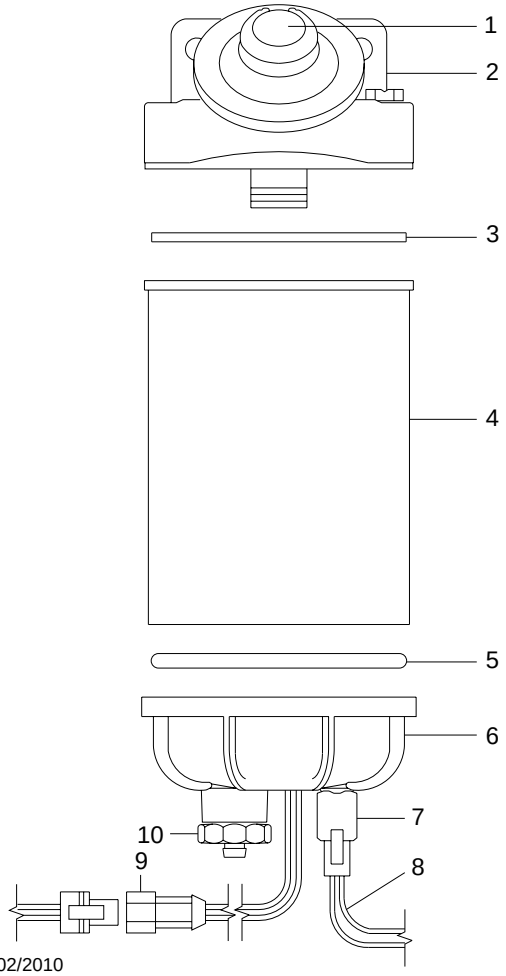
3. Turn the drain plug counterclockwise to open it. If equipped, operate the pump.
4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

⚠ WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

5. If equipped, disconnect the wiring harnesses from the water sensor probe and the heater. See **Fig. 1**.
6. Spin off the sight bowl and the filter element as a unit. Remove the gasket from the top of the filter element.
7. Remove the sight bowl from the filter element. Clean the O-ring seating surface.
8. Apply a thin coating of clean diesel fuel or engine oil to the O-ring and the new gasket.
9. Spin the sight bowl onto the new filter element and then fill the filter element and sight bowl assembly with clean diesel fuel.
10. Spin the entire assembly onto the mounting head and tighten by hand until snug.
11. Connect the heater and water sensor wiring harnesses, if equipped.
12. Prime the fuel/water separator.

    If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.



1. Priming Pump
2. Mounting Head
3. Gasket
4. Filter Element
5. O-Ring
6. Sight Bowl
7. Water Sensor Probe
8. Water Sensor Probe Wiring Harness
9. Heater Wiring Harness
10. Drain Plug

Fig. 1, Fuel/Water Separator Assembly

   If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.

13. Start the engine and check for leaks.
14. Shut down the engine and repair any leaks.

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Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.

   Open the hood.

2. Place a suitable container under the fuel/water separator.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

3. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump.
4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

⚠ WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

5. If equipped, disconnect the wiring harness from the water sensor probe. See **Fig. 1**.

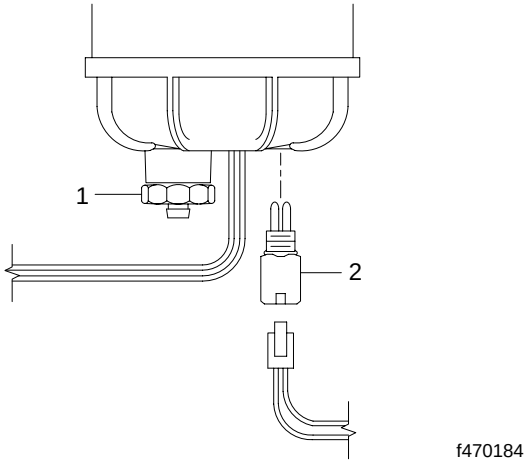


Fig. 1, Water Sensor Probe

6. Disconnect the heater wiring harness. See **Fig. 2**.

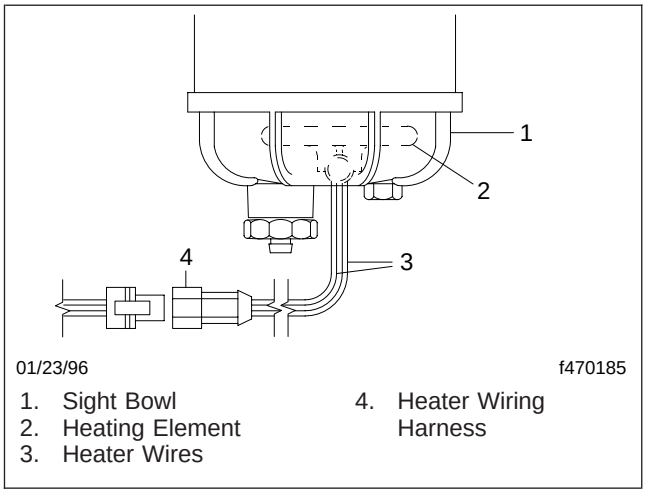


Fig. 2, In-Bowl Heater

7. Spin off the sight bowl and the filter element as a unit.
8. Remove the sight bowl from the filter element.
9. Remove the O-ring from the lip of the new sight bowl. Lubricate the O-ring with a thin film of clean engine oil or diesel fuel and put it back in the sight bowl.
10. Install the sight bowl on the bottom of the filter element and hand-tighten until it is snug.
11. Make sure the drain in the sight bowl is closed, then fill the filter element and bowl assembly with clean fuel.
12. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
13. Connect the heater wiring harness.

    If equipped, connect the water sensor wiring harness to the water sensor probe.

14. Prime the fuel/water separator.

    If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

    If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.

15. Start the engine and check for leaks.
16. Shut down the engine and repair any leaks.

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Replacement

1. Apply the parking brakes, shut down the engine, and chock the tires.

   Open the hood.

2. Place a suitable container under the fuel/water separator.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

3. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump.
4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

⚠ WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

5. Disconnect the water sensor wiring harness from the water sensor probe. See **Fig. 1**.

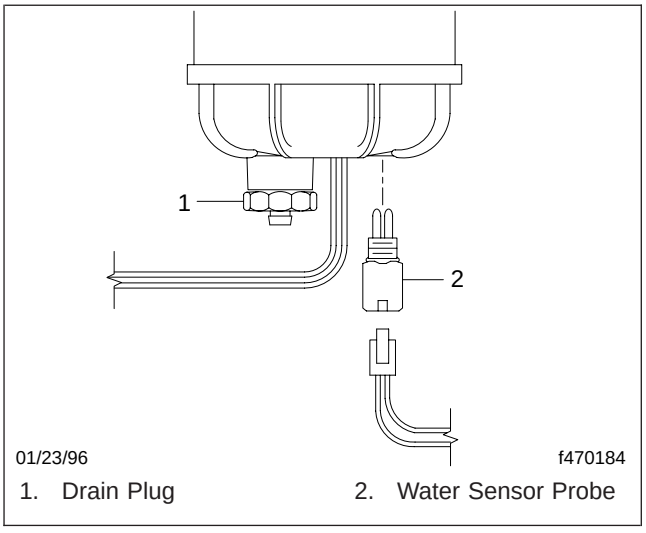


Fig. 1, Water Sensor Probe

6. Spin off the sight bowl and filter element as a unit.
7. Unscrew the water sensor probe from the base of the sight bowl.
8. Install a new water sensor probe in the base of the sight bowl.
9. Make sure the drain plug in the base of the sight bowl is closed snugly.
10. Fill the filter element and sight bowl assembly with clean diesel fuel.
11. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
12. Connect the water sensor wiring harness to the water sensor probe.
13. Prime the fuel/water separator.

    If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

    If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.

14. Start the engine and check for leaks.
15. Shut down the engine and repair any leaks..

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Troubleshooting

Problem—Air Leaking into the Fuel System

Problem—Air Leaking into the Fuel System	
Possible Cause	**Remedy**
The drain is not closed.	Tighten the drain valve.
The sight bowl or filter element is loose.	Hand-tighten the sight bowl or filter element until snug.
There are loose, broken, or clogged fuel fittings, valves, or filters.	Tighten, clean, or repair the fuel fittings, valves, or filters as needed.

Problem—High Water Light Does Not Illuminate For 2 to 5 Seconds When Ignition is Turned to ACCESSORY

Problem—High Water Light Does Not Illuminate For 2 to 5 Seconds When Ignition is Turned to ACCESSORY	
Possible Cause	**Remedy**
Wiring connections are loose.	Tighten connections as needed.
Fuel/water separator is not grounded.	Check that power is on, and the fuel/water separator is grounded.
Wiring is damaged.	Check for damaged wiring and replace as needed. See EZWiring for a diagram of the sensor circuit.
Water sensor probe is damaged.	Replace the water sensor probe. See **Subject 130** for instructions.

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General Information

Fuel/water separators are mounted between the fuel tank and the fuel pump. Fuel drawn to the engine travels through the fuel/water separator, which removes water and impurities.

At the fuel/water separator inlet port, a check valve (**Fig. 1**, Item 8) prevents the fuel from draining back to the fuel tank. Large pieces of dirt and water separate from the fuel in the lower housing, and collect in the bottom to be drained out when the drain valve (**Fig. 1**, Item 13) is opened. From the lower housing, the fuel level rises into the clear cover, which contains the replaceable filter. In the clear cover, the fuel passes through the filter element into the center of the filter, and to the outlet port.

When the filter is new, the fuel is able to pass through the lower part of the filter element. As the element's lower portion clogs, the fuel level rises in order to pass through the filter. This process continues until the filter element is clogged all the way to the top.

For efficiency, the filter should be changed only when the fuel level has reached the top of the filter element. There is no significant restriction to fuel flow until the element is completely clogged.

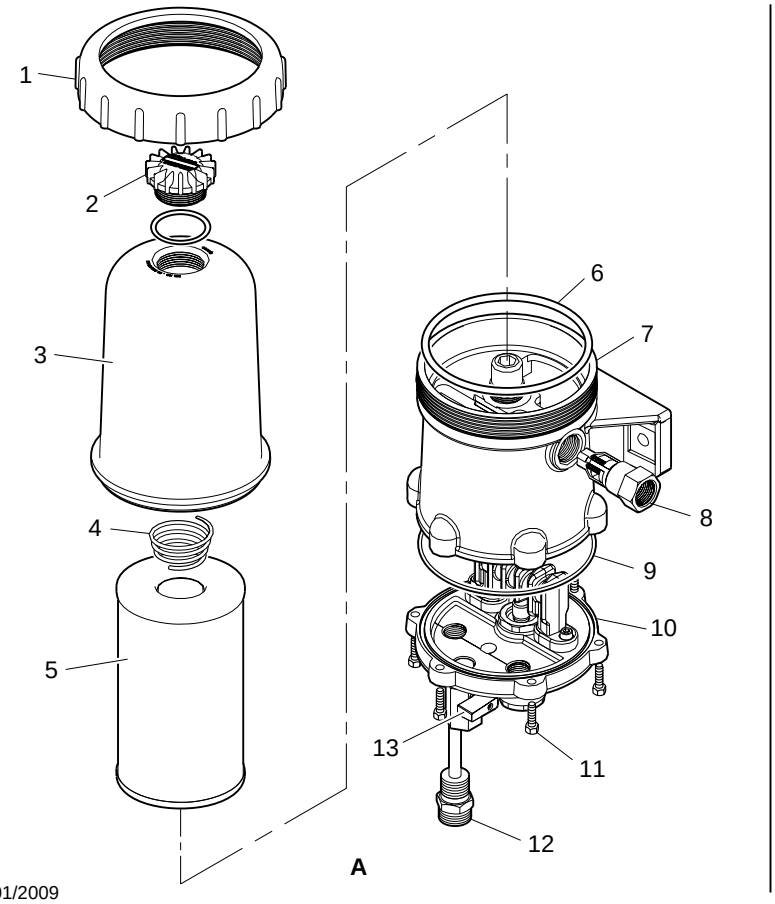
DAVCO fuel/water separators come in a number of different configurations. The lower housing may be screw-assembled (**Fig. 1**, Ref. A) or locking-collar-assembled (**Fig. 1**, Ref. B). There may be an electric heating element (**Fig. 1**, Item 12) installed in the lower housing or there may be fluid heating in the lower housing (**Fig. 1**, Item 15).

If there is fluid heat, the warming fluid may be fuel returning from the engine or engine coolant. **Fig. 2** shows the patterns that fuel and heating fluids follow in fluid-heated units.

NOTE: The Daimler Trucks North America Learning Center (accessible through **www.AccessFreightliner.com**) and DAVCO (**www.DavcoTec.com**) offer excellent online resources for understanding, testing, and diagnosing fuel/water separator problems.

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General Information



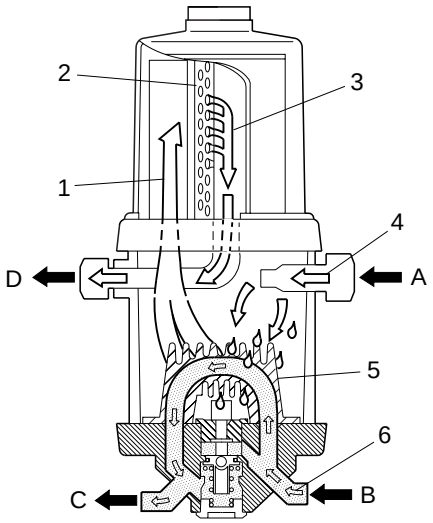
A. Configuration and components with screw-assembled lower housing and electric fuel heater

B. Configuration and components with locking-collar-assembled lower housing and fluid fuel heater

1. Collar
2. Vent Cap with O-Ring
3. Clear Cover
4. Spring
5. Filter Element
6. Cover O-Ring
7. Lower Housing
8. Inlet Port/Check Valve
9. Lower Housing O-Ring
10. Housing O-Ring Groove
11. Housing Assembly Screws
12. Electric Heating Element
13. Drain Valve
14. Lower Collar
15. Fluid Heater Ports
16. Outlet Port

Fig. 1, DAVCO Fuel Pro and Diesel Pro Configurations

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A. Fuel Inlet Flow
B. Heating Fluid Inlet Flow
C. Heating Fluid Outlet Flow
D. Fuel Outlet Flow

1. Unfiltered, Heated Fuel
2. Filter Element
3. Filtered Fuel
4. Fuel From Fuel Tank
5. Heat Exchanger
6. Heating Fluid From Engine

Fig. 2, DAVCO Fluid Circulation, Fluid-Heated Units

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Removal

⚠ WARNING

Fluid circulated through the fuel/water separator to heat the fuel may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with the fuel system near, open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

Most service procedures are done with the fuel/water separator in place, but some procedures, such as pressure testing, require that the fuel/water separator be removed from the vehicle.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
3. Remove the vent cap (**Fig. 1**, Item 2) and open the drain valve (**Fig. 1**, Item 12) to drain the fuel to just below the collar level, then close the drain valve.
4. Unplug the electric heating element, if equipped, or disconnect the heating fluid lines.
5. Disconnect the fuel outlet line.
6. Disconnect the fuel inlet line. If the inlet line is difficult to reach, loosen the connection, then fully disconnect it after the fuel/water separator is removed from the frame rail.
7. Remove the fuel/water separator mounting fasteners and remove the fuel/water separator from the frame rail. If the fuel inlet line was not completely disconnected in the previous step, disconnect it.

Installation

IMPORTANT: All fittings, including the locking collars, must be very clean as they are installed. A piece of grit or a damaged surface on a sealing face or in threads can cause air leaks.

Use paste sealer to ensure that the tapered thread fuel line fittings will not leak. Do not use sealer on compression fittings and do not seal the fittings with tape, which will eventually leak.

1. If the inlet fuel line is inaccessible when the fuel/water separator is mounted on the vehicle, loosely connect the inlet fuel line before mounting the fuel/water separator on the frame rail.

   To minimize restrictions, keep fuel line routing as smooth as possible, with no low-hanging loops that could trap water. If the fuel line is being made to length on the job, be sure that the inner liner of the hose is not cut by the fitting. Be certain the interior of all fuel lines is clean and free of debris before connecting them, and confirm that all fittings are clean.
2. Mount the fuel/water separator on the frame rail and install the mounting fasteners.

NOTICE

The lower housings on DAVCO fuel/water separators are made of aluminum. To avoid damaging threads, be careful not to overtighten fasteners or fittings on the fuel/water separator.

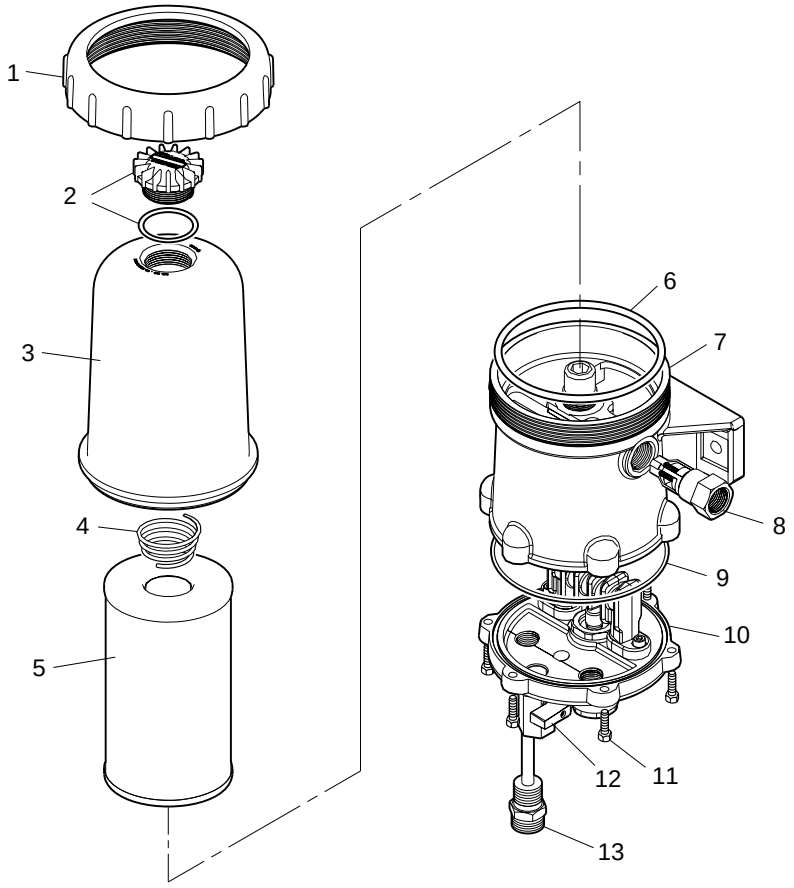
3. If the fuel inlet line was loosely connected previously, tighten it. If it was not connected, connect and tighten it.
4. Connect the fuel outlet line. Tighten the fitting 25 to 40 lbf·ft (34 to 54 N·m).
5. Install the electric heating element, if equipped, and connect the wiring harness, or connect the fluid heater lines. It does not matter which direction the heating fluid flows through the housing; the lines can be reversed.
6. Prime the system

   6.1 Ensure that the drain valve is closed.

   6.2 Remove the vent cap from the cover, and fill the housing to the top with clean diesel fuel.

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Removal and Installation



04/30/2007 f470505

1. Collar
2. Vent Cap with O-Ring
3. Clear Cover
4. Spring
5. Filter Element
6. Cover O-Ring
7. Housing Collar Threads
8. Inlet Port/Check Valve
9. Lower Housing O-Ring
10. Housing O-Ring Groove
11. Housing Assembly Screws
12. Drain Valve
13. Electric Heating Element

Fig. 1, Fuel/Water Separator With Electric Fuel Heater

6.3 Install and hand-tighten the vent cap.

6.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

6.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

6.6 Check for leaks and shut down the engine.

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Filter Replacement

⚠ WARNING

Fluid circulated through the fuel/water separator to heat the fuel may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

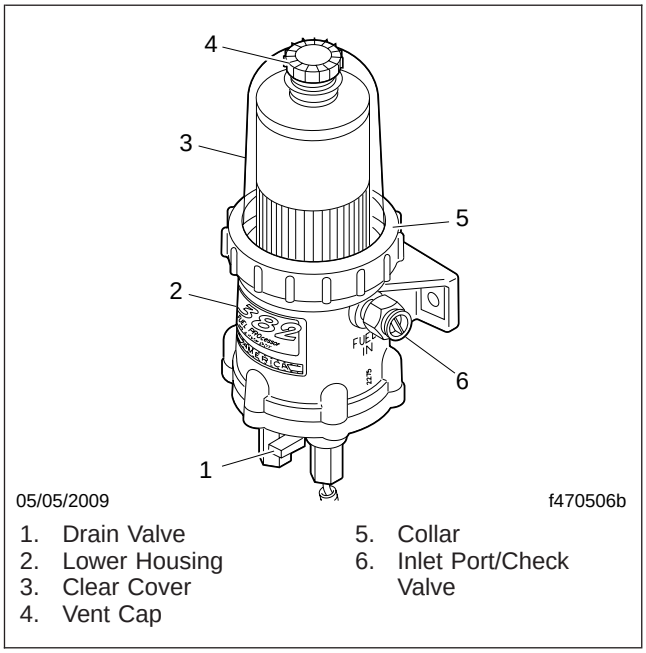
If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with the fuel system near, open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
3. Remove the vent cap (**Fig. 1**, Item 4) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Using a DAVCO Collar Wrench (**Fig. 2**), remove the clear cover and collar.

NOTE: Broken vent cap and collar warranty claims will not be accepted if any tool other than a DAVCO Collar Wrench, p/n 380134 or 382002, is used for removal. During installation, the vent cap and collar are to be **hand-tightened only**, not tightened with a wrench.

5. Remove the filter, cover O-ring, and vent cap O-ring (see **Fig. 3**). Dispose of them in an environmentally acceptable manner.
6. Clean all threads and sealing surfaces very thoroughly. Even a small amount of dirt will prevent the fuel/water separator from sealing, and an air leak will result.
7. Install the grommet on the bottom of the new filter.



1. Drain Valve
2. Lower Housing
3. Clear Cover
4. Vent Cap
5. Collar
6. Inlet Port/Check Valve

Fig. 1, DAVCO Fuel/Water Separator (Fuel Pro 382 shown)

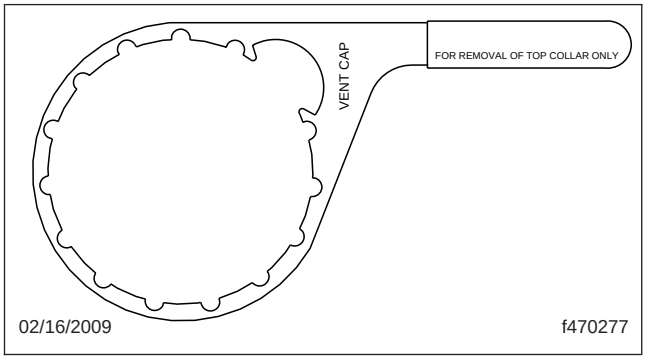
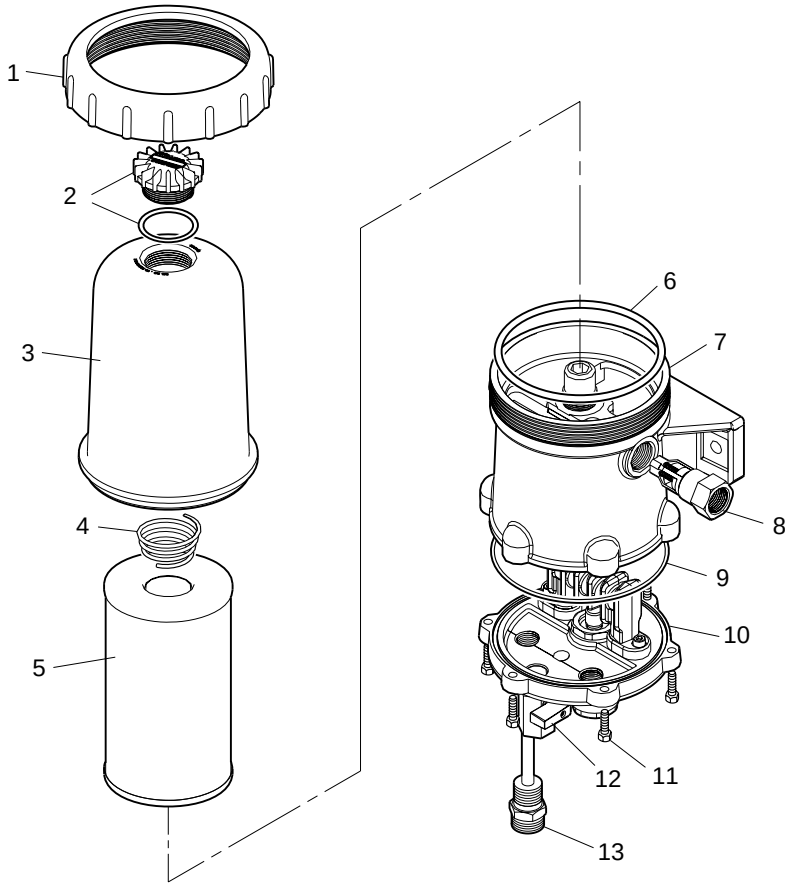


Fig. 2, DAVCO Collar Wrench

8. Install the new filter and grommet assembly and cover O-ring on the housing.
9. Install the clear cover and the collar. Hand-tighten the collar.
10. Prime the system
    - 10.1 Ensure that the drain valve is closed.
    - 10.2 Fill the housing to the top with clean diesel fuel.
    - 10.3 Install and hand-tighten the vent cap O-ring and vent cap.

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Filter and Check Valve Replacement



04/30/2007 f470505

1. Collar
2. Vent Cap with O-Ring
3. Clear Cover
4. Spring
5. Filter Element
6. Cover O-Ring
7. Housing Collar Threads
8. Inlet Port/Check Valve
9. Lower Housing O-Ring
10. Housing O-Ring Groove
11. Housing Assembly Screw
12. Drain Valve
13. Electric Heating Element

Fig. 3, Fuel/Water Separator With Electric Fuel Heater

10.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

10.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

10.6 Check for leaks and shut down the engine.

Emergency Temporary Filter Replacement

⚠ WARNING

Fluid circulated through the fuel/water separator to heat the fuel may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

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Filter and Check Valve Replacement

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with the fuel system near, open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
3. Remove the vent cap (**Fig. 1**, Item 4) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Using a DAVCO Collar Wrench (**Fig. 2**), remove the clear cover and collar.

NOTE: Broken vent cap and collar warranty claims will not be accepted if any tool other than a DAVCO Collar Wrench, p/n 380134 or 382002, is used for removal. During installation, the vent cap and collar are to be **hand-tightened only**, not tightened with a wrench.

5. Remove the filter and dispose of it in an environmentally acceptable manner.
6. Clean all threads and sealing surfaces very thoroughly. Even a small amount of dirt will prevent the fuel/water separator from sealing, and an air leak will result.
7. Ensure that the drain valve is closed.
8. Remove the filter grommet from the filter stud, if equipped.
9. Fill the housing to the top with clean diesel fuel.
10. Install a standard engine spin-on filter (part number FF105 or equivalent) on the filter stud.
11. Install the cover O-ring, clear cover, and the collar. Hand-tighten the collar.
12. Install and hand-tighten the vent cap O-ring and vent cap.
13. Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
14. Check for leaks and shut down the engine.

Check Valve Replacement

⚠ WARNING

Fluid circulated through the fuel/water separator to heat the fuel may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

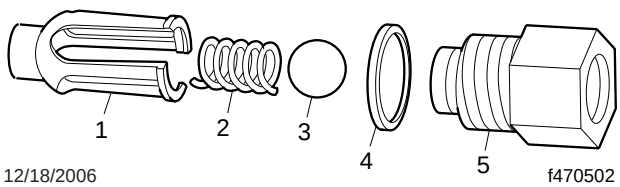
If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with the fuel system near, open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
3. Remove the vent cap (**Fig. 1**, Item 4) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Place a shop towel under the fuel inlet fitting. Hold the check valve body (**Fig. 3**, Item 8) in place with an open-end wrench and, using a flare-nut wrench, carefully remove the fuel inlet fitting. Drain any residual fuel into the container.
5. Remove the check valve assembly from the fuel/water separator housing.
6. Remove and discard the check ball, spring, and plastic retainer. See **Fig. 4**.
7. Carefully clean the threads on the check valve body. Install the new check ball, spring, and plastic retainer on the check valve body.

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Filter and Check Valve Replacement



1. Plastic Spring Retainer
2. Retaining Spring
3. Check Ball
4. Seal
5. Check Valve Body

Fig. 4, Check Valve Assembly

8. Clean the threads on the fuel inlet fitting and fuel/water separator housing. Apply a soft-set pipe thread sealant to the check valve body threads.
9. Install the check valve body in the fuel/water separator housing. Do not use tape to seal the fuel fittings; it will eventually leak.

   Tighten the check valve body 44 to 60 lbf·ft (60 to 81 N·m) on a Fuel Pro 382, or 25 to 40 lbf·ft (34 to 54 N·m) on a Diesel Pro 232/233.
10. Prime the system

    10.1 Ensure that the drain valve is closed.

    10.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.

    10.3 Install and hand-tighten the vent cap.

    10.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

    10.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

    10.6 Check for leaks and shut down the engine.

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Electric Heater, Thermoswitch, and Fluid Heat Tests

Any one of several types of heaters and thermoswitches may be fitted to DAVCO fuel/water separators. They include 12 VDC heaters, 120 VAC heaters, combination heater thermoswitches, and fluid heaters. The voltage and wattage ratings are stamped on the hex or the sheath of each component.

Test procedures under these headings apply to the following heater types, as specified:

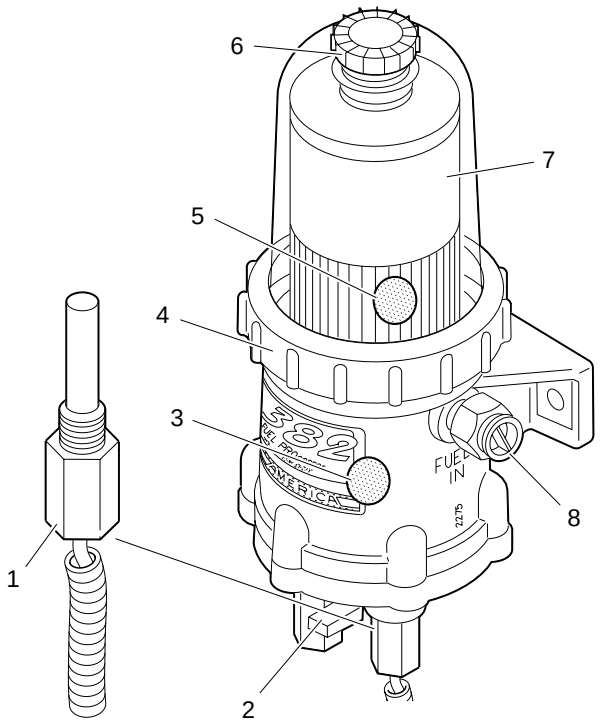
- Electric Heater
- 12 VDC Thermoswitch
- Combination Heater Thermoswitch
- Fluid Heat

The following equipment is recommended to test DAVCO heaters and thermoswitches:

- A precision low-resistance ohmmeter capable of measuring 0.1 ohm or less
- A clamp-on DC current-flow meter
- A means of chilling a thermoswitch, such as ice, dry ice, or compressed carbon dioxide
- A flameless source of heat, such as an infrared heat lamp
- A vortex tube to heat and cool a thermoswitch

Electric Heater

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Disconnect the heater from the wiring harness, see **Fig. 1**.
3. Connect the ohmmeter leads to the pins of the heater (for heaters with one pin, connect to the pin and the bushing).
4. Read the resistance and use **Table 1** to determine whether the heater is within the acceptable resistance range.
5. Connect the heater wiring harness.



1. Electric Heating Element
2. Drain Valve
3. Housing
4. Collar
5. Filter Element
6. Vent Cap
7. Clear Cover
8. Inlet Port/Check Valve

Fig. 1, Fuel Pro 382 With Electric Heating Element

Electric Heater Test Paramaters		
Electric Heater	**Watts**	**Resistance Range: Ohms**
12 VDC (two pin)	250	0.6–0.8
12 VDC (single pin)	250	0.4–0.5
12 VDC (single pin)	150	0.8–1.1
120 VAC	75	173–203
120 VAC	37	369–411

Table 1, Electric Heater Test Parameters

12 VDC Thermoswitch

1. Shut down the engine, apply the parking brake, and chock the tires.

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Electric Heater, Thermoswitch, and Fluid Heat Tests

WARNING

Fluid circulated through the fuel/water separator to heat the fuel may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with the fuel system near, open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.

4. Disconnect the thermoswitch wiring harness, see **Fig. 2**. Remove the thermoswitch from the fuel/water separator.

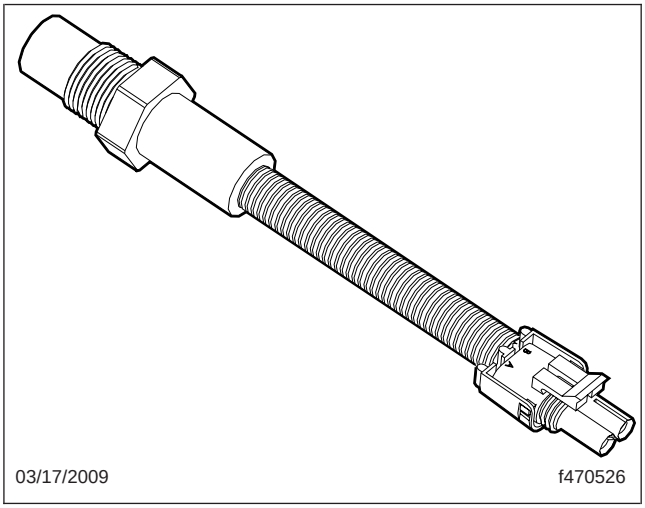


Fig. 2, 12 VDC Thermoswitch

5. Connect the ohmmeter leads to the pins of the thermoswitch.

6. Lower the thermoswitch temperature to below 40°F (4.4°C). The resistance shown on the ohmmeter should be less than 0.1 ohm.

7. Raise the thermoswitch temperature to above 60°F (15.5°C). The resistance should be more than 10 megohms.

8. Install the thermoswitch in the fuel/water separator. Connect the thermoswitch wiring harness.

9. Prime the system

   9.1 Ensure that the drain valve is closed.

   9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.

   9.3 Install and hand-tighten the vent cap.

   9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

   9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

   9.6 Check for leaks and shut down the engine.

Combination Heater Thermoswitch

1. Shut down the engine, apply the parking brake, and chock the tires.

WARNING

Fluid circulated through the fuel/water separator to heat the fuel may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with the fuel system near, open flame or intense

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heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.

4. Disconnect the heater/thermoswitch unit from the wiring harness, see **Fig. 3**.

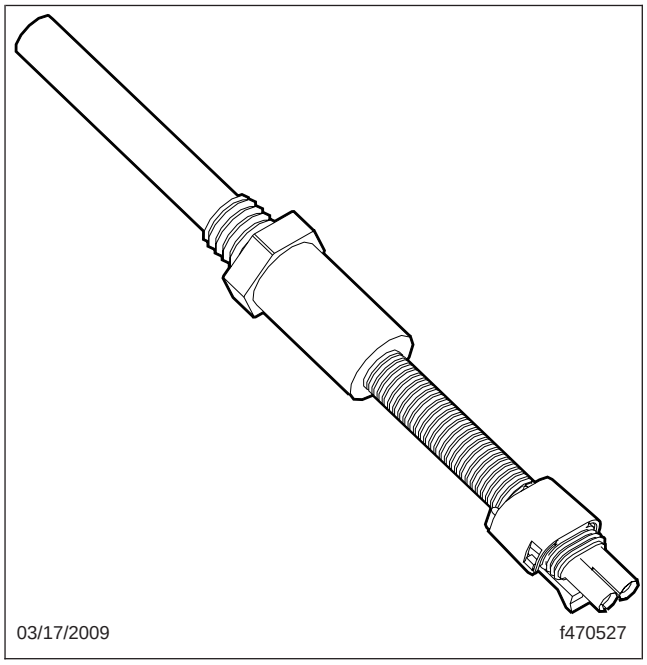


Fig. 3, Combination Heater Thermoswitch

5. Connect the ohmmeter leads to the heater/thermoswitch pins.

6. Lower the heater/thermoswitch unit temperature to below 40°F (4.4°C).

   The resistance shown on the ohmmeter should be:

   - 0.8 to 1.1 ohms for a 12 VDC 150 W unit
   - 0.2 to 2.5 ohms for a 24 VDC 250 W unit

7. Raise the heater/thermoswitch unit temperature to above 70°F (21°C). The heater/thermoswitch unit should show an open circuit.

8. Install the heater/thermoswitch in the fuel/water separator. Connect the heater/thermoswitch wiring harness.

9. Prime the system

   9.1 Ensure that the drain valve is closed.

   9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.

   9.3 Install and hand-tighten the vent cap.

   9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

   9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

   9.6 Check for leaks and shut down the engine.

Fluid Heater

1. Shut down the engine, apply the parking brake, and chock the tires.

⚠ WARNING

Fluid circulated through the fuel/water separator to heat the fuel may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with the fuel system near, open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

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Electric Heater, Thermoswitch, and Fluid Heat Tests

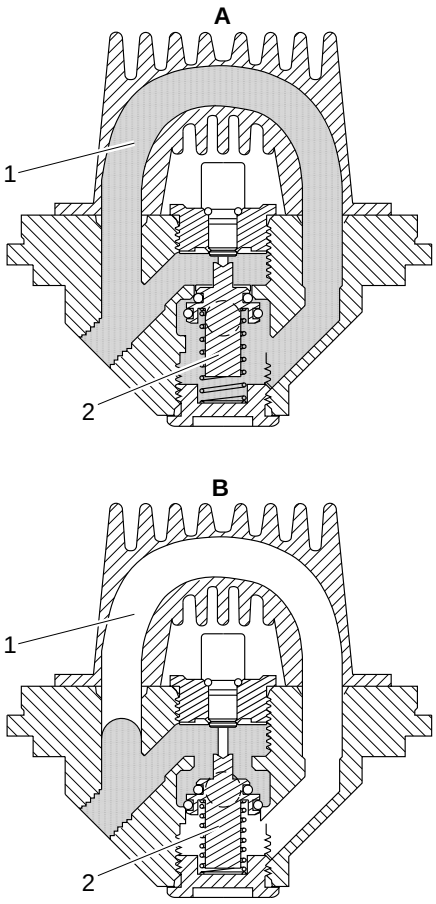
2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Disconnect the heating fluid lines from the bottom plate. These will be either engine coolant lines or return fuel lines. Plug engine coolant lines after removing them from the bottom plate of the housing.
5. Remove the bottom plate and lower housing O-ring.
6. When the fuel entering the fuel/water separator is cold, the thermovalve moves up, allowing warming fluid to enter the heater loop in the heat exchanger. When the fuel is warm, the thermovalve moves down, causing the warming fluid to bypass the heater loop and return directly to the tank. See **Fig. 4**.

   While looking into the fluid port of the bottom plate (**Fig. 5**), flow cold water over the thermovalve for 30 seconds, then run hot water over the thermovalve to determine whether the thermovalve spool is opening and closing.

7. Replace the lower housing O-ring, and install the bottom plate on the fuel/water separator. There are two types of bottom plates: locking-collar-assembled and screw-assembled.
   - Locking-collar-assembled: Apply 2 to 3 drops of Loctite 406 to the bottom collar threads, then tighten 50 to 60 lbf·ft (68 to 81 N·m).
   - Screw-assembled: Install the screws on the bottom plate and tighten them 8 to 10 lbf·ft (11 to 14 N·m).
8. Connect the heating fluid lines.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.



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A. Fuel is Cold, Thermovalve Is Up
B. Fuel is Warm, Thermovalve is Down

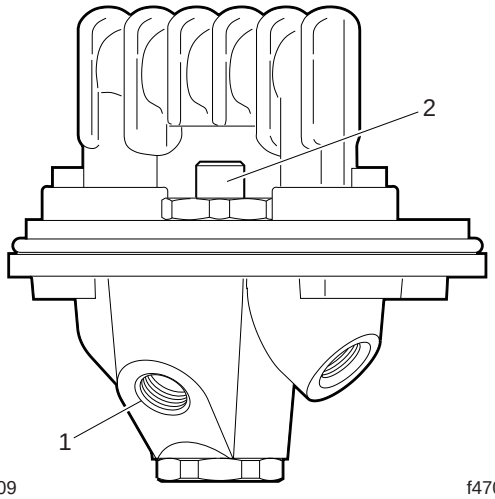
1. Heater Loop 2. Thermovalve

Fig. 4, Heat Exchanger Fluid Flow

   - 9.3 Install and hand-tighten the vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

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Electric Heater, Thermoswitch, and Fluid Heat Tests



1. Fluid Port
2. Top of Thermovalve Spool

Fig. 5, Fluid Heater Thermovalve Test

9.6 Check for leaks and shut down the engine.

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The Daimler Trucks North America Learning Center (accessible through www.AccessFreightliner.com) and DAVCO (www.DavcoTec.com) offer excellent online resources for understanding, testing, and diagnosing fuel/water separator problems.

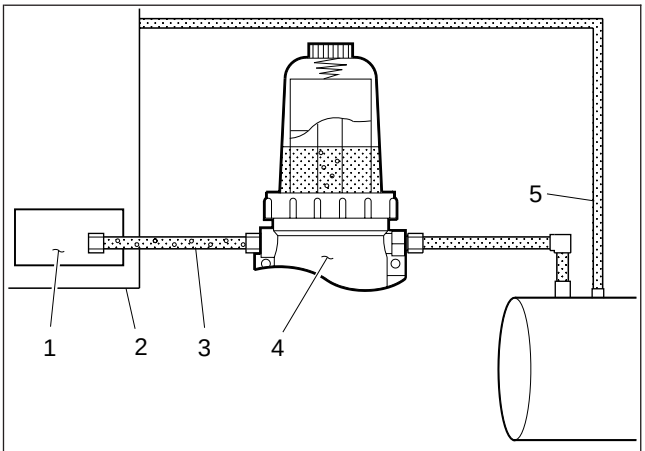
Identifying Bubble Types

Vapor Bubbles

Vapor bubbles are harmless and are present in all diesel fuel systems. Vapor bubbles are often mistaken for air bubbles, but *do not affect engine performance.*

Vapor bubbles (see **Fig. 1**) may be visible in a diagnostic sight tube installed between the fuel/water separator and the fuel pump. They consist of harmless fuel vapor and trapped air, may vary from champagne-size to 1/4-inch (6-mm) diameter, and may increase in volume or size as the engine rpm increases. The lower pressure inside a fuel/water separator filter, caused by the suction of the fuel pump pulling fuel through the fuel/water separator, creates vapor bubbles. These vapor bubbles are normal and harmless to engine operation. In the fuel pump, the fuel is pressurized and the vapor bubbles dissolve. Vapor bubbles do not appear on the fuel return side of the system.

There is no troubleshooting or repair procedure required for vapor bubbles. Vapor bubbles do not cause performance issues and will not be present downstream of the fuel pump.



1. Fuel Pump
2. Engine
3. Fuel Outlet Line, Vapor Bubbles Visible
4. Fuel/Water Separator, Vapor Bubbles Visible *Inside* Filter, *No* Bubbles Visible in Clear Cover
5. Fuel Return Line (no bubbles)

Fig. 1, Harmless Vapor Bubbles

Air and Gas Bubbles

Air or gas bubbles indicate harmful leaks, and can cause hard starting and impaired engine performance. All diesel fuel holds some trapped air, caused by the natural splashing that occurs in the fuel tank. But excessive air bubbles, severe enough to degrade engine performance, indicate an air leak on the suction side of the fuel system, from the fuel tank into the fuel pump.

Air bubbles visible in the clear cover of a DAVCO fuel/water separator may indicate an air leak in the fuel system upstream of the bubbles, or in the fuel/water separator; see **Fig. 2**. If there are no bubbles visible in the clear cover but the engine runs rough, there may be an air leak at or between the fuel/water separator outlet port and the fuel pump inlet. These bubbles will be visible in a diagnostic sight tube installed between the fuel pump and the fuel/water separator, and in a diagnostic sight tube installed in the fuel return hose.

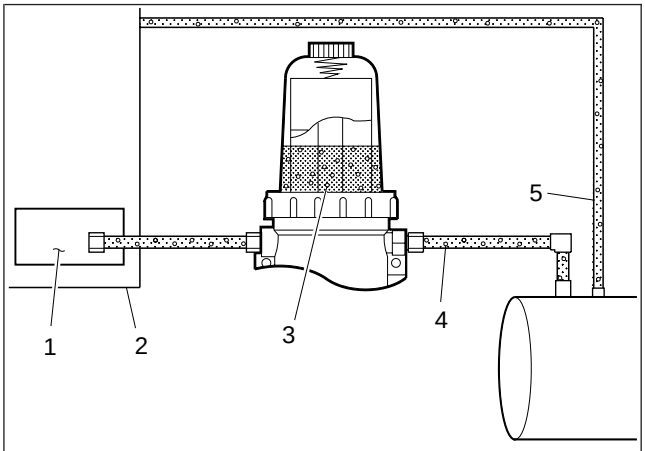
Exhaust gas bubbles may also be visible in the clear filter cover. They are the result of leaking fuel injector seals, which can allow combustion gases to enter the fuel system, pass through the fuel return line into the fuel tank, and be drawn into the fuel/water separator. They may be visible in a diagnostic sight tube installed in the fuel return line. To test for combustion gas in the fuel, disconnect the return line at the tank, submerge the end in a bucket of fuel, run the engine, and watch for bubbles. As they pop, these bubbles may smell like exhaust fumes.

In extreme cases, these combustion gas bubbles cause enough aeration in the fuel tank to create visible bubbles in the clear cover of the fuel/water separator and impair engine performance. See the engine manufacturer's documentation for diagnosis and repair of injector seal leakage.

Use the following procedures to determine which bubbles are present in the fuel system, and whether repair is necessary.

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Troubleshooting



1. Fuel Pump
2. Engine
3. Fuel/Water Separator, Bubbles Visible in Clear Cover
4. Fuel Inlet Line, Bubbles Visible
5. Fuel Return Line, Bubbles Visible

Fig. 2, Air Bubbles Indicating a Leak

Initial Diagnostic Procedure

1. Apply the parking brake, chock the tires, and turn on the engine.
2. Check for air bubbles in the fuel/water separator clear cover.
3. If no bubbles are visible in the clear cover, but the engine continues to run rough, lopes, or has loss of power, there may be an air leak between the fuel/water separator outlet and the fuel pump inlet.

   If so, bubbles should be visible in a diagnostic sight tube installed at the fuel pump inlet. Air bubbles may also be visible in a diagnostic sight tube installed in the fuel return line to the fuel tank.
4. Replace fuel lines and tighten fittings as needed.

Testing Procedures

Air Leak in the Fuel System

Air leaks are sometimes caused by:

- loose fittings;
- a faulty inlet check valve;
- faulty O-rings;
- leakage elsewhere in the fuel system;
- or dirt on threads and sealing surfaces.

Air leaks originating between the fuel tank and the fuel/water separator cause air bubbles visible in the clear cover, as shown in **Fig. 2**.

If there are symptoms of sucking air and there are no bubbles in the clear cover, look for the air leak at:

- the outlet fitting;
- the fuel pump inlet connection;
- the fuel hose connections;
- or at the vent cap O-ring.

1. Shut down the engine, apply the parking brake, and chock the tires.

⚠ WARNING

Fluid circulated through the fuel/water separator to heat the fuel may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with the fuel system near, open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

2. Remove the fuel hose from the fuel pump inlet port.
3. Install a jumper hose from the inlet port into the fuel tank through the fill cap, or into a container of fuel.
4. Start the engine and look for bubbles in the clear filter cover. If the air bubbles are eliminated, the air source (and the leak) is at either the fuel tank fittings, or the hose connections.

   If air bubbles persist after the tank fittings and hose connections are secured, the leak may be in the fuel/water separator.

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5. If the leak is suspected to be in the fuel/water separator, disconnect all fuel connections, coat the threads with liquid or paste sealer, and reconnect the fuel connections and tighten them securely.

Air Pressure Testing

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Remove the fuel/water separator from the chassis. For instructions, see **Subject 100**.

⚠ WARNING

Wear goggles and skin protection when pressure-testing a fuel/water separator, and be careful not to perform this test near a source of possible ignition, such as an open flame. Never exceed the maximum pressure stipulated for the test, and do not perform this test if the clear cover appears to be damaged.

5. Plug the fuel outlet port (**Fig. 3**, Item 16). Do not remove the filter, filter cover, collar, vent cap, drain valve, or check valve. Do not remove the electric heating element (if equipped), and do not plug the fluid heat ports (if equipped).
6. Apply 15 psi (207 kPa) air pressure at the fuel inlet. Immerse the unit in a tank of water and look for air bubbles.
7. Some DAVCO fuel/water separators have locking collars on both the filter cover and the lower housing, as shown in **Fig. 3**. If a lower collar is present, it does not need to be removed for normal service. But if the lower collar is removed and the filter housing disassembled, a new lower housing O-ring (**Fig. 3**, Item 9) must be installed. Apply 2 to 3 drops of Loctite 406 to the bottom collar threads, then tighten 50 to 60 lbf·ft (68 to 81 N·m).
8. Install the fuel/water separator onto the chassis frame rail. For instructions, see **Subject 100**.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
10. If no bubbles appear, the air leak is not in the fuel/water separator.

Restriction Check

A DAVCO fuel/water separator, properly assembled with the rubber grommet in the bottom of the fuel filter, does not restrict fuel flow until the fuel level has risen to the top of the filter. If the fuel level has risen to the top of the filter, replace the filter.

Check Valve Operation Test

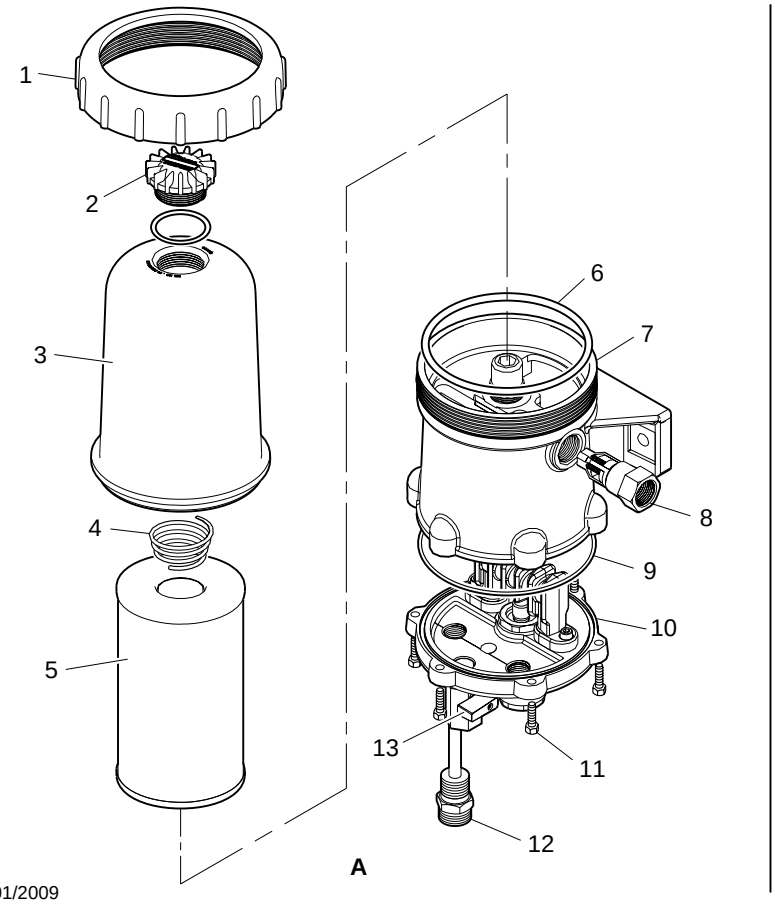
When air is introduced into the fuel system, (e.g. when draining fluid or when replacing the fuel filter), the check valve (**Fig. 4**) works to keep the fuel system primed from the fuel tank to the fuel/water separator.

To test for proper check valve operation, remove the fuel inlet line, then open the vent cap. Fuel should not flow out of the check valve, although a slight seepage of fuel is normal. If fuel drains back out of the check valve, complete the following procedure.

1. Shut down the engine, apply the parking brake, and chock the tires.

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Troubleshooting



A. Configuration and components with screw-assembled lower housing and electric fuel heater

B. Configuration and components with locking-collar-assembled lower housing and fluid fuel heater

1. Collar
2. Vent Cap with O-Ring
3. Clear Cover
4. Spring
5. Filter Element
6. Cover O-Ring
7. Lower Housing
8. Inlet Port/Check Valve
9. Lower Housing O-Ring
10. Housing O-Ring Groove
11. Housing Assembly Screws
12. Electric Heating Element
13. Drain Valve
14. Lower Collar
15. Fluid Heater Ports
16. Outlet Port

Fig. 3, DAVCO Fuel Pro and Diesel Pro Configurations

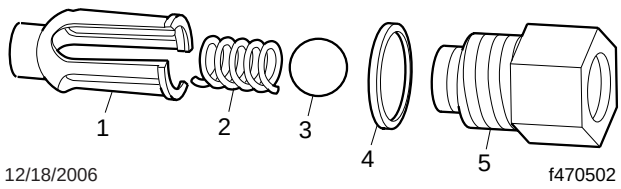
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If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with the fuel system near, open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

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1. Plastic Spring Retainer
2. Retaining Spring
3. Check Ball
4. Seal
5. Check Valve Body

Fig. 4, Check Valve Assembly

The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Place a shop towel under the fuel inlet fitting. Hold the check valve body (**Fig. 3**, Item 8) in place with an open-end wrench and, using a flare-nut wrench, carefully remove the fuel inlet fitting. Drain any residual fuel into the container.
5. Remove the check valve assembly from the fuel/water separator housing, see **Fig. 4**.
6. Clean and inspect the check valve body. If the valve body is damaged, or if the ball seat is not smooth, replace the valve. For instructions, see **Subject 110**.
7. If the valve body and ball seat are not damaged, clean the threads on the check valve body, fuel inlet fitting, and the water separator housing.
8. Apply a soft-set pipe thread sealant to the check valve body threads. Install the check valve body in the fuel/water separator housing. Do not use tape to seal the fuel fittings; it will eventually leak.

   Tighten the check valve body 44 to 60 lbf·ft (60 to 81 N·m) on a Fuel Pro 382, or 25 to 40 lbf·ft (34 to 54 N·m) on a Diesel Pro 232/233.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap O-ring and vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
   - 9.6 Check for leaks and shut down the engine.

Other Conditions Visible Inside the Cover

The clear filter covers fitted to DAVCO fuel/water separators provide the opportunity to monitor several aspects of fuel condition and engine status, as described in **Table 1**.

Conditions Visible Inside DAVCO Clear Filter Covers		
If You See:	**What to Do:**	**Comments:**
Amber-colored fuel below the top of the filter element	Nothing, the filter is doing its job	Do not change the filter.
Amber-colored fuel with dark patches in places on the filter element	Dark patches indicate bacteria or algae may be present. Use Fleetguard Monitor Kit CC2650 to test for microbiological activity.	It may be necessary to use a microbicide, and suggest vehicle operator carry extra filters.

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Troubleshooting

Conditions Visible Inside DAVCO Clear Filter Covers		
If You See:	**What to Do:**	**Comments:**
Extremely dark or cloudy fuel with thick black film or sludge collecting on the filter element	Black film or sludge on the filter media indicates the presence of asphaltenes. It may be necessary to use an asphaltene conditioner.	Do not assume this is oil from the engine. Monitor the vehicle for oil consumption. Refer to engine manufacturer's service literature for more information.
Bubbles inside the clear cover	Check for air leaks anywhere in the fuel system. Any leak in any fitting will cause bubbles to appear in the clear cover.	This problem will lead to power complaints; it must be remedied.
No bubbles in the cover, but the engine is running rough	Check for air leaks between the fuel/water separtor outlet port and the fuel pump inlet. Check and tighten all fuel fittings in the area of the leak.	Do not replace the fuel/water separator.
Coolant in the fluid drained from the fuel/water separator	Check for leaks in the engine, where fuel and coolant are near each other. The most common problem place is the injector cup.	Do not allow the equipment to be operated until the problem is found and repaired.
Anything not listed here	Call DAVCO at 1-800-328-2611, or email: customerservice@DavcoTec.com	—

Table 1, Conditions Visible Inside DAVCO Clear Filter Covers

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Specifications

Torque Values				
Component	Fuel Pro 382		Diesel Pro 232/233	
	lbf·ft (N·m)	lbf·in (N·cm)	lbf·ft (N·m)	lbf·in (N·cm)
Inlet Port/Check Valve	44–60 (60–81)	—	25–40 (34–54)	—
Fuel Outlet Fitting	—	—	25–40 (34–54)	—
Water in Fuel Sensor	—	20–24 (226–271)	—	20–24 (226–271)
Electric Heating Element	15–30 (20–41)	—	15 (20)	—
Drain Valve	25 (34)	—	15 (20)	—
Housing Assembly Screws	8–10 (11–14)	—	—	—

Table 1, Torque Values

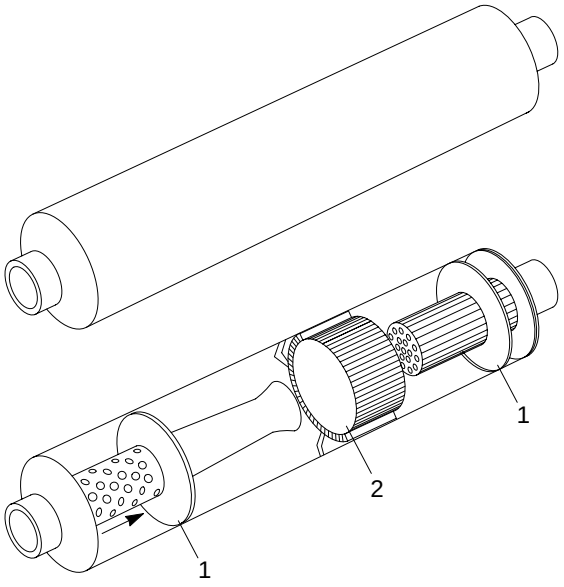
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General Information

To clean vehicle exhaust and reduce exhaust noise, Acterra uses mufflers and catalytic converters with some engines.

Exhaust pipes route the exhaust from the engine to the catalytic converter.

Diesel engines use a combined catalytic converter and muffler. The converter consists of three sections: an inlet muffler section, the catalytic converter, and an outlet muffler section. See **Fig. 1**.



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NOTE: Arrow indicates exhaust flow.

1. Baffle
2. Substrate

Fig. 1, Typical Cylindrical Catalytic Converter Muffler

The catalytic converter consists of:

- A ceramic substrate which acts as a support structure for the catalytic coating;
- A high surface area catalyst coating which reduces emissions from engine exhaust before it enters the atmosphere;
- A fiberous mat which is used as the mounting material to hold the substrate in a sheet metal housing during all modes of engine operation;
- A sheet metal housing for the mat and coated substrate which forms either the catalyst assembly or sub-assembly, the latter to be packaged in another housing to form the catalyst or catalytic converter muffler assembly.

Inside the converter, a series of baffles dampens the noise of the exhaust by breaking the sound waves into shorter lengths. The exhaust is channeled through the catalytic converter, a section of fine ceramic honeycomb called the substrate. The substrate is washcoated for durability with thermal and mechanical properties. The heat of the exhaust heats the coated mat in the substrate. Once the catalytic converter is warmed to operating temperature, the hot mat ignites any unburned fuel and oil in the exhaust. The remaining fuel and oil burn, and the cleaned exhaust passes through another section of baffles that further muffle any noise.

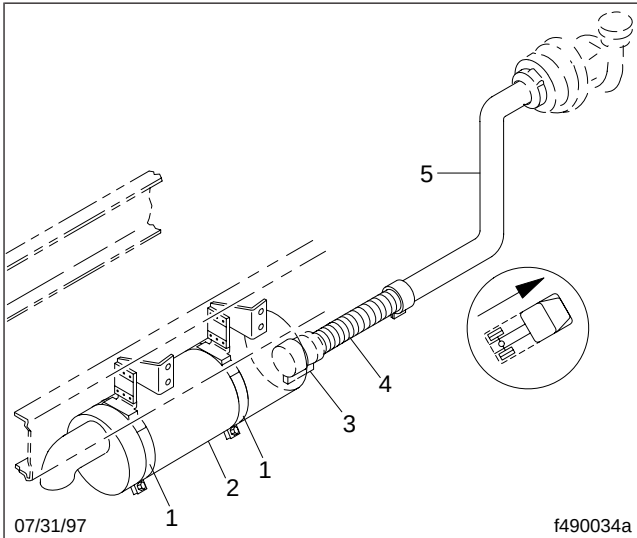
Although the catalytic converter muffler is the same size as a standard muffler assembly, the converter muffler weighs about 50 percent more. A converter muffler will weigh approximately 33 lbs (15 kg). To be fully effective, the mat on the ceramic honeycomb of the substrate must stay clean so that it can contact and burn any fuel and oil in the exhaust. A layer of pollutants on the mat will insulate it and allow unburned fuel and oil to pass through the catalytic converter muffler. To prevent pollution build-up on the mat, the muffler is built with aluminized stainless steel which is thicker and heavier than the aluminized steel used in standard mufflers.

All catalytic converter muffler installations are certified to be in compliance with 1994 EPA standards. Use parts specified by PartsPro® when replacing any of the exhaust system components.

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Replacement

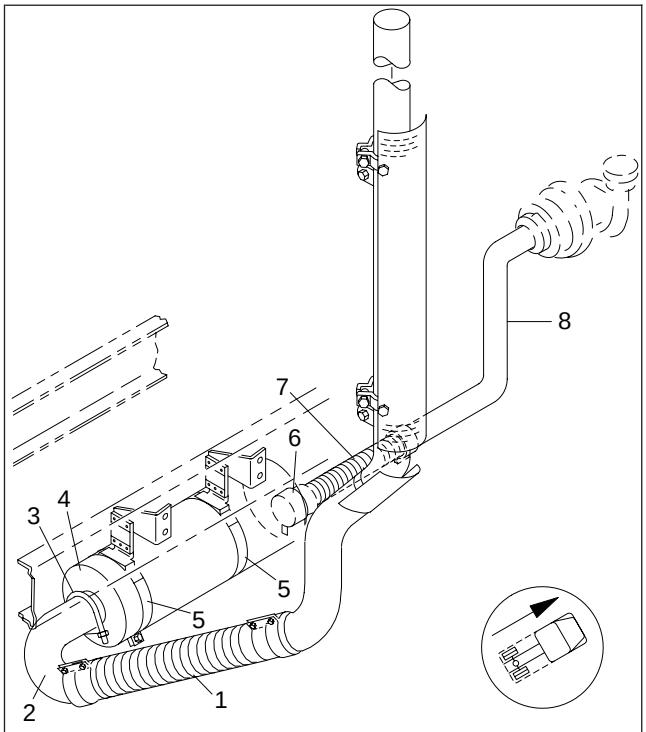
HORIZONTALLY-MOUNTED MUFFLERS (See Fig. 1 and Fig. 2)



1. Muffler Mounting Band
2. Muffler
3. Wide-Band Exhaust Clamp
4. Exhaust Flex Pipe (except Cummins ISB engine)
5. Muffler Inlet Exhaust Pipe

Fig. 1, Exhaust System Without a Stack

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the muffler.
   - 2.1 Remove and discard the wide-band exhaust clamp from the muffler inlet connection.
   - 2.2 On vehicles with a vertical exhaust stack, remove the saddle clamp from the muffler outlet connection. Pull the muffler outlet exhaust pipe out of the muffler outlet tube.
   - 2.3 Remove the bolts and locknuts on the front and rear muffler mounting bands. Remove the mounting bands. Remove the muffler.
3. Install the muffler.
   - 3.1 Slide the new muffler's inlet tube over the muffler inlet exhaust pipe.



1. Flex Pipe
2. Rear Exhaust Outlet
3. Saddle Clamp
4. Muffler (catalytic converter on some engine models)
5. Muffler Mounting Band Muffler
6. Wide-Band Exhaust Clamp
7. Exhaust Flex Pipe (except Cummins ISB engine)
8. Muffler Inlet Exhaust Pipe

Fig. 2, Exhaust System, Rear Outlet

   - 3.2 Install the front and rear muffler mounting bands. Install the bolts and locknuts on the mounting bands, but do not tighten them at this time.
   - 3.3 On vehicles with a vertical exhaust stack, slide the muffler outlet exhaust pipe into the muffler outlet tube.
   - 3.4 Coat the lap joint area with chassis grease, so the clamp will slide freely without scratching the surface of the pipe.
   - 3.5 Wrap a new wide-band exhaust clamp by hand around the lap joint. Place the large end of the clamp around the muffler inlet

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Muffler Replacement

tube, and the small end around the inlet exhaust pipe.

3.6 Install the fasteners in the clamp. Starting from the larger end of the clamp, alternately tighten the fastener in three increments to a final torque of 35 to 45 lbf·ft (47 to 61 N·m).

Clean any excess chassis grease from around the clamp.

3.7 Install the saddle clamp U-bolt on the muffler outlet tube (where applicable). Tighten the saddle clamp flanged nuts alternately in three increments to a final torque of 24 lbf·ft (33 N·m).

3.8 Tighten the muffler mounting band fasteners until the band ears touch; then, tighten the fasteners two full turns or until the ears are in full contact, whichever occurs first.

3.9 Run the engine, and check for exhaust leakage at the exhaust clamp joints. Replace the wide-band exhaust clamps if they leak.

4. Remove the chocks from the tires.

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Specifications

Fastener Torques			
Description	**Grade**	**Size**	**Torque lbf·ft (N·m)**
Wide-Band Exhaust Clamp	—	—	35–45 (47–61)
Saddle Clamp U-Bolt	—	3/8–16	24 (33)
Exhaust Stack Shield Capscrews	302 SS	5/16–18	13 (18)
Mounting Band Fasteners	—	—	10 (14)

Table 1, Fastener Torques

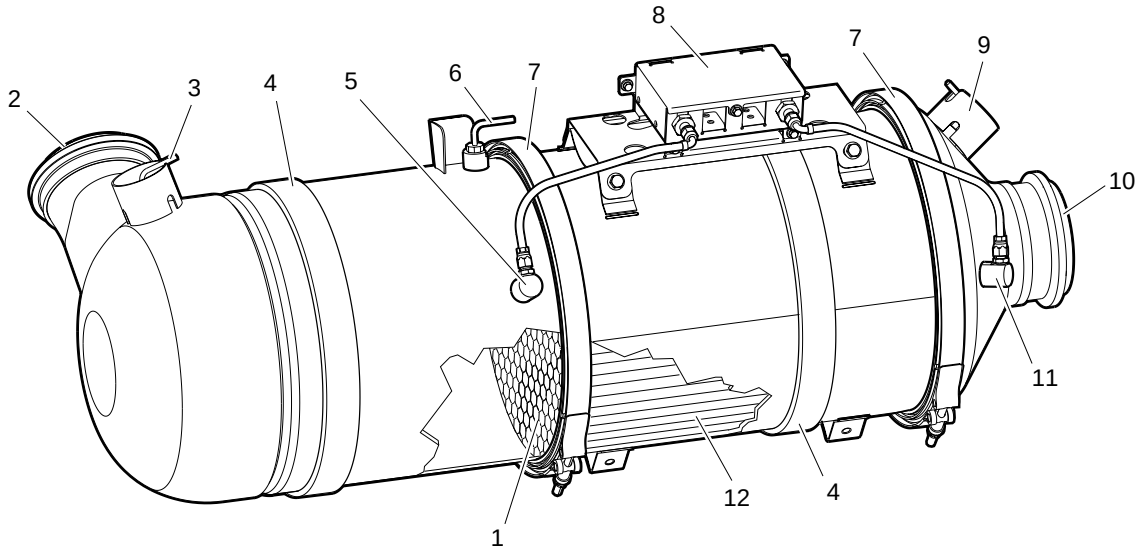
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General Information

The aftertreatment system (ATS), introduced to meet the requirements of the EPA07 emission control regulations, includes all the piping and equipment between the turbocharger outlet and the tip of the exhaust pipe. It resembles the exhaust system on pre-EPA07 vehicles, but includes an aftertreatment device (ATD) instead of a muffler (see **Fig. 1**), and other equipment. Monitoring and operation of the ATS is controlled by an electronic control module (ECM).

ways chassis-mounted, but can be mounted either vertically or horizontally. ATS exhaust piping is stainless steel.

Inside the ATD, the exhaust first passes through the diesel oxidation catalyst (DOC) where combustion gases are chemically broken down to water and carbon dioxide, then through the (DPF), where solid particles are trapped. The trapped particles are almost completely vaporized in the DPF in regeneration, sometimes shortened to the term, "regen." The soot from engine oil additives which cannot be vaporized is burned to ash and held in the DPF until it eventu-



1. Diesel Particulate Filter (DPF) Ceramic Honeycomb Substrate Openings
2. Marmon Fitting at Inlet from Turbocharger
3. Diesel Oxidation Catalyst (DOC) Intake Temperature Sensor
4. ATD Mounting Band
5. DPF Intake Pressure Sensor
6. DOC Outlet Temperature Sensor (connection to sensor housing not shown)
7. DPF V-Band Mounting Clamps
8. Sensor Housing
9. DPF Outlet Temperature Sensor (connection to sensor housing not shown)
10. Exhaust Outlet Marmon Fitting
11. DPF Outlet Pressure Sensor
12. DPF Substrate Tubes

Fig. 1, ATD Components (typical)

EPA07 emissions regulations limit NOx to just over 1 gram per brake horsepower hour (g/bhp-hr) and particulate matter cannot exceed 0.01 g/bhp-hr. EPA07 engines require ultralow sulphur diesel (ULSD) fuel, for low emissions and long life of the diesel particulate filter (DPF), a honeycomb soot filter inside the ATD.

Engine manufacturers use different methods and equipment to reduce emissions from their engines, but an ATD is used on all of them. The ATD is al-

ally builds up, and the DPF must be removed and physically cleaned.

IMPORTANT: To minimize soot buildup on the DPF, low-ash oil is necessary for maximum service between physical cleanings. Only low-ash oil should be used in EPA07 engines.

NOTE: Sterling documentation deals only with removal and installation of the components of the ATS. Refer to the engine manufacturer's ser-

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vice literature for all testing, disassembly, cleaning, and repair of the ATD and other components.

IMPORTANT: The ATS is part of an integrated engine and emissions management system, controlled by the ECM. Follow the engine manufacturer's procedures, and use the correct equipment when diagnosing or working on any part of the ATS.

Regeneration

There are two types of regeneration; passive and active.

Passive regeneration happens whenever the ATD internal temperature is 572°F (300°C) or higher. This happens during normal loaded vehicle operation, and exhaust gas temperature is no higher than normal. Under load and at highway speeds, passive regeneration may be all that is necessary to keep the DPF clear. But running light loads, or at low speeds, does not generate enough heat in the ATD for passive regeneration, and soot builds up in the DPF.

As soot builds up in the DPF, it creates back pressure and decreases engine efficiency. So at intervals determined by the ECM, which keeps track of measurements such as engine hours, fuel consumed, and mileage, the ATS raises the temperature inside the ATD to burn the built-up soot to ash. This reduces the back pressure and allows the DPF to continue operating efficiently for tens of thousands of miles.

During active regeneration, engine rpm rise to fast-idle speed and extra fuel is injected into the ATD to raise its interior temperature very high, over 1112°F (600°C), and turn the trapped soot to harmless ash. There are two types of active regeneration; at-speed and parked.

- When conditions permit, the ECM automatically initiates at-speed regeneration. The exact conditions for regeneration vary, according to the engine manufacturer's design. Generally, it can happen only when the vehicle speed is above 7.5 mph, and active regeneration stops when the vehicle slows to 5 mph or below.
- Parked regeneration is initiated by a driver or technician when the vehicle is safely parked with the exhaust outlet well away from any flammable substance, a specific sequence of procedures is followed, and the driver pushes the regeneration button on the dashboard. The parked regeneration sequence varies according to engine and vehicle configuration, but it must be exactly followed or regeneration cannot happen. Follow the exact sequence prescribed for the vehicle, according to the engine manufacturer's literature.

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EPA07 Aftertreatment Device Removal and Installation

Removal

These instructions are generalized, because vehicle configurations vary widely. The basic procedures apply to all aftertreatment systems. For service and repair beyond removal and installation, refer to the engine manufacturer's service literature.

NOTE: For test or service procedures on components of the ATS, consult the engine manufacturer's service literature.

NOTICE

The ATD assembly weighs from 125 to 150 pounds (57 to 68 kg) and must be protected from impact or sharp jolts. Dropping the ATD, or subjecting it to jarring impact can crack the diesel particulate filter (DPF) inside, which is built on a ceramic substrate. If that happens, the DPF is ruined and must be replaced.

A secure support is necessary to remove and install the ATD safely. The ATD must be held securely to protect it from falling, or hitting hard against something else.

The horizontal ATD lifting device (TLZ00785) is designed to handle a horizontal ATD. Vertical ATDs require a shop hoist secured to the lifting ears on top.

The aftertreatment device (ATD) is constructed so that its exterior operating temperature is comparable to that of a standard muffler, but during active regeneration, when a fuel mist is injected to raise its temperature and destroy soot deposits, its interior (see **Fig. 1**) and the outlet become hot enough to melt or ignite many common materials.

⚠ WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

1. Set the parking brake and chock the tires.

NOTE: Never attempt to start the vehicle with the ATD removed or with the ATD sensors disconnected, unless the engine manufacturer's documentation allows it for a diagnostic procedure.

2. Disconnect the connections at the sensor housing and the diesel oxidation catalyst (DOC) inlet temperature sensor. See **Fig. 1**.
3. Mark the Marmon fitting joints and mounting bracket orientation to the ATD, so that it can be installed exactly as it was removed. See **Fig. 2**.

NOTE: There are guide pins (see **Fig. 3**) to position the ATD during vehicle manufacture, but they are designed to break off if they are stressed. The most important thing about ATD mounting is that the other ATS components, particularly the bellows, must align correctly.

4. If the ATD is horizontally mounted, raise the ATD-handling device into place against it, so that the ATD is supported securely. If the ATD is vertically mounted, attach a shop crane or similar device to the lifting ears and take up the slack so that the lifting device is beginning to take the weight of the ATD.
5. The exhaust pipe may require support, such as a rope sling, to support it when the ATD is removed. If such support is required, install it now.

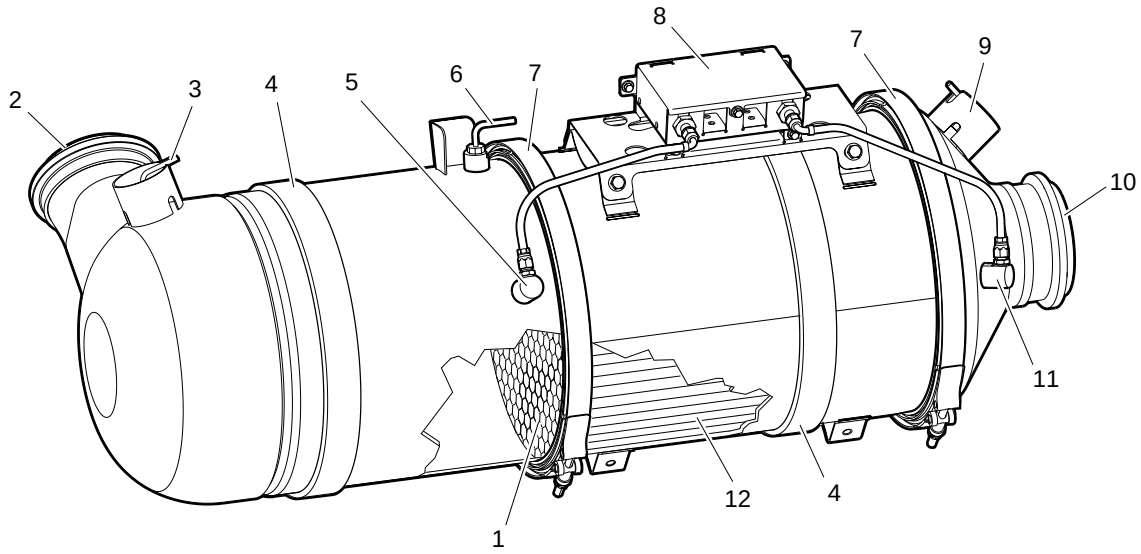
NOTICE

Be careful not to stress or twist the bellows as the ATD is manipulated. The bellows is not designed to support weight or withstand undue stress and can easily be damaged, requiring expensive replacement.

6. Remove the clamps from the Marmon fittings at the ATD inlet and outlet.
7. Remove the two mounting bands that hold the ATD to its mounting brackets, so that the ATD is held by the ATD handling device.

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EPA07 Aftertreatment Device Removal and Installation



1. Diesel Particulate Filter (DPF) Front End Honeycomb
2. Marmon Fitting at Inlet from Turbocharger
3. Diesel Oxidation Catalyst (DOC) Intake Temperature Sensor
4. ATD Mounting Band
5. DPF Intake Pressure Sensor
6. DOC Outlet Temperature Sensor (connection to sensor housing not shown)
7. DPF V-Band Mounting Clamp
8. Sensor Housing
9. DPF Outlet Temperature Sensor (connection to sensor housing not shown)
10. Exhaust Outlet Marmon Fitting
11. DPF Outlet Pressure Sensor
12. DPF Ceramic Substrate

Fig. 1, Typical ATD

NOTE: It may be necessary to raise the vehicle, or remove heat shields or body panels, to remove the ATD.

8. Move the ATD handling device slightly, so that the ATD positioning pin (see **Fig. 4**) clears its hole in the mounting bracket. Carefully remove the ATD from the vehicle.

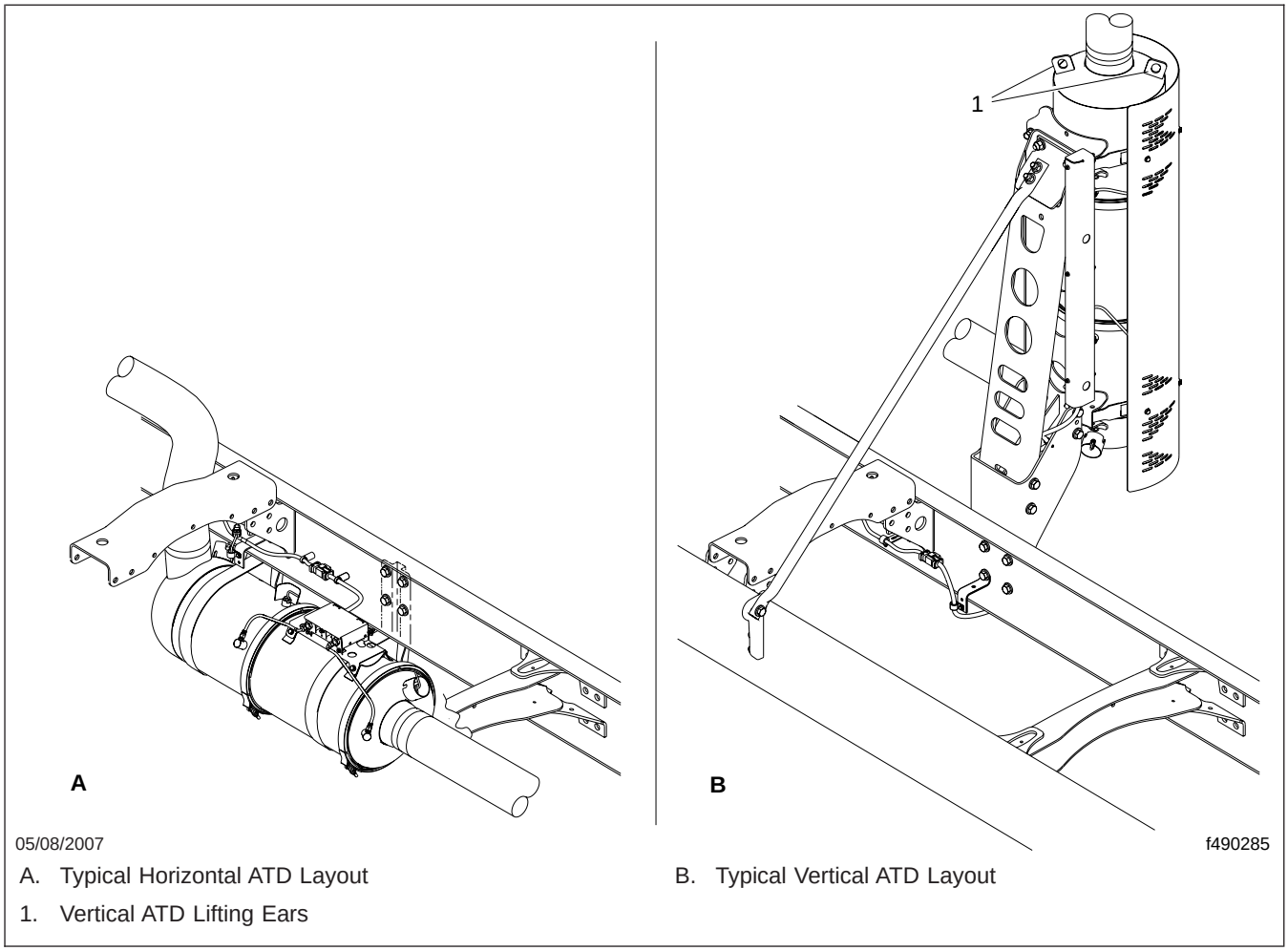
NOTE: ATD component service procedures, such as cleaning the DPF or servicing the sensors, are documented in the engine manufacturers' service literature.

Installation

1. Use the ATD handling device to move the ATD into position, so the inlet and exhaust align with the inlet and exhaust piping. Be sure the ATD positioning pin engages its hole in the ATD mounting bracket, or that the positioning marks align.
2. Install the ATD mounting bands, but do not tighten them yet.
3. Position the V-band clamps on the Marmon fittings and tighten them to the value shown in **Table 1**.
4. Tighten the ATD mounting bands to the value shown in **Table 1**.
5. Connect the harness to the sensor housing and the front temperature sensor.
6. Remove the ATD handling device.
7. If a support was fastened around the exhaust pipe, remove it.
8. Operate the vehicle and check for leaks.

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EPA07 Aftertreatment Device Removal and Installation



A. Typical Horizontal ATD Layout

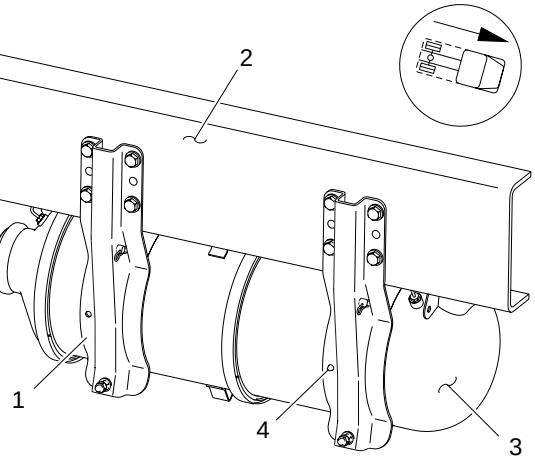
B. Typical Vertical ATD Layout

1. Vertical ATD Lifting Ears

Fig. 2, ATD Mounting Options

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EPA07 Aftertreatment Device Removal and Installation



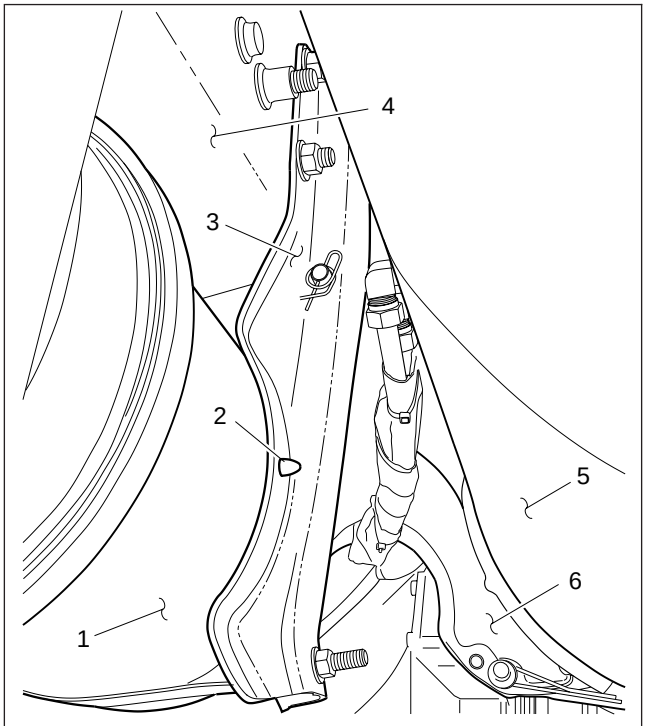
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1. ATD Mounting Bracket
2. Chassis Frame Rail
3. ATD Inlet End
4. ATD Positioning Pin

Fig. 3, ATD Mounting on Frame Rail

ATD Torque Values	
Fitting	**Torque: lbf·ft (N·m)**
Mounting Bands	Initial: 15 (20) Final: 30 (41)
Temperature Sensor Nuts	26–29 (35–39)
Pressure Line Tube Nuts	11–13 (15–17)
Pressure Sensor Jam Nuts	15–18 (20–25)
Marmon V-Band Clamps	12–13 (16–17)
Compression Fittings	15–18 (20–25)
Bellows Torco Clamps	Target: 41 (56) Range: 35–48 (48–64)

Table 1, ATD Torque Values



06/11/2007 f490293

1. ATD
2. ATD Positioning Pin
3. ATD Mounting Bracket
4. Chassis Frame Rail
5. Fuel Tank
6. Fuel Tank Mounting Bracket

Fig. 4, ATD Mounting Bracket

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EPA07 Aftertreatment System Bellows Replacement

Replacement

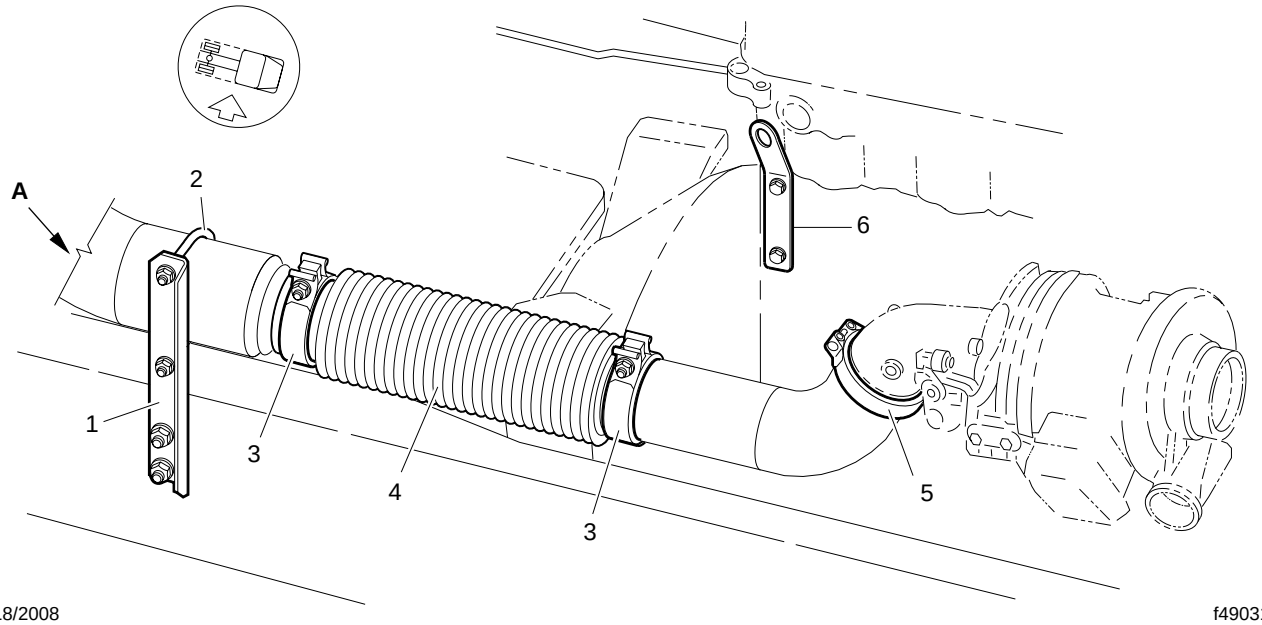
1. Open the hood.
2. Open the tool box under the passenger-side door, and remove the cover.
3. Remove the right quarter fender and mud flap. For instructions, see **Group 88**.
4. Remove the V-clamp (**Fig. 1**, Item 5) that holds the turbo outlet pipe to the turbocharger.
5. Remove the U-clamp that holds the aftertreatment device (ATD) inlet pipe to the support bracket on the frame rail (**Fig. 1**, Item 2).
6. Remove the clamp that holds the exhaust pipe to the front of the ATD, then disconnect the exhaust pipe from the ATD.
7. Remove the bellows and exhaust pipes as a unit from under the vehicle. If the vehicle is equipped with side fairings, remove the parts from the rear of the vehicle.
8. Place the assembly on a work bench. Loosen and spread the seal clamps on the ends of the bellows. Pry the ends of the bellows off the exhaust pipes, being careful not to damage the exhaust pipe ends. If it is not possible to remove the bellows this way, proceed as follows:

⚠ WARNING

Always wear a face shield and other appropriate protection when using a cutting wheel.

The cut edges of the bellows are extremely sharp, and can cause serious injury. Wear appropriate protective gear, including heavy gloves and a face shield, when removing the bellows from the exhaust pipes.

9. If you cannot remove the bellows by prying, use a cutoff wheel to cut through each end of the bellows between the exhaust pipe ends. Be careful not to cut the exhaust pipes. Discard the center section of the bellows when it is cut loose.



02/18/2008 f490313

A. To the Aftertreatment Device (ATD)

1. Frame-rail Support Bracket
2. U-Clamp
3. Seal Clamp
4. Bellows
5. V-Clamp
6. Bellows Support Bracket

Fig. 1, Bellows Installation

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EPA07 Aftertreatment System Bellows Replacement

10. Carefully remove the bellows ends and clamps from the exhaust pipes, either by prying them off, or by driving them off with a soft drift. Be careful not to damage the exhaust pipes.

IMPORTANT: Take the following measurements *before* installing the bellows.

The main section of the ATD inlet pipe is a larger diameter than the turbo outlet pipe. Make sure you measure at the **end** of the pipe, where it inserts into the bellows. The two measurements should be identical. If they are not, loosen the U-clamp nuts that hold the ATD inlet pipe to the frame-rail support bracket, and move the pipe up or down as needed.

NOTICE

The ends of the ATD inlet pipe and the turbo outlet pipe must be in exact vertical and horizontal alignment before installing the new bellows. If they are not aligned the bellows will be twisted, and will fail after a short time.

11. Attach the turbo outlet pipe to the turbocharger, then to the bellows support bracket. Tighten the clamps enough to hold the pipe in place.
12. Attach the ATD inlet pipe to the ATD and the frame-rail support bracket. Tighten the clamps enough to hold the pipes in place.
13. Using a ruler or tape measure, measure the vertical distance between the end of the ATD inlet pipe and the frame rail. See **Fig. 2**. Do the same for the end of the turbo outlet pipe. The two measurements must be the same. If the measurements are different, loosen the U-clamp nuts on the frame-rail support bracket, and raise or lower the ATD inlet pipe as needed. Tighten the U-clamp nuts enough to hold the pipe in place.
14. Using a ruler (or a T-square) and a tape measure, measure the distance between each pipe end and the frame rail. See **Fig. 3**. If these two measurements are different, do one or more of the following adjustments (see **Fig. 4**):
    - Check that the U-clamp on the bellows support bracket is installed correctly, and is not crooked.
    - Rotate the turbo outlet pipe at the turbocharger.
    - Support the ATD with a suitable jack, then loosen the ATD straps and rotate the ATD.
    - Rotate the ATD inlet pipe at the Marmon flange on the ATD.
15. With the two pipe ends in horizontal and vertical alignment and the bellows not installed, measure the distance between them. See **Fig. 5**.

    The distance between the pipe ends is to be at least 14 inches (35.5 cm), but not more than 14-3/8 inches (36.5 cm).

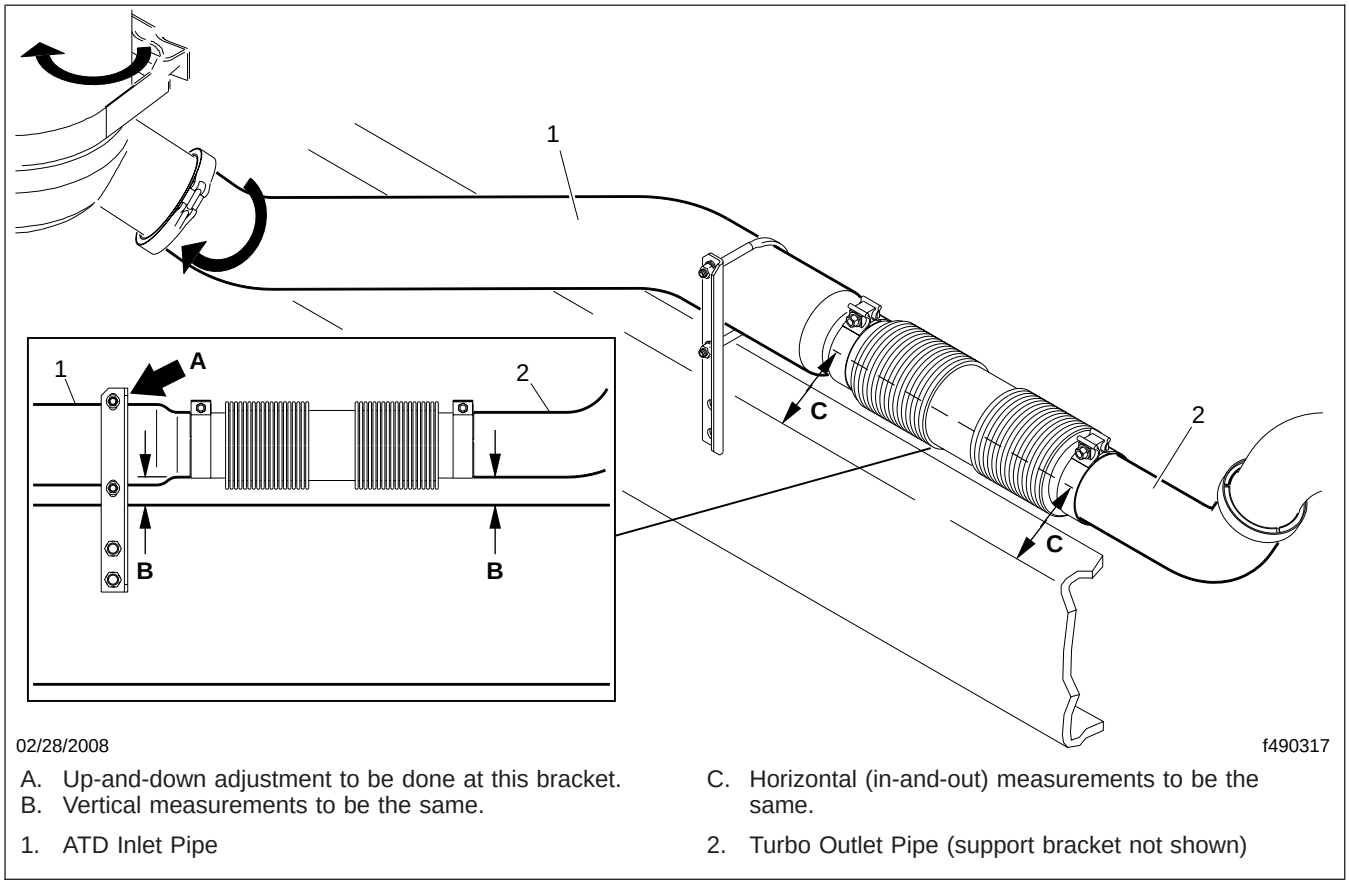
    If the distance is less than the above, remove the turbo outlet pipe and the ATD inlet pipe, and cut off an equal amount from each pipe end, as needed; otherwise, go to the next step. Make sure you remove all burrs from the cut ends of the pipes.

IMPORTANT: If they were loosened, do not tighten the ATD mounting straps until the U-clamp nuts on the frame-rail support bracket are tightened to their final torque. To do otherwise will affect the alignment of the exhaust pipes.

16. When the horizontal and vertical alignment is the same for both exhaust pipes and the distances between the pipe ends is correct, tighten the U-clamp nuts on the frame-rail support bracket that holds the ATD inlet pipe in place. See **Subject 100** for torque values.
17. Tighten the V-clamp that holds the inlet pipe to the ATD. See **Subject 100** for torque values.
18. If applicable, tighten the mounting straps on the ATD, then remove the jack.
19. Remove the turbo outlet pipe from the turbocharger.
20. Remove any dirt or soot from the outer surface of the exhaust pipe ends to ease the installation of the new bellows.
21. Install the new bellows on the ATD inlet pipe, with the clamp nuts on top and facing outboard (**Fig. 2**).
22. Insert the end of the turbo outlet pipe into the bellows, then connect the pipe to the turbocharger and to the new bellows support bracket. See **Subject 100** for torque values.
23. Tighten the bellows seal clamps; see **Subject 100** for torque values.

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EPA07 Aftertreatment System Bellows Replacement



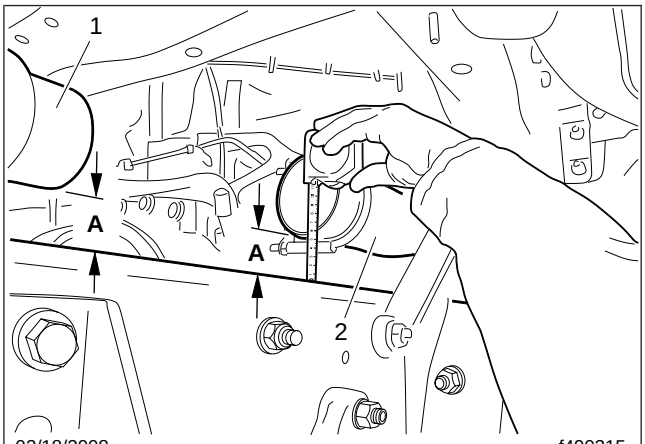
A. Up-and-down adjustment to be done at this bracket.
B. Vertical measurements to be the same.
C. Horizontal (in-and-out) measurements to be the same.
1. ATD Inlet Pipe
2. Turbo Outlet Pipe (support bracket not shown)

Fig. 2, Rotation and Adjustment Areas for Exhaust Pipe alignment (vertical ATD installation shown)

24. Start the engine and check for leaks. Shut down the engine, and tighten any clamps as needed.

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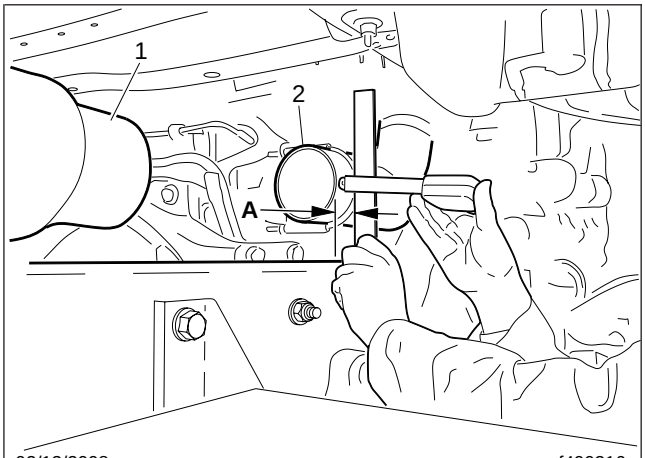
EPA07 Aftertreatment System Bellows Replacement



A. This distance must be the same at both exhaust-pipe ends.

1. ATD Inlet Pipe 2. Turbo Outlet Pipe

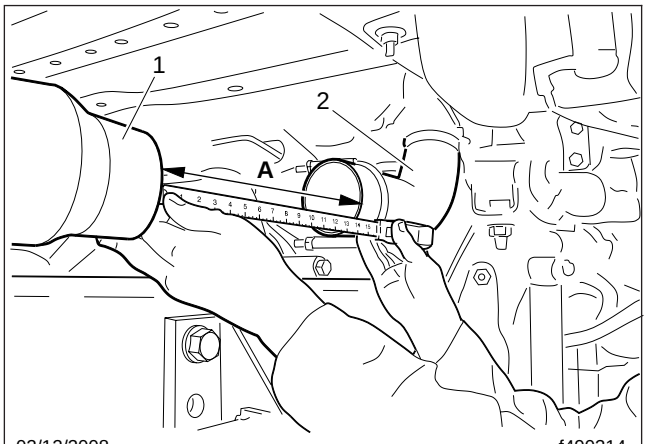
Fig. 3, Measuring the Vertical Distance



A. This distance must be the same at both exhaust-pipe ends.

1. ATD Inlet Pipe 2. Turbo Outlet Pipe

Fig. 4, Measuring the Horizontal Distance



A. This distance should be a minimum of 14 inches (35.5 cm) and a maximum of 14-3/8 inches (36.5 cm).

1. ATD Inlet Pipe 2. Turbo Outlet Pipe

Fig. 5, Measuring the Distance Between Pipe Ends

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General Information

The on-highway environment places severe demands on a vehicle's electrical system. The following material describes the methods for repairing and sealing electrical connections that will provide the durability necessary for this environment.

There are four distinct concerns for making a wire repair. A proper repair must:

- withstand the mechanical demands of vibration, strain, and thermal cycling;
- maintain oxidation-free electrical conductivity;
- insulate sufficiently to resist shorting to adjacent objects;
- seal for corrosion protection.

When troubleshooting electrical systems, consider body height and suspension travel. Interference and strain may be caused by normal frame flexing and body accessories that are not apparent when a vehicle is stationary.

Sterling vehicles have a 12-volt, negative-ground electrical system. See **Specifications 400** for a list of standard circuit numbers and circuit descriptions.

Wire Repair and Splicing

Disconnect the batteries at the negative terminals before performing any repairs to the electrical system.

IMPORTANT: Before repairing or replacing any damaged electrical system components, locate and correct the cause of the damage before continuing with the repair.

Wire that is discolored or melted due to an external heat source may need to be re-routed or installation of a heat shield may be necessary. If wire length permits, a splice may be made with a single connector. Often a length of wire will need to be added and two splices made. Carefully check damaged wire for signs of corrosion that has wicked up into the insulation and through the wire. If the wire conductor has become green or black, cut off the discolored wire and replace it with a new section.

Corrosion on battery cable terminals may be cleaned with a mild solution of baking soda and water, and scrubbed with a wire brush.

Fuses and Circuit Breakers

Sterling vehicles use blade-type fuses and have a transparent plastic housing enclosing the metal fuse element. A fuse is designed to melt the metal element at a certain amperage to protect the circuit wiring and components from damage due to an overcurrent condition. The ampere rating of a fuse can be determined by reading the number molded into the top end of the fuse or by color. See **Specifications 400** for the fuse amperage rating and color for that amperage rating.

Wire Color Code

Colored wiring aids in the diagnosis and testing of electrical systems. It allows for faster identification when testing circuits for failure. See **Specifications 400** for a list of standard wiring color-coding information.

Shielded Wires

Shielding is necessary when a critical circuit is susceptible to electromagnetic interference. Shielded wire has three conducting strands. The outermost strand is grounded, which creates a ground plane around the two inner conductors. Any interference that enters the shielded cable will be conducted to ground instead of affecting the circuit's signal.

Engine and Cab Wiring

Sterling vehicles have two PDMs, one in the engine compartment and one in the cab. Both contain fuses, circuit breakers and relays used in the electrical system.

Engine Wiring

The engine compartment PDM (see **Fig. 1**) is located in the engine compartment and has a decal identifying the location of the fuses, circuit breakers and relays on the outside of the PDM cover. To gain access, open the cover. Depending on vehicle options, fuse/circuit breaker/relay locations may vary from those shown. See **Table 1** for fuse/circuit breaker/relay identification information.

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General Information

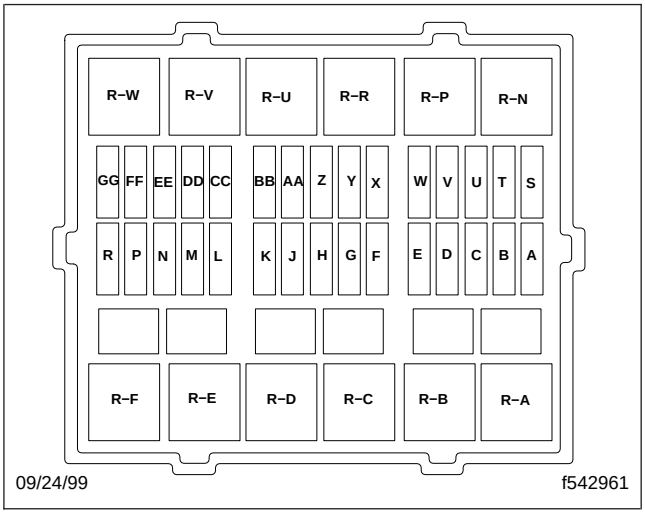


Fig. 1, Engine Compartment PDM (typical; for vehicles built before February 27, 2001)

Engine Compartment PDM Identification (typical; for vehicles built before February 27, 2001)		
Position	**Description**	**Rating**
Relays		
R-A	Fuel Heater	—
R-B	Taillight	—
R-C	Marker Light	—
R-D	Transmission - Reverse Light	—
R-E	Trailer ABS	—
R-F	Transmission Neutral	—
R-N	Trailer Left Turnlight	—
R-P	Trailer Right Turnlight	—
R-R	Trailer Parking Light	—
R-U	Trailer Marker Light	—
R-V	Trailer Taillight	—
R-W	Not Used	—
Fuses		
A	Relay R-A, Fuel Heater	40A
B	Fuses 1 and 2, PDM	30A
C	Relays R-B and R-C	40A
D	Fuses 13, 14 and 15, PDM	40A
E	Relay R2, Left Door	40A
F	Fuse F36, PDM	40A
G	Relay R8, HVAC Blower Motor	40A
H	Relay R6, Ignition Run	40A
J	Ignition to Relay R5	60A
K	Fuses 31, 32 and 33, PDM	40A
L	Fuse 37, Headlights	40A
M	Fuse 26, ABS Power	40A
N	Not Used	—
P	Not Used	—
R	Not Used	—
S	Fuses 3 and 4, Windshield Wiper	40A
T	Relays R-N and R-P, Trailer Turnlights	40A
U	Fuses 23 and 24, CB Radio	40A
V	Relay R1, Right Door	40A
W	Relays, R-R and R-U, Trailer Marker and Parking Lights	40A
X	Open	30A
Y	Open	30A
Z	Fuse 42, Taillight and Flashers	40A
AA	Customer Access Panel	40A
BB	Open	30A
CC	Relay R-V, Trailer Taillight	40A
DD	Not Used	—
EE	Relay R-E, Trailer	40A
FF	Not Used	—
GG	Not Used	—

Table 1, Engine Compartment PDM Identification (typical; for vehicles built before February 27, 2001)

Cab Wiring

The cab PDM (see **Fig. 2**) is located on the passenger side within the instrument panel. A trim panel covers the PDM and is attached to the instrument panel by quarter-turn fasteners. A decal identifying the location of the fuses, circuit breakers and relays is attached to the back side of the trim panel. See **Table 2** for fuse/circuit breaker/relay identification information.

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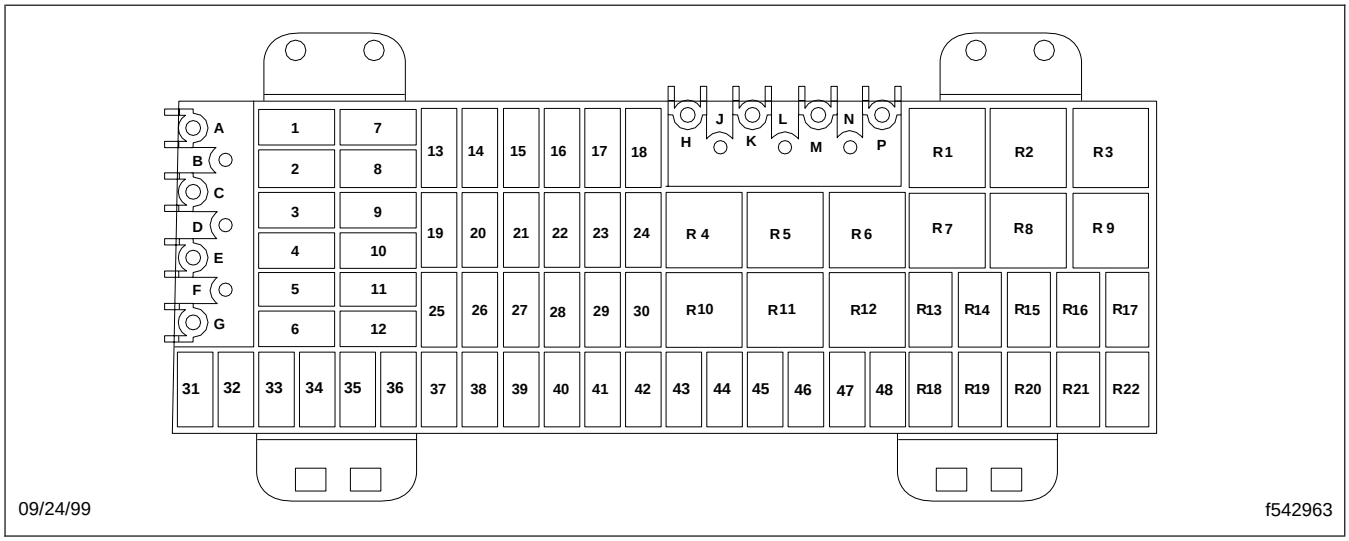


Fig. 2, Cab Power Distribution Module (typical; for vehicles built before February 27, 2001)

Cab PDM Identification (typical; for vehicles built before February 27, 2001)		
Position	**Description**	**Rating**
Fuses/Circuit Breakers		
1	Not Used	—
2	Power Door Lock	10A
3	Horn/Buzzer	10A
4	Washer/Wiper	11A/CB
5	Low Coolant Level/Hydraulic Module	15A
6	Air Dryer Heater	10A
7	Not Used	—
8	Axle Shift Supply	15A
9	Not Used	—
10	Reverse Light	10A
11	Not Used	—
12	Not Used	—
13	Diagnostic Supply	10A
14	Not Used	—
15	Radio System	20A
16	Radio System	10A
17	Heated Mirror, Power	25A
18	Accessory Supply	15A
19	Transmission	10A

Cab PDM Identification (typical; for vehicles built before February 27, 2001)		
Position	**Description**	**Rating**
20	Not Used	—
21	Not Used	—
22	Ignition Run/Start	10A
23	Not Used	—
24	CB Radio Post	15A
25	Start, Ignition	25A
26	ABS Hydraulic Pump Relay Feed	10A
27	Not Used	—
28	Not Used	—
29	Not Used	—
30	Not Used	—
31	Interior Light	15A
32	Marker Light	15A
33	Cluster Diagnostic Connector	15A
34	Left-Side Power Window	18A/CB
35	Right-Side Power Window	18A/CB
36	Trailer Utility Light	10A
37	Parking Light	15A
38	Not Used	—
39	Fog/Road Light	10A

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General Information

Cab PDM Identification (typical; for vehicles built before February 27, 2001)		
Position	**Description**	**Rating**
40	Not Used	—
41	Not Used	—
42	Taillight/Flasher Supply	30A
43	Engine Supply	10A
44	Not Used	—
45	ABS	5A
46	Not Used	—
47	ABS	5A
48	Not Used	—
Relays		
R1	Right-Side Power Window	—
R2	Left-Side Power Window	—
R3	Two-Speed Axle	—
R4	Ignition Run	—
R5	Ignition Run/Accessory	—
R6	Ignition Run	—
R7	Fog/Road Light	—
R8	HVAC Blower Motor	—
R9	Flasher	—
R10	Not Used	—
R11	Wiper/Washer	—
R12	ABS Power	—
R13	Transmission	—
R14	Brake Cut-Out	—
R15	Not Used	—
R16	Not Used	—
R17	Hydraulic Brake Pump	—
R18	Engine Brake	—
R19	ABS Warning Light	—
R20	Axle Shift, MBE900 Engine	—
R21	Electrical Engine (Service) Brake	—
R22	Transmission ABS	—
Customer Access Terminals		
A	Battery (positive)	—
B	Run/Accessory	—

Cab PDM Identification (typical; for vehicles built before February 27, 2001)		
Position	**Description**	**Rating**
C	Ground	—
D	Feed Number 1 from Chassis	—
E	Feed Number 2 from Chassis	—
F	Auxiliary Switch Number 1	—
G	Auxiliary Switch Number 1	—
H	Battery (positive)	—
J	Road Speed	—
K	Datalink (positive)	—
L	Datalink (negative)	—
M	Taillights	—
N	Auxiliary Switch Number 2	—
P	Auxiliary Switch Number 2	—

Table 2, Cab PDM Identification (typical; for vehicles built before February 27, 2001)

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Wiring Repair Using Phillips STA-DRY® Solderless Connectors

Parts are available through the Parts Distribution Centers (PDCs) in packages of 25 connectors. Use the connectors and adhesive-coated shrinkable tubing shown in **Table 1** when making a wiring splice.

Tools needed for wiring repair using solderless connectors include the following.

- A dimple-type crimp tool with a minimum 3/16 inch width. See **Fig. 1** for an example of a proper crimp tool. A typical manufacturer for this tool is Thomas & Betts.
- A heat gun rated at 1000°F (538°C).

Procedure

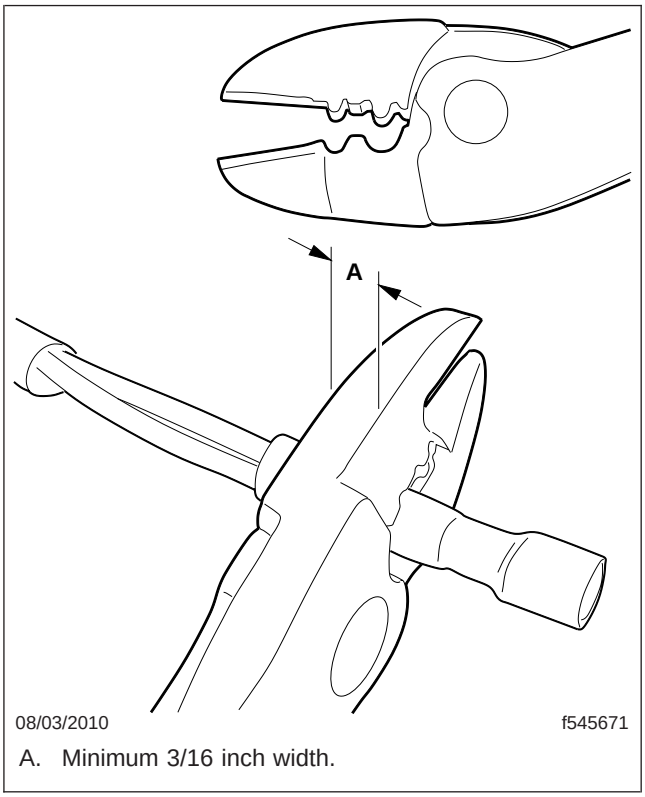
1. Dress the wires to be spliced by stripping the insulation to expose 1/4 inch of copper. Slide a 3-inch section of adhesive-coated shrinkable tubing onto one of the wires.
2. Crimp the splice connector onto the wires. Use the type of crimp tool that makes a dimple in the connector. The dimple must be at least 3/16 inch wide or there will be too much space inside the connector and the solder will not flow into the wire. This crimp provides the mechanical retention needed. See **Fig. 2**.
3. Pull test the wires by hand to ensure the crimp is mechanically solid.
4. A crimp tool that is too narrow will leave excessive air gaps in the crimp. The connection will not have the required amount of mechanical strength and the solder will not bond the wire to the connector. **Figure 3** shows an example of a bad crimp when the wrong tool is used.
5. Heat the properly crimped splice connector with the heat gun while slowly rotating the wire. The solder will take longer to flow than it will for the shrinkable insulation to contract. Heat until the solder band has completely melted into the connector. If the shrinkable insulation ruptures and a small amount of solder bubbles out, gently shake the splice to remove the solder. See **Fig. 4**.
6. When the connector has cooled, center the shrinkable tubing over the splice and heat the tubing until it has completely sealed the splice and a small fillet of adhesive is visible at the ends of the shrink tube. See **Fig. 4**.
7. A three-wire tap splice can be made following the same procedure. Use a connector that is large enough to fit all the strands of the wires. See **Fig. 5** for an example of the completed splice.

Solderless Connector Parts		
Wire Size: gauge (mm)	**Connector Part Number***	**Shrinkable Tubing (Daimler Part Number)**
20 to 18 (0.5 to 0.8)	PHM 1 1863	1/4 inch with internal adhesive coating (48-02461-025)
16 10 14 (1 to 2)	PHM 1 1862	1/4 inch with internal adhesive coating (48-02461-025)
12 to 10 (3 to 5)	PHM 1 1861	3/8 inch with internal adhesive coating–4 foot length (48-02461-038)
8 or larger (5 or larger)	Replace the terminal or the entire cable	Use adhesive lined red for positive cables and black for negative cables.

* Twenty-five connectors per pack.

Table 1, Solderless Connector Parts

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A. Minimum 3/16 inch width.

Fig. 1, Dimple-Type Crimp Tool

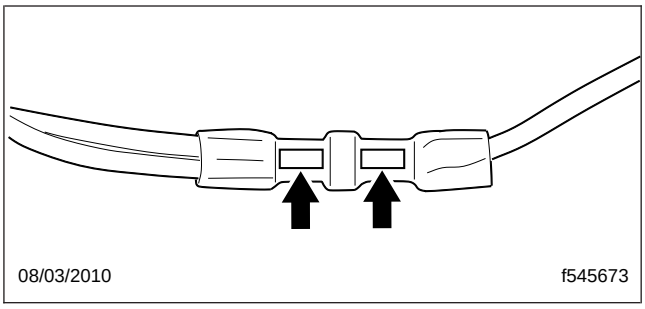
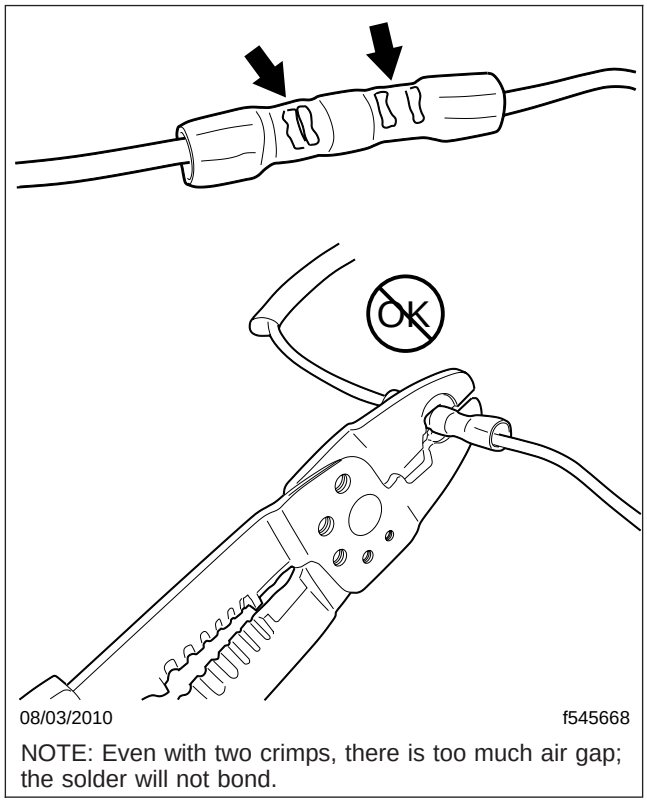


Fig. 2, Properly Crimped Splice

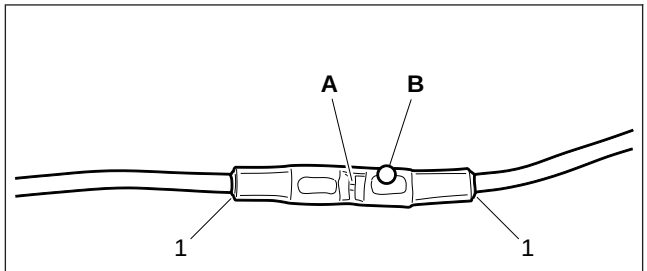
Wiring Repair Using Daimler Trucks North America (DTNA) Kit ESY ES66 404

Parts are available through the Parts Distribution Centers (PDCs) in kits with material for 50 splices. This kit may be used on 16 to 14 gauge (1 to 2 mm) wire.



NOTE: Even with two crimps, there is too much air gap; the solder will not bond.

Fig. 3, Wrong Tool Being Used and a Crimp That Will Fail



A. The solder band is completely melted.
B. Insulation rupture; gently shake off the solder bead.

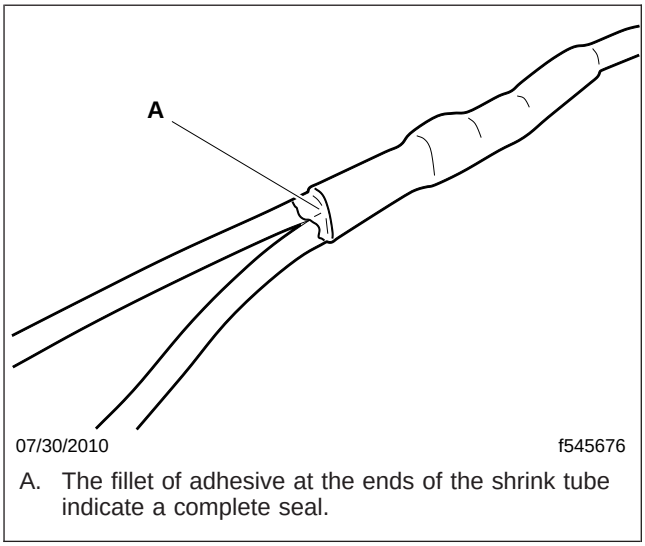
1. Adhesive Fillet

Fig. 4, Solder Bead Rupture

Tools needed for wiring repair using solderless connectors include the following.

- A dimple-type crimp tool with a minimum 3/16 inch width. See **Fig. 6** for an example of a

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A. The fillet of adhesive at the ends of the shrink tube indicate a complete seal.

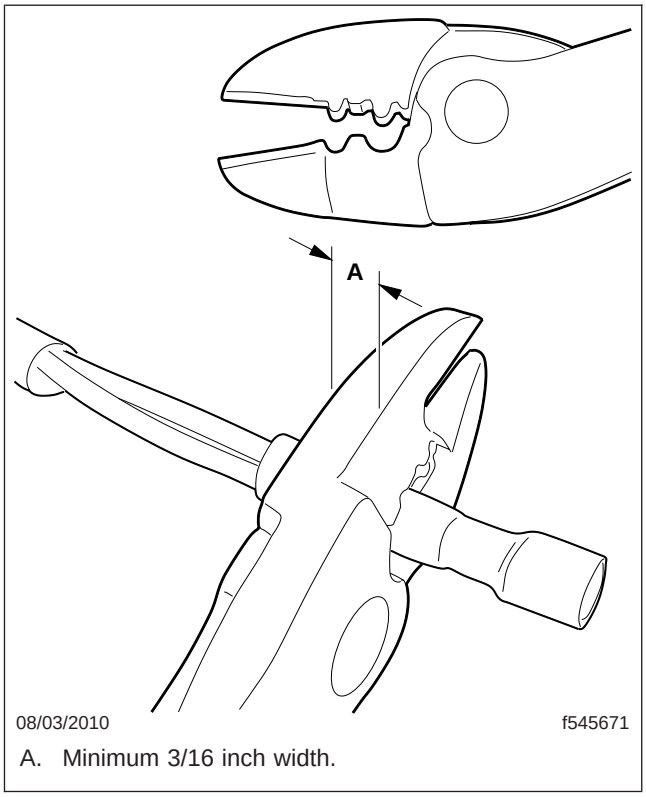
Fig. 5, Completed Three-Wire Tap Splice

proper crimp tool. A typical manufacturer for this tool is Thomas & Betts.

- A heat gun rated at 250°F (121°C).

Procedure

1. Dress the wires to be spliced by stripping the insulation to expose 1/4 inch of copper. Slide a piece of the shrink tubing from the kit onto one of the wires.
2. Slide a shrinkable solder sleeve from the kit onto one of the wires.
3. Place the wires that will be spliced into each end of the barrel connector. See **Fig. 7** for an example of the splice.
4. Crimp each end of the barrel using a dimple-type crimp tool to secure the wires. See **Fig. 6** for an example of a proper crimp tool.
5. Pull test the wires by hand to ensure the crimp is mechanically solid.
6. Slide the shrinkable solder sleeve onto the barrel connector so the solder band is at the center of the barrel connector.
7. Heat the splice using a heat gun rated at 250°F (121°C) until the sleeve has completely shrunk against the wire and the solder flows into the barrel connector. A small fillet of adhesive may be visible at the ends of the connector. See **Fig. 8**.



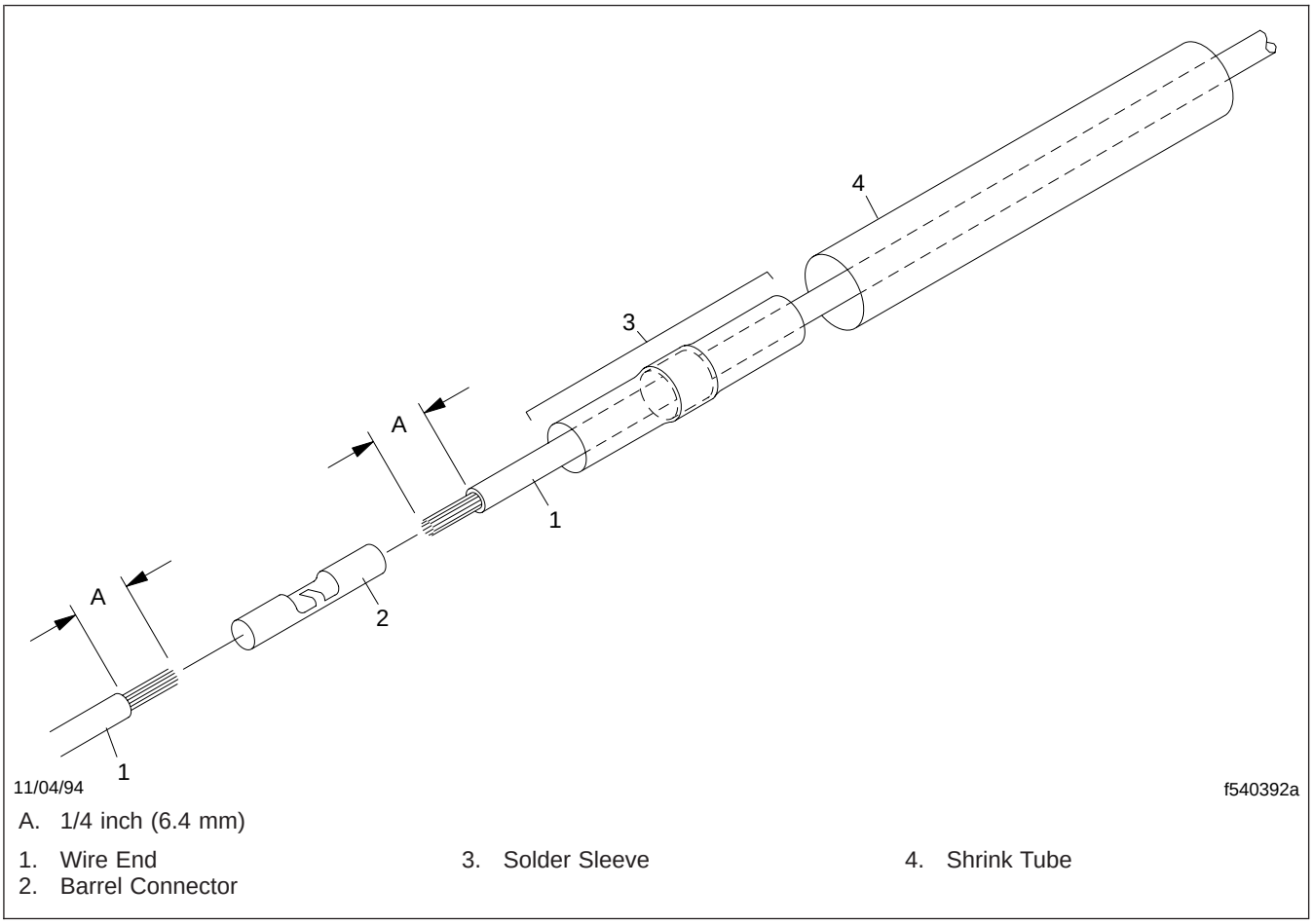
A. Minimum 3/16 inch width.

Fig. 6, Dimple-Type Crimp Tool

8. Slide the shrinkable tubing over the splice and apply heat with a heat gun rated at 250°F (121°C) until it has completely shrunk against the wire insulation. A small fillet of adhesive should be visible at the ends of the shrinkable tubing.

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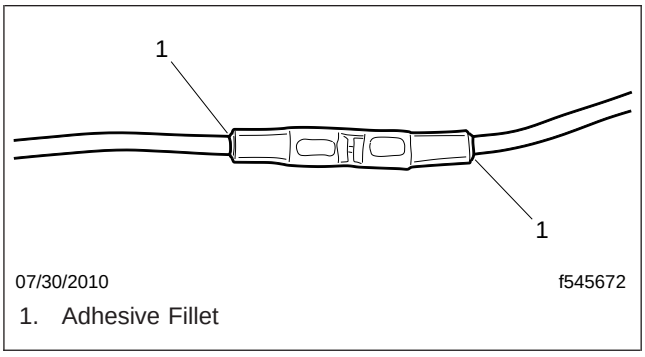
Wiring Repair and Replacement



A. 1/4 inch (6.4 mm)

1. Wire End
2. Barrel Connector
3. Solder Sleeve
4. Shrink Tube

Fig. 7, Splice Prepared with Parts in Kit ESY ES66 404



1. Adhesive Fillet

Fig. 8, Heated Solder Sleeve with Solder Band Melted into the Splice

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Wiring Diagrams

See **Fig. 1** for a full view of the power distribution wiring (ignition).

See **Fig. 2** and **Fig. 3** for partial views of the power distribution wiring (ignition).

See **Fig. 4** for a full view of the power distribution wiring (battery).

See **Fig. 5** and **Fig. 6** for partial views of the power distribution wiring (battery).

See **Fig. 7** for a full view of the customer access wiring.

See **Fig. 8** and **Fig. 9** for partial views of the customer access wiring.

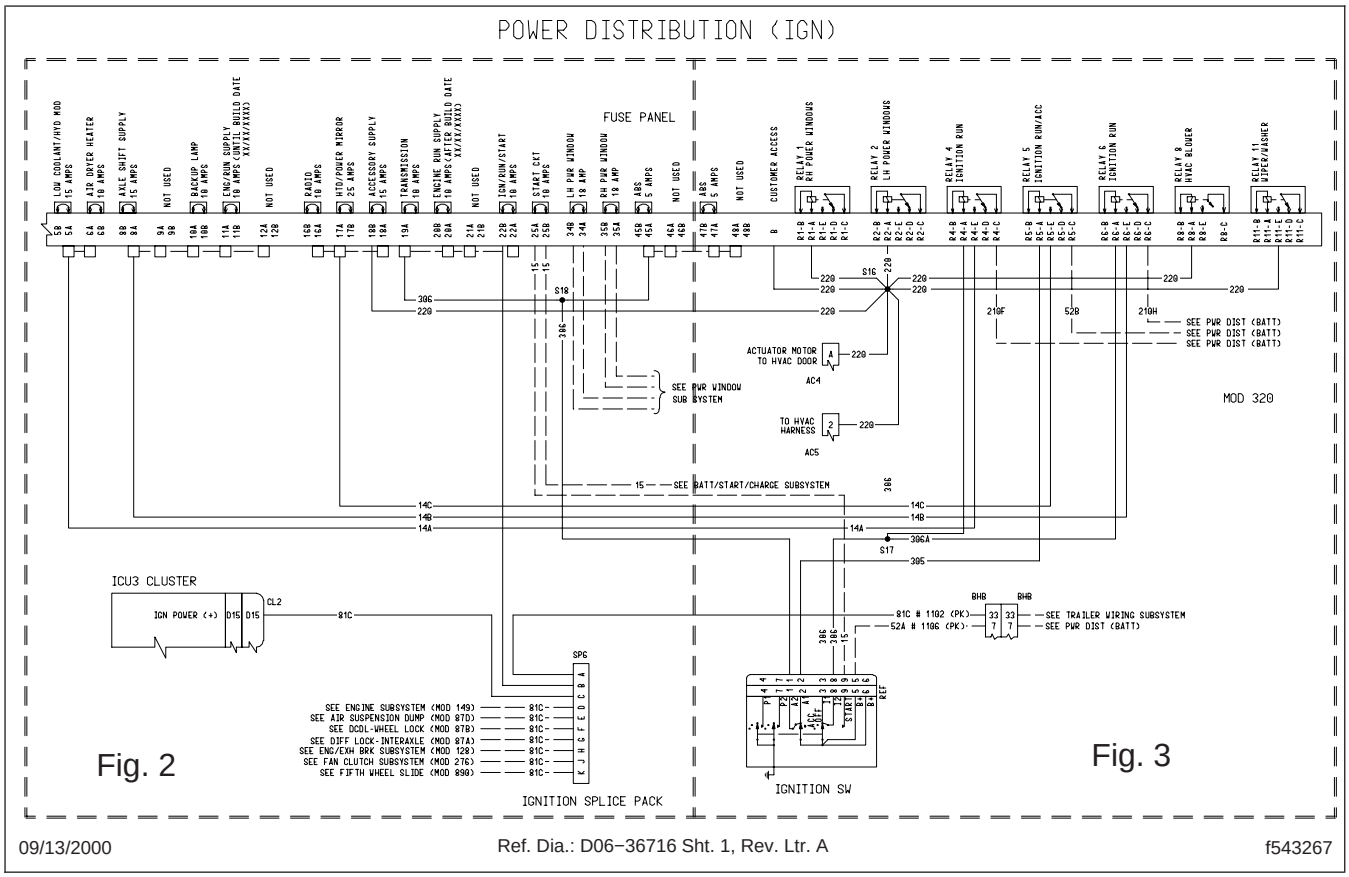


Fig. 1, Power Distribution Wiring, Ignition (full view)

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Power Distribution Schematics

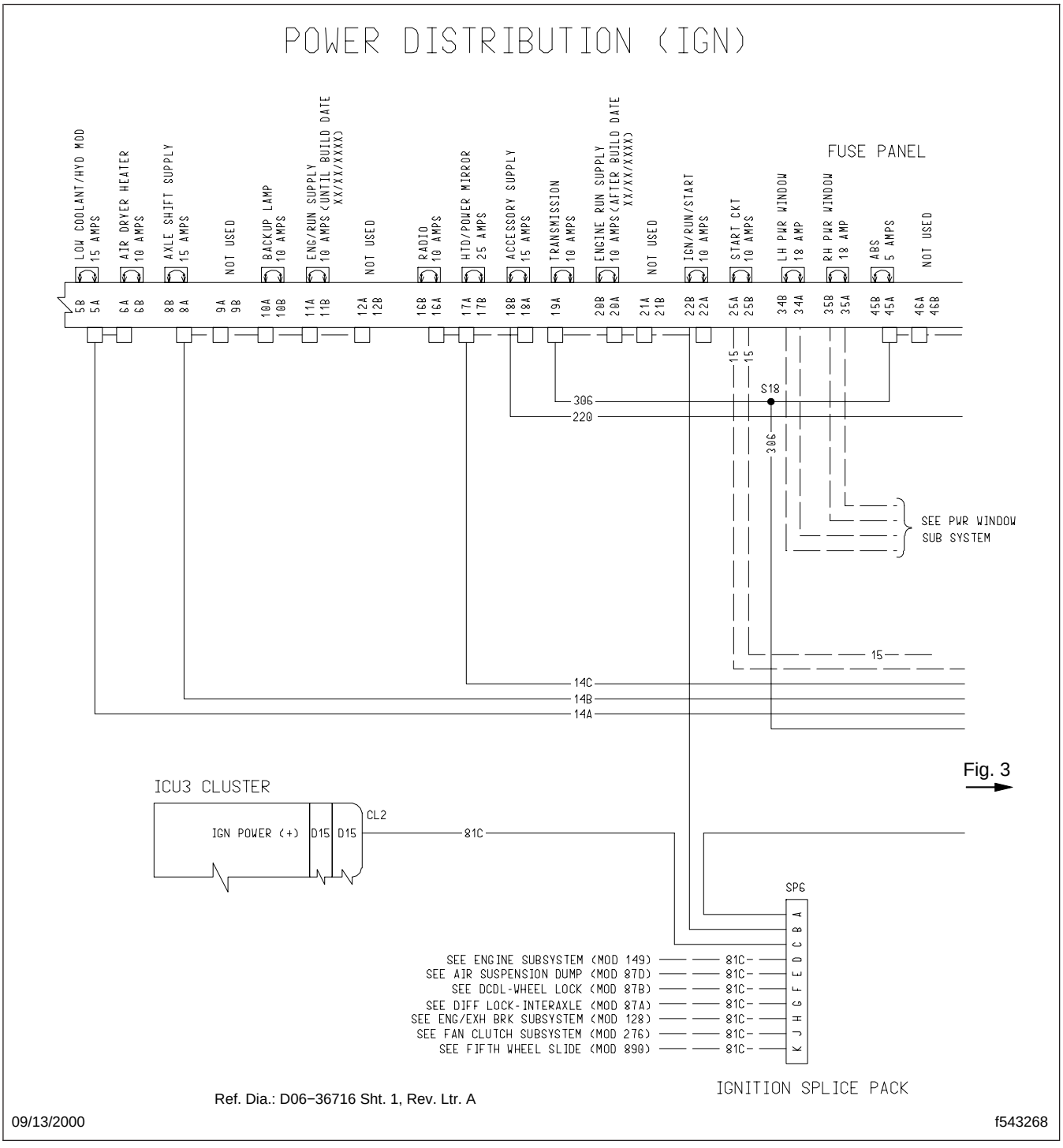


Fig. 2, Power Distribution Wiring, Ignition (partial view)

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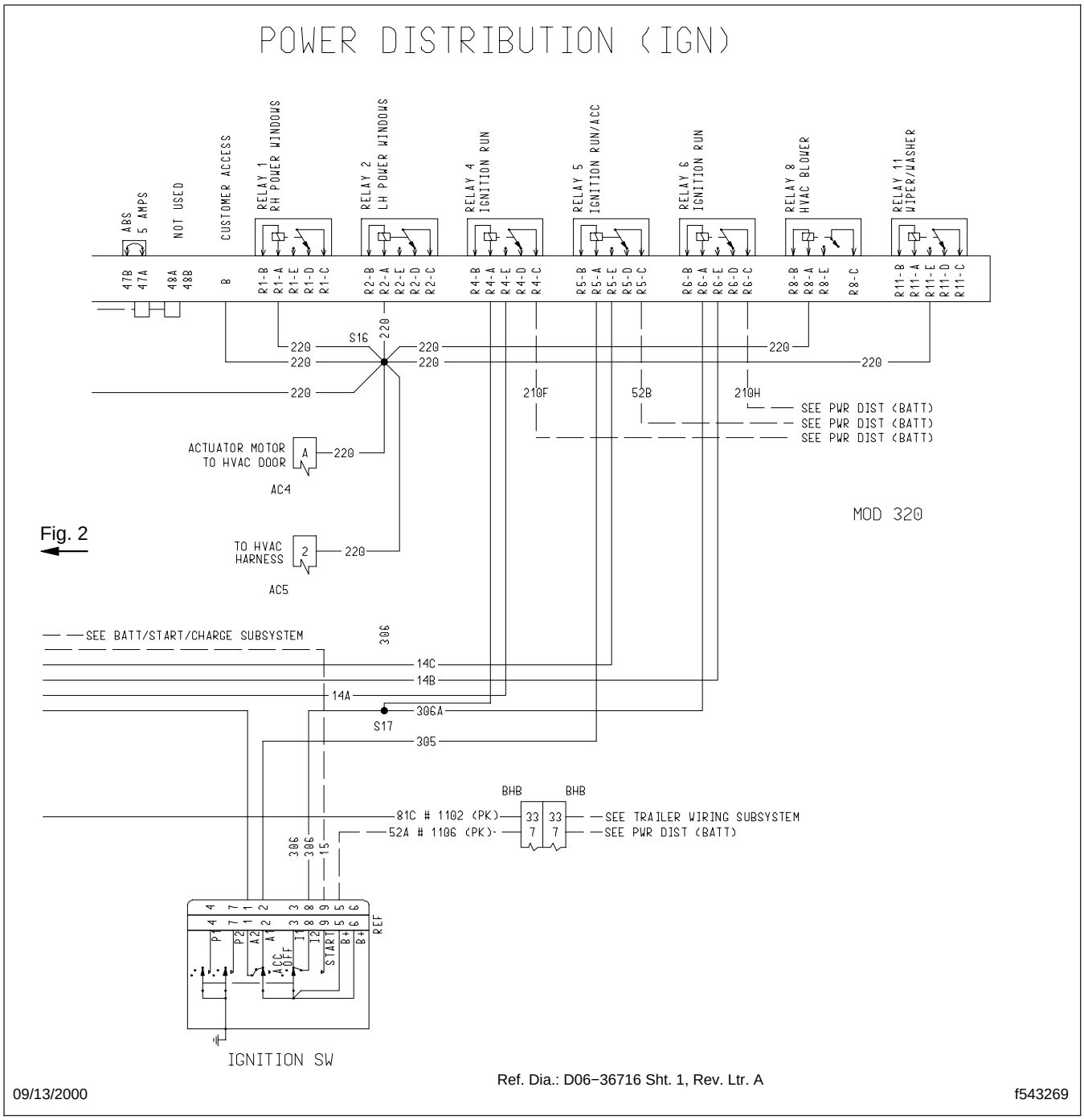
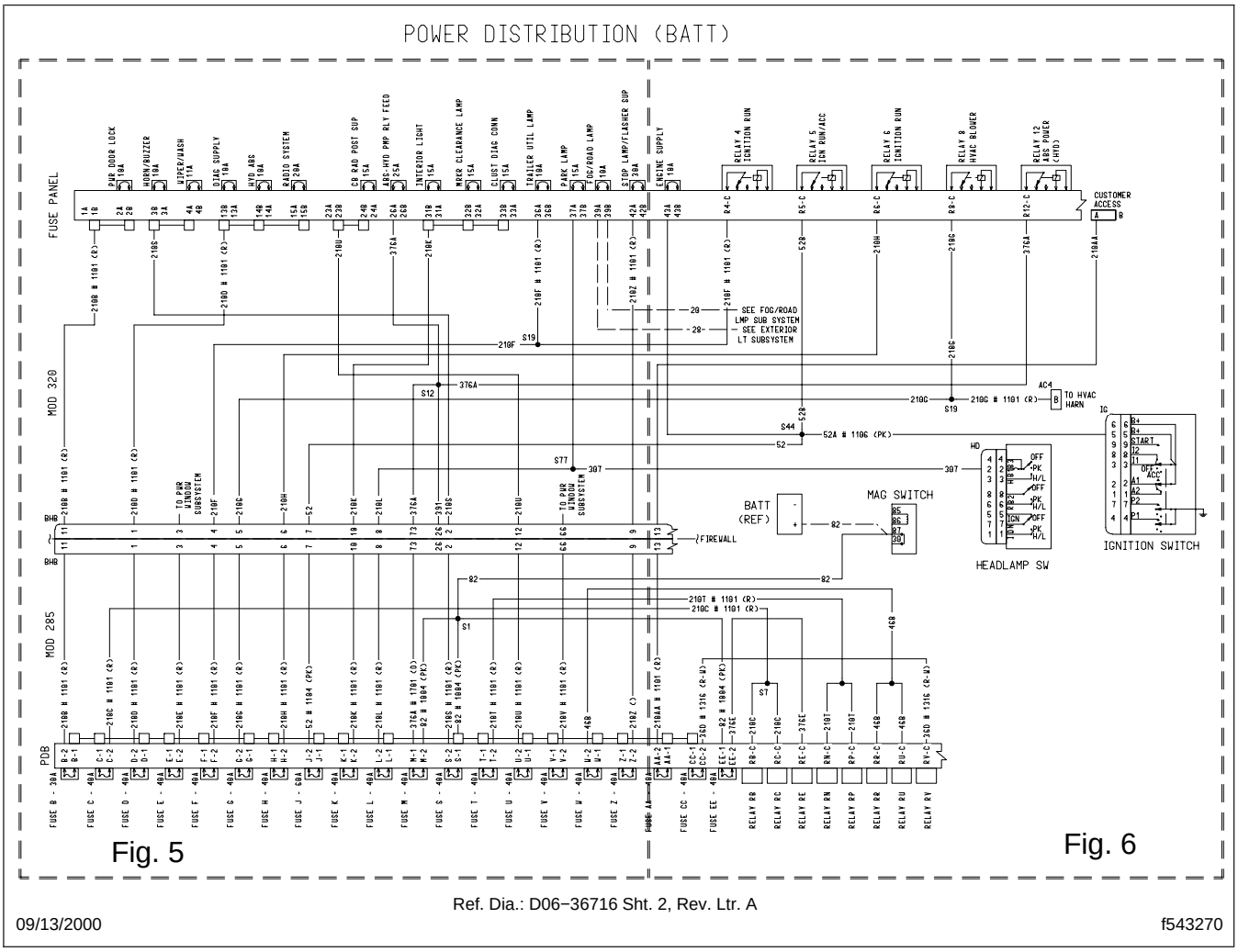


Fig. 3, Power Distribution Wiring, Ignition (partial view)

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Power Distribution Schematics



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Fig. 4, Power Distribution Wiring, Battery (full view)

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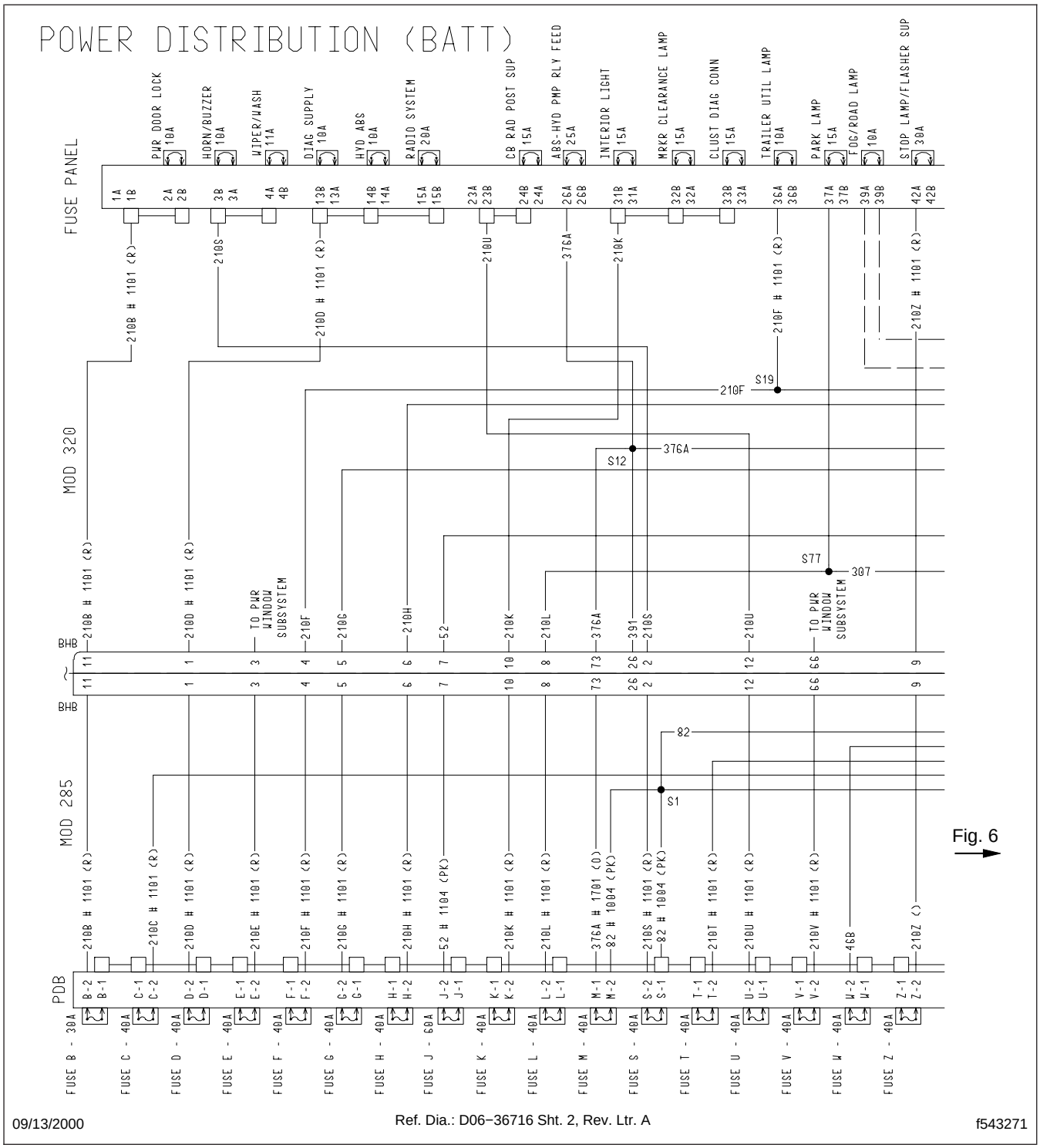


Fig. 5, Power Distribution Wiring, Battery (partial view)

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Power Distribution Schematics

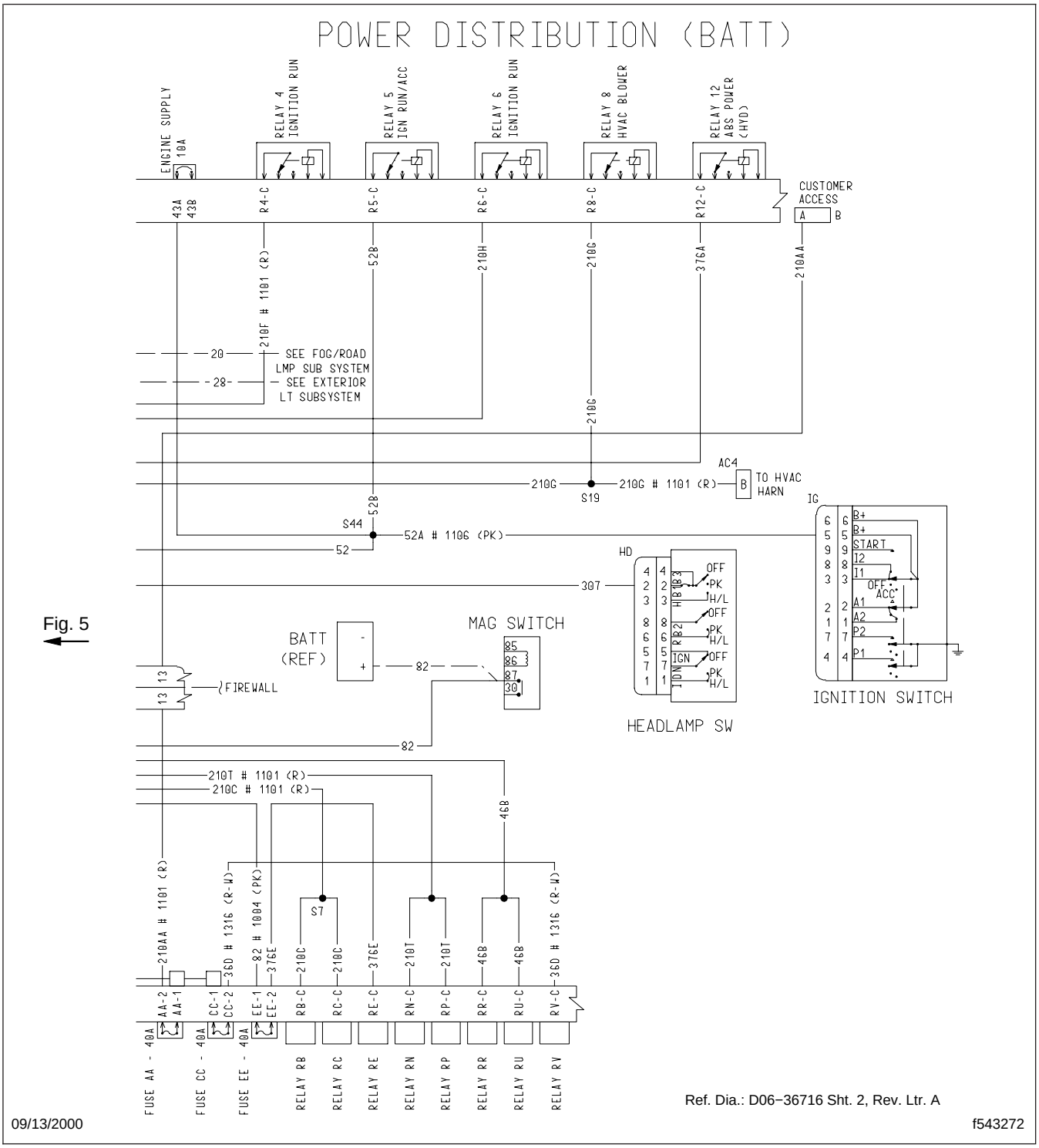


Fig. 5

Fig. 6, Power Distribution Wiring, Battery (partial view)

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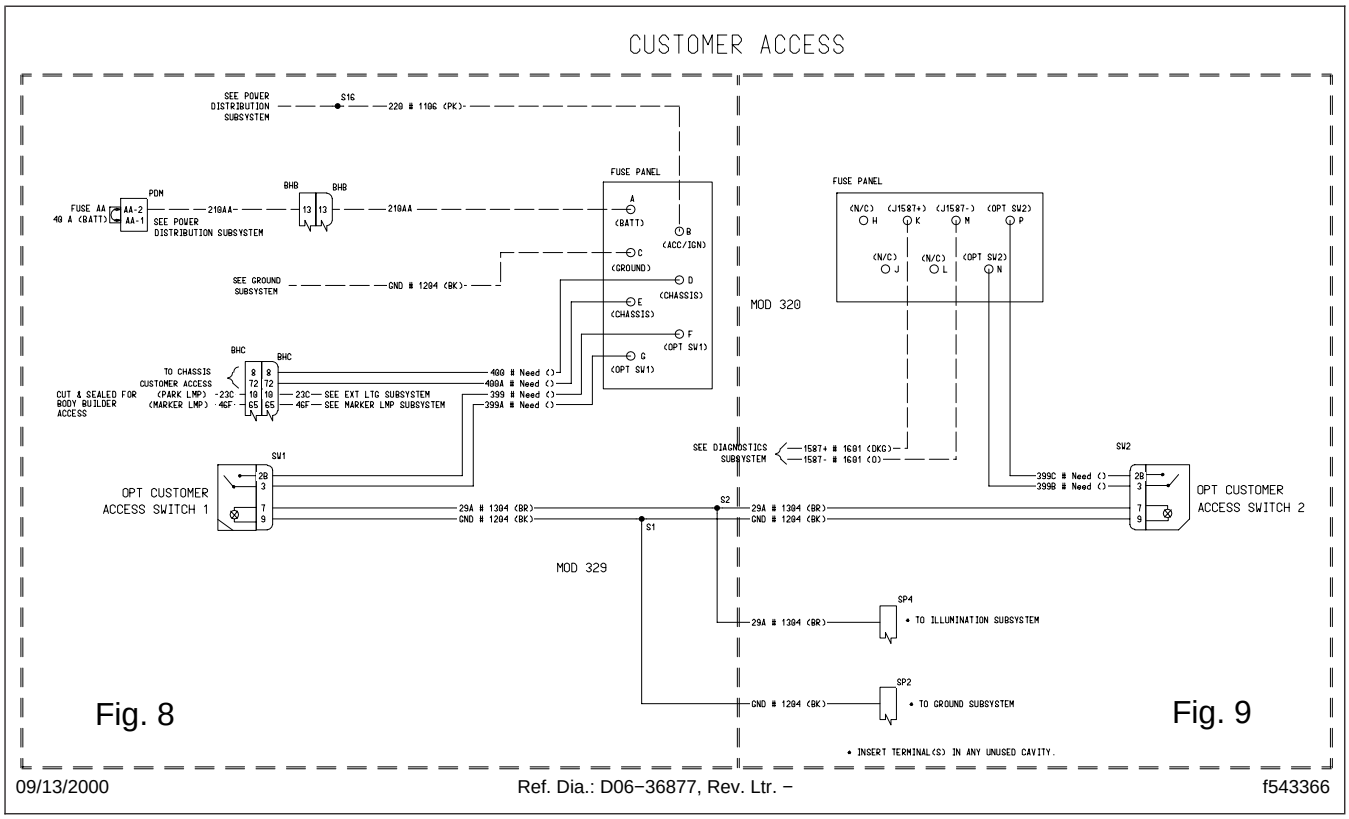


Fig. 7, Customer Access Wiring (full view)

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Power Distribution Schematics

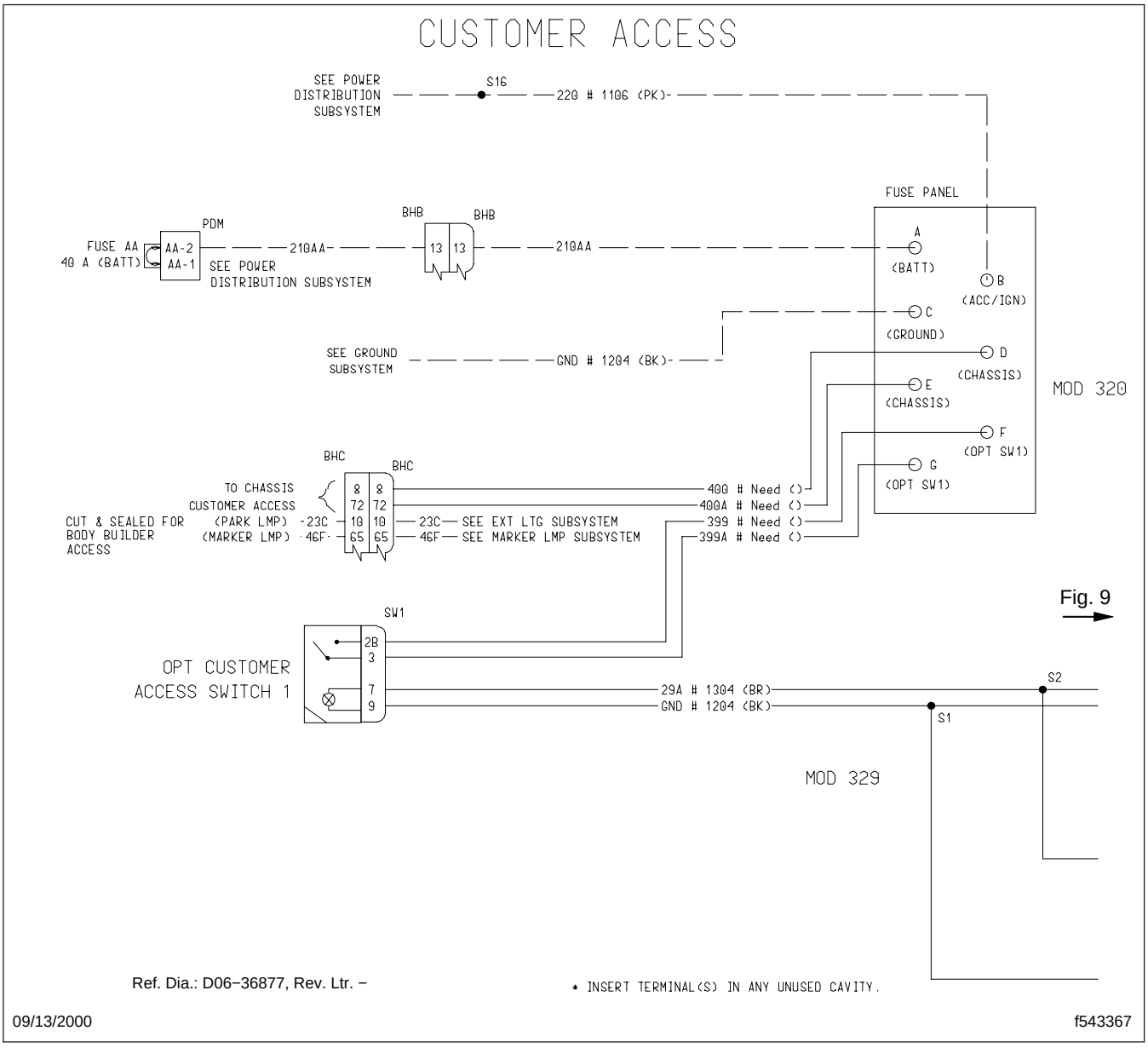


Fig. 8, Customer Access Wiring (partial view)

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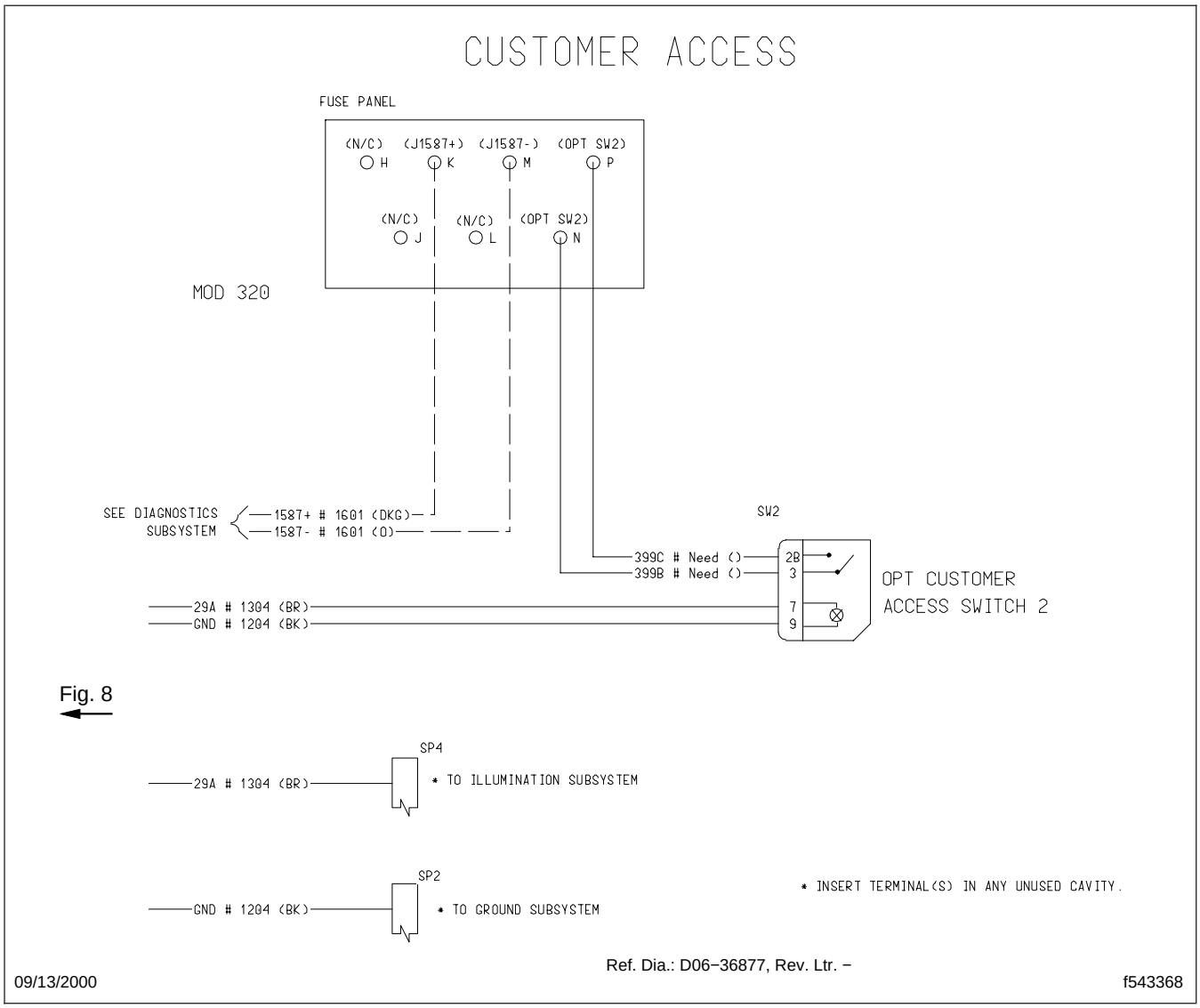


Fig. 9, Customer Access Wiring (partial view)

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Wiring Diagrams

See **Fig. 1** for a full view of Sheet 1 for ground summary wiring.

See **Fig. 2** for a full view of Sheet 2 for ground summary wiring.

See **Fig. 3** for a full view of Sheet 3 for ground summary wiring.

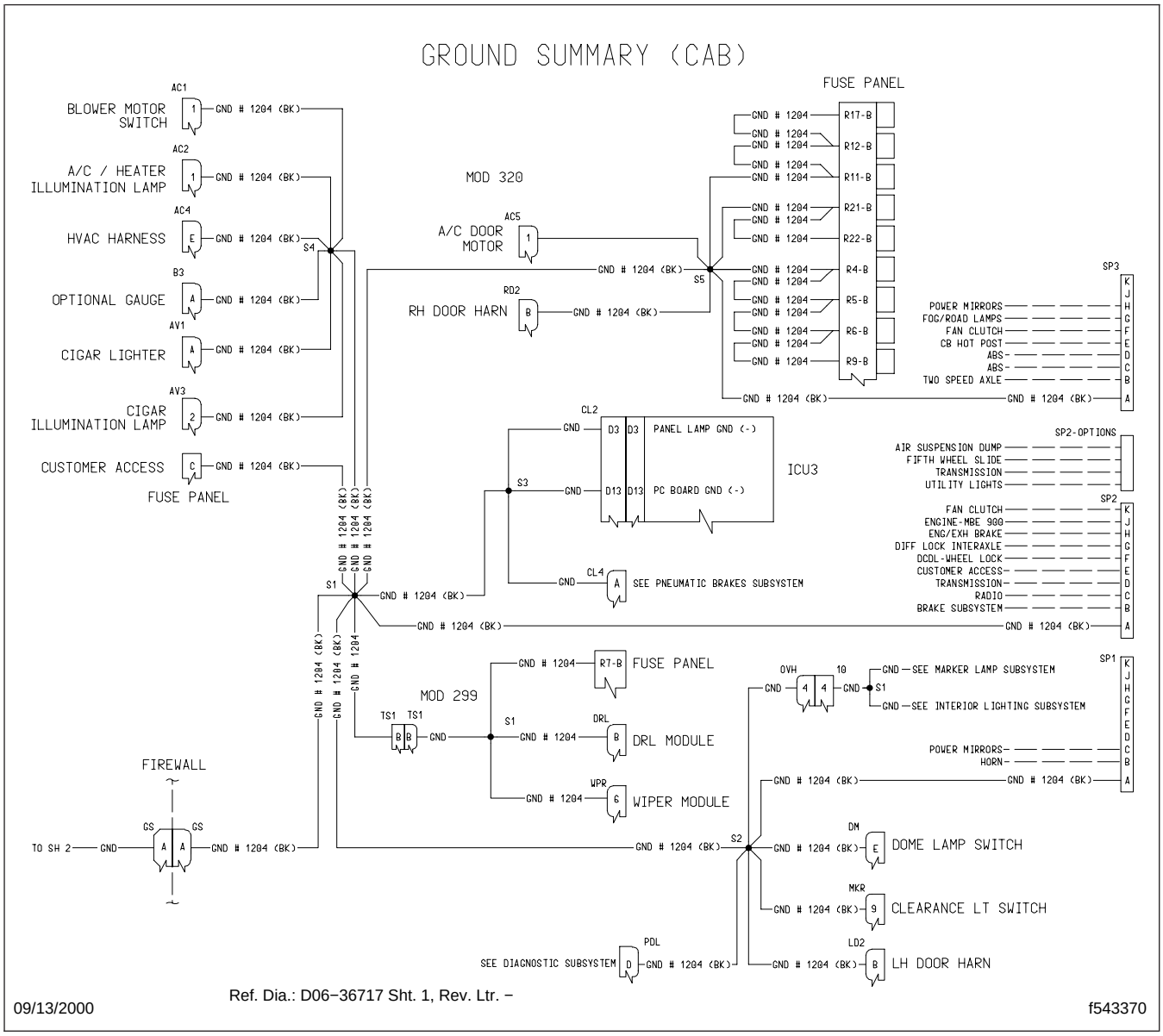


Fig. 1, Ground Summary Wiring, Sheet 1 (full view)

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Ground Summary Schematics

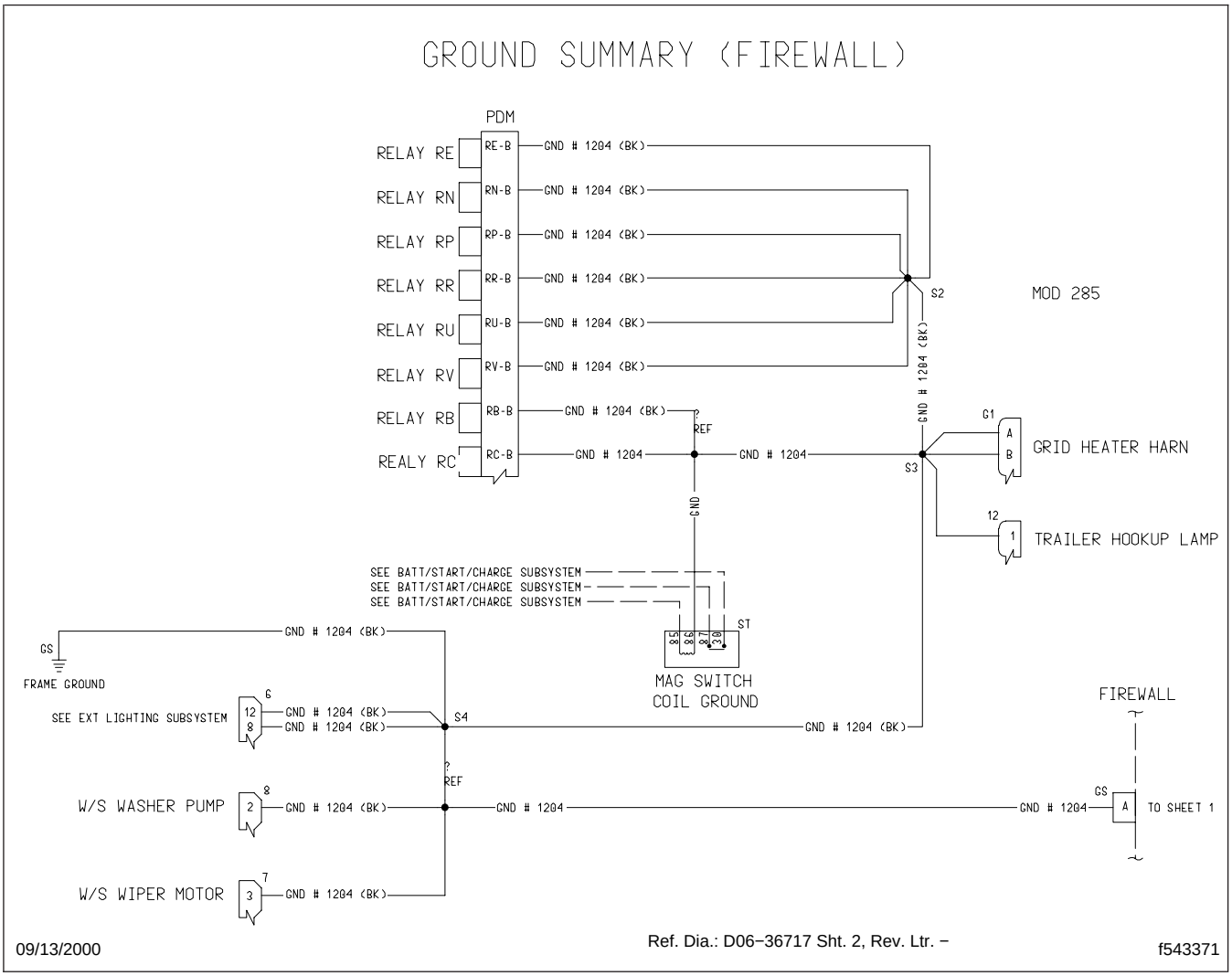


Fig. 2, Ground Summary Wiring, Sheet 2 (full view)

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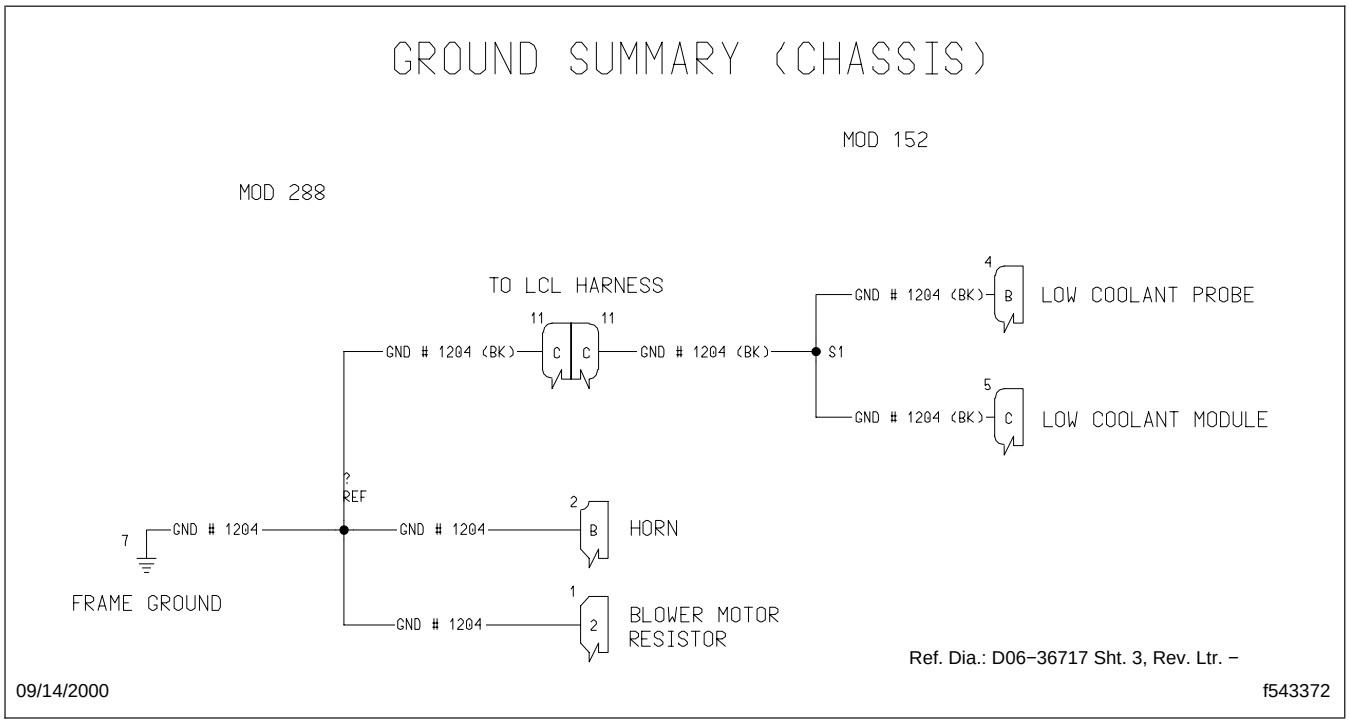


Fig. 3, Ground Summary Wiring, Sheet 3 (full view)

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Wiring Diagrams

See **Fig. 1** for a full view of the main cab harness.

See **Fig. 2**, **Fig. 3**, **Fig. 4** and **Fig. 5** for partial views of the main cab harness.

See **Fig. 6** for a full view of the cigar lighter wiring.

See **Fig. 7** for a full view of the CB radio and hot posts wiring.

See **Fig. 8** for a full view of the Delco radio wiring.

See **Fig. 9** for a full view of the Ford premium radio wiring.

See **Fig. 10** for a full view of the Ford standard radio wiring.

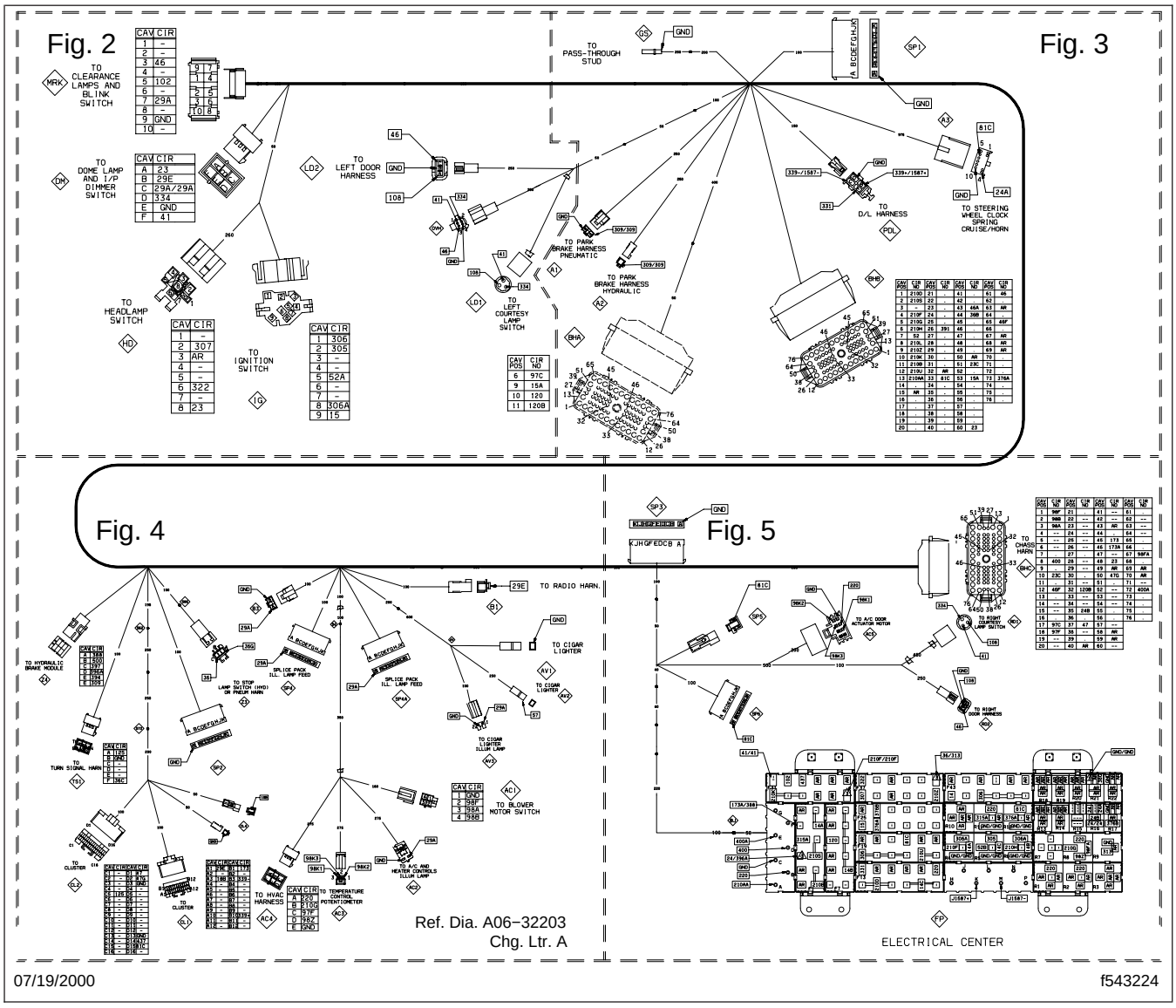


Fig. 1, Main Cab Harness (full view)

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Cab Schematics and Harnesses

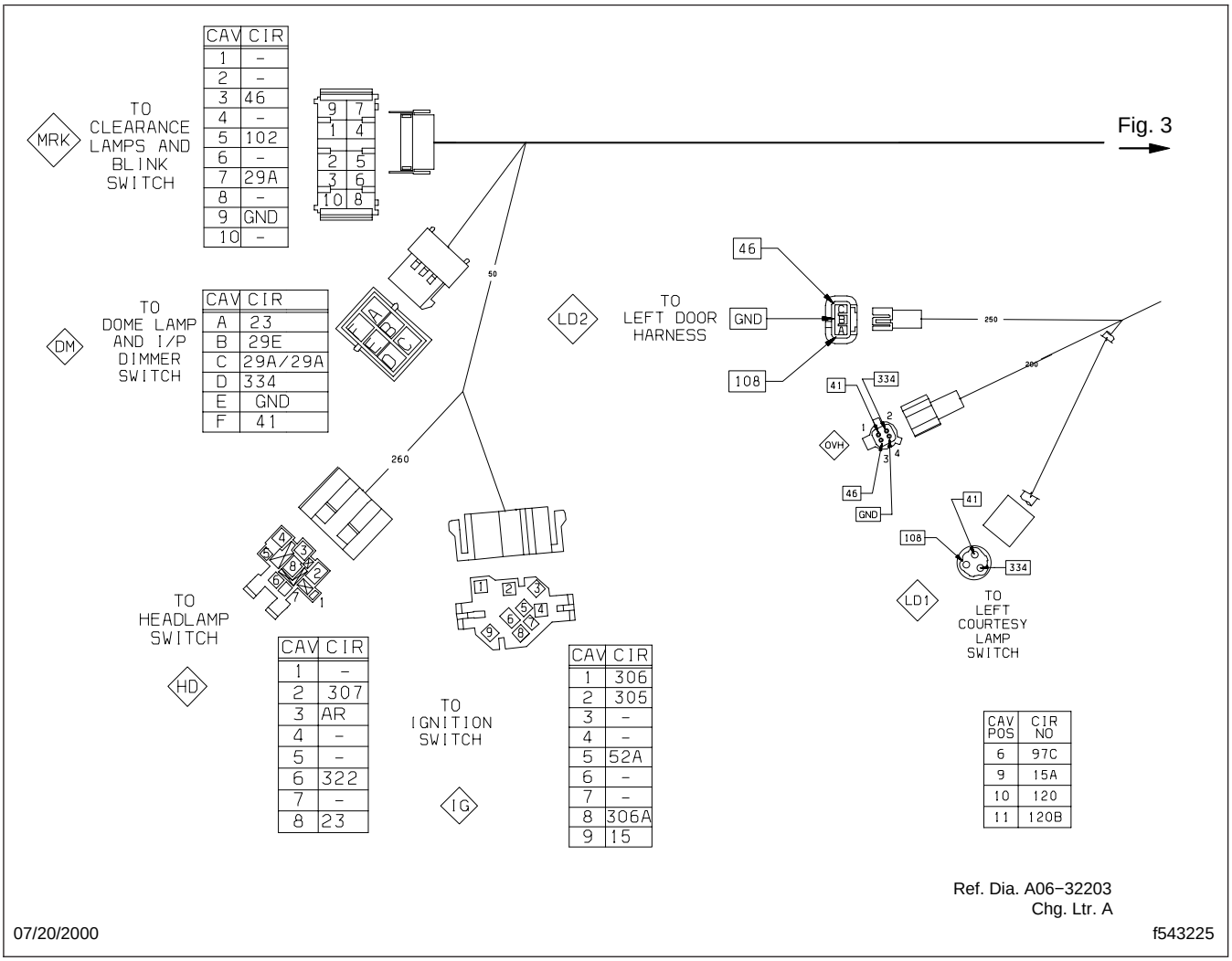
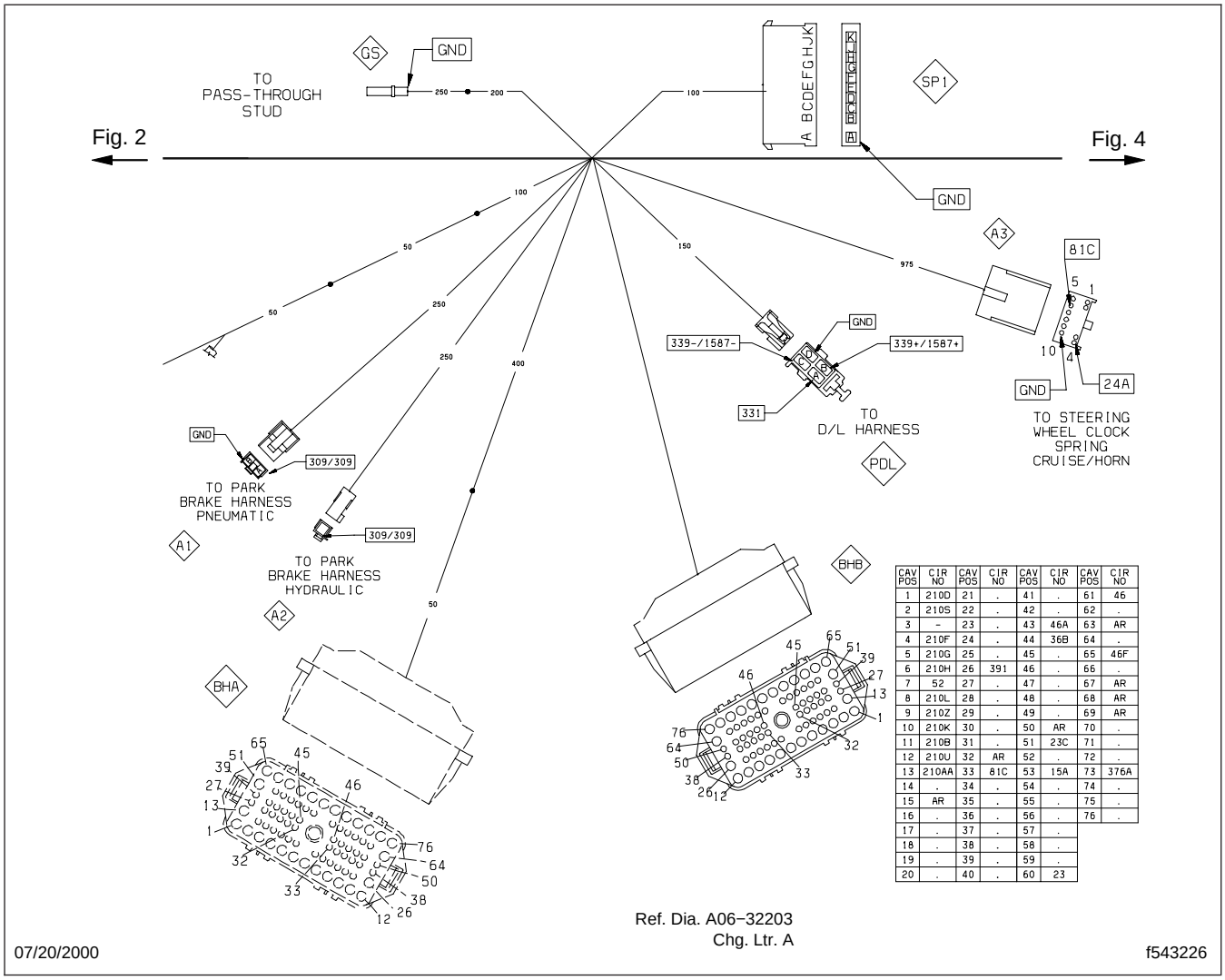


Fig. 2, Main Cab Harness (partial view)

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CAV POS	CIR NO	CAV POS	CIR NO	CAV POS	CIR NO	CAV POS	CIR NO
1	210D	21	.	41	.	61	46
2	210S	22	.	42	.	62	.
3	–	23	.	43	46A	63	AR
4	210F	24	.	44	36B	64	.
5	210G	25	.	45	.	65	46F
6	210H	26	391	46	.	66	.
7	52	27	.	47	.	67	AR
8	210L	28	.	48	.	68	AR
9	210Z	29	.	49	.	69	AR
10	210K	30	.	50	AR	70	.
11	210B	31	.	51	23C	71	.
12	210U	32	AR	52	.	72	.
13	210AA	33	81C	53	15A	73	376A
14	.	34	.	54	.	74	.
15	AR	35	.	55	.	75	.
16	.	36	.	56	.	76	.
17	.	37	.	57	.		
18	.	38	.	58	.		
19	.	39	.	59	.		
20	.	40	.	60	23		

Fig. 3, Main Cab Harness (partial view)

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Cab Schematics and Harnesses

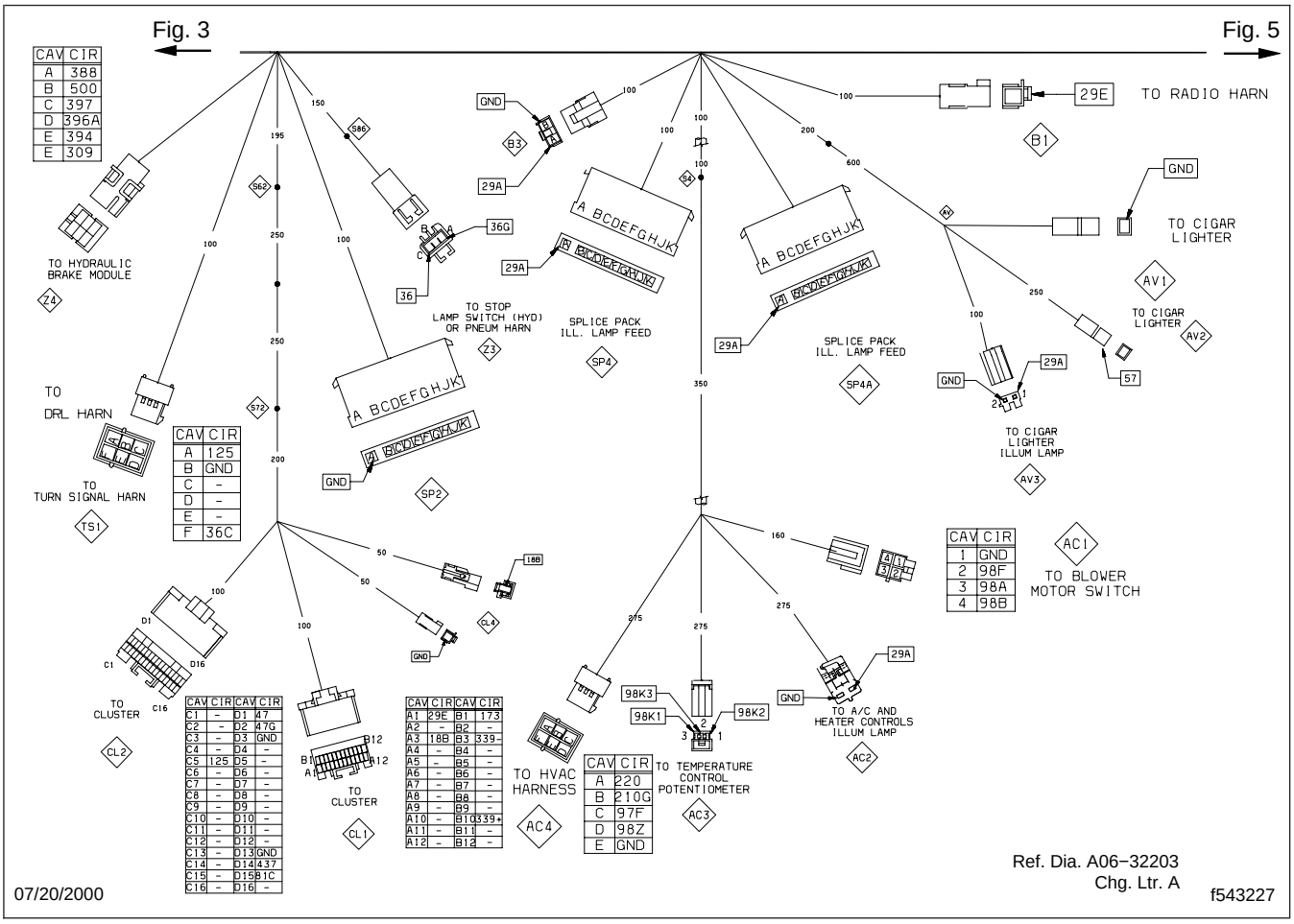
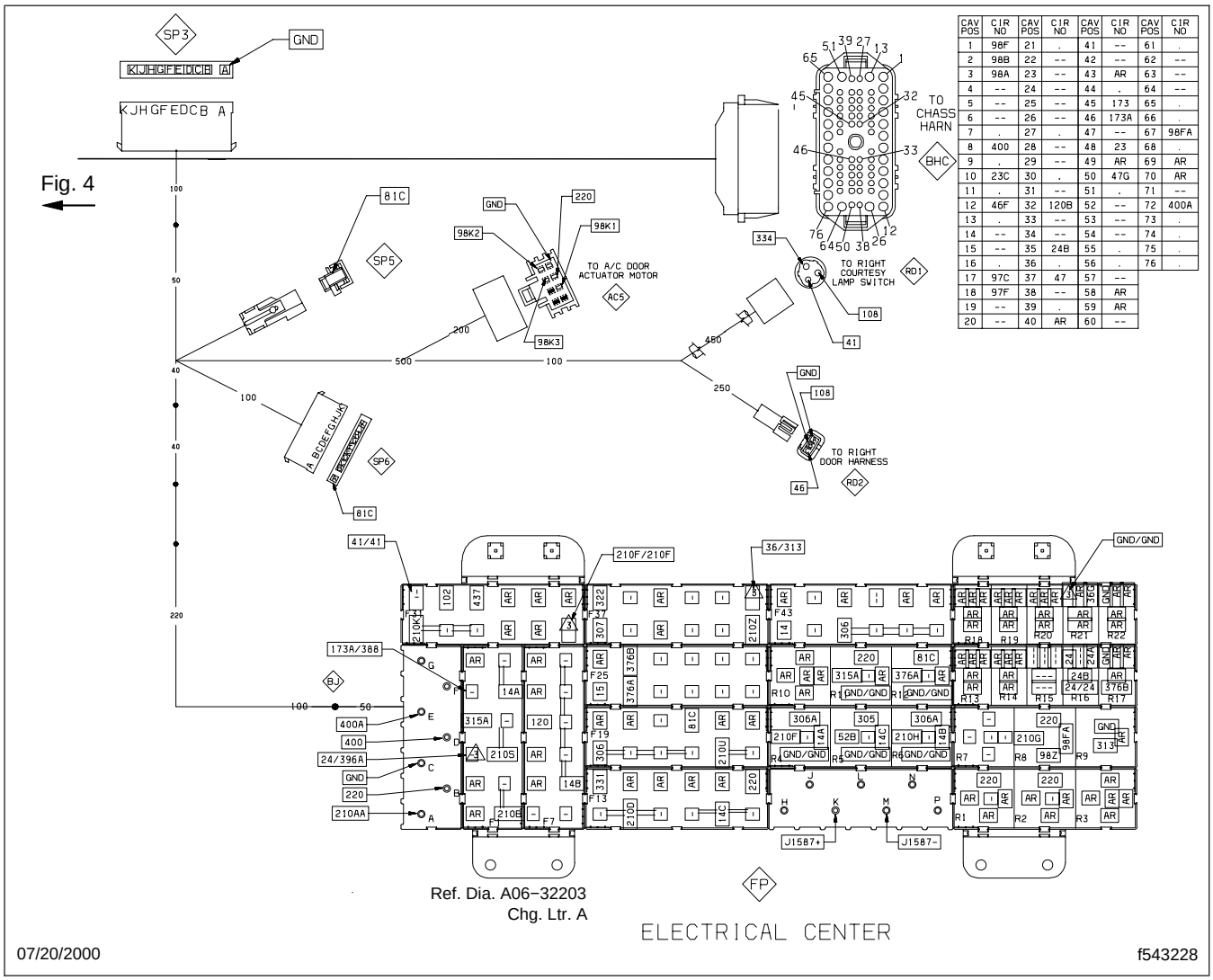


Fig. 4, Main Cab Harness (partial view)

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CAV POS	CIR NO	CAV POS	CIR NO	CAV POS	CIR NO	CAV POS	CIR NO
1	98F	21	.	41	--	61	.
2	98B	22	--	42	--	62	--
3	98A	23	--	43	AR	63	--
4	--	24	--	44	.	64	--
5	--	25	--	45	173	65	.
6	--	26	--	46	173A	66	.
7	.	27	.	47	--	67	98FA
8	400	28	--	48	23	68	.
9	.	29	--	49	AR	69	AR
10	23C	30	.	50	47G	70	AR
11	.	31	--	51	.	71	--
12	46F	32	120B	52	--	72	400A
13	.	33	--	53	--	73	.
14	--	34	--	54	--	74	.
15	--	35	24B	55	.	75	.
16	.	36	.	56	.	76	.
17	97C	37	47	57	--		
18	97F	38	--	58	AR		
19	--	39	.	59	AR		
20	--	40	AR	60	--		

Fig. 5, Main Cab Harness (partial view)

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Cab Schematics and Harnesses

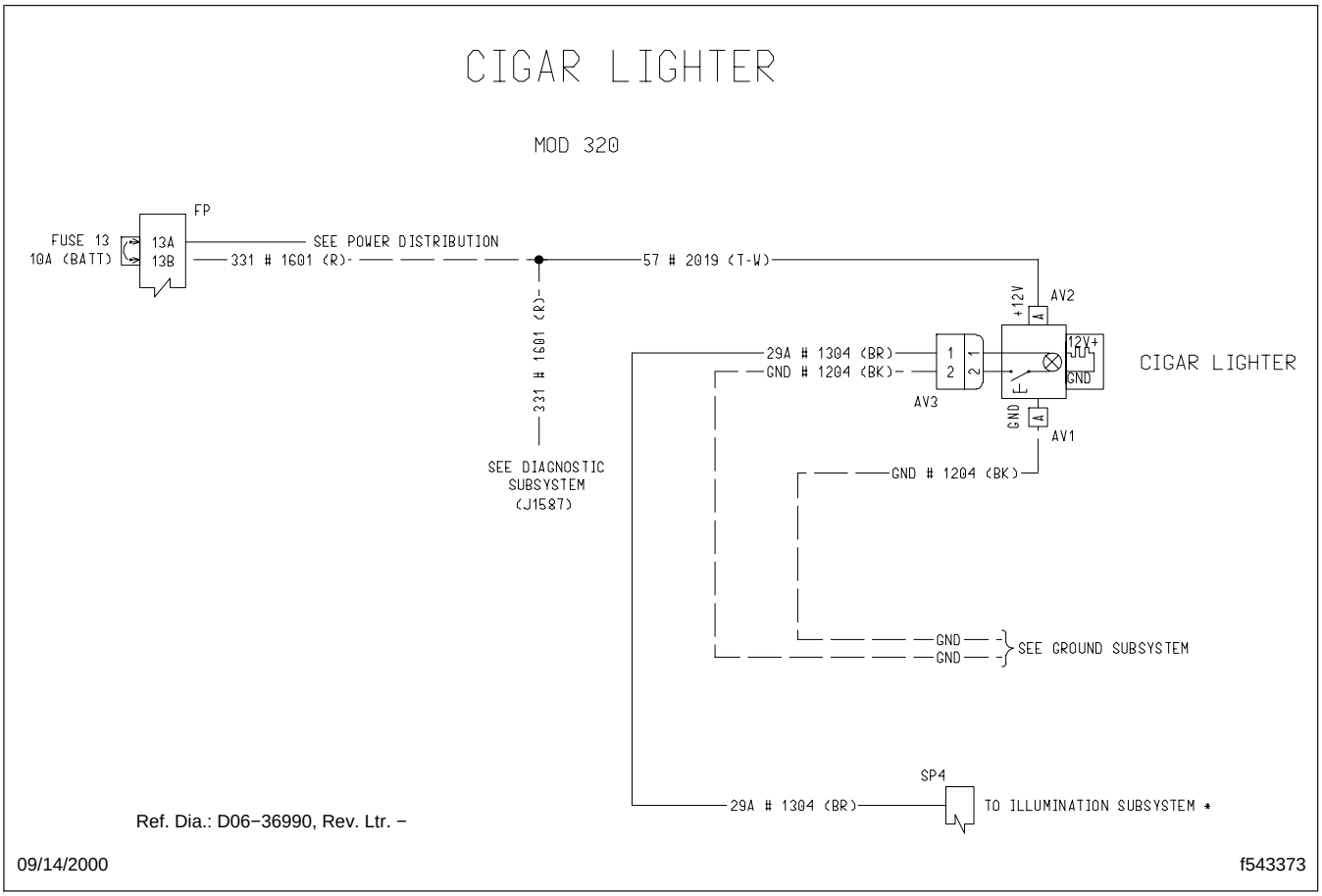


Fig. 6, Cigar Lighter Wiring

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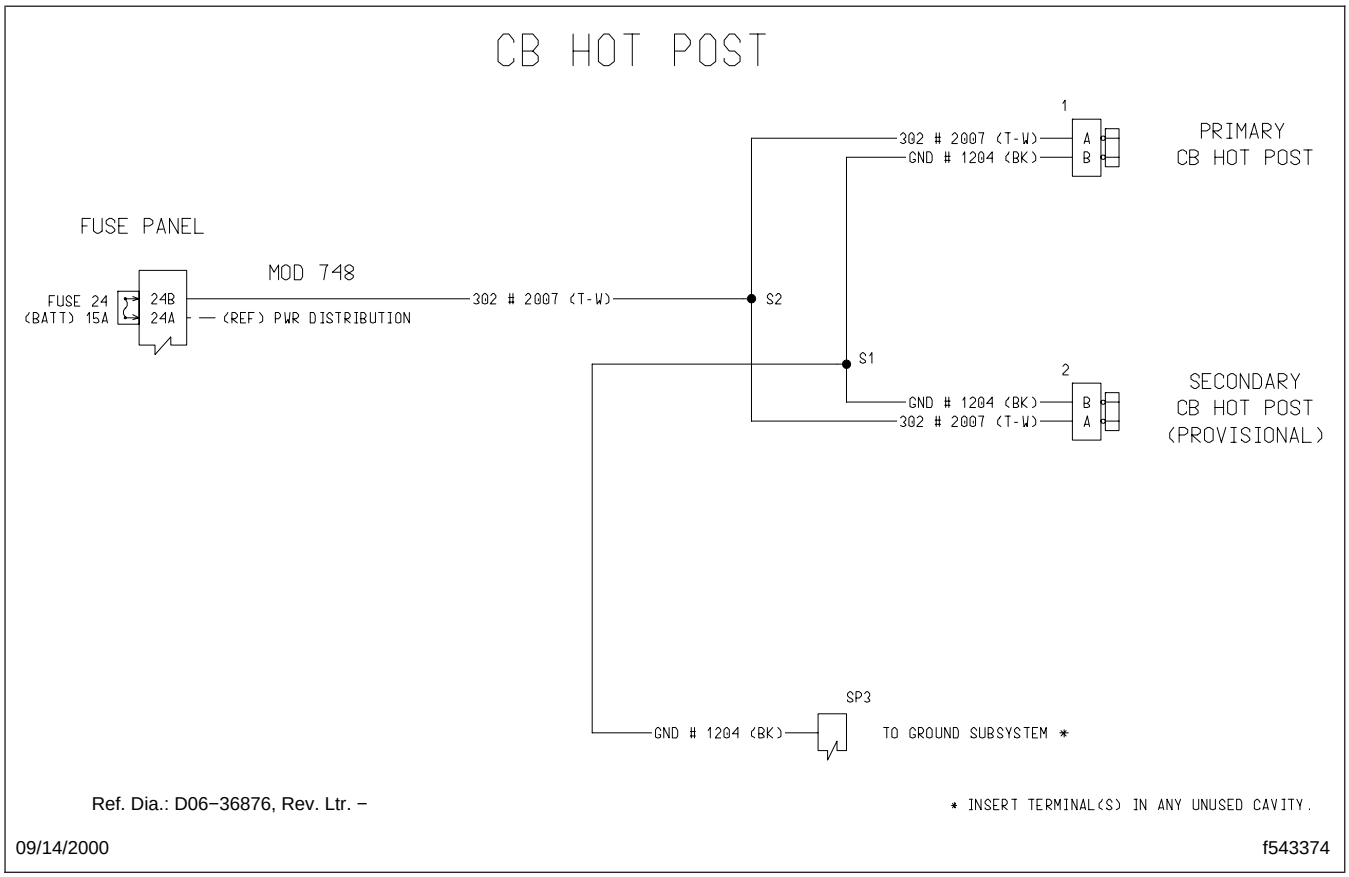


Fig. 7, CB Radio and Hot Posts Wiring

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Cab Schematics and Harnesses

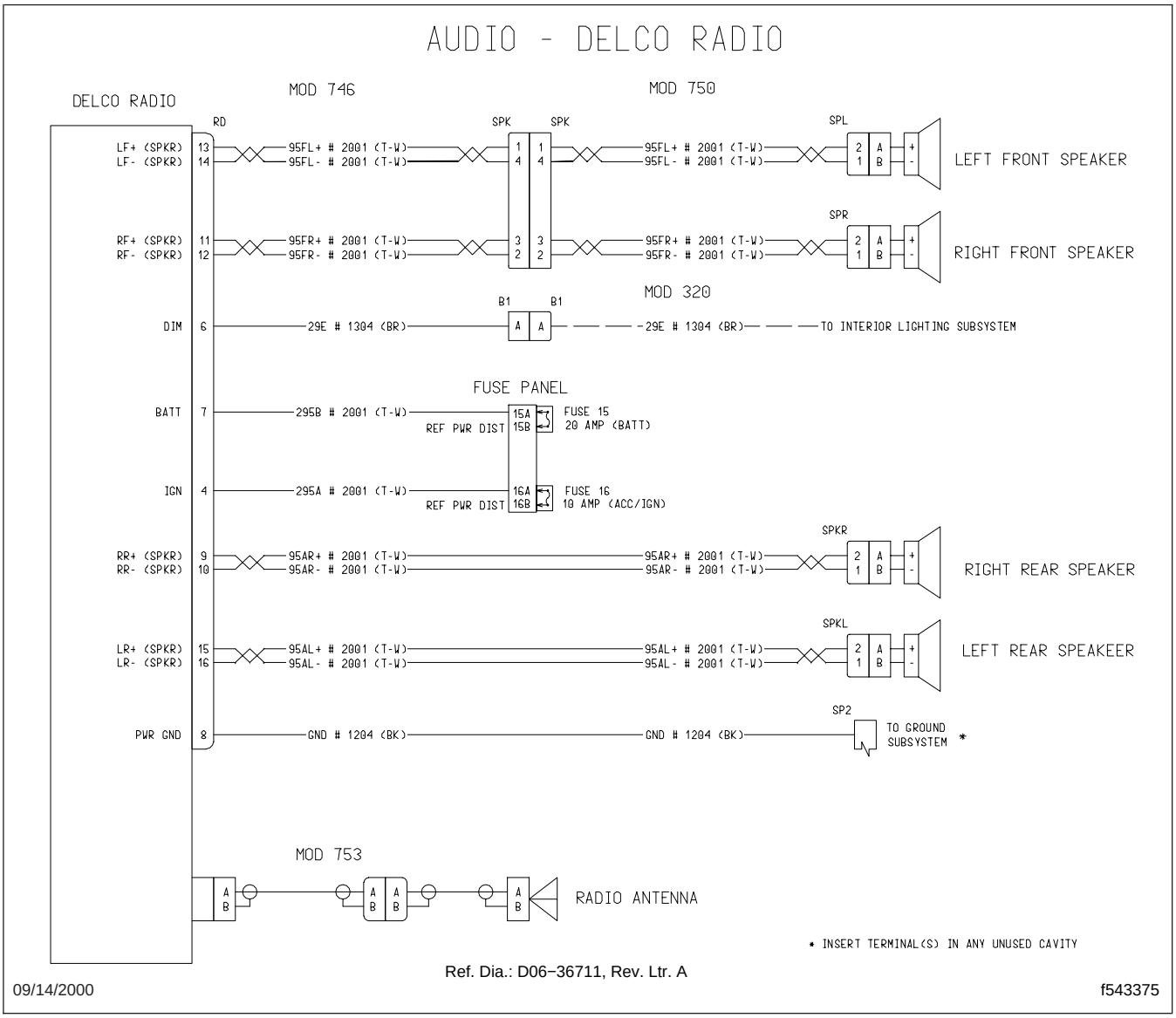


Fig. 8, Delco Radio Wiring

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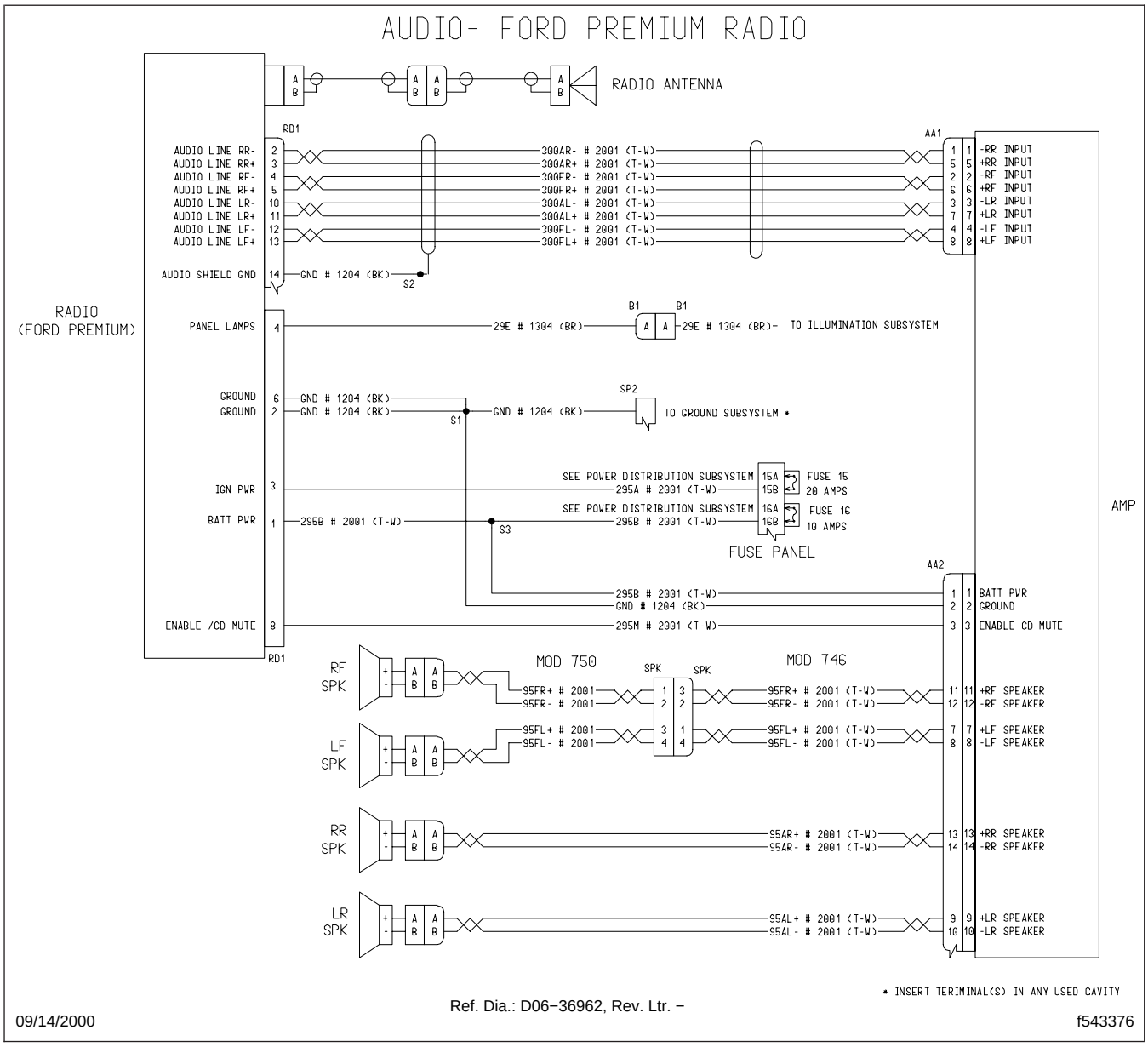


Fig. 9, Ford Premium Radio Wiring

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Cab Schematics and Harnesses

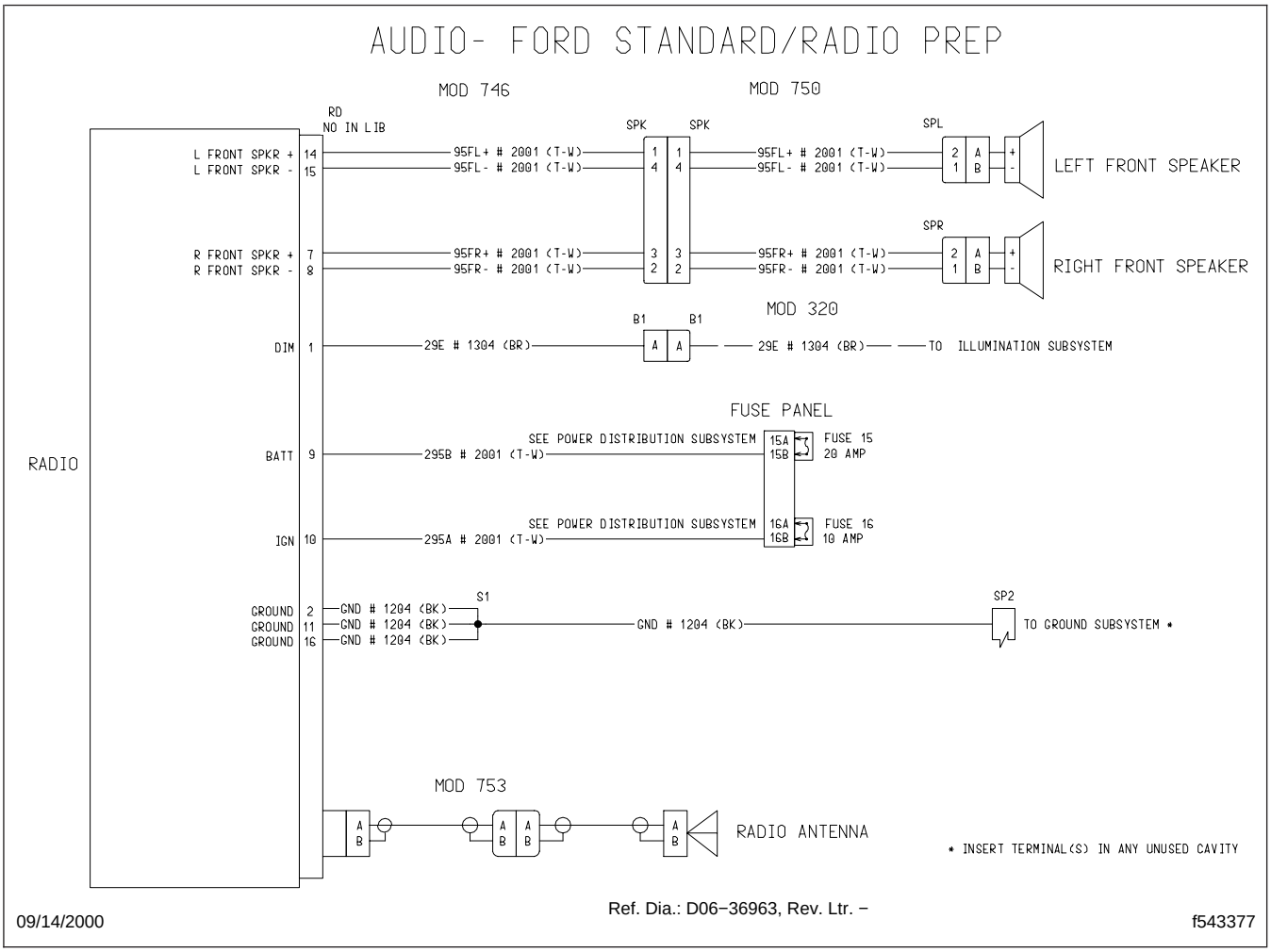


Fig. 10, Ford Standard Radio Wiring

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Wiring Diagrams

See **Fig. 1** for a full view of the trailer wiring.

See **Fig. 2** for a full view of the main chassis harness.

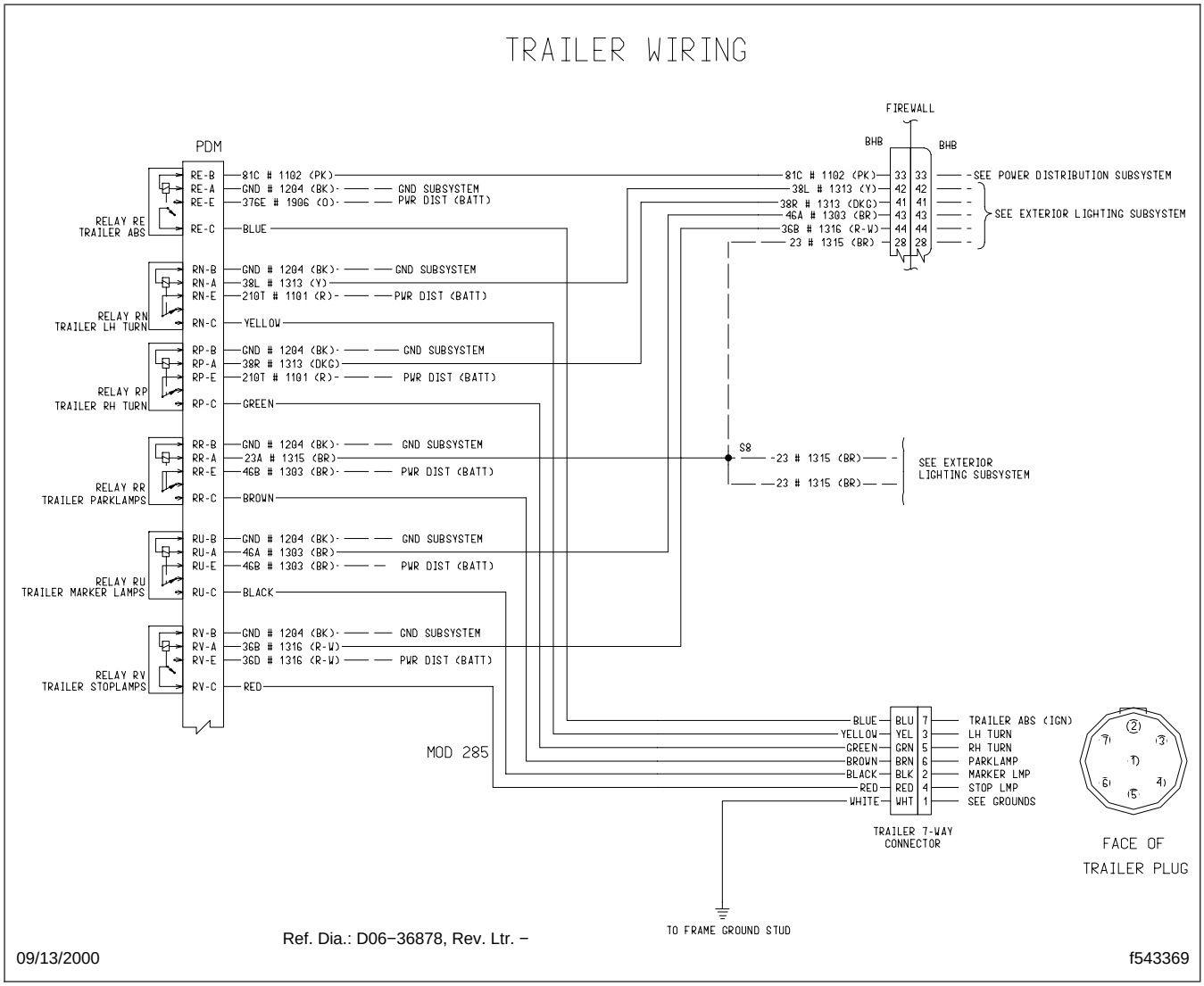
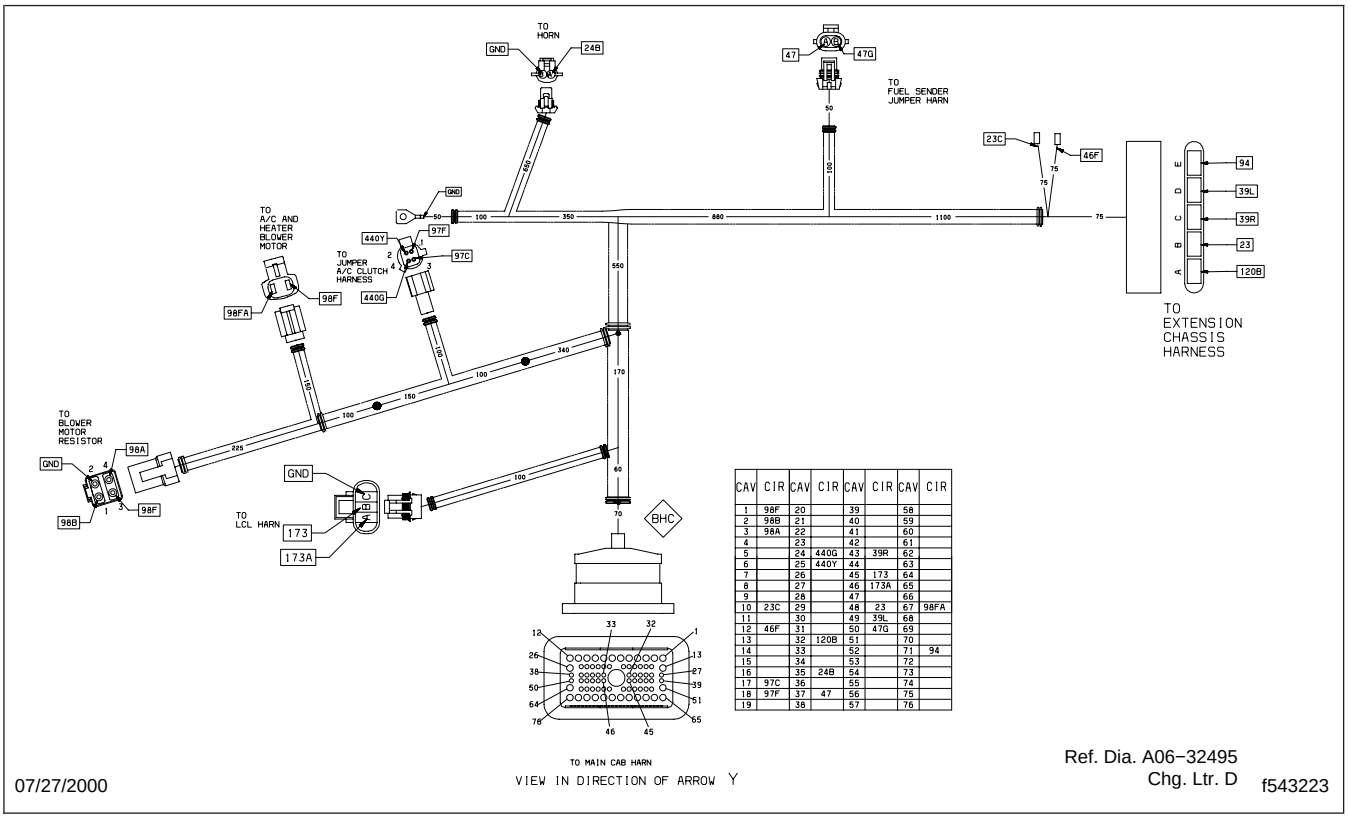


Fig. 1, Trailer Wiring

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Chassis Schematics and Harnesses



CAV	CIR	CAV	CIR	CAV	CIR	CAV	CIR
1	98F	20		39		58	
2	98B	21		40		59	
3	98A	22		41		60	
4		23		42		61	
5		24	440G	43	39R	62	
6		25	440Y	44		63	
7		26		45	173	64	
8		27		46	173A	65	
9		28		47		66	
10	23C	29		48	23	67	98FA
11		30		49	39L	68	
12	46F	31		50	47G	69	
13		32	120B	51		70	
14		33		52		71	94
15		34		53		72	
16		35	24B	54		73	
17	97C	36		55		74	
18	97F	37	47	56		75	
19		38		57		76	

Fig. 2, Main Chassis Harness

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Wiring Diagrams

See **Fig. 1** for a full view of the two-speed rear axle wiring with a Mercedes-Benz MBE900 engine and a manual transmission.

See **Fig. 2** for a full view of the two-speed rear axle wiring with a Mercedes-Benz MBE900 engine and an automatic transmission.

See **Fig. 3** for a full view of the two-speed rear axle wiring with a Caterpillar™ 3126B engine and a manual transmission.

See **Fig. 4** for a full view of the two-speed rear axle wiring with a Caterpillar 3126B engine and an automatic transmission.

See **Fig. 5** for a full view of the two-speed rear axle wiring with a Cummins ISB or ISC engine and a manual transmission.

See **Fig. 6** for a full view of the two-speed rear axle wiring with a Cummins ISB or ISC engine and an automatic transmission.

See **Fig. 7** for a full view of the interaxle differential lock wiring.

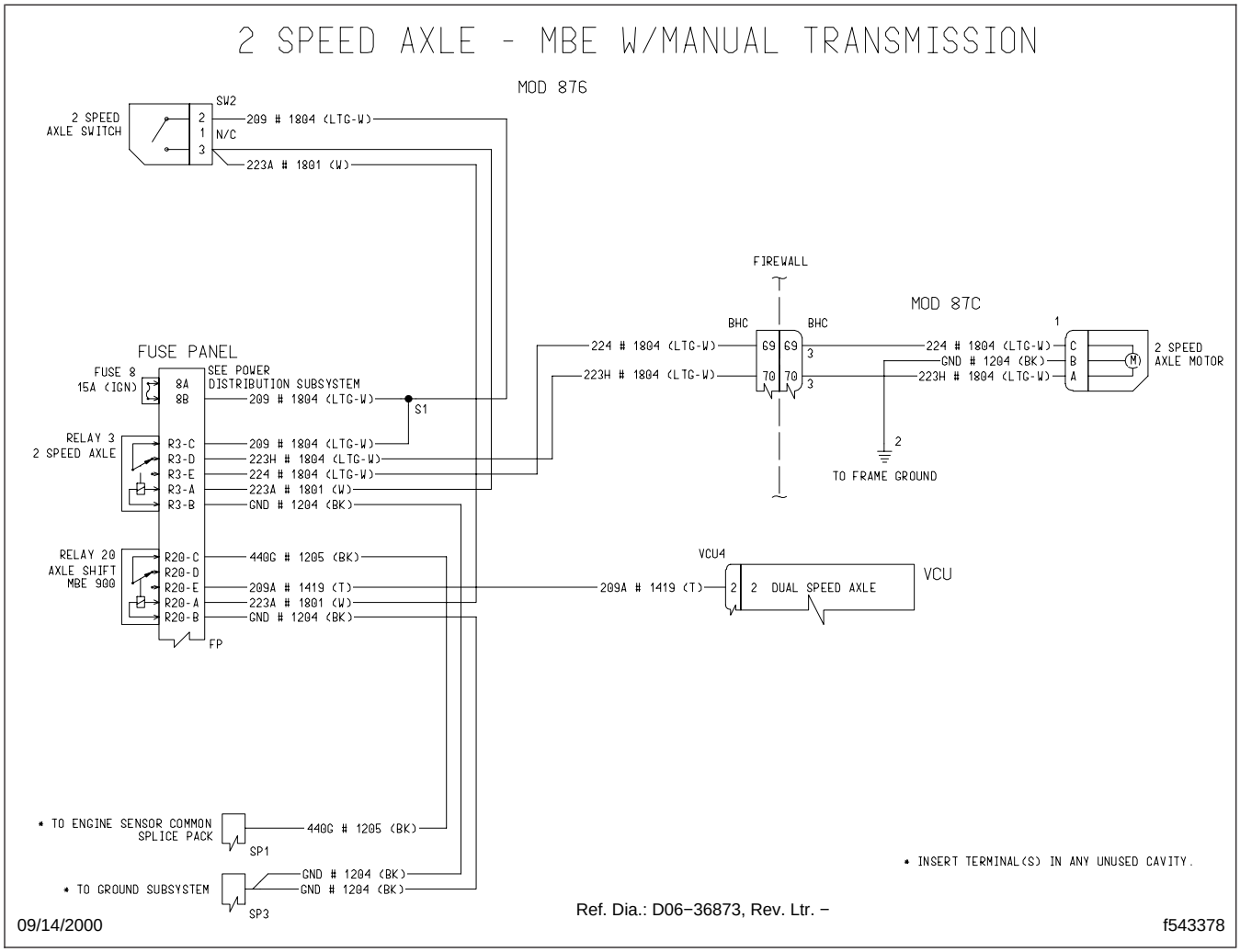


Fig. 1, Two-Speed Rear Axle Wiring With Mercedes-Benz MBE900 Engine and Manual Transmission

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Rear Axle Schematics

See **Fig. 8** for a full view of the driver-controlled, differential lock wiring.

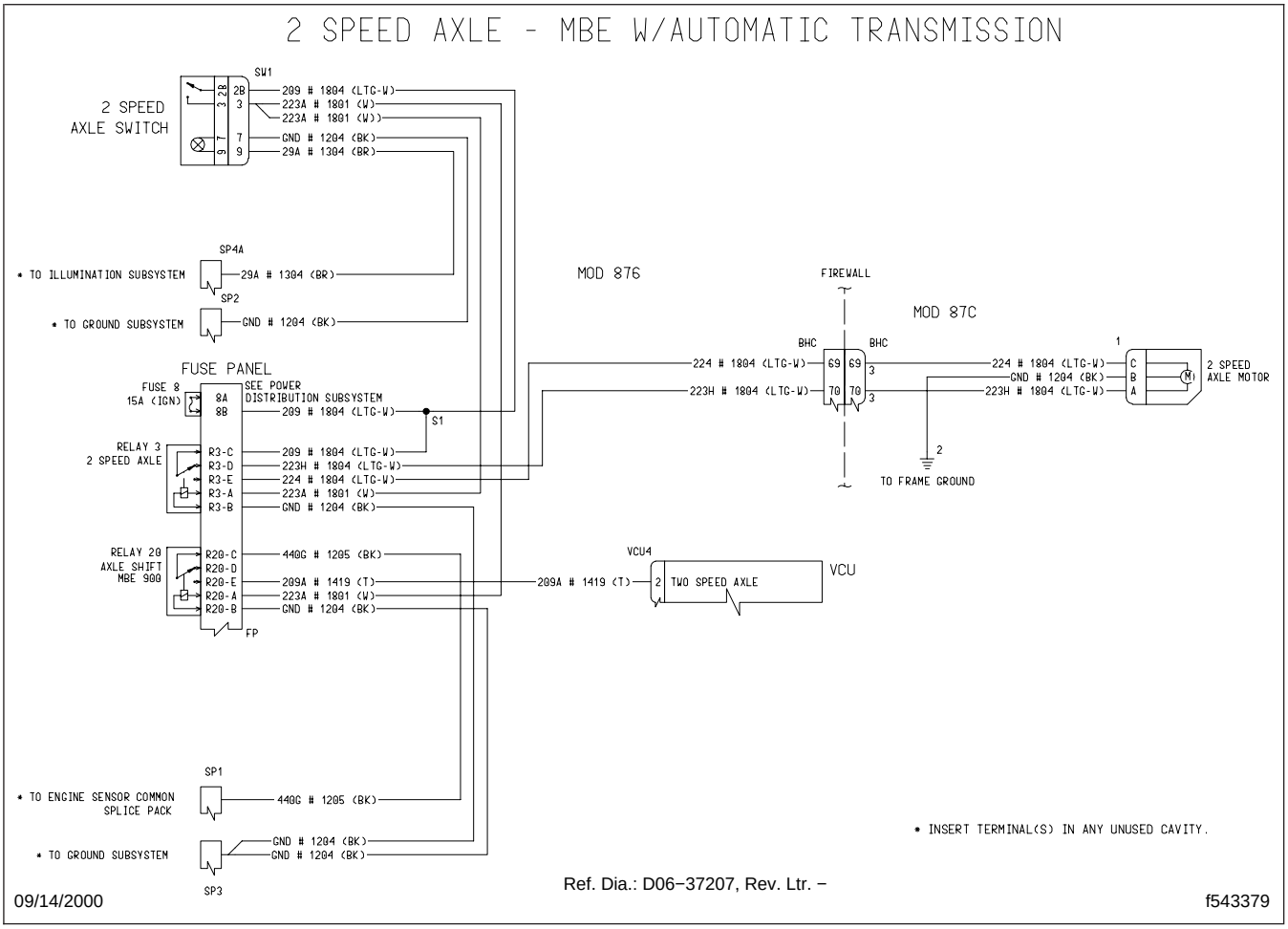


Fig. 2, Two-Speed Rear Axle Wiring With Mercedes-Benz MBE900 Engine and Automatic Transmission

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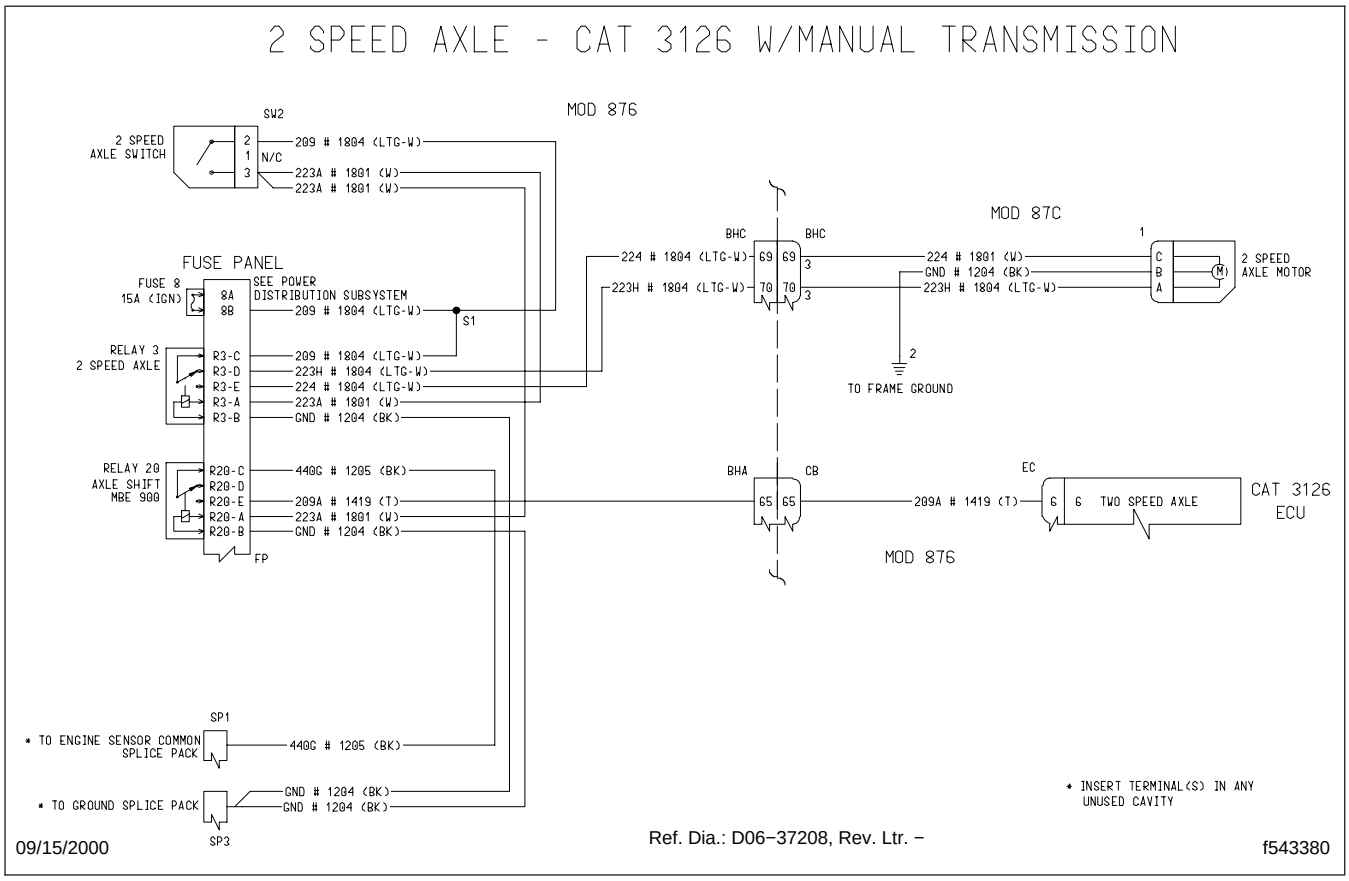


Fig. 3, Two-Speed Rear Axle Wiring With Caterpillar 3126B Engine and Manual Transmission

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Rear Axle Schematics

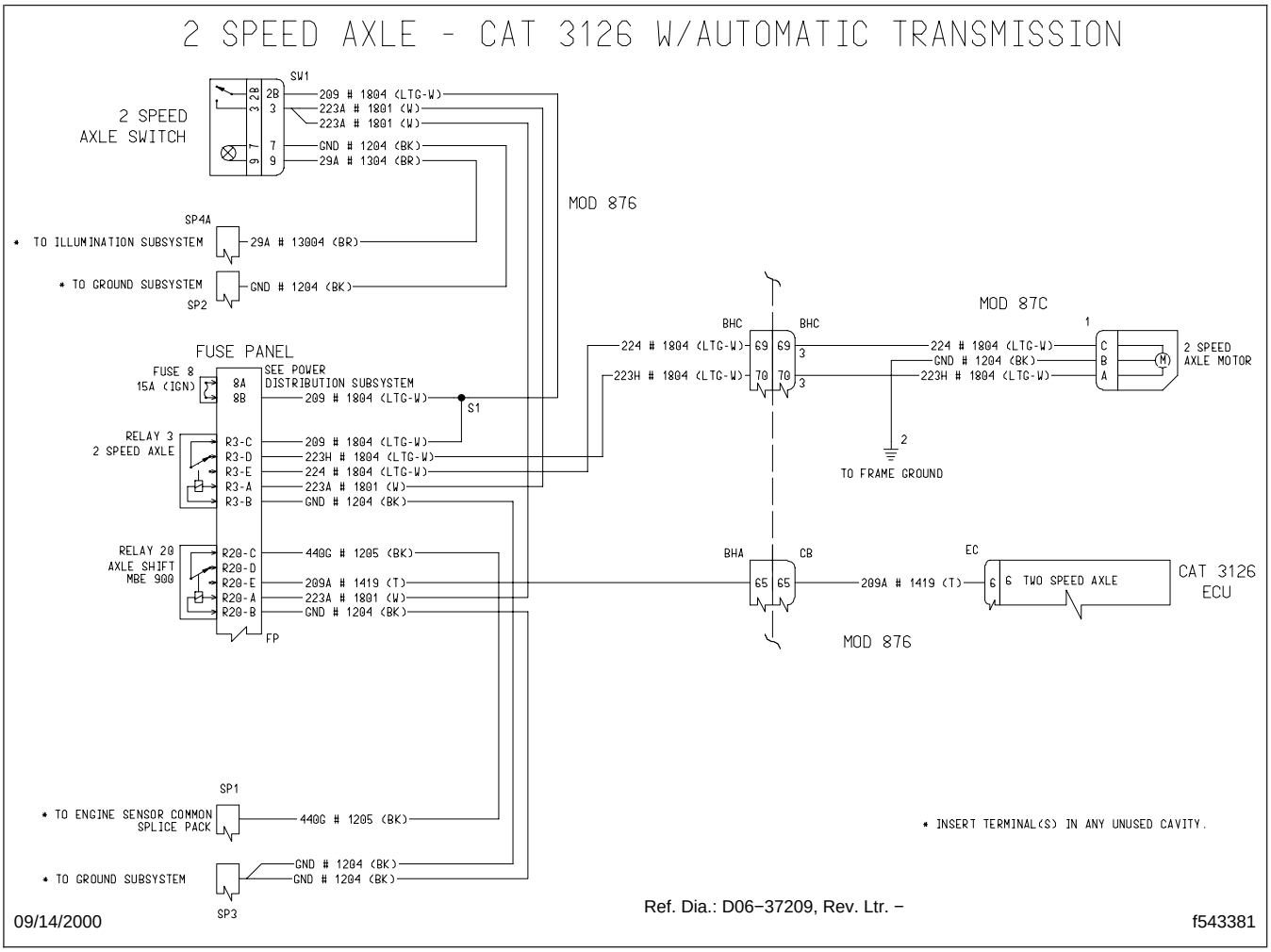


Fig. 4, Two-Speed Rear Axle Wiring With Caterpillar 3126B Engine and Automatic Transmission

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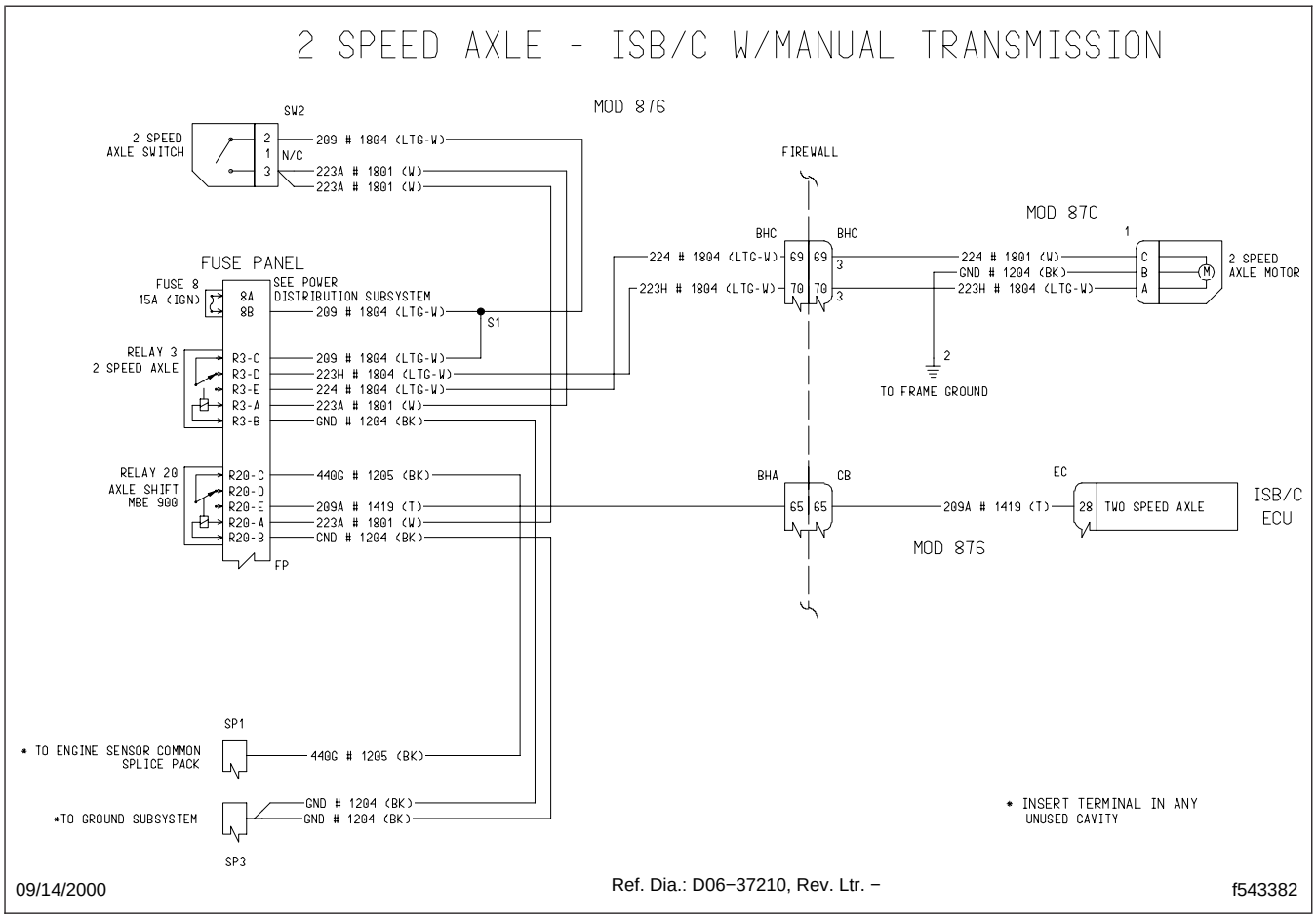


Fig. 5, Two-Speed Rear Axle Wiring With Cummins ISB or ISC Engine and Manual Transmission

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Rear Axle Schematics

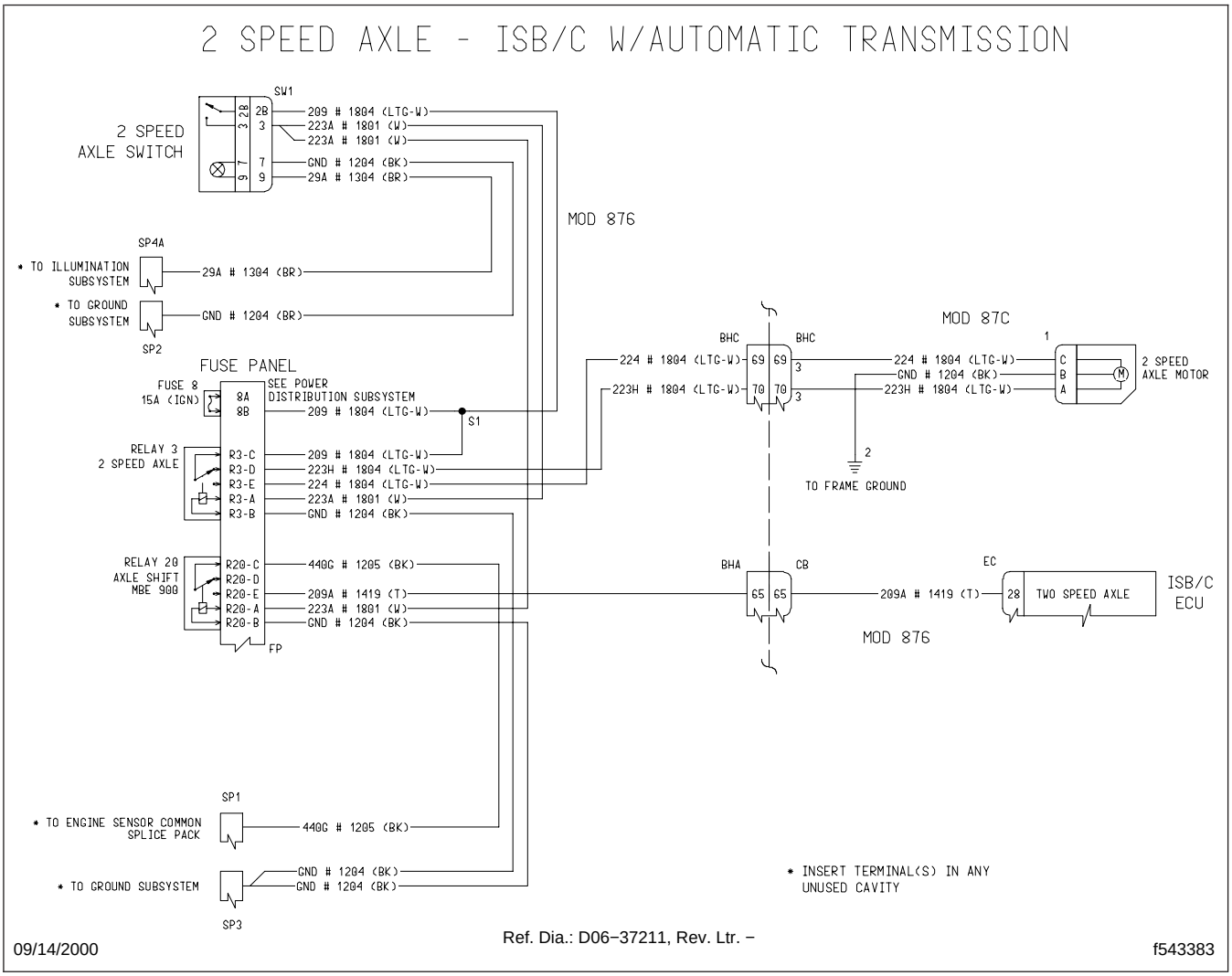


Fig. 6, Two-Speed Rear Axle Wiring With Cummins ISB or ISC Engine and Automatic Transmission

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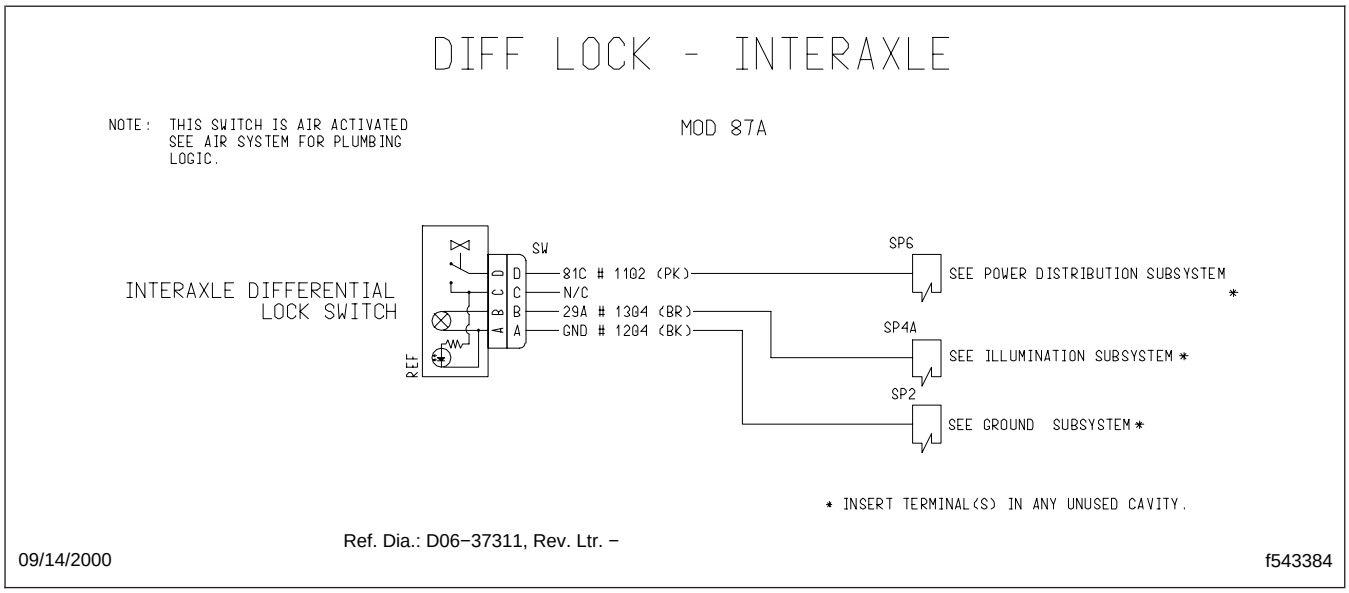


Fig. 7, Interaxle Differential Lock Wiring

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Rear Axle Schematics

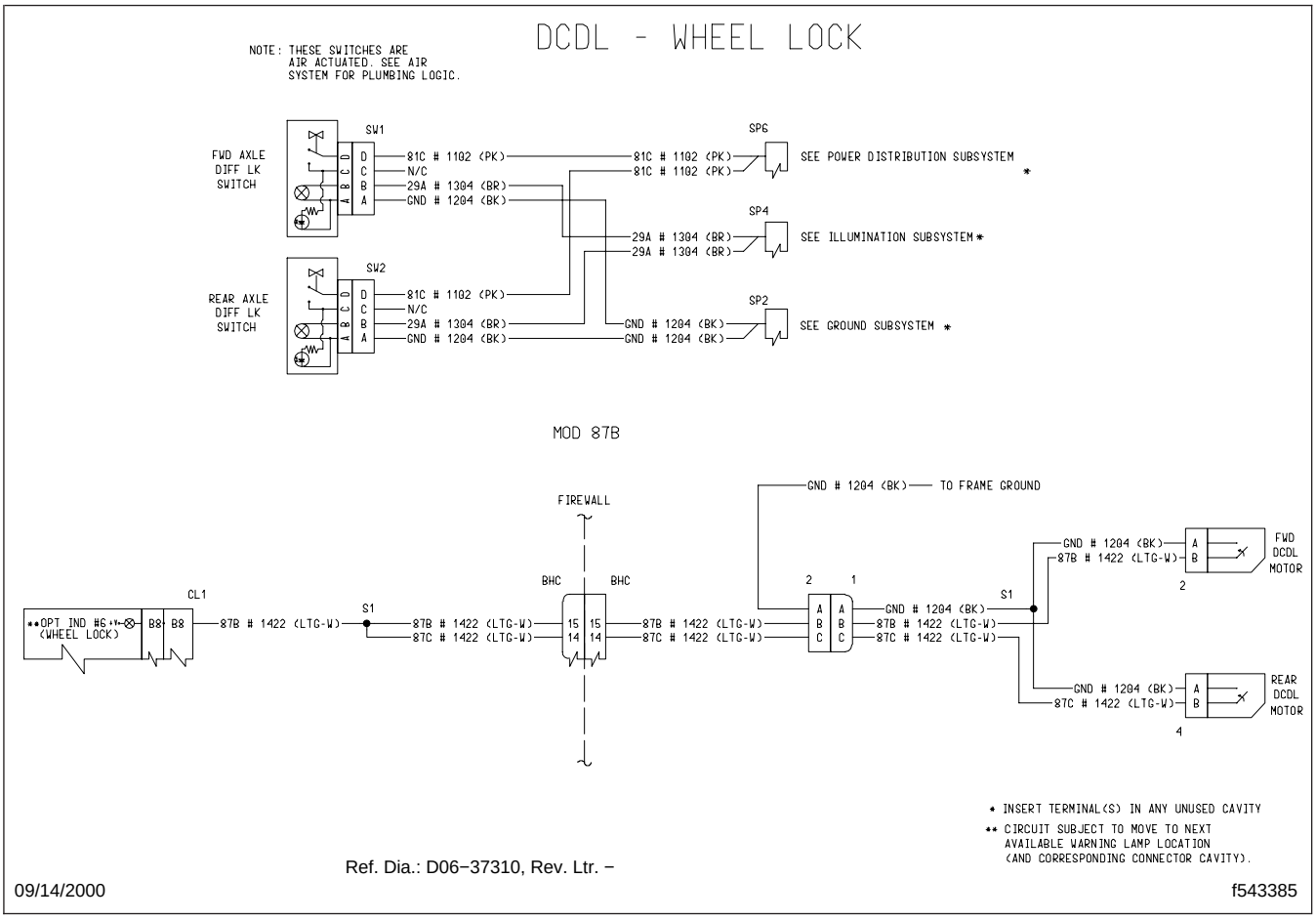


Fig. 8, Driver-Controlled, Differential Lock Wiring

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Specifications

See **Table 1** for fuse amperage ratings and colors for each amperage rating.

See **Table 2** for standard wiring color-coding information.

See **Table 3** for circuit numbers and descriptions.

Blade Fuse Color-Coding Chart	
Ampere Rating	**Color**
5A ATO	Tan
10A ATO	Red
15A ATO	Light Blue
20A ATO	Yellow
25A ATO	Natural
30A ATO or Maxi	Light Green
40A Maxi	Amber

Table 1, Blade Fuse Color-Coding Chart

Standard Wiring Color-Coding		
Color	**Abbr**	**Typical Usage**
Black	BK	Ground, General
Black-White	BK-W	Ground, Clean or Isolated
Blue DK	DKBL	Backup/Windshield Wiper/Trailer Auxiliary
Blue LT	LTBL	HVAC/Circulation Fans/1922+
Blue LT-White	LTBL-W	Water, Oil Gauge and Indicator (Engine and Transmission)
Brown	BR	Marker, Tail and Panel Lamps
Gray	GY	Electronic Engine (or TXL Insulation)
Green DK	DKG	Turn Signal, RH/Driver's Display/Data Record/1587+/1939–
Green DK-White	DKG-W	Starting Aids/Fuel Heaters/Material Control/Winch/Tailgate
Green LT	LTG	Headlamp/Roadlamp/DRL
Green LT-White	LTG-W	Axle Controls and Indicators/Suspension/Fifth Wheel
Orange	O	ABS/EBS/1587–
Pink	PK	Start Control/Ignition/Charging/Volt and Ammeter/1922–
Pink-White	PK-W	Fuel Control and Indicators/Shutdown/Speed Limiter
Purple	PRP	Engine Fan/PTO/Auto Lube and Oil
Purple-White	PRP-W	Utility/Spot/Ad/Interior/Emergency Lighting
Red	R	Power Distribution, Constant
Red-White	R-W	Brake/Pneumatic/Hydraulic/Retarder/Stop
Tan	T	MPH, RPM Signals/Horn/Flasher/Pyro/Turbo
Tan-White	T-W	Audio/Video/Security/Window/Computer/Seat/Mirror/Cab Tilt

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Specifications

Standard Wiring Color-Coding		
Color	**Abbr**	**Typical Usage**
White	W	Transmission (or SXL Insulation)
Yellow	Y	Turn Signal, LH/1939+ (or GXL Insulation)
Yellow-White	Y-W	Air Bag and SPACE

Table 2, Standard Wiring Color-Coding

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
1	Battery cable, ground
2	Battery cable, 6v positive
3	Battery cable, 6v negative
5	Battery cable, 6v, series/parallel terminal
6	Battery cable, 12v positive
7	Ground, starter terminal
8	Starter, battery terminal
9	Starter, solenoid switch terminal
13	Ground stud, series/parallel terminal
14	Cab power, main
15	Starter, engine
16	Alternator, main power cables, ammeter
18	Ignition switch power, misc. components
19	Voltage, meter/alarm
20	Headlamp, LH
21	Headlamp, high beam, LH/RH
22	Headlamp, low beam, LH/RH
23	Tail/marker lamps
24	Horn, electric
25	Horn, electric, button
26	Horn, electric, supply
27	Roadlamp/foglamp
28	Roadlamp/foglamp
29	Panel/instrument lamps
30	Transmission oil temperature
31	Transmission oil temperature, auxiliary
32	Heater, RH auxiliary
33	Heater, auxiliary

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
34	Oil pressure, engine
35	Oil temperature, engine
36	Stop lamp
37	Turn signal flasher supply
38	Turn signal LH, EOF and trailer
39	Stop/turn combination lamp
40	Fan, windshield/sleeper
41	Dome lamp, interior
42	Axle oil temperature, forward
43	Axle oil temperature, rear
44	Axle oil temperature, center auxiliary
45	Receptacle, trailer
46	Marker/parking lamps
47	Fuel level
48	Fuel control and level, natural gas
52	Ignition switch and controls
54	Data recorder, speed and tach graph
55	Data recorder, speed and tach graph
57	Outlet, 12v power receptacle/cigar lighter
58	Heater, auxiliary
60	Turn signal, LH cab
61	Turn signal, RH cab
71	Ignition switch and controls
73	Utility lamp, back of cab
74	Starter mag switch/solenoid
75	Starter mag switch, ground, thermal protection
76	Mirror heat
77	Mirror heat, RH mirror supply

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Specifications

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
78	Spot lamp
80	Mirror heat, switch and controls
81	Ignition switch control devices
82	Starter mag switch, power supply
83	Alternator ground
84	Starting aid, glow plug heater
85	Starting aid, glow plug heater
86	Axle lock, switch, interaxle
87	Axle lock
88	Lubrication system, automatic
90	Sander, road
91	Heater, diesel-fired auxiliary
94	Air dryer, heated
95	Speaker, radio
96	Oil level warning
97	Coolant level alarm, Perry
98	Heater A/C motor, blower
99	Fuel solenoid, engine run
101	Alternator control bus
102	Parking lamps
103	Parking lamps, RH
108	Door control dome lamp, LH
109	Door control dome lamp, RH
113	Baggage compartment lamps
116	Ground, cab stud
117	Speed sensor "+", vehicle, MPH/KPH
118	Speed sensor "–", vehicle, MPH/KPH
119	Coolant temperature, engine
120	Back-up/reverse lamp
121	Brake, engine/retarder/compression
122	Backup/reverse alarm
123	Alternator, voltage regulator/rectifier
124	Alternator regulator, ground
125	Park brake indicator/warning
130	Alternator/generator multi-voltage

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
131	Alternator "No Charge" indicator/warning
132	Alternator "No Charge" indicator/warning
137	Alternator "No Charge" indicator/warning
138	Starter lockout, alternator, ADLO
139	Starter lockout, alternator, ADLO
140	Oil pressure gauge, electronic
141	Starter lockout, alternator, ADLO
147	Fan control, engine, manual override
148	Fan control, engine, manual override
149	Fan manual controls, engine
150	Engine protection, shutdown/warning
151	Power inverter/converter 12v/110v
153	Axle declutch, front
154	Auxiliary air pressure
155	Axle lift controls
157	Mirror remote power controls
158	Engine protection, Kysor, shutdown/warning
159	Fan indicator/warning, engine
160	Power inverter/converter 110v to 12v
162	Tach sensor "+", engine, RPM
163	Tach sensor "–", engine, RPM
164	Axle indicator/warning, front
166	Starting aid, engine, ether
167	Oil fill system, leveler
168	Hour meter, engine
170	Fifth wheel slide lock indicator
171	Brakesaver, CAT
172	Clock
173	Coolant level, engine coolant
174	Engine protection, Nycal, warning
175	Engine protection, Nycal, warning
177	Engine protection, Robert Shaw, warning
178	Idle timer, delayed shutdown, cool down
179	Starting aid, glow plug heater
180	Engine protection, Corning Glass, warning

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Specifications

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
182	Fuel pressure
183	Air cleaner restriction indicator/warning
184	Starter lockout, neutral
185	Security system, Britec System 5
187	Fan ignition supply, engine
188	Antilock Brake System (ABS)
189	Antilock Brake System (ABS)
190	Air dryer, heated, Graham-White
191	Starting aid, glow plug, heater
192	Axle indicator/warning, pusher
193	Cab tilt pump
196	Fuel/water separator heater
197	Transmission lockup sensor
198	Axle, two-speed shift control
200	PTO controls
202	Alternator, 24v
203	Exhaust brake
204	Seat belt indicator/warning
205	Fan controls and headlamp
206	Heater A/C with oil pressure controls
208	Axle control, tri-axle, steer lock
209	Axle, two-speed shift control
210	Power Distribution Module (PDM), outside cab
211	Security system; see 185
212	Refrigerator, power, (no outlet)
213	Power inverter/converter 110v to 12v
214	Generator, auxiliary
215	Heater, diesel-fired auxiliary, Webasto
216	Engine idler, Sterling Tech (SLG)
217	Fuel solenoid, engine, synchro start
218	Pyrometer, gauge
219	Turbo pressure gauge
220	Ignition switch, accessory
221	Suspension dump controls
222	Headlamp dimmer controls

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
223	Transmission controls, auto shift (axle shift, see 209)
224	Transmission controls (axle shift, see 209)
225	Air pressure gauge, primary
226	Air pressure gauge, secondary
227	Air pressure gauge, application
228	Oil pressure gauge, electronic
229	Retarder, Telma (TLM)
230	Retarder, Telma (TLM)
231	Cab tilt alarm
232	Transmission controls, power harness
233	Retarder, transmission (Allison)
234	Fan controls, engine
235	Speed limiter, vehicle, Lenmar (LNM)
236	Transmission neutral indicator
237	Axle lock, auto, Meritor
238	PTO controls, Chelsea
239	Axle lock, auto, Meritor
240	Fuel/water separator indicator/warning
241	Data recorder, Sangamo tacho graph
242	Seat controls
243	Power inverter/converter
244	Speed limiter, vehicle, Hewitt
245	Engine protection, warning, P & N Co. (PNC)
246	Fuel pump, electric
248	Engine protection, shutdown, Ulanet Watchdog (ULN)
250	Cruise control, Bendix (BW)
251	Speed limiter, vehicle, Cummins Arrest (CUM)
252	Engine protection, shutdown, Lenmar (LNM)
253	Cab tilt indicator
254	Emergency lamp, beacon
255	Advertising lamp
256	Optional power wire
257	Windshield wiper delay
258	Fifth wheel, indicator

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Specifications

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
259	Alternator multi-voltage
260	Engine protection, shutdown, Murphy (MUR)
261	Axle lock, controlled differential
262	Retarder, transmission (Allison)
263	Engine protection, shutdown, Sterling Tech (SLG)
264	Coolant level alarm, Webb (WEI)
265	Oil level warning, Webb (WEI)
266	PTO controls, transfer case
268	Gauge alarm, Murphy (MUR)
269	Speedometer, Engler (ENG)
270	Tachometer, Engler (ENG)
271	Oil pressure gauge, electronic
272	Transmission, deep reduction indicator
273	Axle oil temperature indicator, rear
274	Transmission oil temperature
275	TRW ETEC
276	Oil fill system, leveler, Webb (WEI)
277	Idle limiter, Kysor Idlestop (KYS)
278	Windshield wiper control, RH
279	Windshield wiper control, LH
280	Pyrometer alarm/shutdown, Hewitt (HEW)
281	Oil filter change indicator/warning
282	Engine protection, shutdown
283	Engine idler, cycler, Webb (WEI)
284	Oil filter change indicator/warning, Big Cam3
285	Suspension electrical/air controls
286	Fuel/water separator indicator/warning, Racor (RAI)
287	Tachometer, Sangamo (SNG)
288	Engine protection, alarm, Sterling Tech (SLG)
289	Transmission indicator, neutral
290	Engine protection, alarm, Hewitt (HEW)
291	Engine protection, warning, Webb (WEI)
292	Fuel tachometer, Flowscan (FOS), Argo (ARG)
293	Starting aid, engine, ether, Lubristart

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
294	Air tank auto-drain valve, SAB
295	Radio, AM/FM/CB
296	Fuel transfer pump
297	Data recorder warning buzzer
298	Fuel pressure gauge
299	Air temperature, outside cab
300	Radio line level signals
301	Security system
302	CB Radio
303	Air pressure, low
304	Back-up/reverse lamp
305	Ignition switch, accessory
306	Ignition switch, run position
307	Headlamp switch
308	Fifth wheel, controls
309	Park brake indicator/warning
310	Axle lock
311	Ignition accessory option block
312	Radio
313	Turn signal flasher supply
314	Turn signal switch supply
315	Windshield wiper
316	Windshield wiper motor low speed
317	Windshield wiper motor park
318	Windshield wiper motor high speed
319	Windshield wiper motor park
320	Windshield wiper washer
321	Marker lamps, trailer, ICC
322	Headlamp switch, park mode
323	Odometer output
324	Lightbar high coolant temperature
325	Lightbar, engine oil pressure
326	Lightbar turn signal flasher control
327	Tachometer sensor, engine, RPM
328	Speed sensor, vehicle, MPH/KPH

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Specifications

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
329	Pyrometer sensor positive
330	Pyrometer sensor negative
331	Datalink signal, positive
332	Datalink return, negative
333	Air dryer, heated
334	Door-activated dome lamp
335	A/C cold control jumper
336	Headlamp relay jumper
337	Roadlamp switch
338	Heater A/C electronic controls
339	Lightbar/cluster power
340	A/C cold control switch
341	Marker lamps, trailer
342	Ammeter gauge
343	Starting aid, glow plug switch, heater
344	Starting aid, glow plug pressure switch, heater
345	Starting aid, glow plug solenoid, heater
346	Speaker, radio, ground
347	Shutter, engine fan
348	Shutter control, engine fan
349	Shutter, engine fan
350	Lightbar, turn signal flasher timing
351	Speed limiter, vehicle, lightbar
352	Engine protection, delayed shutdown
353	Engine protection, delayed shutdown
354	Shutter transmission temperature control, engine fan
355	Fan transmission temperature control, engine
356	Speed control
357	Fuel solenoid delay shutdown
358	Trailer relay
359	Headlamp ON signal, lightbar/cluster
360	Fan controls, engine, Kysor lightbar
362	Fuel/water separator heater
363	Window power
364	Window power, up

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
365	Window power, down
367	Coolant temperature gauge, Kysor VIP
368	Coolant temperature gauge, Kysor VIP
369	Coolant temperature gauge, Kysor VIP
370	Receptacle auxiliary terminal, trailer
371	Marker lamp, fender guides
372	Receptacle, heavy duty, trailer
373	Fuel solenoid, engine run
374	Starter lockout
375	Daylight Running Lamps (DRL), neutral
376	Antilock Brake System (ABS) controls
377	Antilock Brake System (ABS) sensors
378	Antilock Brake System (ABS) valves
379	Daylight Running Lamps (DRL)
380	Daylight Running Lamps (DRL)
381	Daylight Running Lamps (DRL)
382	Daylight Running Lamps (DRL), LH headlamp
383	Daylight Running Lamps (DRL), RH headlamp
384	Daylight Running Lamps (DRL), program
385	Daylight Running Lamps (DRL), controls
386	Daylight Running Lamps (DRL), LH headlamp
387	Daylight Running Lamps (DRL), RH headlamp
388	Hydraulic brake power
389	Hydraulic brake relay
390	Hydraulic brake lamp
391	Hydraulic brake relay
392	Hydraulic brake motor
393	Hydraulic brake flow/relay
394	Hydraulic brake, park brake lamp
395	Hydraulic brake fluid sensor
396	Hydraulic brake buzzer/alarm
397	Hydraulic brake cab door signal
398	Hydraulic brake motor sense
399	Optional wire, cab/chassis, customer furnished
400	Optional wire, cab/chassis, customer furnished

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Specifications

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
401	Block coolant heater, Truck Comfort Sys (TCS)
403	Fuel restriction indicator, Hewitt (HEW)
404	Data recorder, ARI Trip
405	Data recorder
406	Emergency lamp, alternating flashing
407	Emergency lamp, cross-fire lights
408	Emergency lamp, alley lights
409	Emergency lamp, bin lights
410	Emergency siren
411	Emergency fire truck miscellaneous
412	Data recorder, Isspro (ISP)
414	Tracking system, vehicle, Sony Geostrat RGSS
415	Idle governor, high
416	Refrigerator/television power, (no outlet)
417	Phone power, mobile
418	Tool box lamp, LH
419	Tool box lamp, RH
420	Military 24v lighting, blackout
421	Military 24v lighting, blackout
422	Military auxilliary 24v heater
423	Military, winch controls
424	Headlamp wiper/washer
425	Battery cutoff switch controls and bypass
426	Air inside/outside indicator
427	Tracking system, vehicle, satellite
428	Battery isolator protection system
429	Pyrometer alarm/warning
430	Windshield wiper heater
431	Starting aid, engine preheater, grid/flame
432	Seat controls
433	Data recorder, Data Hub (DDE)
434	Suspension controls, ECAS
435	Seat belt indicator/warning
436	Camera, rear and side view
437	Instrumentation Control Unit (ICU), dash display

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
439	Electronic engine ECU
440	Electronic engine ECU
442	Data recorder, Data Logger Unit (DLU)
443	Door lock
444	Obstacle Detection Sys (ODS), VORAD
445	Body controls, dump lock
446	Tire inflation, Central Tire Inflation Sys (CTIS)
447	Battery cutoff protection system, Hewitt (HEW)
448	Tailgate controls, material
449	Fueling data recording and transmitter
450	Mirror dimming controls (MSI)
454	Air Bag and Seat Pretention System (SPACE)
455	Instrument LH/RH side selection control
457	Dash controls, datalink, (BPU)
459	Steering pump controls
460	Transmission, automatic, Aisin Seiki, cab controls
461	Transmission, automatic, Aisin Seiki, chassis/ transmission controls
462	Headlamp, LH auxilary, snow plow
463	Headlamp, RH auxilary, snow plow
464	Transmission SmartShift control
465	Headlamp flashing control
466	Lane departure indicator/tracking system
467	Coolant flow, engine
468	Obstacle Detection Sys (ODS), VORAD
469	Level control power, body/chassis
500	Hydraulic brake ECU, brake signal
501	Buzzer
502	Oil level warning, engine low
503	Starting aid, engine preheater, flame start
505	Gauge sender, optional
516	Starting aid, engine preheater, flame start
1587	Databus, diagnostics, SAE J1587
1922	Databus, controls, SAE J1922
1939	Databus, controls, SAE J1939

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Specifications

Circuit Numbers and Descriptions	
Circuit Number	**Circuit Description**
BAT	Main battery power
GND	Ground, miscellaneous cab/chassis
NEW	Circuit number required
OPT	Optional wiring, spare or customer furnished
B###	Bendix Antilock Brake System (ABS)
C###	Caterpillar electronic engine
D###	Detroit Diesel electronic engine (DDE)
E###	Allison electronic transmission
N###	Cummins electronic engine
S###	Spicer AutoMate transmission
T###	Twin Disc automatic transmission
W###	Eaton Ceemat/AutoShift transmission
X###	WABCO Anitlock Brake System (ABS); see 376, 377 and 378

Table 3, Circuit Numbers and Descriptions

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General Information

The engine monitoring system for Mercedes-Benz electronic engines alerts the driver to any problem associated with low oil pressure, high coolant temperature and low coolant level. If a problem occurs in one of these systems, indicator lights will illuminate on the dashboard.

If an out-of-range condition is reached on any of these parameters, the engine first flashes the "Check Engine" light. If any of these parameters become even more critical, the engine will flash the "Stop Engine" light. After a period of time the engine will derate and then shutdown.

⚠ WARNING

When the "Stop Engine" light is flashing, the driver must pull to the side of the road (when it is safe to do so) to reduce the possiblity of an accident or engine damage.

Engine shutdown can cause loss of vehicle control which may result in serious personal injury or property damage.

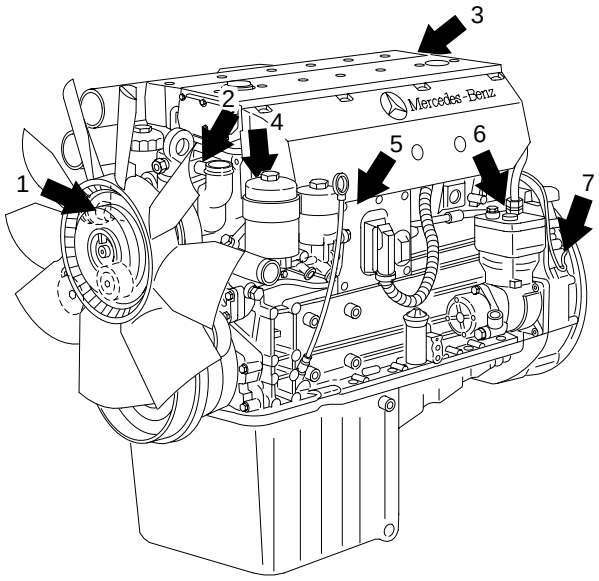
The oil pressure sensor and the coolant temperature sensor are located on the engine. See **Fig. 1**. When oil pressure is low, the "Check Engine" light flashes. When oil pressure is very low, the "Stop Engine" light flashes. If the condition persists, engine derate and shutdown will occur if the engine is programmed with these features.

When coolant temperature reaches 221°F (105°C), the "Check Engine" light flashes. When coolant temperature reaches 230°F (110°C), the "Stop Engine" light flashes. If the condition persists, engine derate and shutdown will occur if the engine is programmed with these features.

The engine warning and shutdown sensors are located on the surge tank. See **Fig. 2**.

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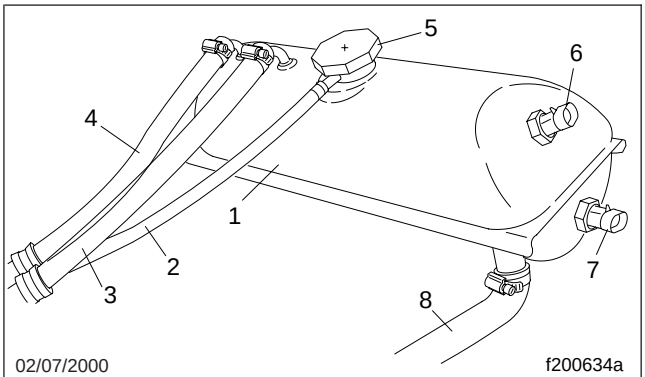
General Information



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1. Oil Pressure/Temperature Sensor
2. Coolant Temperature Sensor
3. Charge Pressure/Air Temperature Sensor
4. Fuel Temperature Sensor
5. Ambient Air Pressure Sensor (integrated into PLD control unit)
6. TDC Sensor (on camshaft)
7. Crank Angle Position Sensor (on timing case)

Fig. 1, Location of Sensors on the MBE900 Engine



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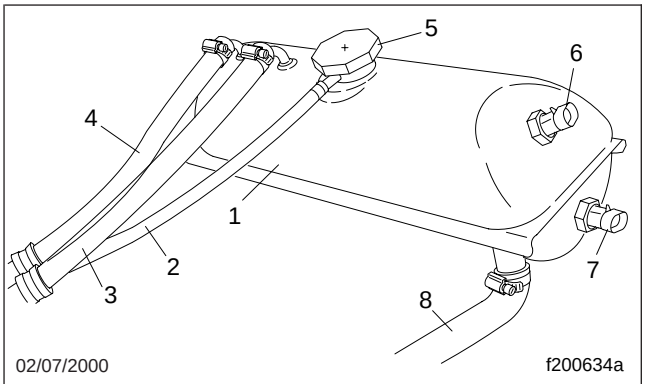
1. Surge Tank
2. Overflow Hose
3. Inlet Hose
4. Inlet Hose
5. Cap
6. Engine Warning Sensor
7. Engine Shutdown Sensor
8. Outlet Hose

Fig. 2, Surge Tank

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Replacement (See Fig. 1)

NOTE: The oil pressure/temperature sensor and the coolant temperature sensor are located on the engine. See the *Mercedes-Benz Components Workshop Manual* for service information.



1. Surge Tank
2. Overflow Hose
3. Inlet Hose
4. Inlet Hose
5. Cap
6. Engine Warning Sensor
7. Engine Shutdown Sensor
8. Outlet Hose

Fig. 1, Surge Tank

1. Park the vehicle on a level surface and apply the parking brakes. Chock the rear tires.
2. Turn off the ignition switch and let the engine cool.
3. Open the hood.
4. Remove the surge tank cap to release the system pressure.

⚠ WARNING

Drain the coolant only when the coolant and engine are cool. Draining the coolant when the engine and coolant are hot could cause severe personal injury due to scalding.

5. Drain the coolant from the surge tank.
6. Disconnect the electrical connector from the sensor.
7. Unscrew the sensor from the surge tank.
8. Apply pipe thread sealant to the sensor threads and install the sensor in the surge tank.
9. Connect the electrical connector to the sensor.
10. Add coolant to the system as needed. Install the cap.
11. Start the engine and confirm that the "Check Engine" light does not illuminate. Check the system to be sure there are no coolant leaks.
12. Remove the chocks from the tires.

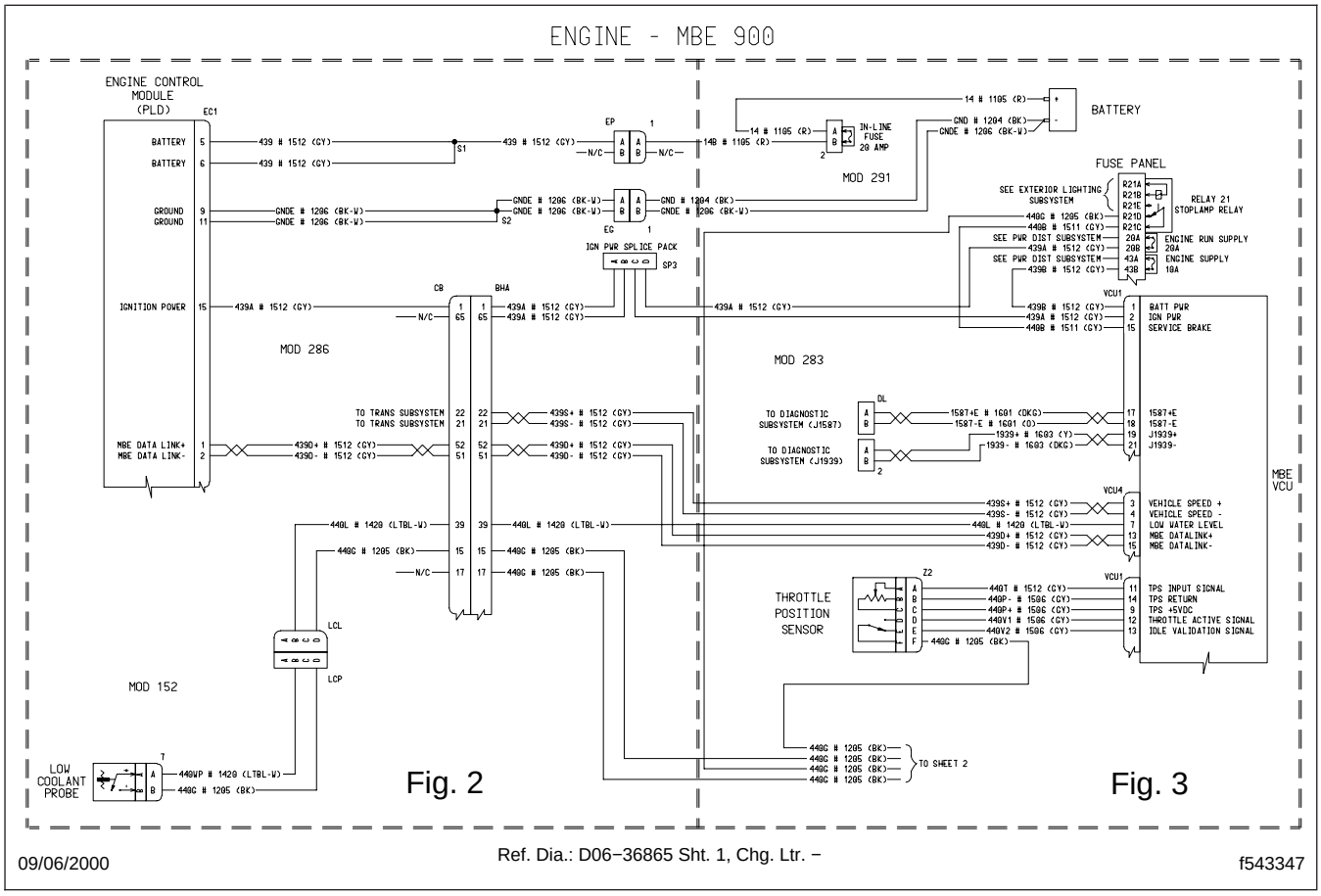
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See **Fig. 1** for a full view of Sheet 1 for Mercedes-Benz MBE 900 engine wiring.

See **Fig. 2** and **Fig. 3** for partial views of Sheet 1.

See **Fig. 4** for a full view of Sheet 2 for Mercedes-Benz MBE 900 engine wiring.

See **Fig. 5** and **Fig. 6** for partial views of Sheet 2.



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Fig. 1, Engine Wiring, Sheet 1 (full view)

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Specifications

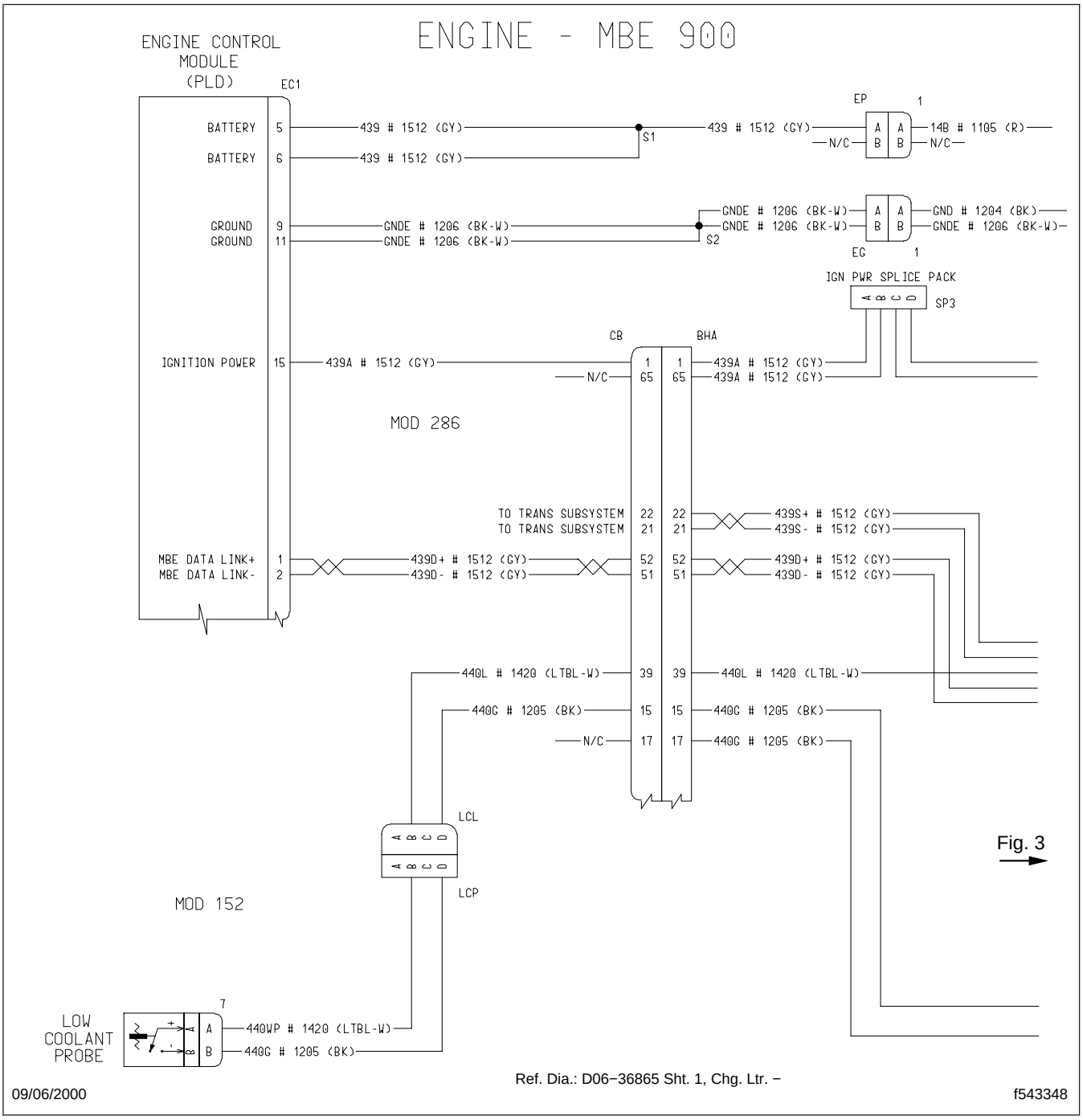


Fig. 2, Engine Wiring, Sheet 1 (partial view)

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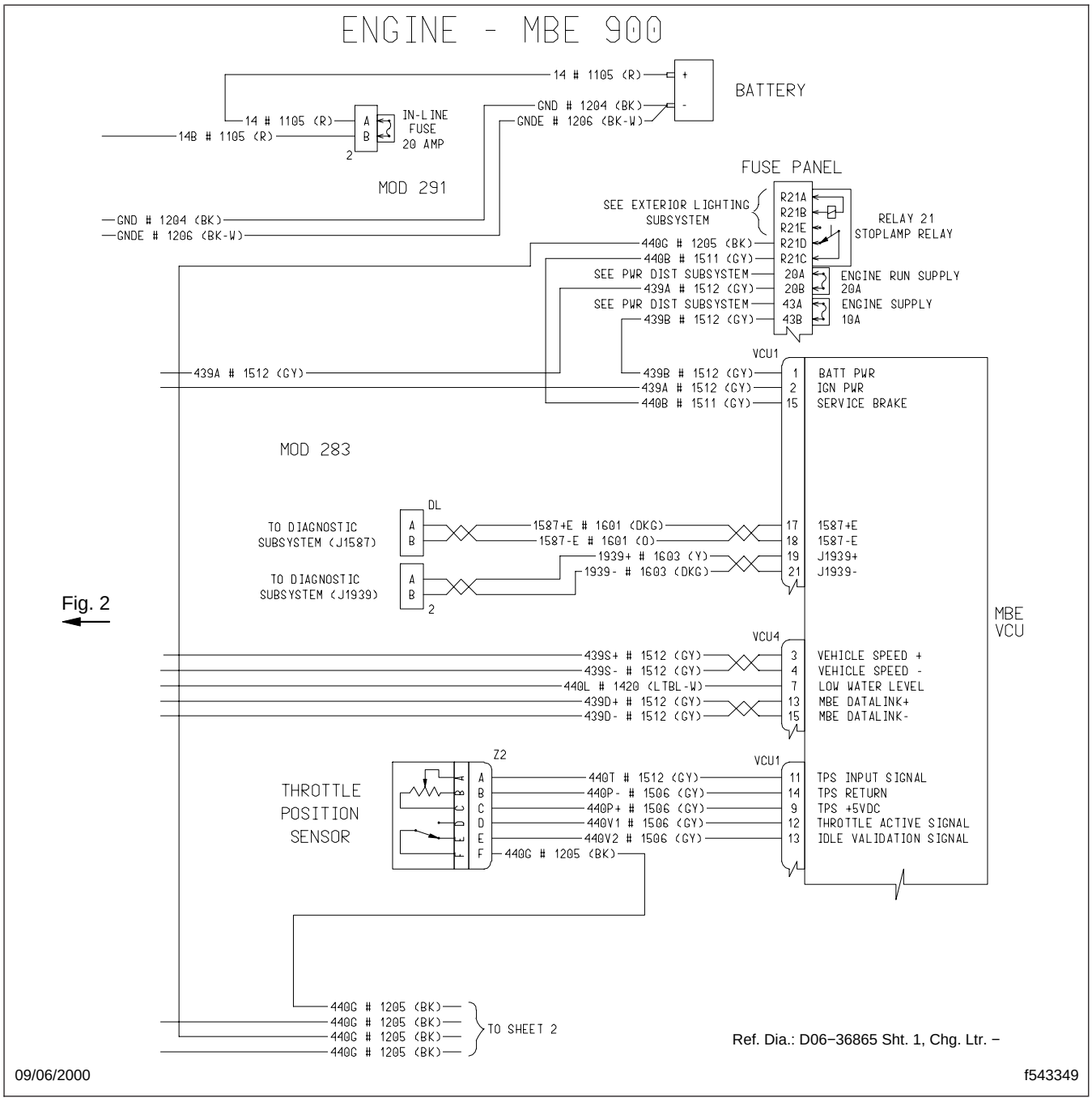


Fig. 2

Fig. 3, Engine Wiring, Sheet 1 (partial view)

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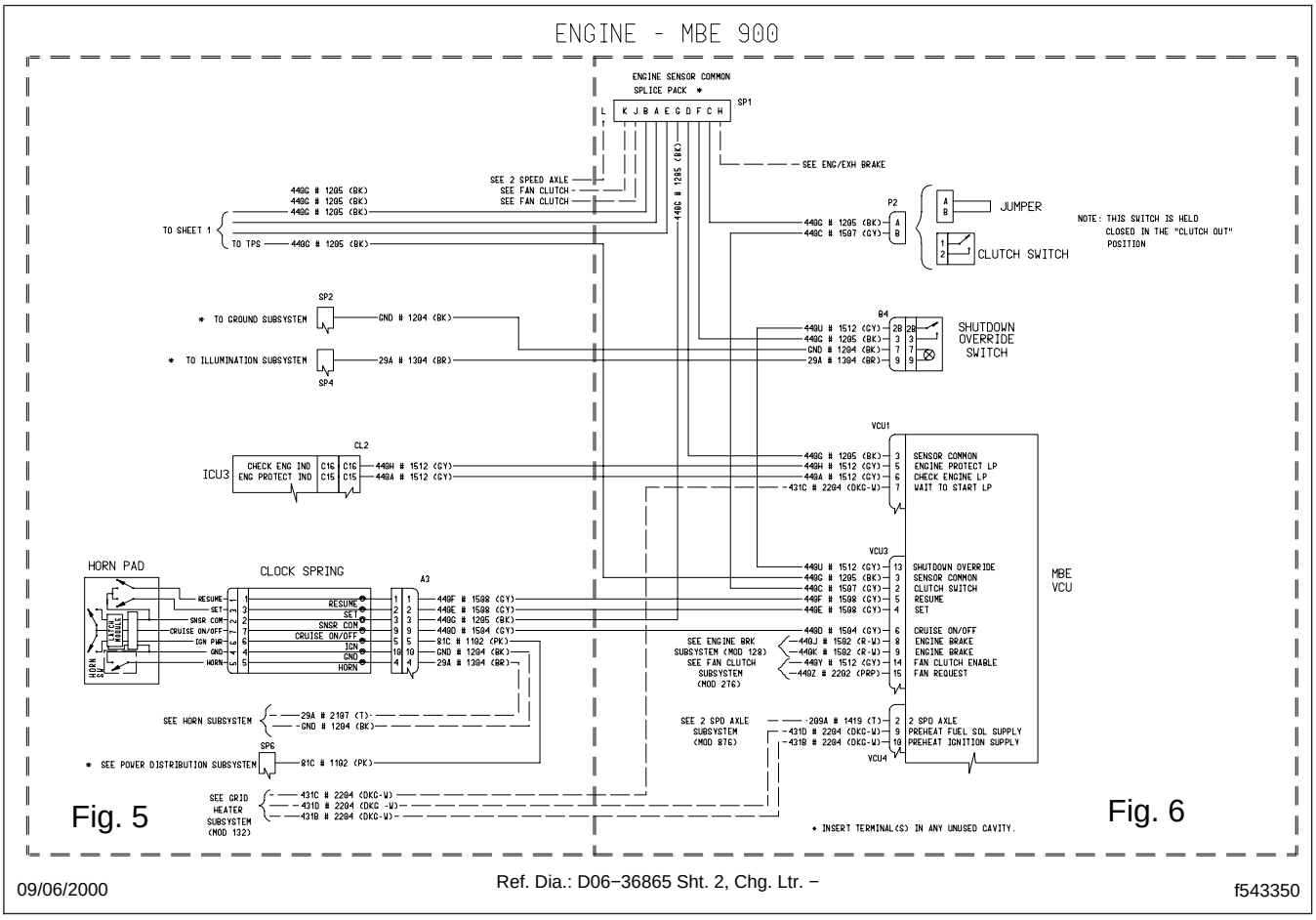


Fig. 4, Engine Wiring, Sheet 2 (full view)

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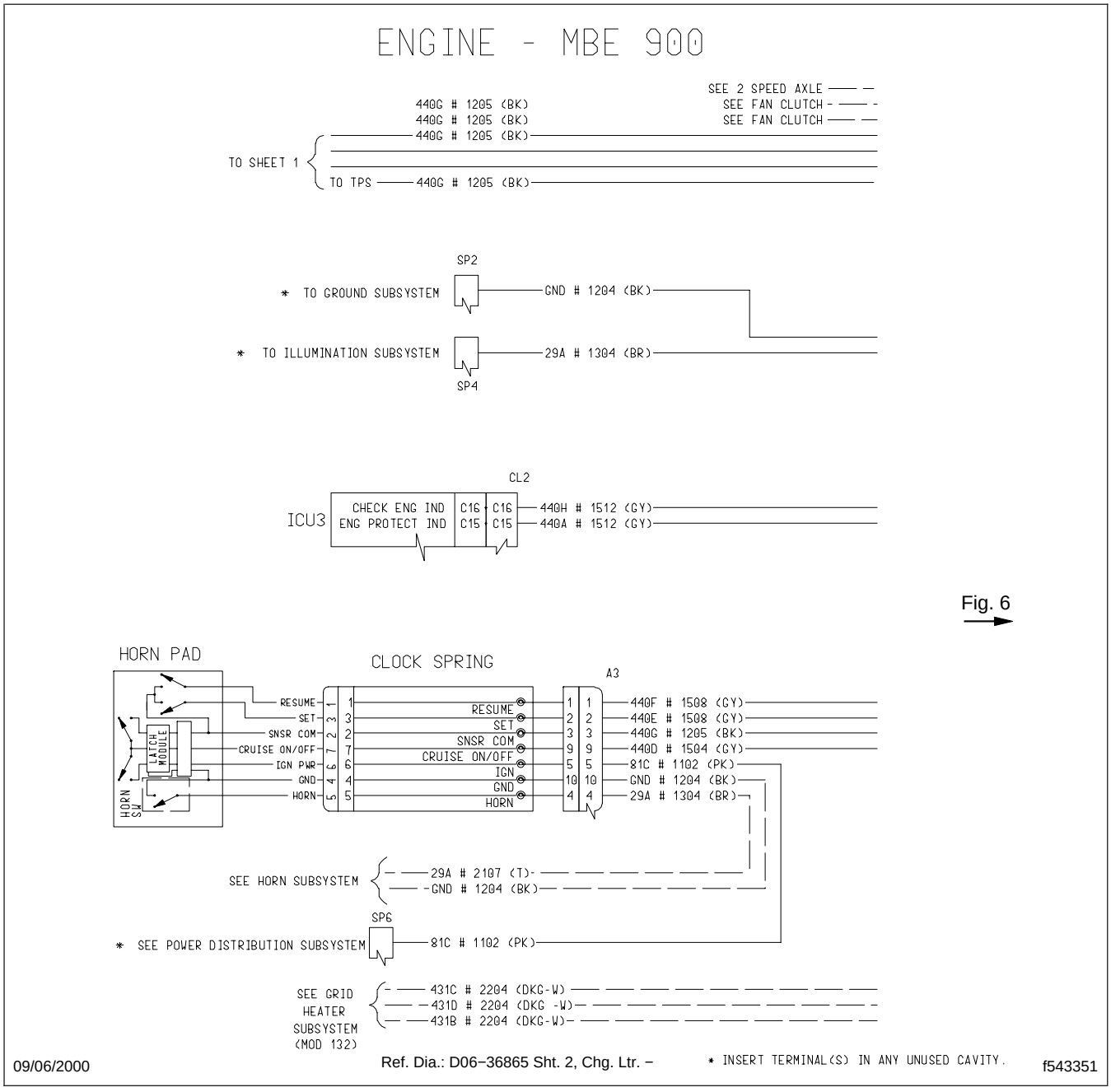


Fig. 5, Engine Wiring, Sheet 2 (partial view)

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Specifications

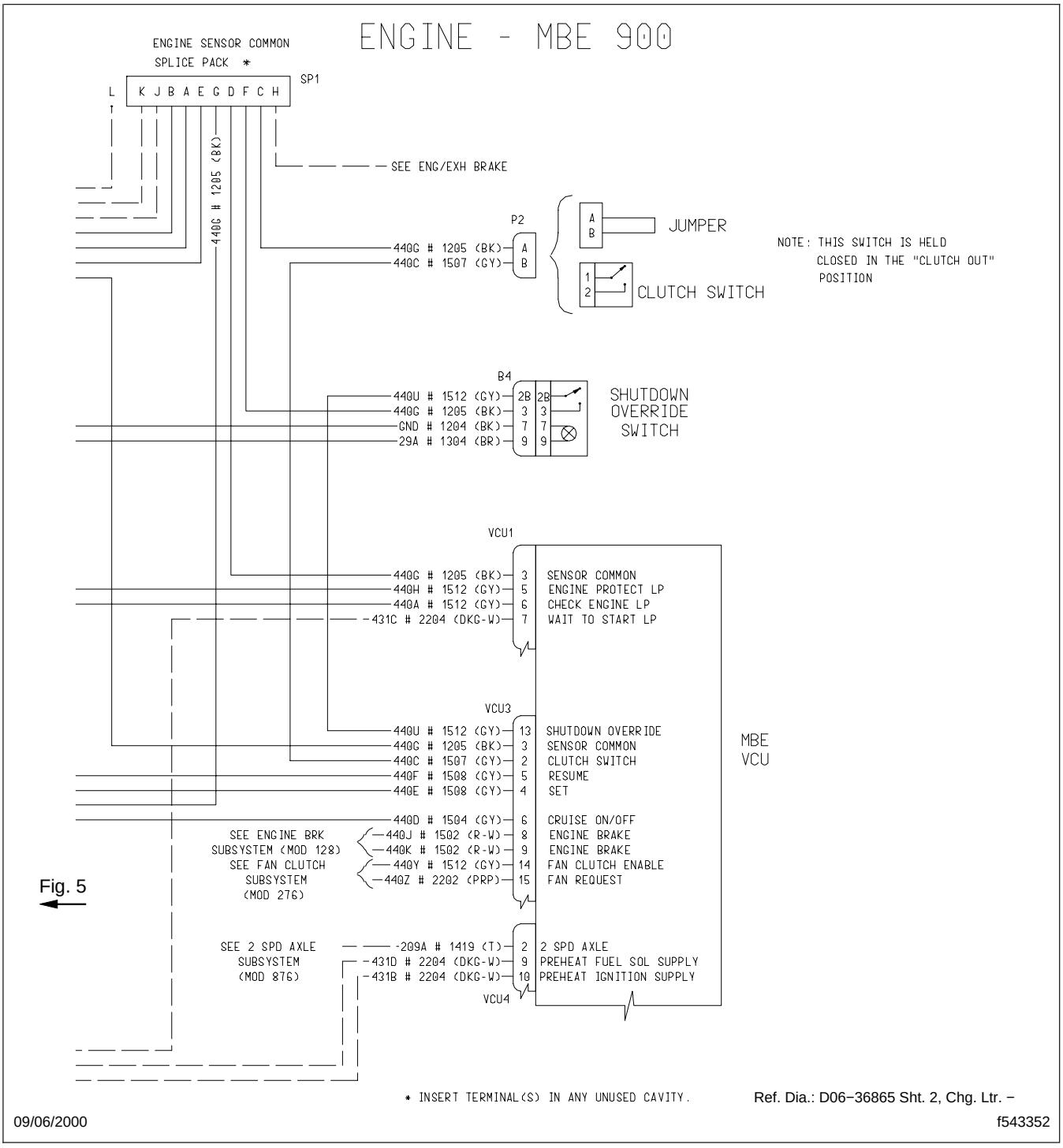


Fig. 5

Fig. 6, Engine Wiring, Sheet 2 (partial view)

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General Information

Lead-Acid Batteries

Batteries are electrochemical devices that store chemical energy. When the battery is connected to an external load, such as a starter, the chemical energy is converted into electrical energy and current flows through the circuit.

The battery has three functions:

- To supply power to start the engine.
- To stabilize the voltage in the electrical system. The battery filters high voltage transients and protects electronic components in the vehicle.
- To supply power when the vehicle's electrical load requirements go beyond what the charging system can supply or when the engine is not running.

All lead-acid batteries use plates made of two unlike metals held apart by separators. One of the metals becomes the positive plate, the other the negative plate. These plates are then grouped in pairs, alternating negative and positive. The groups are connected in series, and each plate group (cell) produces about two volts. Thus, a battery with six cells is a 12-volt battery.

In conventional liquid-electrolyte batteries (wet cells), each battery contains a group of plates immersed in a solution of electrolyte (dilute sulfuric acid).

Batteries may produce hydrogen gas when being charged. The vents allow the escape of gases produced in the battery.

NOTE: Liquid-electrolyte batteries must be kept in an upright position to prevent electrolyte leakage. Tipping a wet cell beyond a 45-degree angle in any direction can allow a small amount of electrolyte to leak out the vent holes.

Proper testing will indicate the battery condition. For more information, see **Troubleshooting 300**.

Absorbed Glass Mat (AGM) Batteries

Absorbed Glass Mat (AGM) batteries are lead-acid batteries in which the electrolyte is contained in a fiberglass mat. AGM batteries are physically similar to standard batteries. Carefully check the label on every battery to be certain it is AGM, and **never install AGM batteries in the same circuit with other types of batteries.**

AGM batteries are designed for high cranking amps and repeated cycle service to accommodate many of the auxiliary loads on vehicle electrical systems. They offer good protection against damage due to vibration, and are leak- and spill-proof, even if cracked or broken. Also, they self-discharge more slowly, and generate less heat when charging or discharging.

IMPORTANT: AGM batteries may be damaged or ruined by equipment designed for other types of batteries. AGM battery chargers must be regulated to a charge voltage less than 15.4 DCV; many chargers provide excessive voltage. To get full service from AGM batteries, carefully follow the battery manufacturer's instructions regarding charging rates and procedures.

Parasitic Battery Drain

Batteries are replenished each time the vehicle is driven with normal vehicle use. In long-term parking situations, however, parasitic drains may discharge the batteries enough that the starter will not be able to crank the engine.

A parasitic drain is an electrical load that draws current from the batteries when the ignition remains off.

A typical parasitic drain falls into the 25 to 325 mA (0.025 to 0.325 amps) range. Multiply the drain (in amps) by the time (in hours) the batteries sit without being recharged. The result is the amount of ampere-hours consumed by the parasitic drain. The actual drain may be small, but over time the batteries grow steadily weaker.

At warm temperature of 77°F (25°C), using approximately 40 percent of the total available ampere-hours will bring fully charged batteries to a no-start condition. In colder temperatures, the batteries will reach a no-start condition sooner.

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General Safety Precautions

WARNING

Keep sparks, flames, burning cigarettes, etc. away from batteries. Batteries generate explosive gases, which could cause a battery to explode, causing serious personal injury, including blindness.

When charging the batteries, gas forms in each cell and escapes through the vent holes. In poorly ventilated areas, the gas lingers around the battery several hours after it has been charged. The gas is explosive around sparks, flame, or other intense heat; if ignited, it could cause the battery to explode. Follow these precautions when charging the batteries.

- Wear safety glasses or a face shield when working with batteries. When many batteries are handled, wear rubber gloves and an apron to protect clothing.
- Make sure that the area is well ventilated.
- Do not install any lead-acid battery in a sealed container or enclosure. Allow hydrogen gas caused by overcharging to escape. Exploding hydrogen gas can cause blindness or other bodily injury.
- Make sure that the charger cable leads are clean and making good connections. A poor connection could cause an electrical arc which could ignite the gas mixture and explode the battery.
- Do not break live circuits at the terminals because a spark usually occurs at the point where a live circuit is broken. Use care when connecting or disconnecting booster leads or cable clamps on chargers.
- Do not smoke near batteries that are being charged or have recently been charged. Keep the batteries away from open flames or sparks.
- If the battery is frozen, let it reach room temperature and completely thaw before trying to charge it. Check for leaks and cracks before charging the battery. Replace the battery if leaks or cracks are seen.
- Take care that tools or metal objects do not fall across the battery terminals.

WARNING

Do not install any lead-acid battery in a sealed container or enclosure. Allow hydrogen gas caused by overcharging to escape. Exploding hydrogen gas can cause blindness or other bodily injury.

CAUTION

If a metal object connects an ungrounded battery terminal to a nearby metal part of the vehicle which is grounded, it could short out the batteries, causing sparks and possible property damage.

Battery Electrolyte Safety Precautions

WARNING

Protect skin and eyes from battery electrolyte (acid). Electrolyte is corrosive and could result in serious personal injury if splashed on your skin or in your eyes.

If electrolyte is splashed on your skin or in your eye, force the eye open, rinse it with cool, clean water for about five minutes and call a doctor immediately. Do not add eye drops or other medication unless advised by the doctor.

If electrolyte is swallowed, drink several large glasses of milk or water. Follow with milk of magnesia, a beaten raw egg, or vegetable oil. Call a doctor immediately.

Use extreme care to avoid spilling or splashing electrolyte. Electrolyte spilled or splashed on your body or clothing should be neutralized with baking soda or household ammonia, then rinsed with clean water.

Electrolyte can also damage painted or unpainted metal vehicle parts. If electrolyte is spilled or splashed on any metal surface, neutralize and rinse it with clean water.

To prevent possible skin burns, do not wear watches, rings, or other jewelry while performing maintenance work on the batteries.

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Safety Precautions

⚠ WARNING

Do not apply pressure to the end walls of a plastic-case battery. This could cause electrolyte to squirt from the vents, possibly resulting in serious injury to skin or eyes.

When handling plastic-case batteries, use a battery carrier. If one is not available, lift these batteries with your hands placed at opposite corners of the battery.

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Battery Removal, Cleaning and Inspection, and Installation

WARNING

Before doing any of the following procedures, see "Safety Precautions" in Subject 100. Failure to follow the safety precautions could result in personal injury.

WARNING

Before doing any of the following procedures, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

Removal

1. Before working on the battery, make sure all electrical loads such as lights, ignition, and accessories, are turned off.
2. Chock the tires.
3. Remove the battery box cover.
4. Disconnect the negative battery cable leads.
5. Disconnect the positive battery cable leads.
6. Disconnect the battery interconnect cables.
7. Remove the battery holddowns. Then remove the batteries from the carrier.

Cleaning and Inspection

1. Inspect all battery cables and interconnectors for wear, and replace them if necessary. Remove corrosion from cables, terminals, and battery posts with a wire brush and a solution of baking soda and water. Rinse thoroughly with clean water, and dry.
2. Clean and tighten the battery ground cable at the weld stud on the frame rail. Inspect and ensure that the nut is self-locking and that a flat washer is used. Do not use a split-lock washer or star washer. Torque the nut 15 to 18 lbf·ft (20 to 24 N·m). Seal the area with red dielectric enamel.
3. Inspect the retainer assembly and battery box. Replace worn or damaged parts. Remove any corrosion with a wire brush and wash with a weak solution of baking soda and water. Rinse with clean water and dry. To prevent rusting, paint the retainer assembly if needed.
4. Be sure foreign objects, such as stones, bolts, and nuts, are removed from the battery box.

Installation

1. Be sure that the replacement battery has a sufficient capacity to cover the electrical needs of the vehicle.

NOTICE

Using an under-capacity battery will result in poor performance and premature battery failure, resulting in damage or reduced life of the starter.

2. Be sure the battery is at full charge when installed. If the battery has been in storage for some time, or if the installation is being made in subfreezing temperatures, give the battery a top-off charge before installing it. For instructions, see **Subject 130**.
3. Place the batteries in the carrier with the terminals in the proper position as referenced earlier. The batteries must rest level in the carrier.
4. Install the battery holddown and tighten it to 12 lb·ft (8 N·m). See **Fig. 1**.

NOTICE

Do not overtighten the battery holddown. Overtightening could damage the batteries.

5. To provide corrosion protection, apply lithium dielectric grease liberally to the terminal pads, then install the interconnectors.

IMPORTANT: Many electrical components are located outside of the cab in areas subjected to harsh weather and road spray. Some components also have exposed metal electrical terminals, which, when subjected to harsh conditions, may suffer corrosion at the electrical connection.

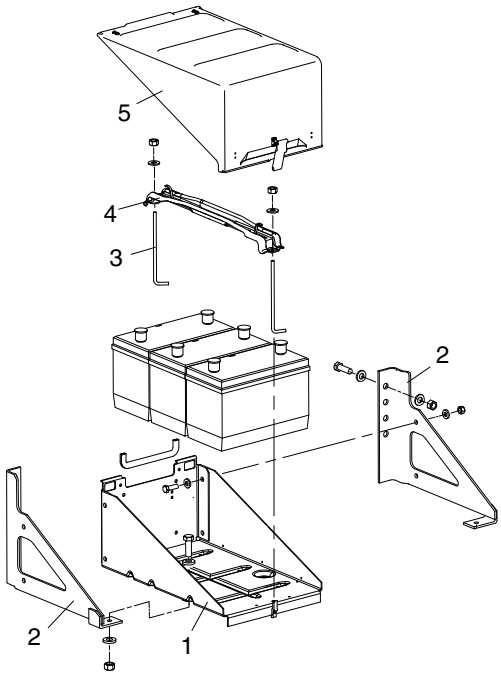
6. Connect the battery interconnecting cables to the batteries and check for correct polarity with respect to the vehicle. Connect the ground cables last.

NOTICE

Reversed polarity may cause serious damage to the electrical system.

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Battery Removal, Cleaning and Inspection, and Installation



1. Battery Box
2. Bracket, Battery Box
3. Holddown Bolt
4. Holddown
5. Battery Box Cover

Fig. 1, Battery Box, Battery, and Battery Holddown

7. Tighten all battery connections to the torque specifications listed on the battery. Generally those are 10 to 15 lbf·ft (14 to 20 N·m). Proper torque is important for electrical system operation.
8. Start the engine and check the operation of the charging system. If needed, repair the charging system to obtain the correct charging output. For instructions, see the appropriate section in **Group 15**.

NOTICE

Make sure all battery posts are covered with dielectric grease to protect against corrosion.

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Emergency Starting Using Booster Cables

⚠ WARNING

Before jump-starting a vehicle, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

⚠ WARNING

Batteries release explosive gas. Do not smoke when working around batteries. Put out all flames and remove all sources of sparks or intense heat in the vicinity of the battery. Do not allow the vehicles to touch each other. Do not lean over the batteries when making connections, and keep all other persons away from the batteries. Failure to follow these precautions could lead to severe personal injury as a result of an explosion or acid burns.

NOTICE

Make sure both electrical systems are the same voltage. Electronic devices on both vehicles can be damaged when connected to a vehicle with a different operating voltage.

1. Apply the parking brakes and turn off all lights and other electrical devices. Ensure that the vehicles are not touching and both ignition switches are turned to the OFF position.

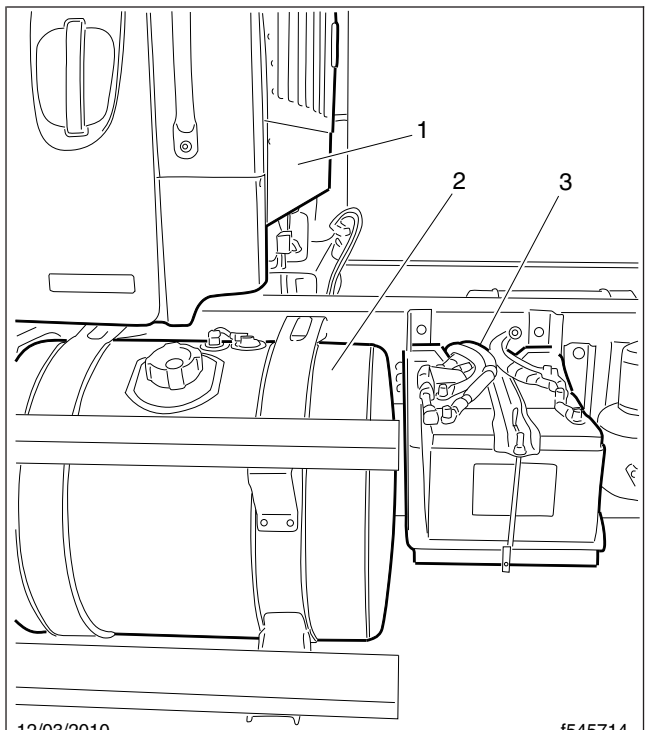
IMPORTANT: Do not attempt to jump start a damaged battery.

2. Remove the battery box cover. See **Fig. 1** for the standard battery compartment location.

NOTICE

Always connect the batteries and jumper cables correctly (positive-to-positive and negative-to-negative). Connecting a charging device backwards (positive-to-negative) can severely damage the vehicle electrical content and cause non-warrantable failures.

IMPORTANT: On vehicles equipped with optional jump start posts, connect to these posts instead of the battery terminals. Jump start



1. Back of Cab
2. Fuel Tank
3. Battery Compartment

Fig. 1, Standard Battery Compartment Location

posts may be installed in various locations on the vehicle. See **Fig. 2**.

3. Connect the positive (+) jumper cable to the positive terminal or jump start post on the discharged battery. See **Fig. 3**.
4. Connect the other end of the positive jumper cable to the positive terminal or jump start post on the booster battery providing the charge.

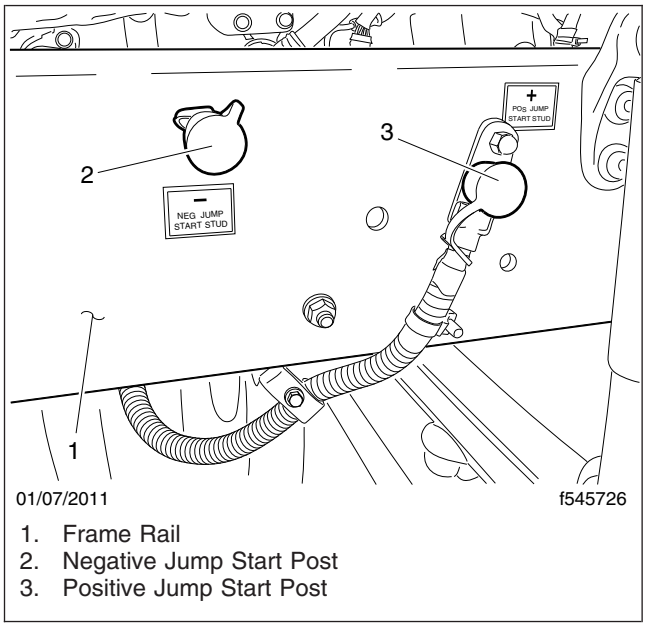
⚠ WARNING

Do the next step exactly as instructed and do not allow the clamps of one cable to touch the clamps of the other cable. Otherwise, a spark could occur near a battery, possibly resulting in severe personal injury from explosion and acid burns.

5. Connect the negative (-) jumper cable to the negative terminal or jump start post on the booster battery.

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Emergency Starting Using Booster Cables



1. Frame Rail
2. Negative Jump Start Post
3. Positive Jump Start Post

Fig. 2, Possible Jump Start Post Location (passenger-side engine compartment)

6. Connect the other end of the negative jumper cable to the negative ground stud on the vehicle requiring the jump start.
7. Start the engine of the vehicle providing the jump start and let the engine run a few minutes to charge the batteries of the other vehicle.
8. Attempt to start the engine of the vehicle receiving the jump. Do not operate the starter longer than 30 seconds, and wait at least two minutes between starting attempts to allow the starter to cool.
9. When the engine starts, let it idle a few minutes.

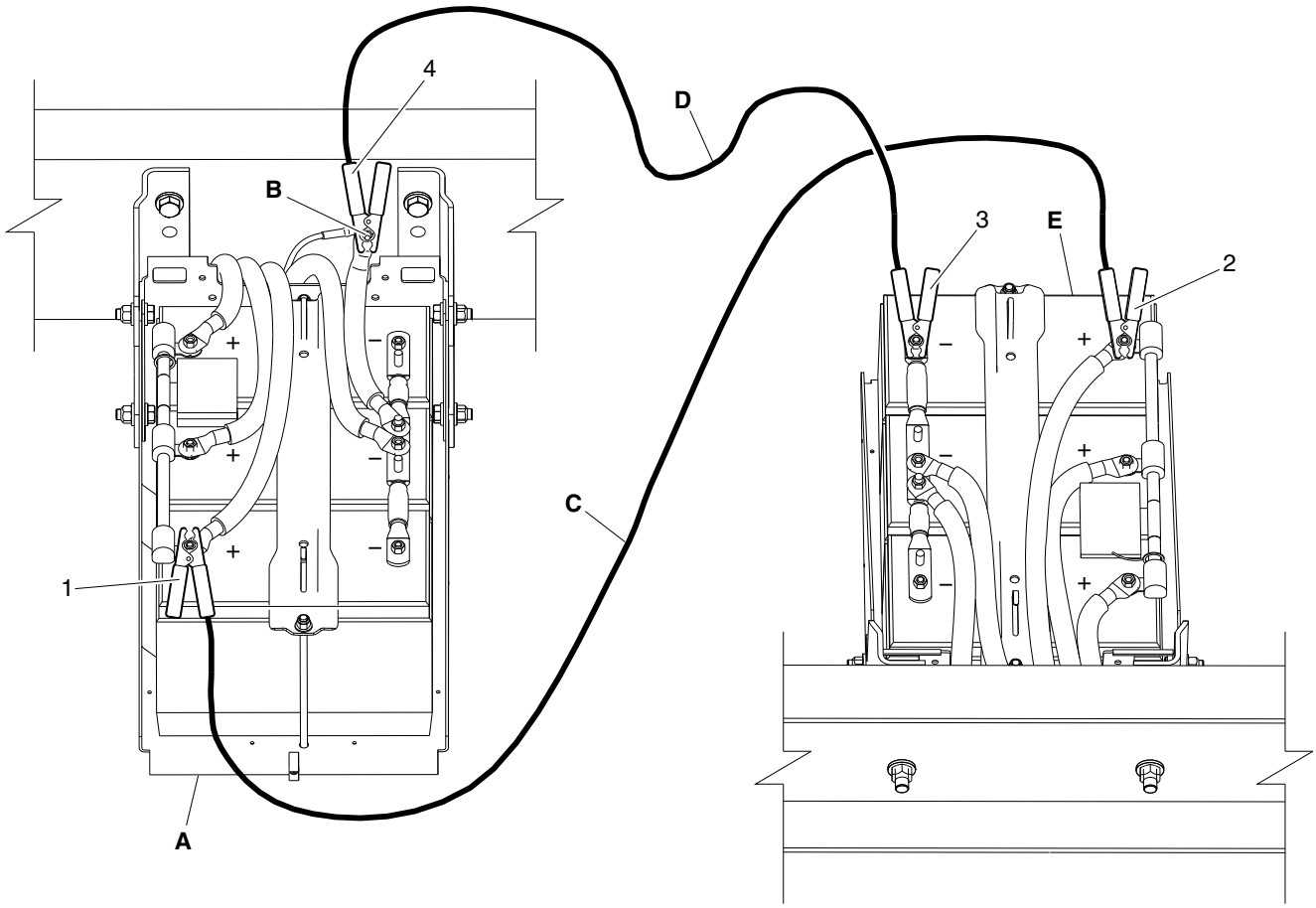
⚠ WARNING

Do the next step exactly as instructed and do not allow the clamps of one cable to touch the clamps of the other cable. Otherwise, a spark could occur near a battery, possibly resulting in severe personal injury from explosion and acid burns.

10. Disconnect the negative jumper cable from the negative cable stud on the jump-started vehicle.
11. Disconnect the negative jumper cable from the booster battery.
12. Disconnect the positive cable from the booster battery.
13. Disconnect the other end of the positive jumper cable from the jump-started vehicle.
14. Install the battery box cover; be sure it is positioned properly before fastening the latch.

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Emergency Starting Using Booster Cables



Disconnect jumper cables in the REVERSE order that they were connected.

A. Discharged Battery
B. Negative Ground Stud
C. Positive Jumper Cable
D. Negative Jumper Cable
E. Booster Battery

1. 1st Connection: Positive Jumper Cable to Discharged Battery
2. 2nd Connection: Positive Jumper Cable to Booster Battery
3. 3rd Connection: Negative Jumper Cable to Booster Battery
4. 4th Connection: Negative Jumper Cable to Negative Ground Stud (discharged battery)

Fig. 3, Jumper Connections

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⚠ WARNING

Before charging a battery, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

When charging batteries, always wear eye protection. During charging, batteries give off explosive hydrogen gas. Exploding gas can cause blindness or other bodily injury.

Battery Charging

AGM batteries may be charged only with a charger that is specified for AGM batteries. Many older chargers operate at a voltage that is too high for AGM batteries and will cause permanent damage. Never combine AGM and flooded batteries together for charging or for use in a vehicle.

See **Table 1** for voltage to approximate battery state of charge for flooded batteries.

Voltage to Approximate Battery State of Charge for Flooded batteries		
Voltage		State of Charge
Flooded	AGM	
12.6	12.8	100%
12.4	12.6	75%
12.2	12.3	50%
12.0	12.0	25%
11.8	11.8	0%

Table 1, Voltage to Approximate Battery State of Charge for Flooded batteries

1. If the batteries are not installed in the vehicle, install the lead adapters on the battery positive and negative posts.
2. Connect the charger to the battery following the manufacturer's instructions. Slightly rock the charger's clamps to insure a complete connection.

IMPORTANT: If the battery feels hotter than 125°F (52°C) or if rapid gassing or spewing of electrolyte occurs, lower the charging rate or stop charging the battery and allow it to cool.

3. When finished, turn the charger off.

⚠ WARNING

Always turn the charger off before disconnecting it. Touching a charger lead when the circuit is live could create a spark and cause an explosion, resulting in personal injury.

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General Information

WARNING

Before testing a battery, see "Battery Safety Precautions" in this section. Failure to follow the safety precautions could result in personal injury.

Test any maintenance-free battery that does not hold a charge to see if it needs to be replaced, or if the problem lies elsewhere in the electrical system. Accuracy of the test depends on variables such as temperature and age of the battery. Follow the recommended testing instructions listed below.

IMPORTANT: Two types of battery tests are discussed in this subject. The first test uses the Midtronics Micro740 battery tester, and must be used by all U.S. and Canadian dealers for battery warranty claims. The second test is a load test using a carbon pile type tester and should **not** be used by U.S. or Canadian dealers for battery warranty claims.

Visual Inspection

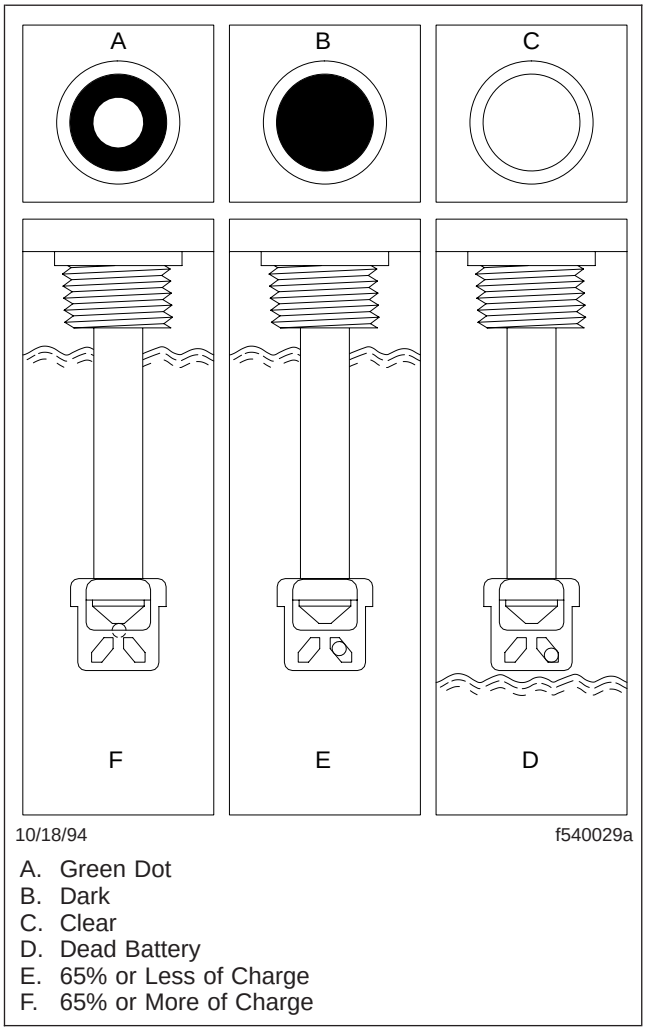
Check for obvious damage such as a cracked or broken case that could permit loss of electrolyte. If there is physical damage replace the battery. Find the cause of the damage and correct it as needed.

On maintenance-free batteries without a built-in hydrometer, perform the Midtronics PowerSensor Micro740 test or the load test.

On maintenance-free batteries with a built-in hydrometer, check the sight glass. If a green dot shows in the sight glass, test the battery. If the sight glass is dark, recharge the battery, then test it. See **Subject 150**. If the sight glass is clear, replace the battery. See **Fig. 1**.

Prior to Testing

1. Clean the battery terminals with a soft wire brush before testing.
2. At the start of the test, make sure all vehicle accessory loads are off and the ignition is in the off position.



A. Green Dot
B. Dark
C. Clear
D. Dead Battery
E. 65% or Less of Charge
F. 65% or More of Charge

Fig. 1, Built-In Hydrometer or Charge Indicator (on optional batteries only)

Midtronics PowerSensor Micro740 Test

NOTE: This test must be used by all U.S and Canadian dealers for battery warranty claims.

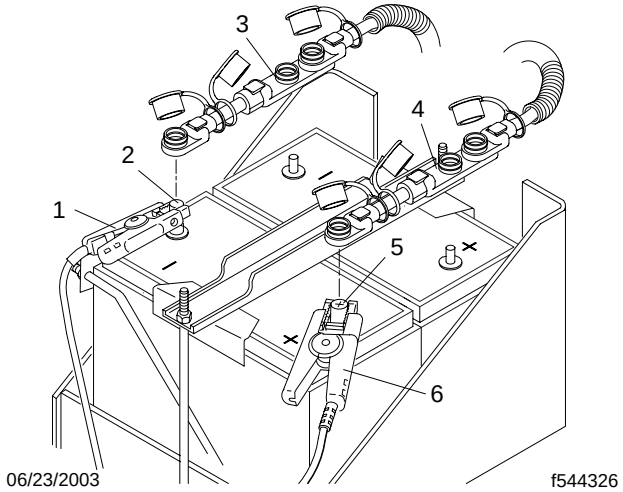
Every battery in a pack of two or more must be disconnected before testing. If more than one battery is selected to be tested, the analyzer will test the first battery, then prompt you to connect to the next battery after the test has been completed. If the analyzer detects that the batteries are connected, it will remind you to disconnect the pack before starting the test.

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Battery Testing

Connecting the Midtronics Tester

1. Screw an adapter onto the negative-terminal stud and one onto the positive-terminal stud. See **Fig. 2**.



1. Negative-Terminal Clamp
2. Negative-Terminal Adaptor
3. Negative-Terminal Battery Jumper
4. Positive-Terminal Jumper
5. Positive-Terminal Adaptor
6. Positive-Terminal Clamp

Fig. 2, Battery Connection

IMPORTANT: For accurate test results, connect the clamps to the lead adaptors or to the lead bases of threaded studs. Lead stud adaptors are included with the Micro740. Do not connect the clamps directly onto the threaded studs or an inaccurate test result may occur.

2. Connect the red clamp to the positive-terminal stud adaptor.
3. Connect the black clamp to the negative-terminal stud adaptor.
4. Rock the clamps back and forth to ensure a secure connection. Both sides of the clamp must be firmly connected to the adaptors before testing. If the test message CHECK CONNECTION appears, clean the terminals and/or reconnect the clamps.

Battery Test

NOTE: If the analyzer displays a test message after you start the test, see *Test Messages* to determine the cause and remedy.

1. Use the arrow buttons at the top of the keypad to scroll to menu choices. Select BATTERY TEST. Press ENTER to select.
2. Enter the number of batteries being tested (1 to 6) and press ENTER to select.
3. Select the rating system; CCA, SAE, EN, IEC, DIN, or JIS then press ENTER.
4. Select the appropriate rating value (see **Table 1**) then press ENTER.
5. If the analyzer detects that the temperature of the battery may make a difference in the results it will ask you to select whether the battery temperature is above or below 32°F (0°C). It will resume the test after you make the selection and press ENTER.
6. At the end of the test, the Micro740 will display one of the following results from **Table 2** and the measured voltage and CCA, if applicable.

   If the result is REPLACE BATTERY or BAD CELL—REPLACE the analyzer will prompt you to press ENTER to generate a battery code.

   When the prompt BAT.SERIAL # appears enter the battery serial number. Use the ARROW buttons to scroll to the correct digit, then press ENTER to select it and move to the next digit. Pressing the BACK button will move the cursor back one space. When finished, press ENTER.
7. Turn on the printer and align the analyzer transmitter with the printer receiver. Press and hold the MENU button. Select PRINT RESULTS from the option menu by using the arrow buttons and pressing ENTER. It will take about 30 seconds to print all test results, which are displayed simultaneously on the screen.

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Battery Rating Systems		
Rating System	**Description**	**Value Range**
CCA	Cold Cranking Amps, as specified by SAE. The most common rating for cranking batteries at 0°F (-18°C)	100 to 1700 A
SAE	European labeling of CCA	100 to 1700 A
EN	Europa-Norm	100 to 1700 A
IEC	International Electrotechnical Commission	100 to 1000 A
DIN	Deutsche Industrie-Norm	100 to 1000 A
JIS	Japanese Industrial Standard: (shown on a battery as a combination of numbers and letters, for example: 80D26)	43 values from 26A17 to 245H52

Table 1, Battery Rating Systems

Battery Test Results	
Result	**Recommendation**
Good Battery	Return to service.
Good—Recharge	The battery is good, but has an insufficient state of charge. Fully charge the battery and return to service.
Charge and Retest	The battery has a very low state of charge. Fully charge the battery and retest. Failure to fully charge the battery before retesting may cause false readings.
Replace Battery	Replace the battery and generate a test code.
Bad Cell—Replace	Replace the battery and generate a test code.

Table 2, Battery Test Results

Test Messages

Test Message—SYSTEM NOISE	
Possible Cause	**Remedy**
The analyzer has detected computer or ignition noise and will attempt to retest.	Make sure all vehicle loads are off and the ignition is in the off position. The analyzer will automatically retest when it no longer detects system noise
You may be testing too close to a noise source.	Move away from any high-current device and retest.
Battery charge is too low to test properly.	Recharge the battery and retest. If the message reappears, replace the battery.
Poor connection at battery terminal.	Connect the battery cables and retest.

Test Message—NON 12-VOLT BATTERY DETECTED	
Possible Cause	**Remedy**
You are attempting to test both batteries in a 24-volt system at the same time.	Disconnect the batteries and test each one individually.

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Battery Testing

Test Message—INTERNAL ERROR, SERVICE REQUIRED	
Possible Cause	**Remedy**
The analyzer has detected a hardware or software problem.	See the Midtronics Micro740 *Instruction Manual*.

Test Message—REVERSE CONNECTION	
Possible Cause	**Remedy**
The clamps are connected in reverse polarity. i.e., Red to negative (–), and black to positive (+).	Disconnect the clamps and reclamp to proper polarity. i.e., Red to positive (+), and black to negative (–).

Test Message—UNSTABLE BATTERY	
Possible Cause	**Remedy**
Batteries that are very weak or that have just been charged may have sufficient electrical activity to alter test results. The analyzer will automatically retest when the battery has stabilized. Fully charged batteries should stabilize quickly.	Charge weak batteries and then retest.

Test Message—CHECK CONNECTION	
Possible Cause	**Remedy**
Poor connection. Both sides of the clamps must be firmly connected before testing.	Clean the battery terminals using a wire brush and a mixture of baking soda and water. Inspect and clean the clamps. Liberally apply baking soda and water with a clean cloth and thoroughly rub the jaw and spring. Use a soft wire brush to remove corrosion buildup. Rinse with water and let dry.

Load Test

NOTE: This test must **not** be used by U.S and Canadian dealers for battery warranty claims.

1. Test each battery separately, either installed or removed. Disconnect the battery cables from the battery, ground cable first.

⚠ WARNING

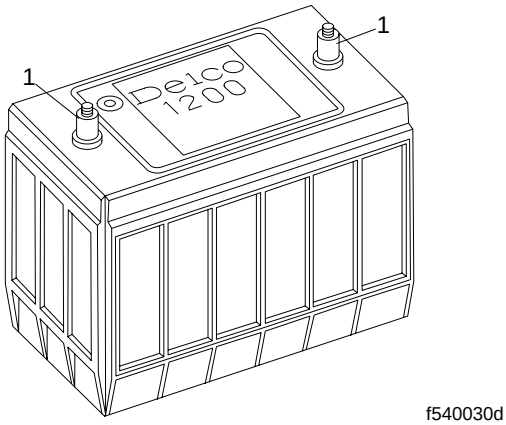
Before charging a battery, see "Battery Safety Precautions" in this section. Failure to follow the safety precautions could result in personal injury.

When charging batteries, always wear eye protection. During charging, batteries give off explosive hydrogen gas. Exploding gas can cause blindness or other bodily injury.

2. Before beginning the load test, check the open circuit voltage (OCV) of each battery. If the voltage is below 12.4 volts, charge the battery on a shop charger for at least 2 hours. If the voltage is above 12.4 volts, proceed to the next step. See **Subject 150** for battery charging instructions.
3. Connect the tester leads to the battery terminals following the tester manufacturer's instructions. Batteries with sealed terminals require adaptors

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to provide a place for attaching the tester's leads. See **Fig. 3**.



1. Terminal Adaptor

Fig. 3, Sealed Battery

4. Check the rated CCA of the battery. Apply a load equal to one-half the rated CCA across the terminals for 15 seconds to remove the surface charge from the battery. Remove the load and wait 15 seconds for the battery to recover.

   Example: For a battery rated at 620 CCA, apply a load of 310 amperes across the terminals.

5. Estimate the battery temperature by touch and by the ambient temperature the battery was exposed to before this test, then find the voltage in **Specifications 400** that must be maintained while the battery supplies a specified electrical load.

   Example: At 70°F, (21°C) the battery must supply 9.6V minimum.

6. Apply the specified test load to the battery for 15 seconds. The test load (amperes) is equal to one-half of the cold-cranking amperes of the 0°F (–18°C) rating of the battery.

7. Read the terminal voltage at the end of 15 seconds with the load still connected. Do not keep the load attached for a longer period of time before reading the voltage, as this would alter the test results.

8. Remove the load after 15 seconds and note the tester reading.

If the voltage drops below the minimum listed in the table replace the battery.

If the voltage is the same or greater than the minimum listed in the table the battery is capable of further service.

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⚠ WARNING

Before charging a battery, read the instructions in Subject 120. Failure to follow the safety precautions could result in personal injury.

When charging batteries, always wear eye protection. During charging, batteries give off explosive hydrogen gas. Exploding gas can cause blindness or other bodily injury.

Charging a Conventional Battery

To ensure the general well being of the electrical system, the starting battery(s) should be kept at a high state of charge. In particular, if operating a vehicle with undercharged battery(s), the alternator can be overworked and may cause premature failure.

To charge a conventional liquid-electrolyte battery (wet cell), apply a charge rate in amperes for several hours. For example, a 10-ampere charge rate for five hours would produce a 50 ampere-hour charge to the battery.

General Guidelines for Charging Batteries

When charging multiple batteries on one charger, group batteries that have similar voltages and are of similar age. If not, the group will only charge as fast as the battery with the lowest state of charge. Batteries below 5 volts should be charged individually.

Important: Do not overcharge maintenance-free batteries. Overcharging causes excessive loss of water from the electrolyte and eventual battery damage.

Refer to **Table 1**, **Table 2**, **Table 3**, and **Table 4** for determining how long to charge the batteries.

Recharge Time Using Shop Charger for a Single Battery					
Voltage	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6	100%	Ready to Use			
12.4	75%	0.6 hrs	0.9 hrs	1.3 hrs	2.5 hrs
12.2	50%	1.2 hrs	1.9 hrs	2.7 hrs	5.1 hrs
12.0	25%	1.8 hrs	2.9 hrs	4.3 hrs	7.8 hrs
11.8	0%	2.5 hrs	4.0 hrs	5.7 hrs	10.7 hrs

Table 1, Recharge Time Using Shop Charger for a Single Battery

Recharge Time Using Shop Charger for a Two Battery System					
Voltage	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6	100%	Ready to Use			
12.4	75%	1.2 hrs	1.8 hrs	2.6 hrs	5.0 hrs
12.2	50%	2.4 hrs	3.8 hrs	5.4 hrs	10.2 hrs
12.0	25%	3.6 hrs	5.8 hrs	8.6 hrs	15.4 hrs
11.8	0%	5.0 hrs	8.0 hrs	11.4 hrs	21.4 hrs

Table 2, Recharge Time Using Shop Charger for a Two Battery System

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Battery Charging

Recharge Time Using Shop Charger for a Three Battery System					
Voltage	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6	100%	Ready to Use			
12.4	75%	1.8 hrs	2.7 hrs	3.9 hrs	7.5 hrs
12.2	50%	3.6 hrs	5.7 hrs	8.1 hrs	15.3 hrs
12.0	25%	5.4 hrs	8.7 hrs	12.9 hrs	23.1 hrs
11.8	0%	7.5 hrs	12.0 hrs	17.1 hrs	32.1 hrs

Table 3, Recharge Time Using Shop Charger for a Three Battery System

Recharge Time Using Shop Charger for a Four Battery System					
Voltage	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6	100%	Ready to Use			
12.4	75%	2.4 hrs	3.6 hrs	5.2 hrs	10.0 hrs
12.2	50%	4.8 hrs	7.6 hrs	10.8 hrs	20.4 hrs
12.0	25%	7.2 hrs	11.6 hrs	17.2 hrs	31.2 hrs
11.8	0%	10.0 hrs	16.0 hrs	22.8 hrs	42.8 hrs

Table 4, Recharge Time Using Shop Charger for a Four Battery System

Batteries below 11.8 volts should be charged at no more than 10 amps for a minimum of 24 hours per battery. Check after the first hour and ensure that the battery is not getting hot.

If after using the above charging method you receive a Charge and Retest result from a Midtronics battery tester and the voltage is above 11.8 volts, continue to charge normally. If the battery voltage is below 11.8 volts, condemn the battery.

On optional batteries with built-in hydrometer (charge indicator), the battery is sufficiently charged when the green dot in the hydrometer is visible. Gently shake or tilt the battery at hourly intervals during charging to mix the electrolyte and check to see if the green dot appears. Do not tilt the battery beyond a 45-degree angle.

If the green dot does not appear after a 75 ampere-hour charge, continue charging for another 50 to 75 ampere-hours. If the green dot still does not appear, replace the battery.

NOTE: Batteries with built-in hydrometers (charge indicators) cannot be charged if the indicator color is clear or light yellow; this indicates low electrolyte level. Replace these batteries.

Refer to the following steps to charge a wet cell battery.

1. Clean the battery terminals.

NOTE: If the battery is cold, let it warm up. This will allow a normal charging rate.

2. Make sure that the charger is turned off.
3. Connect the charger to the battery following the manufacturer's instructions. Rock the charger lead clamps to make sure there is a good connection.
4. Turn on the charger and slowly increase the charging rate until the recommended ampere value is reached.

IMPORTANT: If the battery feels hotter than 125°F (52°C), or if rapid gassing or spewing of electrolyte occurs, lower the charging rate or stop charging the battery and allow it to cool.

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5. After the battery(s) has charged for the recommended time, turn the charger off.

⚠ WARNING

Always turn the charger off before disconnecting it. Touching a charger lead when the circuit is live could create a spark and cause an explosion, resulting in personal injury.

6. Disconnect the charger cables from the battery.

NOTE: If the vehicle is equipped with an isolated battery system, be sure that both battery systems are charged.

7. If the engine does not crank satisfactorily when a charged battery is installed, test the battery using a Midtronics™ battery tester.

   If the battery passes the Midtronics test, check the fuel, ignition, cranking, and charging systems to find and correct the problem.

   If the battery does not pass the Midtronics test, replace it.

Gel Cell Charging

⚠ CAUTION

To avoid shortening the life of a gel cell, carefully regulate the charging voltage—between 13.8 and 14.1 volts.

It is hard to determine how long to charge a gel cell. Recharging time depends on the following factors:

- Depth of discharge
- Temperature
- Size and efficiency of the charger
- Age and condition of the battery

Because the chemical charging reaction slows down as it nears completion, about 60% of the total charging time will be spent bringing the battery from 10.5 volts under load (11.8 volts with no load) to 90% of full charge (12.92 volts, including surface charge). The other 40% of the time is required to charge the remaining 10% (full charge = 13.0 volts, including surface charge).

Example: If it takes 3-1/2 hours to charge a battery to 90%, it will take another 2-1/2 hours to bring it to full (100%) charge.

See **Table 5** for a list of estimated charging times to 90% of full charge. See **Table 6** for a list of estimated charging times to 100% of full charge. All charging times are based on the initial charge current accepted by the battery, using an automatic, temperature-sensing, voltage regulating charger set at 13.8 volts (2.30 to 2.35 volts per cell) on a totally discharged battery (at 11.80 to 12.00 volts, with no load).

Charging Time to 90% of Full Charge			
Battery	Initial Amps Needed to Recharge In		
	13 Hours	6 Hours	3-1/2 Hours
G27	8	21	41
G31*	9	24	45

* Freightliner uses the G31 (Group 31) gel cell.

Table 5, Gel Cell Charging Guide (90% charge)

HOW TO USE THESE CHARTS: Read amps about one minute after the charger is first turned on. Use this initial reading to estimate the approximate charging time.

Example: If a G31 battery reads about 24 amps charge current when first turned on, the battery will be at 90% charge in about six hours, and will be fully charged (100%) in about ten hours.

Charging Time to 100% of Full Charge			
Battery	Initial Amps Needed to Recharge In		
	22 Hours	10 Hours	6 Hours
G27	8	21	41
G31*	9	24	45

* Freightliner uses the G31 (Group 31) gel cell.

Table 6, Gel Cell Charging Guide (100% charge)

To charge a gel cell, do the following steps:

1. Remove the gel cell from the vehicle.
2. Clean the battery terminals.

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Battery Charging

NOTE: If the gel cell is cold, let it warm up to 68°F (20°C). This will allow a normal charging rate.

3. Make sure that the charger is turned off.

CAUTION

Use a reliable, automatic, temperature-sensing, voltage-regulated charger to charge gel cells. Any other type of charger will damage the gel cell.

4. Connect the charger leads directly to the battery following the charger manufacturer's instructions. Rock the charger lead clamps to make sure there is a good connection.
5. Turn on the charger and set the charging rate between 13.8 and 14.1 volts (2.30 to 2.35 volts per cell).

CAUTION

To prevent damage, do not open a sealed gel cell or charge it in excess of 14.1 volts (2.35 volts per cell).

6. After about one minute, check the initial charge current. To charge to 90% of full charge, see **Table 5** to determine the approximate time of completion. To charge to 100% of full charge, see **Table 6** to determine the approximate time of completion.

IMPORTANT: If the battery feels hotter than 125°F (52°C), or if rapid gassing occurs, stop charging the battery and allow it to cool.

7. When finished, turn the charger off.

WARNING

Always turn the charger off before disconnecting it. Touching a charger lead when the circuit is live could create a spark and cause an explosion, resulting in personal injury.

8. Disconnect the charger cables from the battery.

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Troubleshooting

If the batteries pass testing, check for the following causes:

1. Accessories were left on overnight.
2. A slipping alternator belt, high resistance in the wiring, or a defective alternator is causing the batteries to discharge.
3. The electrical loads are exceeding the charging system capacity.
4. Wires in the electrical system are shorted or pinched.
5. There are loose or damaged battery cable-to-terminal connections.
6. The batteries are still connected in a vehicle that has been out of service. Small current drains of accessories that are connected all the time can discharge the batteries in a few days. Batteries left in a discharged condition are subject to freezing.

Electrical Drain and Parasitic Load

Batteries are replenished each time the vehicle is driven with normal vehicle use. In long-term parking situations, however, parasitic drains may discharge the batteries enough to cause a no-start condition.

A parasitic drain is an electrical load that draws current from the batteries when the ignition remains off. Some devices, such as the electronic control unit (ECU), the bulkhead module (BHM), the chassis module (CHM), the antilock braking system (ABS), and radio memory are intended to draw a very small current continuously. These draws are measured in milliamps (mA). Current draw should be less than 325 milliamps with no circuits active and the ECU, BHM, CHM, and ABS turned off.

Problem—The Batteries Are Undercharged

Problem—The Batteries Are Undercharged	
Possible Cause	**Remedy**
The drive belt is loose.	Check the drive belt and tensioner. Refer to the drive belt subject in the appropriate engine section in **Group 01** for instructions. If necessary, tighten to the manufacturer's specifications. Start the engine and check the alternator voltage and output. Refer to the troubleshooting subject in the alternator section in **Group 15** for instructions.
The drive belt is damaged or missing.	Check the drive pulleys for locked bearings. Repair or replace any damaged components. Replace the drive belt and start the engine. Check the alternator voltage and output. Refer to the troubleshooting subject in the alternator section in **Group 15** for instructions.
The batteries are undercharged.	Perform a battery test. Charge or replace batteries as needed. If the batteries were discharged, start the engine and check the alternator voltage and output. Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The alternator or battery cables are undersized.	Perform a cable load drop test.
The alternator is malfunctioning.	Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The isolator relay is not operating correctly (optional battery isolator system only).	Refer to **Group 82, Subject 300** in this manual for instructions.

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Battery Troubleshooting

1. **Check battery pack voltage to determine state of charge**.

   If equipped, set Load Disconnect Switch to "Off." With the DMM probes on the positive and negative posts of the battery pack, record the voltage. Due to differences in their design and operation, flooded cell and AGM batteries have different voltages at the same state of charge.

   Batteries should be fully charged before further testing. If batteries are not fully charged, they will draw current to recharge during testing, invalidating the troubleshooting test results. Fully charged batteries ensure reliable diagnosis.

   See **Table 1** for voltage as an approximate indicator of state of charge for AGM and flooded batteries.

   If the battery pack will not charge to 100% state of charge, there may be a shorted cell. Break the pack into individual batteries and test individually using an approved tester. Go to **Check 3, Individual Battery Testing**. After batteries have been tested individually, verify pack voltage once again.

Flooded	AGM	SoC
12.6	12.8	100%
12.4	12.6	80%
12.3	12.4	60%
12.1	12.2	40%
12	12	20%
11.8	11.8	0%

Table 1, Voltage to Approximate State of Charge (SoC)

2. **Remove surface charge: HVAC blower, lights on, 5 min.**

   Surface charge refers to a higher initial charge (volts), when discharging, in recently-charged batteries. This charge is a "shallow" charge, meaning that the charging-induced chemical reaction has mostly occurred at the surface of the lead plates, and has not equalized throughout the lead. Drawing current from the batteries before testing removes the surface charge, allowing for a better assessment of the "deep charge" state of the lead plates.

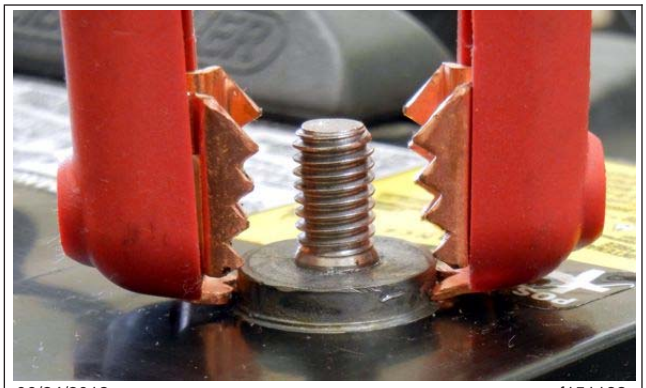
   After the surface charge is removed, the batteries need to be at least 80% SoC for further testing. See **Table 1** for voltage as an approximate indicator of state of charge.

3. **Test Individual Batteries**.

   IMPORTANT: Batteries should only be tested individually.

   3.1 Remove the negative cables of the batteries first, and secure the leads out of the way before touching the positive cables. Remove the battery cables and clean the terminal pads with a wire brush. The adapters will not make sufficient contact with dirty or corroded contact pads.

   3.2 Connect the battery tester's positive and negative clamps to the lead base terminal pads at the positive and negative studs. See **Fig. 1**.



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Fig. 1, Tester Clamps Attached to the Post

The threaded portion of the battery posts are *not* the right place to clip: the steel threads won't make a good connection. The base of the post, on the lead, is the best place to clip. Taking a few extra seconds to make sure the tester, DMM, and carbon pile clips are well-connected can be the difference between a useful and a useless test.

NOTE: If the lead base is too small to clamp to, only lead stud adapters should be used, never nuts. The lead stud adapters must be screwed down tight against the cleaned lead base using a

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hand tool. Lead adapters are available at most tool vendors.

Refer to the battery tester instruction manual for complete testing instructions.

If the battery tester requires the CCA rating of the battery, it should be on the battery label. See **Fig. 2**.

3.3 If the battery fails, enter the battery serial number and print out the result. The sensor windows on the tester and printer must be aligned to transmit the test results to the printer.



Fig. 2, Battery Label

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Specifications

See **Table 1** for recharge times. Refer to the commercial batteries page at **www.dekabatteries.com** for more information.

Recharge Time Using a Typical Charger (hours)						
Open Circuit Voltage		State of Charge	Charger Maximum Rate			
Flooded	AGM		50 Amps	30 Amps	20 Amps	10 Amps
12.6V	12.8V	100%	Ready to Use			
12.4V	12.6V	75%	0.6	0.9	1.3	2.5
12.2V	12.3V	50%	1.2	1.9	2.7	5.1
12.0V	12.0V	25%	1.8	2.9	4.3	10.7
11.8V	11.8V	0%	2.5	4.0	5.7	10.7

Table 1, Recharge Time Using a Typical Charger

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Replacement

DOME LIGHT

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the negative battery cable from the battery.
3. Remove the dome light cover.
4. Remove the bulb.
5. Remove the screws fastening the dome light to the cab roof panel.
6. Disconnect the electrical connector and remove the light assembly.
7. Connect the electrical connector and install the light assembly.
8. Install the screws.
9. Install the bulb.
10. Install the dome light cover.
11. Connect the negative battery cable.
12. Remove the chocks from the tires.

DOOR COURTESY LIGHT

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the negative battery cable from the battery.
3. Remove the screws. See **Fig. 1**.
4. Remove the bulb.
5. Disconnect the electrical connector and remove the light assembly. See **Fig. 2**.
6. Connect the electrical connector and place the light assembly into position.
7. Install the bulb.
8. Install the screws.
9. Connect the negative battery cable.
10. Remove the chocks from the tires.

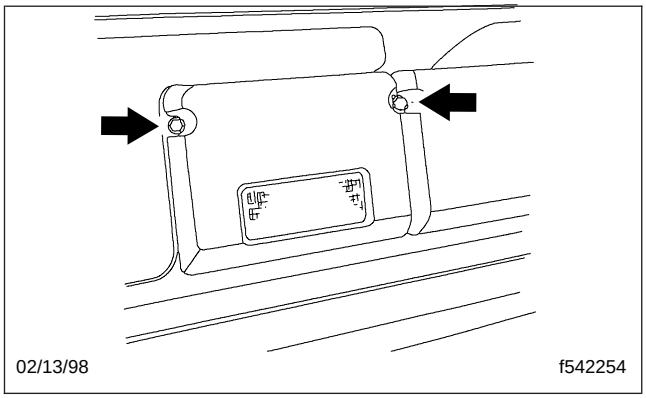


Fig. 1, Door Courtesy Light Screws

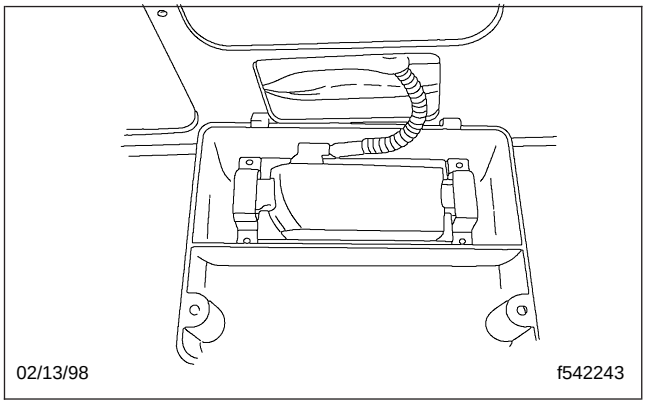


Fig. 2, Door Courtesy Light Electrical Connector

DOOR COURTESY LIGHT SWITCH

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the negative battery cable from the battery.
3. Remove the door courtesy light switch. See **Fig. 3**.
4. Disconnect the electrical connector. See **Fig. 4**.
5. Connect the electrical connector.
6. Install the courtesy light switch.
7. Connect the negative battery cable.
8. Remove the chocks from the tires.

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Interior Light Replacement

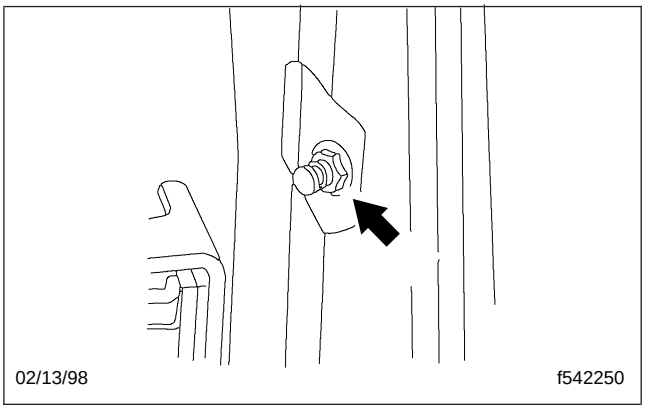


Fig. 3, Door Courtesy Lamp Switch

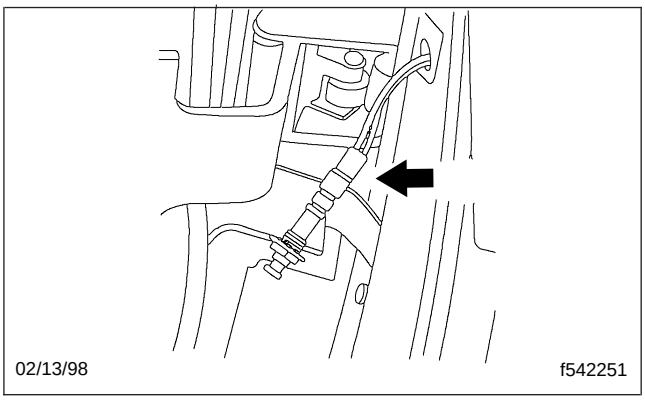


Fig. 4, Door Courtesy Lamp Switch Electrical Connector

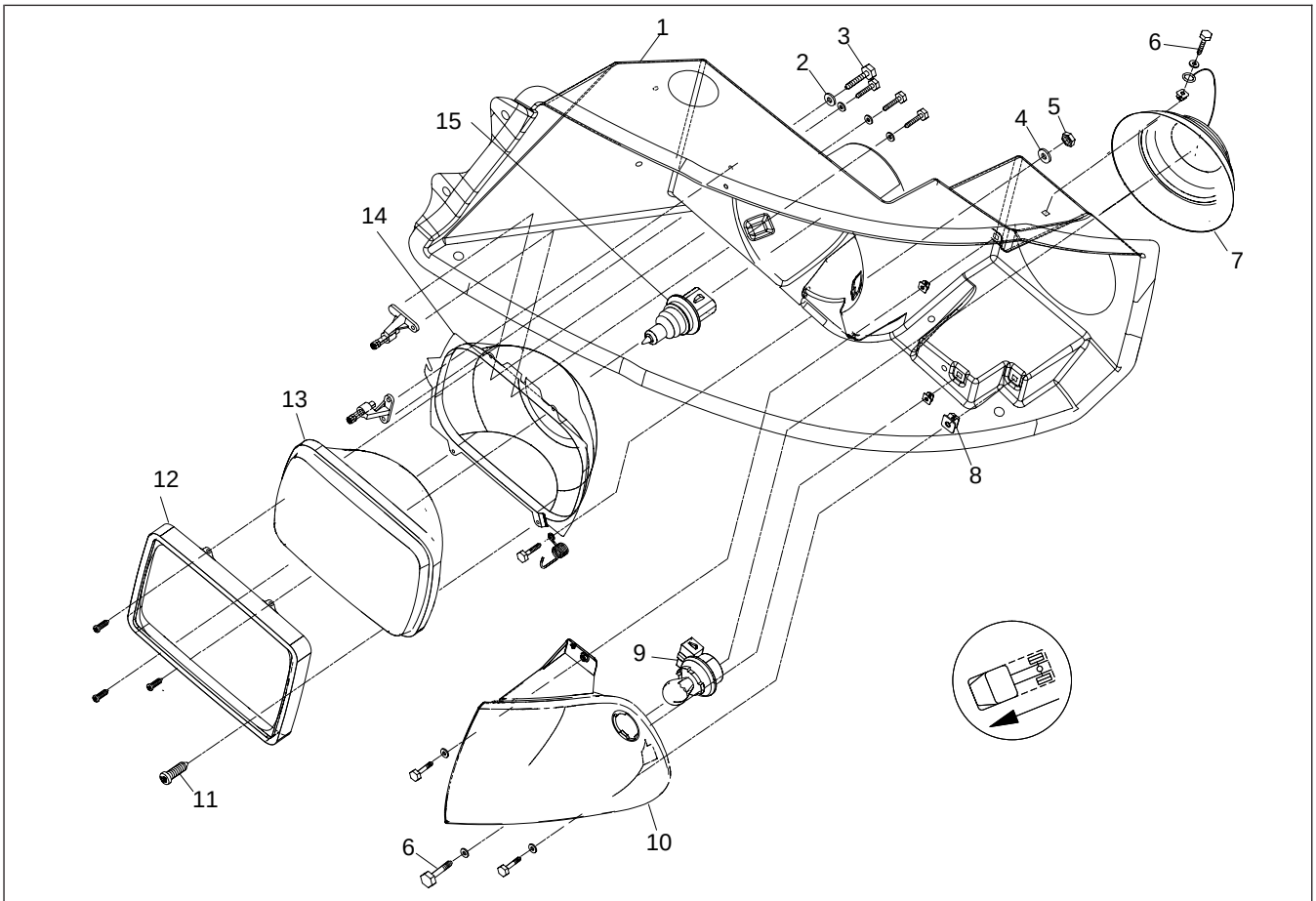
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Replacement

HEADLIGHT ASSEMBLY

(See Fig. 1)

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Open the hood to gain access to the headlight.
3. Disconnect the negative battery cable from the battery.
4. Remove the headlight cover panel bolts.
5. Disconnect the electrical connectors and remove the headlight assembly. See **Fig. 2**.
6. Remove the headlight assembly.
7. Install the headlight assembly.
8. Connect the electrical connectors.
9. Install the headlight cover panel bolts.



1. Headlight Bucket
2. Washer
3. Bolt
4. Washer
5. Nut
6. Bolt
7. Access Cover
8. Collar
9. Turn Signal Bulb
10. Turn Signal Assembly
11. Screw
12. Headlight Bezel
13. Headlight Assembly
14. Headlight Back Cover
15. Headlight Bulb

Fig. 1, Headlight and Turn Signal Assembly

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Exterior Light Replacement

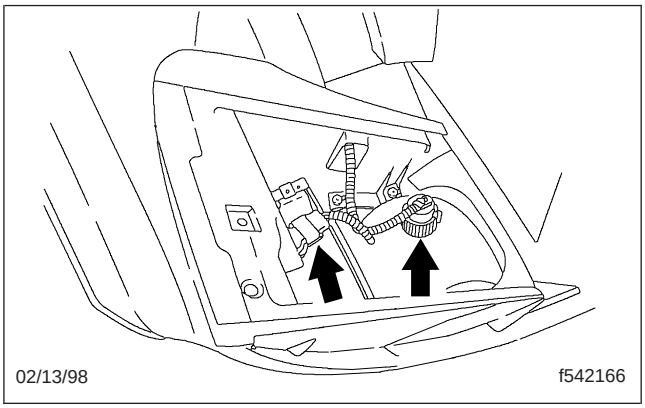


Fig. 2, Electrical Connectors

10. Close and latch the hood.
11. Connect the negative battery cable.
12. Remove the chocks from the rear tires.

TURN SIGNAL ASSEMBLY

(See Fig. 1)

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. From under the hood, remove the access cover.
4. Remove the bulb from the turn signal assembly.
5. From the front of the vehicle, remove the fasteners holding the turn signal assembly to the hood and remove the assembly.
6. Position the turn signal assembly and install the fasteners.
7. Install a new bulb in the turn signal assembly.
8. Install the access cover.
9. Close and latch the hood.
10. Connect the negative battery cable.
11. Remove the chocks from the rear tires.

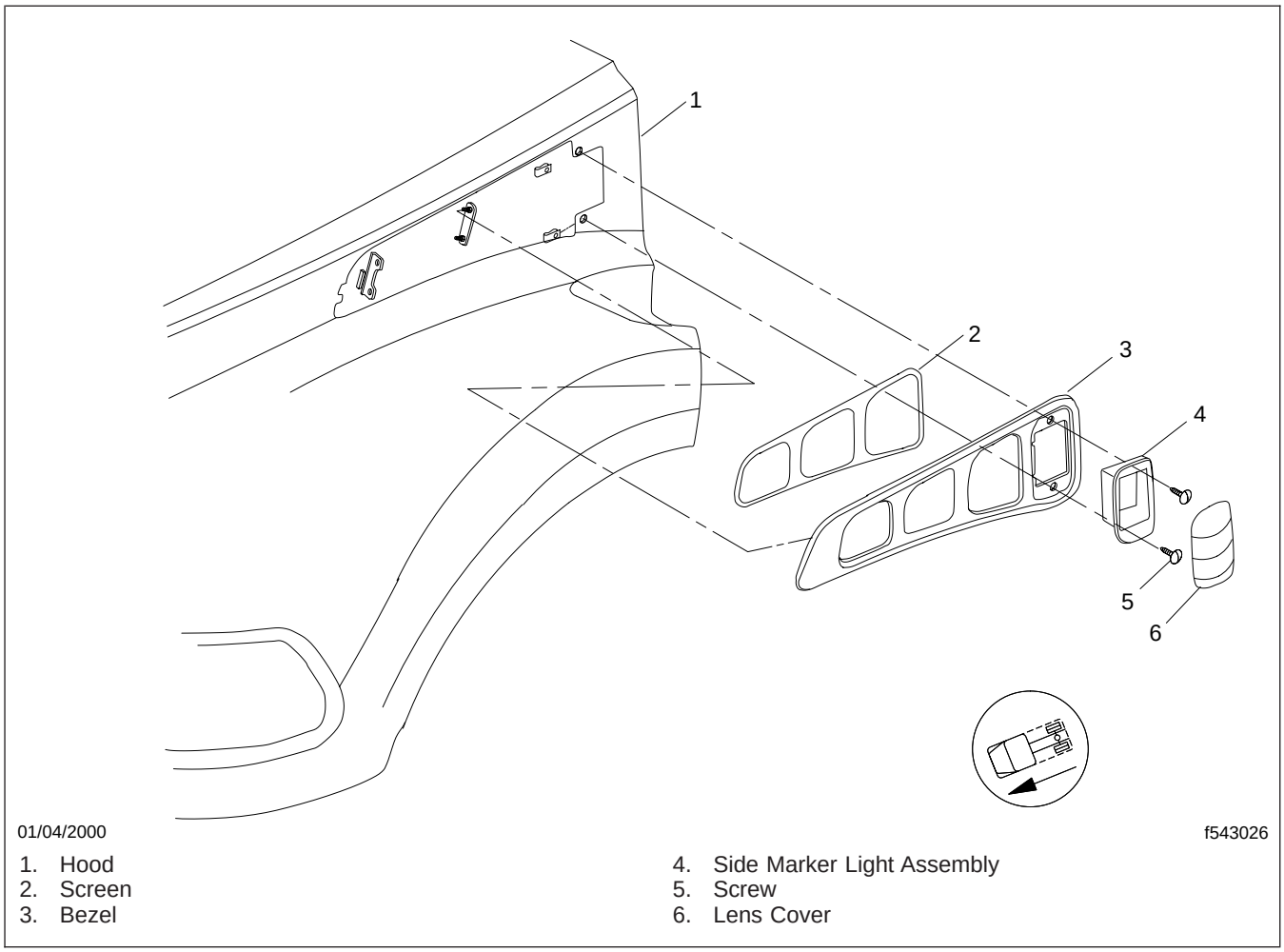
SIDE MARKER LIGHT ASSEMBLY **(See Fig. 3)**

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the negative battery cable from the battery.
3. Pry the lens cover from the light assembly.
4. Remove the bulb from the light assembly.
5. Remove the screws.
6. Disconnect the electrical connector and remove the light assembly.
7. Connect the electrical connector and install the light assembly.
8. Install a new bulb in the light assembly. Make sure you hear it fully seat; the tabs will click when the bulb is fully seated.
9. Install the screws.
10. Install the lens cover onto the turn lamp.
11. Connect the negative battery cable.
12. Remove the chocks from the rear tires.

ROOF-MOUNTED MARKER LIGHT ASSEMBLY

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the negative battery cable from the battery.
3. Remove the screw and the marker light cover. See **Fig. 4**.
4. Remove the bulb from the light assembly.
5. Remove the screws. See **Fig. 5**.
6. Disconnect the electrical connector and remove the light assembly. See **Fig. 6**.
7. Connect the electrical connector and install the light assembly.
8. Install the marker lamp assembly retaining screws.
9. Install a new bulb in the light assembly.
10. Install the marker lamp cover.
11. Connect the negative battery cable.
12. Remove the chocks from the rear tires.

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1. Hood
2. Screen
3. Bezel
4. Side Marker Light Assembly
5. Screw
6. Lens Cover

Fig. 3, Side Marker Light Assembly

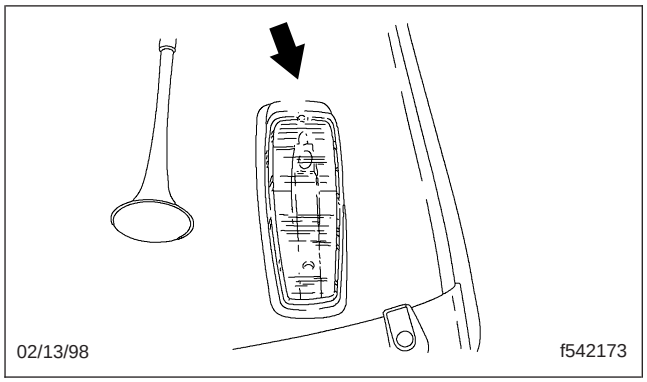


Fig. 4, Screw and Marker Light Cover

TAILLIGHT ASSEMBLY

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the negative battery cable from the battery.
3. Disconnect the electrical connector. See **Fig. 7**.
4. Remove the fasteners and remove the taillight assembly. See **Fig. 8**.
5. Remove the four screws from the taillight cover and remove the cover from the taillight assembly.
6. Remove the bulb from the taillight assembly by turning the bulb counterclockwise.

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Exterior Light Replacement

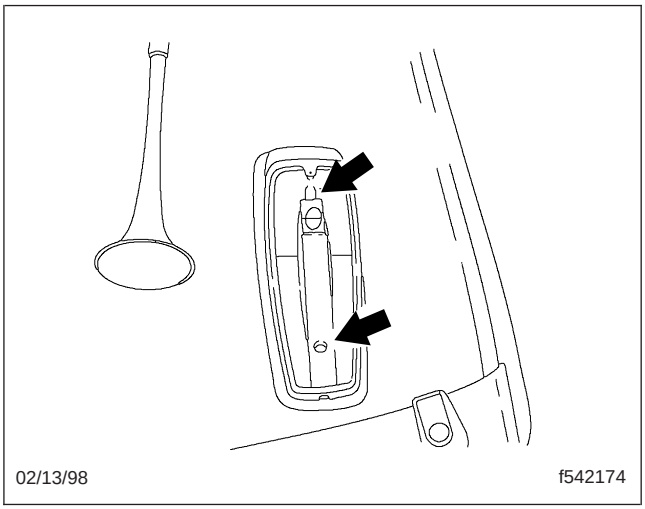


Fig. 5, Roof-Mounted Marker Light Screws

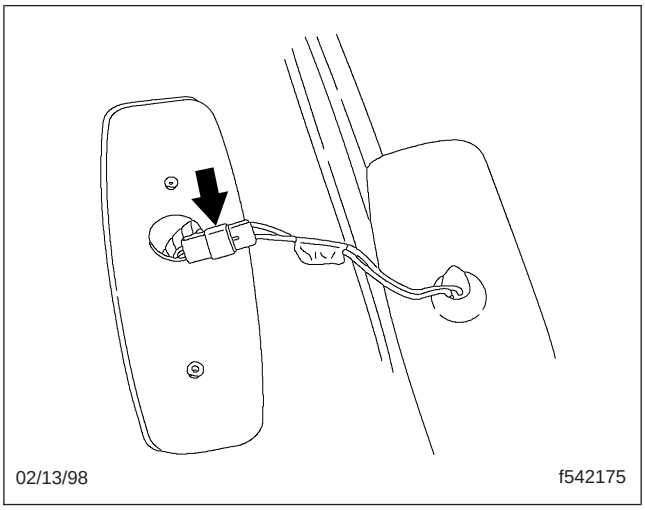


Fig. 6, Roof-Mounted Marker Light Electrical Connector

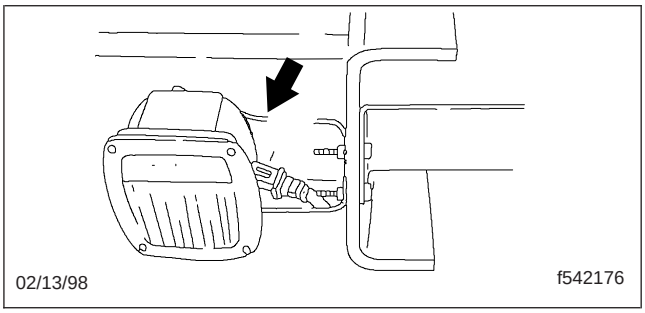


Fig. 7, Taillight Electrical Connector

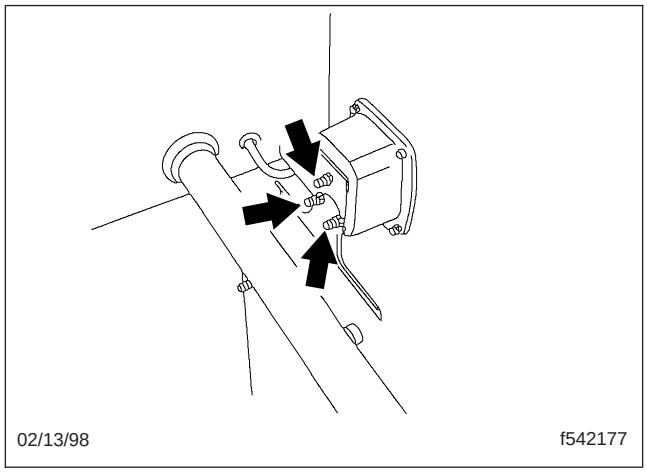


Fig. 8, Taillight Fasteners

7. Install a new bulb in the taillight assembly by turning the bulb clockwise.
8. Install the taillight cover with the four screws.
9. Position the taillight assembly and install the taillight assembly retaining screws.
10. Connect the electrical connector.
11.
12. Connect the negative battery cable.
13. Remove the chocks from the rear tires.

BACK-OF-CAB LIGHT

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the negative battery cable from the battery.
3. Pry the cover off of the light assembly.
4. Remove the bulb.
5. Remove the screws holding the light assembly to the cab.
6. Disconnect the electrical connector.
7. Connect the electrical connector.
8. Position the light assembly and install the retaining screws.
9. Install a new bulb in the light assembly.
10. Install the cover on the light assembly.

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11. Connect the negative battery cable.
12. Remove the chocks from the rear tires.

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Headlight Aim Check and Adjustment

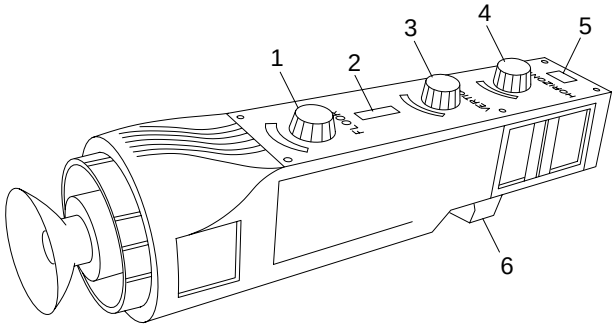
Before checking or adjusting the headlight aim, do the following:

- Remove large amounts of mud or ice from the undersides of the fenders.
- Check the springs for sagging or broken leaves. Check the suspension for proper functioning of the leveling mechanism.
- Clean the headlight lenses and aiming pads.
- Check the bulbs for burnout and broken aiming pads. Switch the beams from low to high to make sure they switch properly.
- With the vehicle unloaded, check that the tires are inflated to the recommended air pressure.

Check

For a quick check to see if the headlights need aiming, do the following procedure.

1. Move the vehicle onto a flat surface that has been calibrated for slope. Shut down the engine, set the parking brake, and chock the rear tires.
2. Attach a headlight aimer to each headlight. See **Fig. 1**.

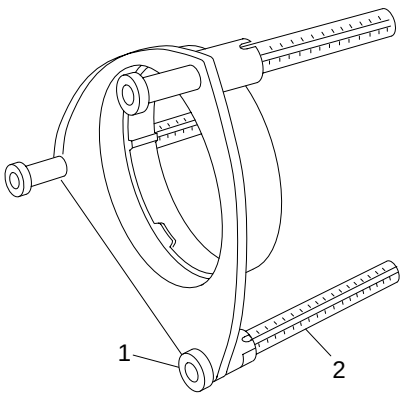


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1. Floor Slope Dial
2. Level Vial
3. Vertical Dial
4. Horizontal Dial
5. Split Image View Port
6. Piston Handle

Fig. 1, Headlight Aimer

2.1 Attach the black universal adaptor to the aimer. Set the adjustment rods to "0" (zero). See **Fig. 2**.



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Set the adjustment rods to "0" (zero).

1. Adaptor Foot
2. Adjustment Rod

Fig. 2, Universal Adaptor

2.2 Align the adaptor with the aiming pads on the headlight lens.

2.3 Push the piston handle on the base of the aimer forward to engage the vacuum cup. Immediately pull the handle backward until it locks. See **Fig. 3**.

2.4 Do the same procedure with the other aimer.

3. Check the floor slope dial for the correct setting. See **Fig. 4**.
4. Check the horizontal aim. See **Fig. 5**.

4.1 Turn the horizontal dial until the split image is in alignment.

4.2 If the horizontal dial scale on either aimer reads more than "4," re-aim the headlight.

NOTE: If adjustment is required, see the procedures under "Adjustment" below.

5. Check the vertical aim. See **Fig. 6**.

5.1 Turn the vertical dial until the level vial is centered.

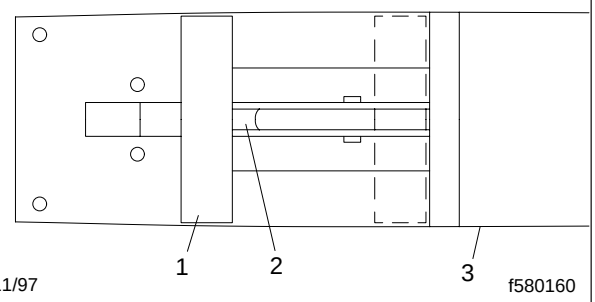
5.2 If the vertical dial scale on either aimer reads more than "4," re-aim the headlight.

NOTE: If adjustment is required, see the procedures under "Adjustment" below.

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Headlight Aim Check and Adjustment

6. Remove the two headlight aimers. Hold each aimer securely, and then press the vacuum release button.
7. Remove the chocks from the rear tires.



To attach, push the piston handle forward to engage the vacuum cup. Immediately pull the handle backward until it locks.
To remove, press the vacuum release button.

1. Piston Handle
2. Vacuum Release Button
3. Base of Aimer

Fig. 3, Aimer Attachment and Removal

Adjustment

If the headlights need adjusting, do this procedure.

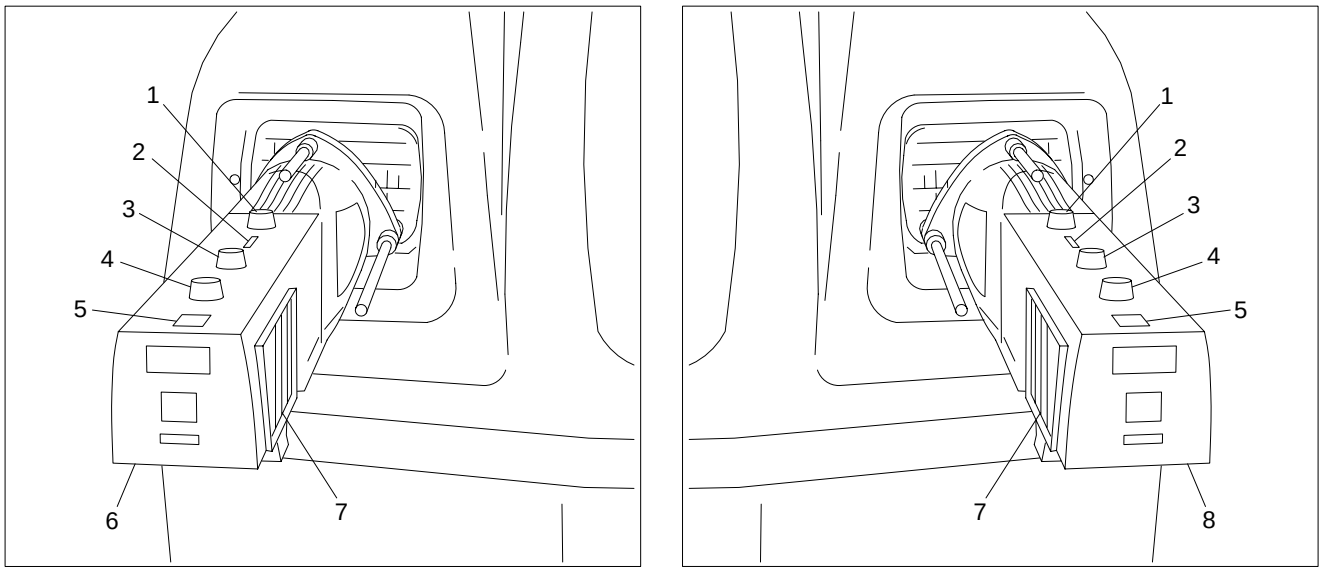
1. If not already there, move the vehicle onto a flat surface that has been calibrated for slope. Shut down the engine, set the parking brake, and chock the rear tires.
2. Attach a headlight aimer to each headlight. See the procedures above under "Check" for detailed instructions.
3. Check the floor slope dial for the correct setting. See **Fig. 4**.
4. Adjust the horizontal aim. See **Fig. 5**.
   - 4.1 Set the horizontal dial to "0" (zero).
   - 4.2 Look in the viewing port for the split image target lines. If necessary, rotate either or both aimers until the lines are visible.
   - 4.3 Turn the horizontal adjustment screw as needed to make the split image appear as one solid line. See **Fig. 7**.

     IMPORTANT: To avoid backlash, make the final adjustment by turning the screw clockwise.
   - 4.4 Do the same procedure for the other headlight.
5. Adjust the vertical aim. See **Fig. 6**.
   - 5.1 Set the vertical dial to "0" (zero).
   - 5.2 Turn the vertical adjustment screw as needed to center the bubble in the level vial between the lines. See **Fig. 7**.

     IMPORTANT: To avoid backlash, make the final adjustment by turning the screw clockwise.
   - 5.3 Do the same procedure for the other headlight.
6. Recheck the horizontal alignment on both aimers. Readjust if necessary.
7. Remove both headlight aimers. While holding the aimer securely, press the vacuum release button. See **Fig. 3**.
8. Remove the chocks from the rear tires.

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Headlight Aim Check and Adjustment

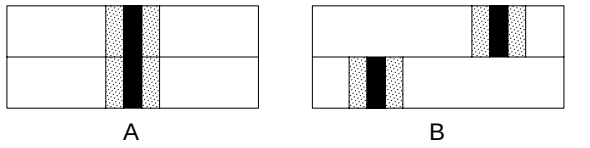


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The sight openings must face each other.

1. Floor Slope Dial
2. Vertical Aim Level Vial
3. Vertical Dial
4. Horizontal Dial
5. Split Image View Port
6. Aimer (right-hand side)
7. Sight Opening
8. Aimer (left-hand side)

Fig. 4, Set-Up for Aiming



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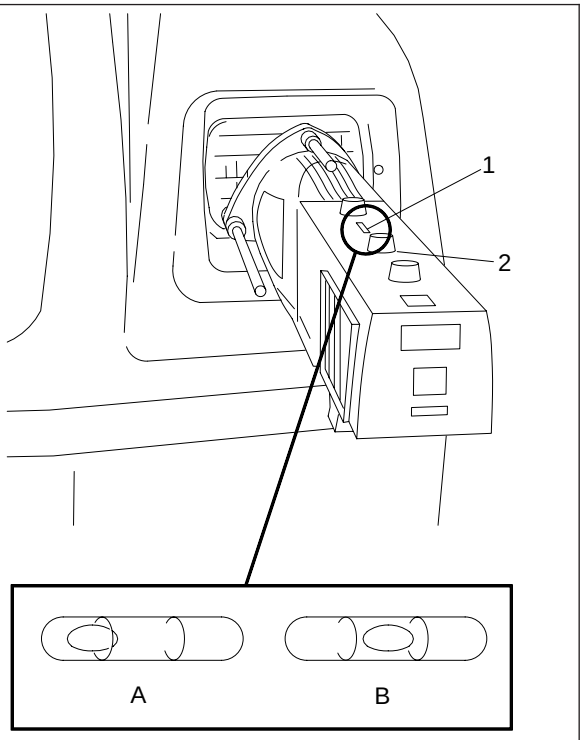
View through the split image view port.

A. Split Image Aligned
B. Split Image Not Aligned

Fig. 5, Horizontal Aim Split Image

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Headlight Aim Check and Adjustment

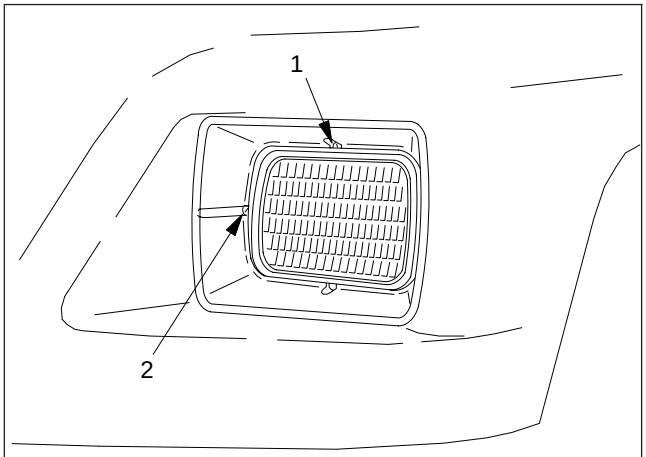


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Set the vertical dial to "0" (zero).

A. Bubble Not Centered
B. Bubble Centered
1. Level Vial
2. Vertical Dial

Fig. 6, Vertical Aim Level Vial



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1. Vertical Adjustment
2. Horizontal Adjustment

Fig. 7, Headlight Adjustment Screws

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See **Fig. 1** for a full view of Sheet 1 for exterior lighting with Signal-Stat switch wiring.

See **Fig. 2** and **Fig. 3** for partial views of Sheet 1.

See **Fig. 4** for a full view of Sheet 2 for exterior lighting with Signal-Stat switch wiring.

See **Fig. 5** and **Fig. 6** for partial views of Sheet 2.

See **Fig. 7** for a full view of the marker lamp wiring.

See **Fig. 8** and **Fig. 9** for partial views of the marker lamp wiring.

See **Fig. 10** for a full view of the interior lighting wiring.

See **Fig. 11** for a full view of the hood wiring harness.

See **Fig. 12** for a full view of the fog/road lights wiring.

See **Fig. 13** for a full view of the utility lights wiring.

See **Fig. 14** for a full view of the illumination summary wiring.

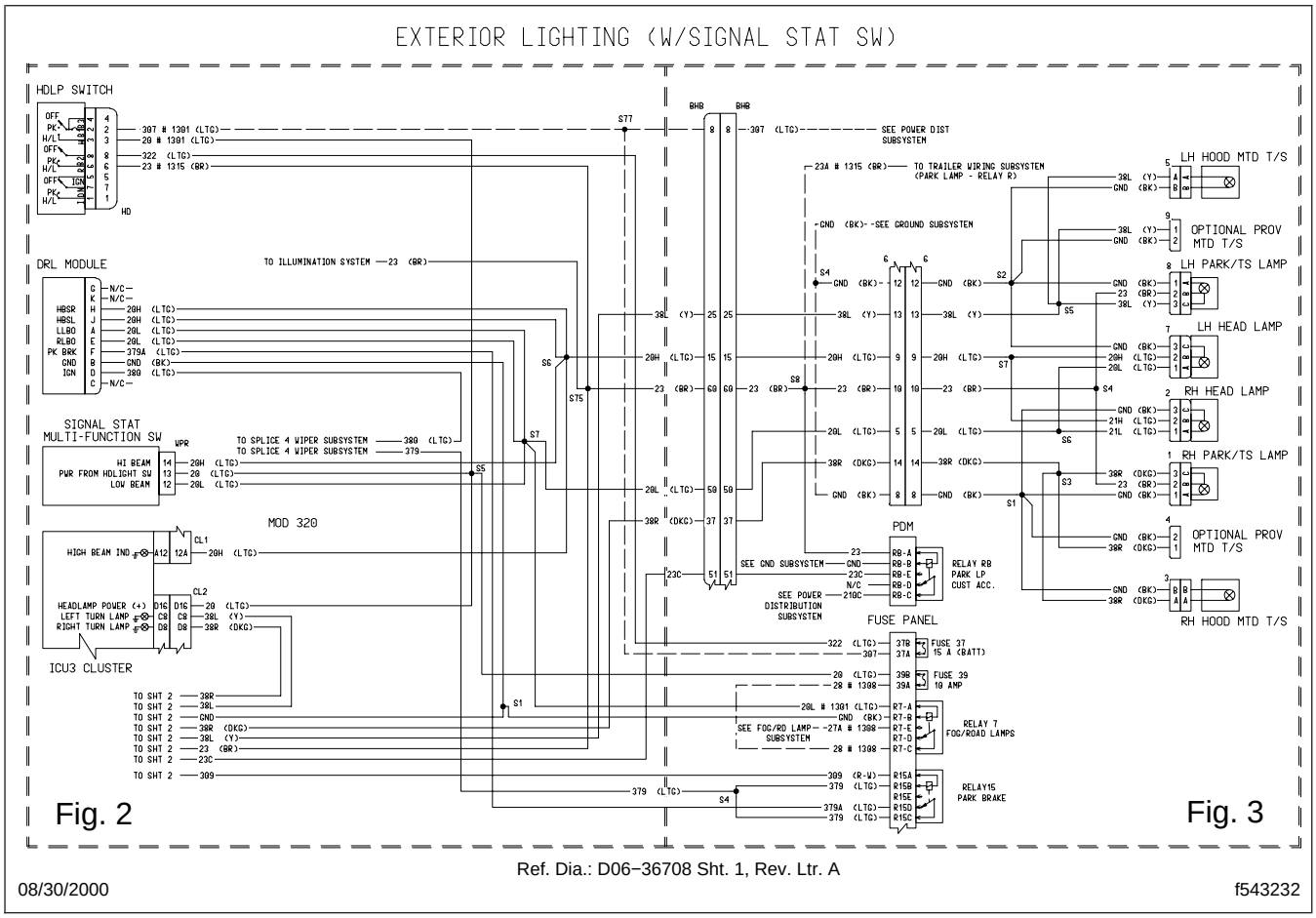
See **Fig. 15** and **Fig. 16** for partial views of the illumination summary wiring.

See **Fig. 17** for a full view of Sheet 1 for exterior lighting with United Technologies switch wiring.

See **Fig. 18** and **Fig. 19** for partial views of Sheet 1.

See **Fig. 20** for a full view of Sheet 2 for exterior lighting with United Technologies switch wiring.

See **Fig. 21** and **Fig. 22** for partial views of Sheet 2.



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Fig. 1, Exterior Lighting With Signal-Stat Switch Wiring, Sheet 1 (full view)

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Specifications

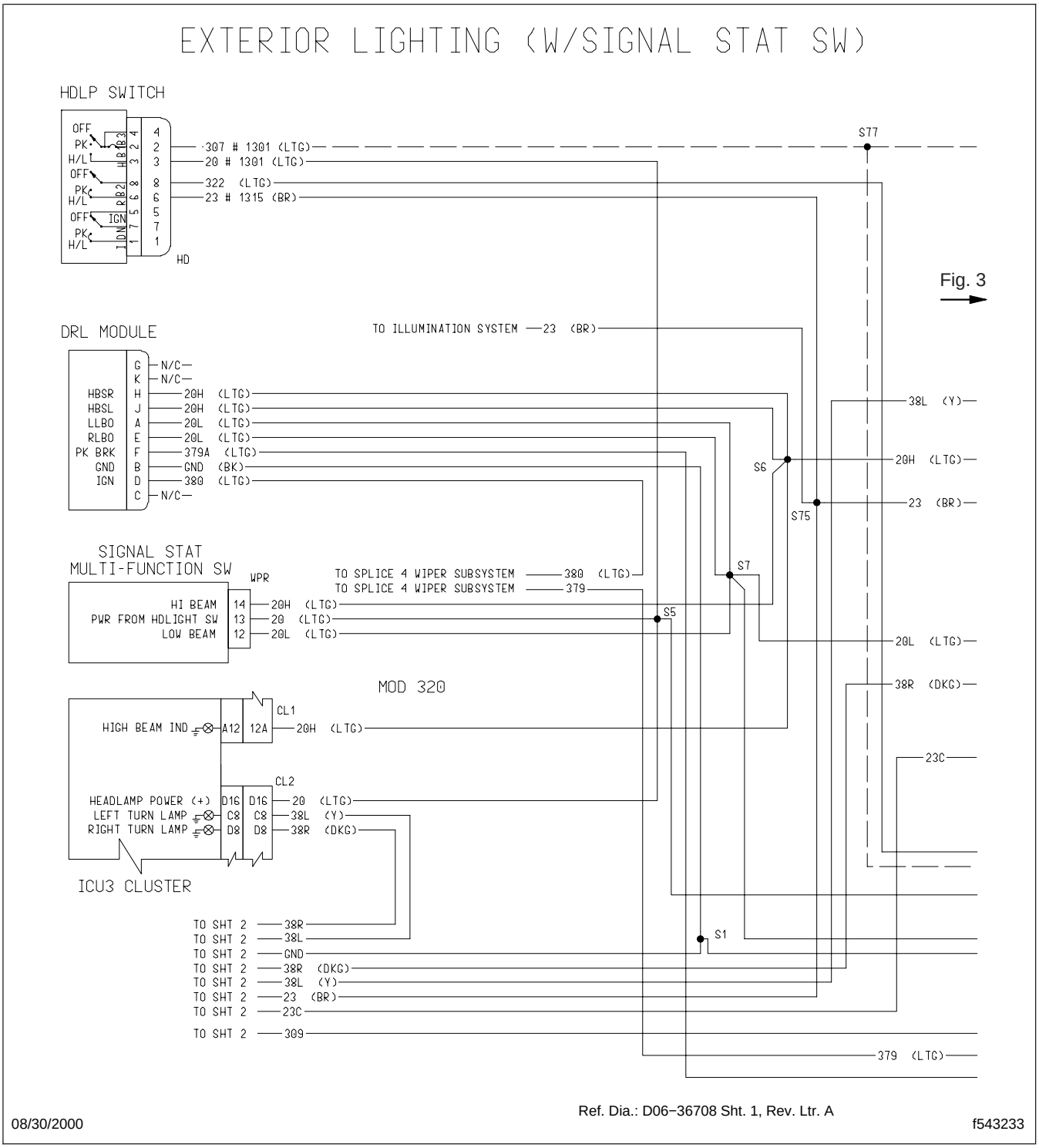


Fig. 2, Exterior Lighting With Signal-Stat Switch Wiring, Sheet 1 (partial view)

https://truckmanualshub.com/

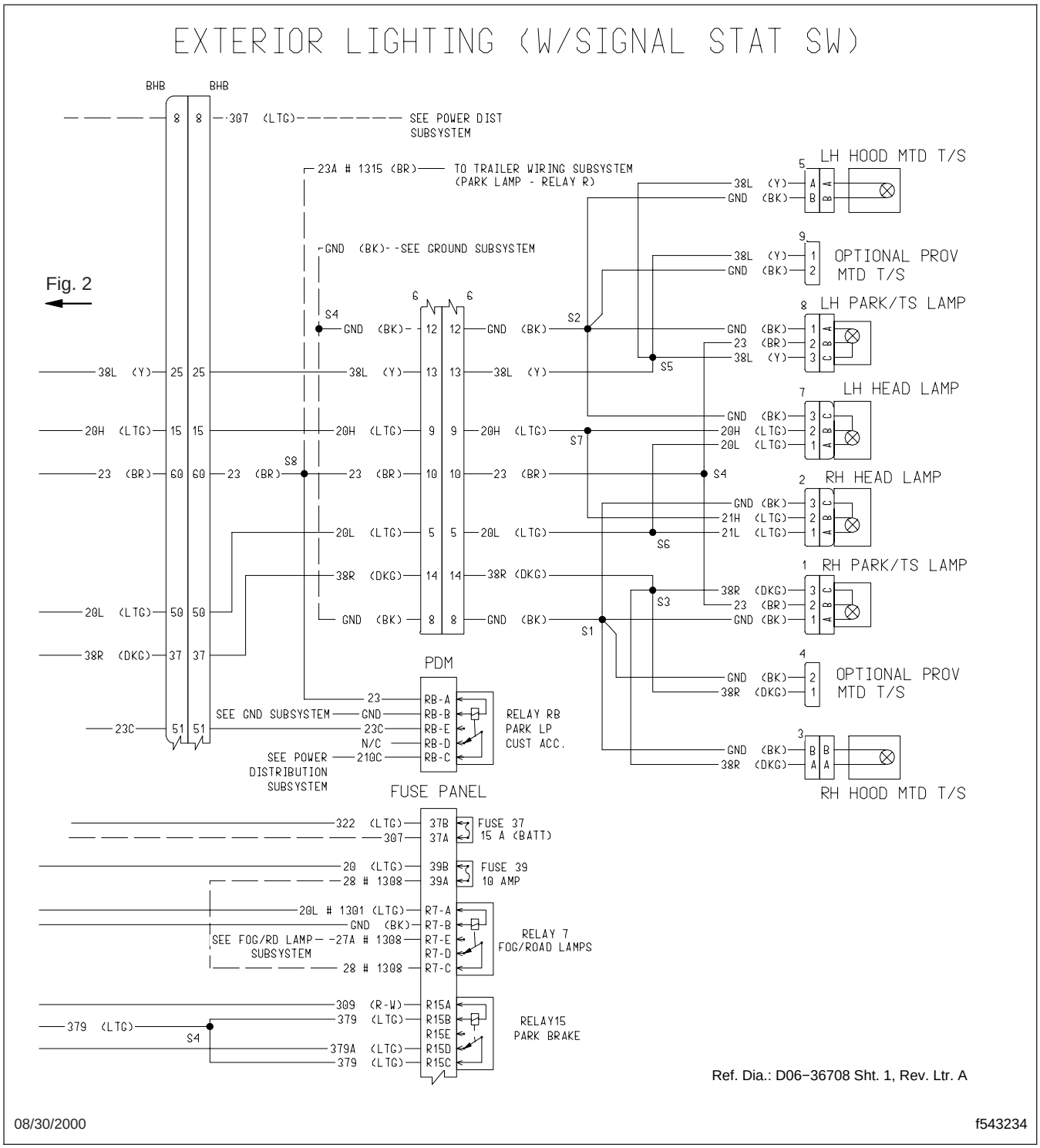


Fig. 3, Exterior Lighting With Signal-Stat Switch Wiring, Sheet 1 (partial view)

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Specifications

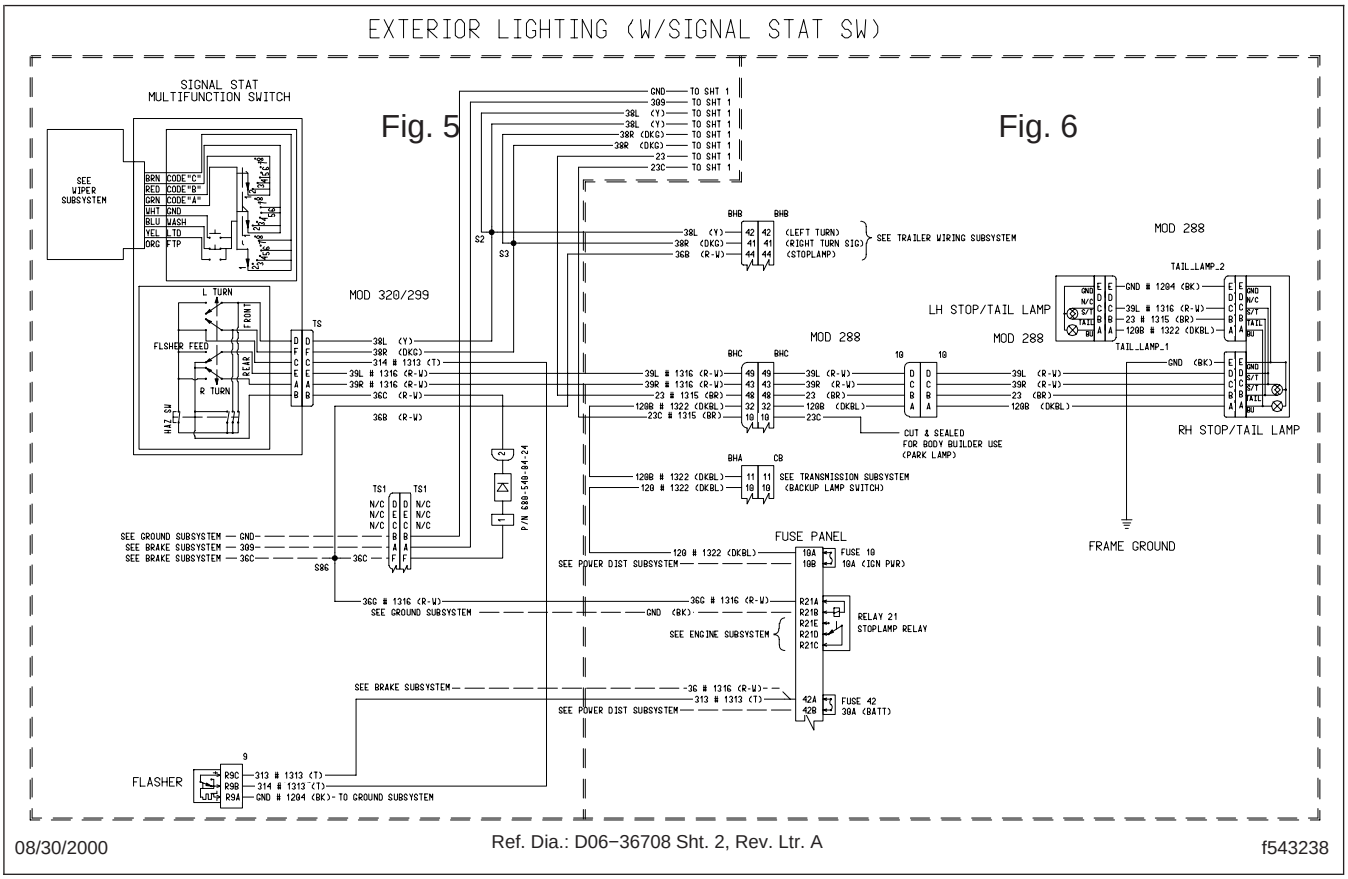


Fig. 4, Exterior Lighting With Signal-Stat Switch Wiring, Sheet 2 (full view)

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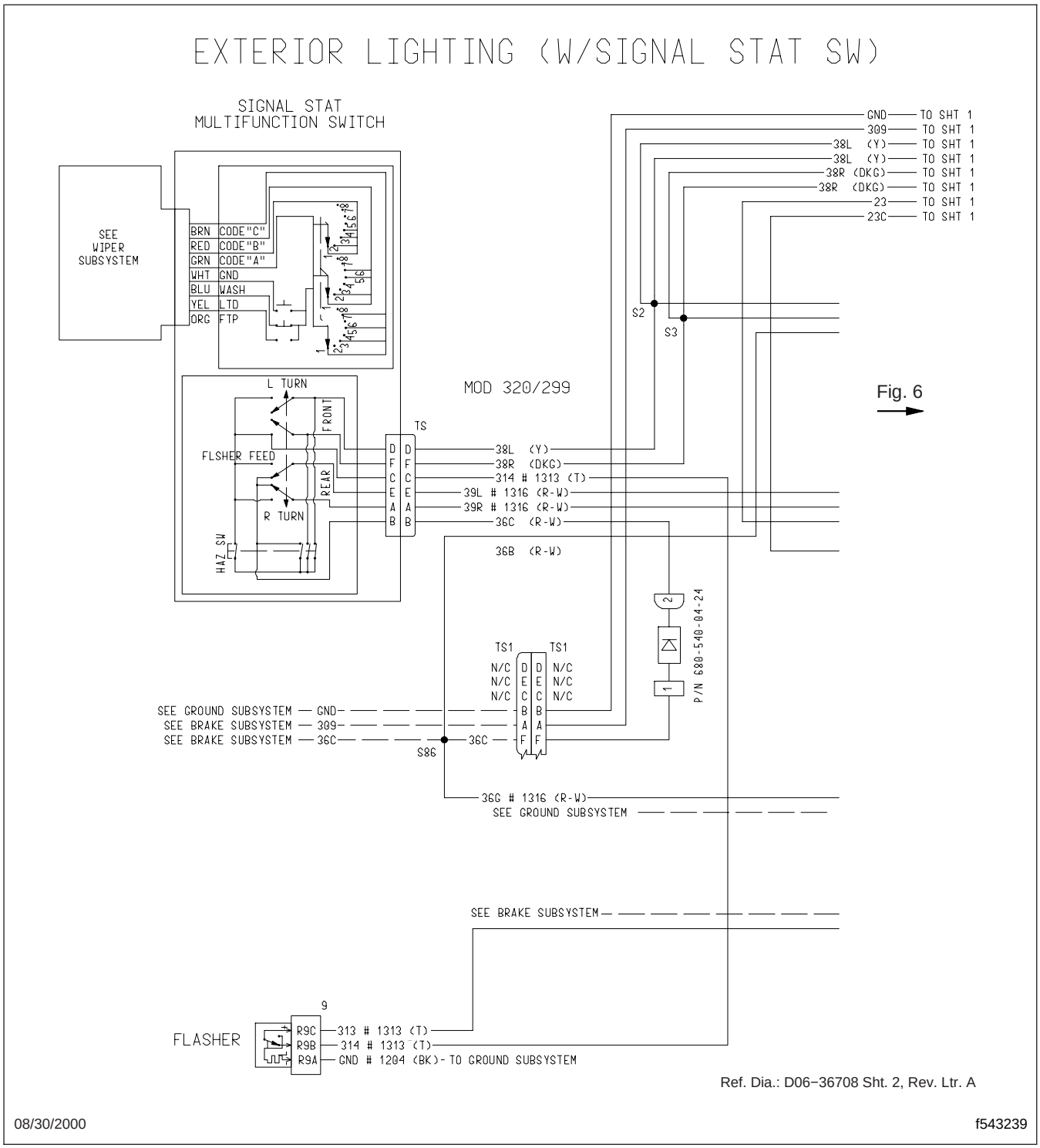


Fig. 5, Exterior Lighting With Signal-Stat Switch Wiring, Sheet 2 (partial view)

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Specifications

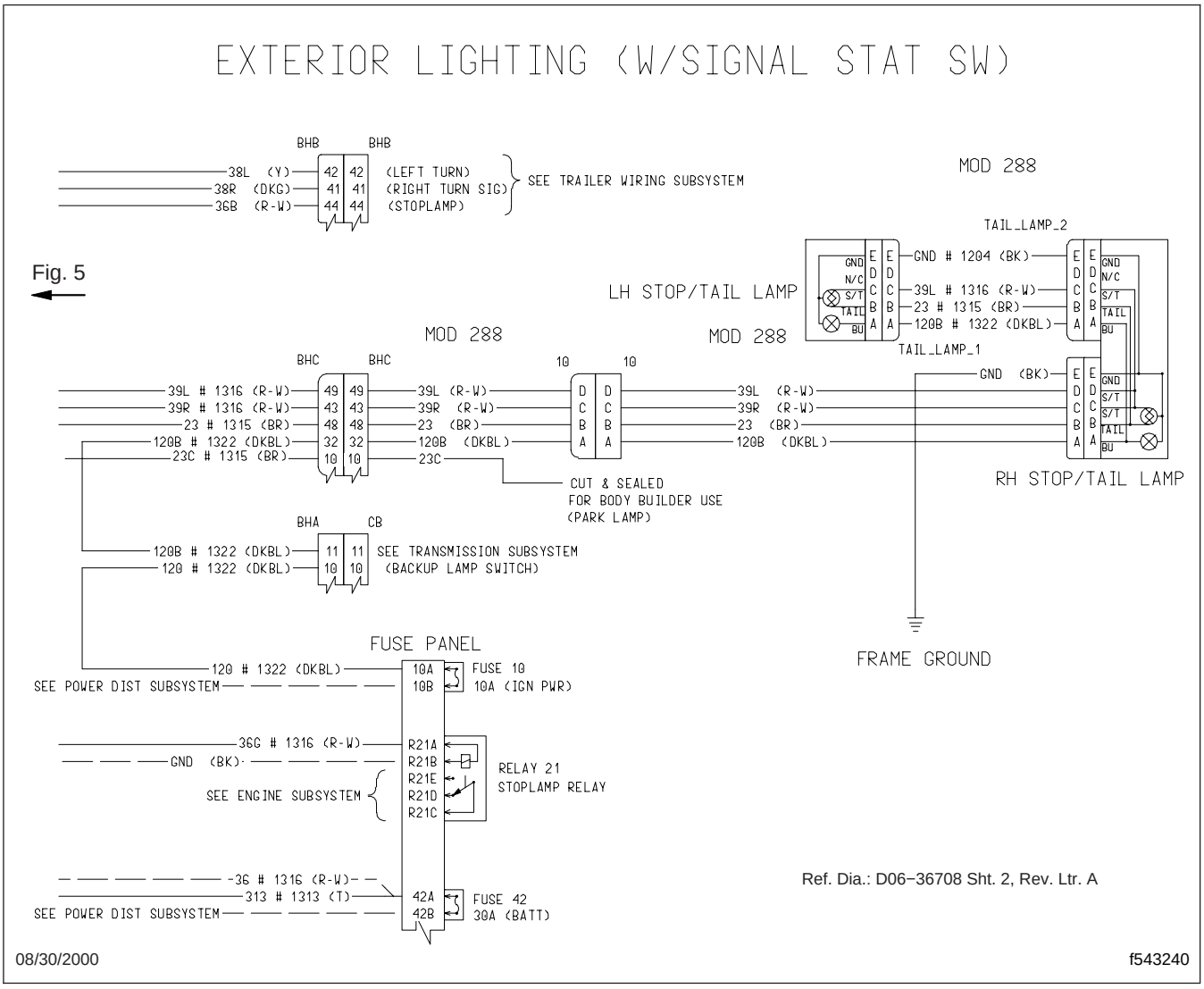
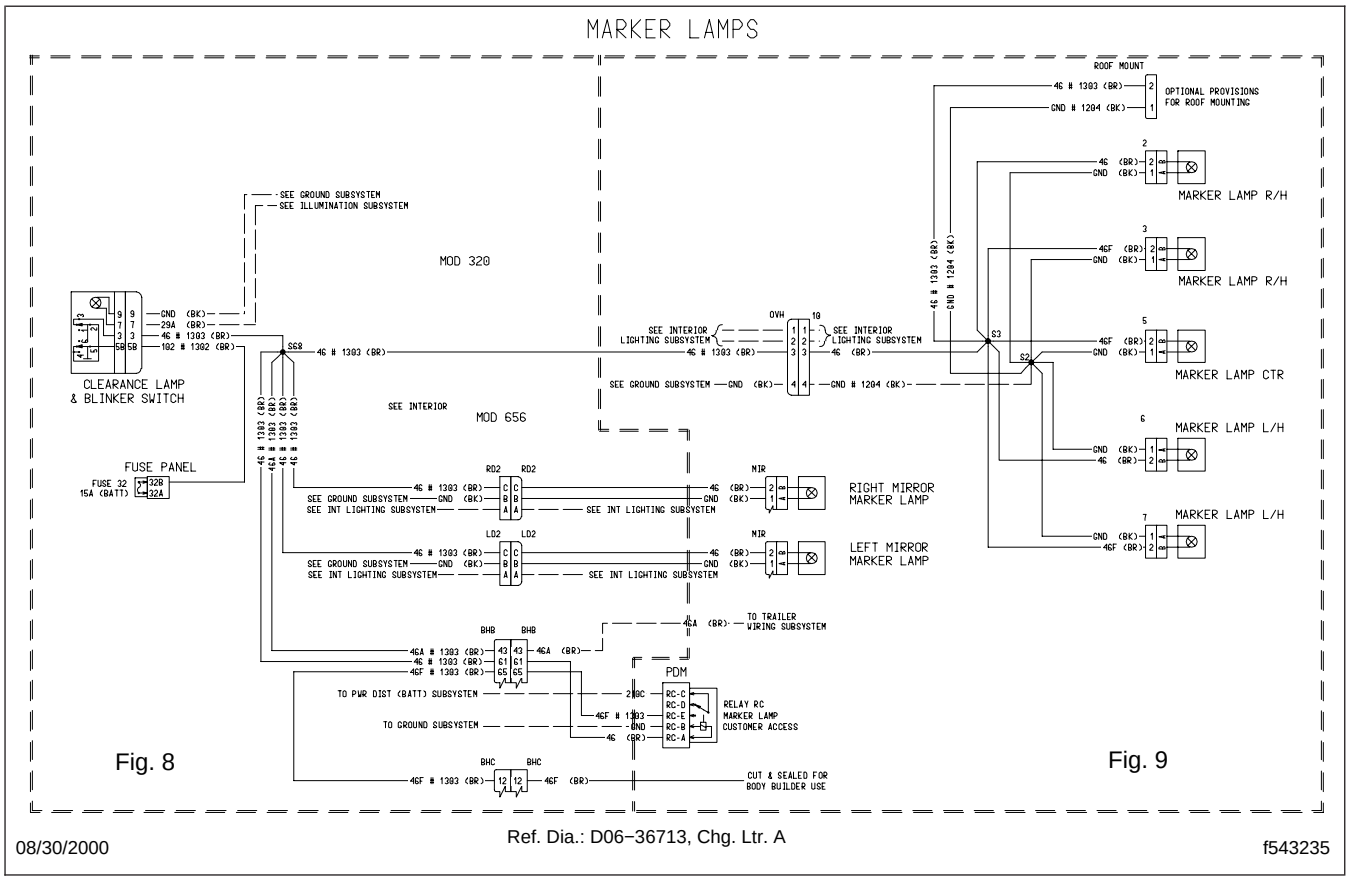


Fig. 6, Exterior Lighting With Signal-Stat Switch Wiring, Sheet 2 (partial view)

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Fig. 7, Marker Lamps Wiring (full view)

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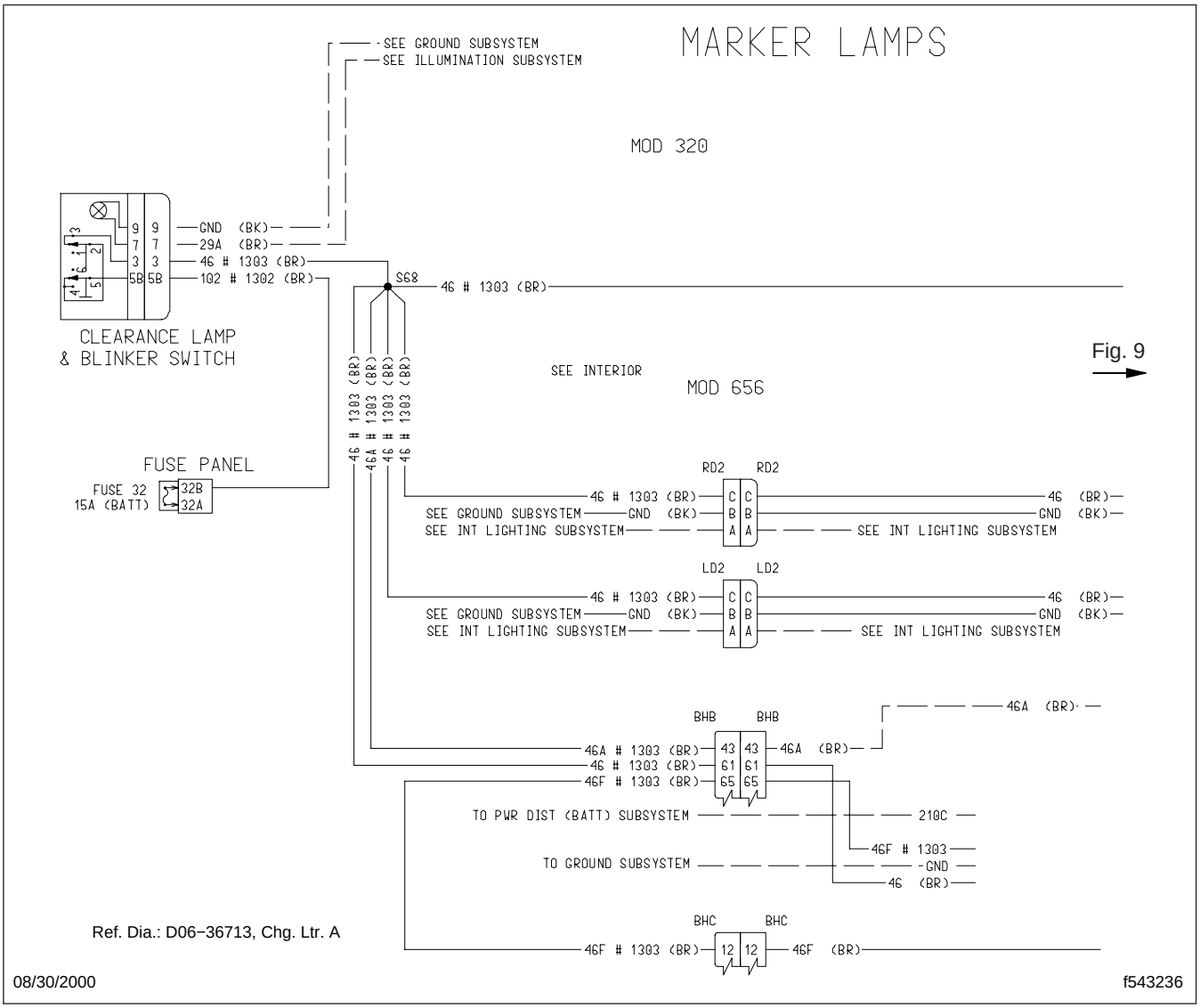


Fig. 8, Marker Lamps Wiring (partial view)

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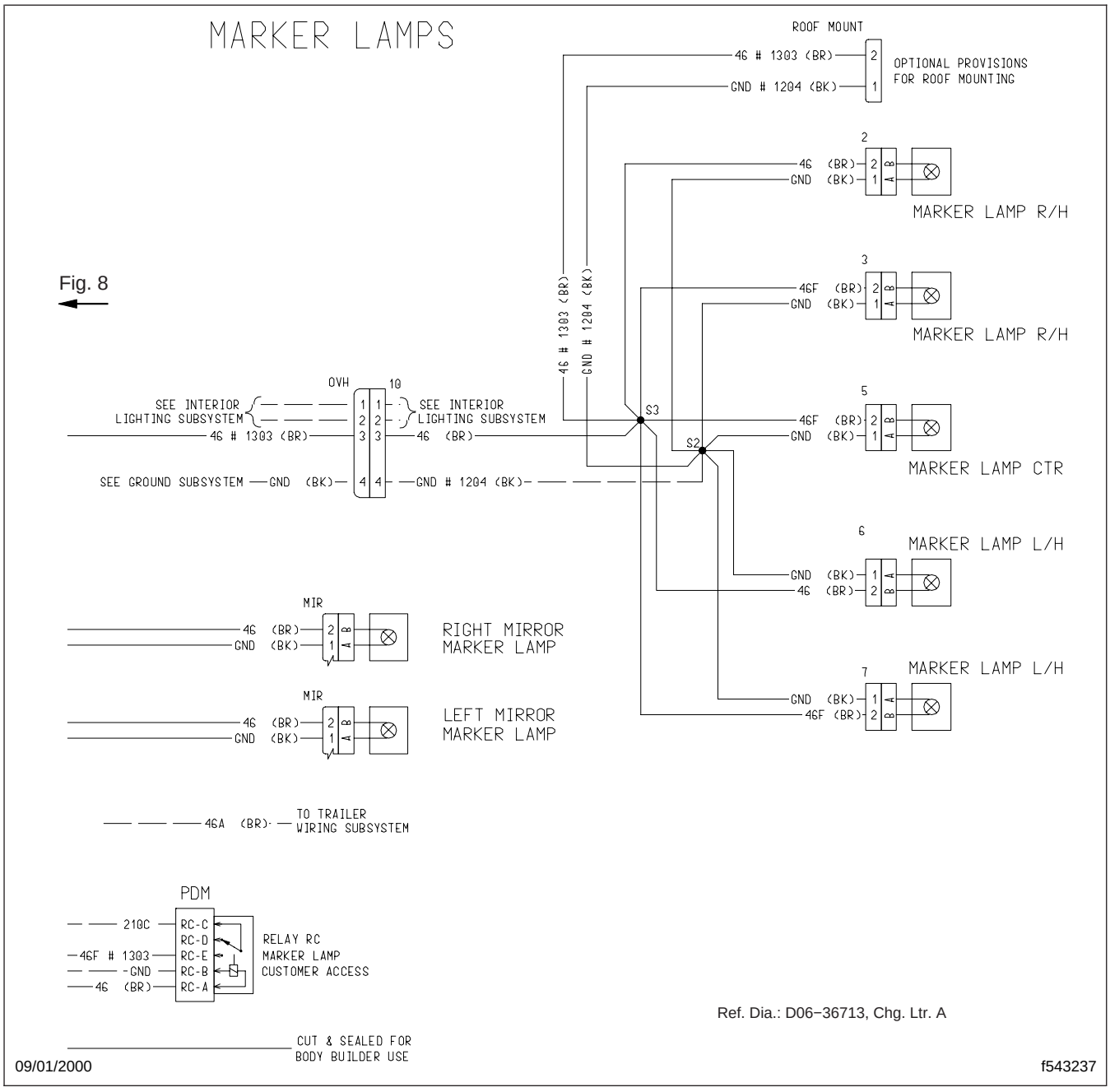


Fig. 8

Fig. 9, Marker Lamps Wiring (partial view)

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Specifications

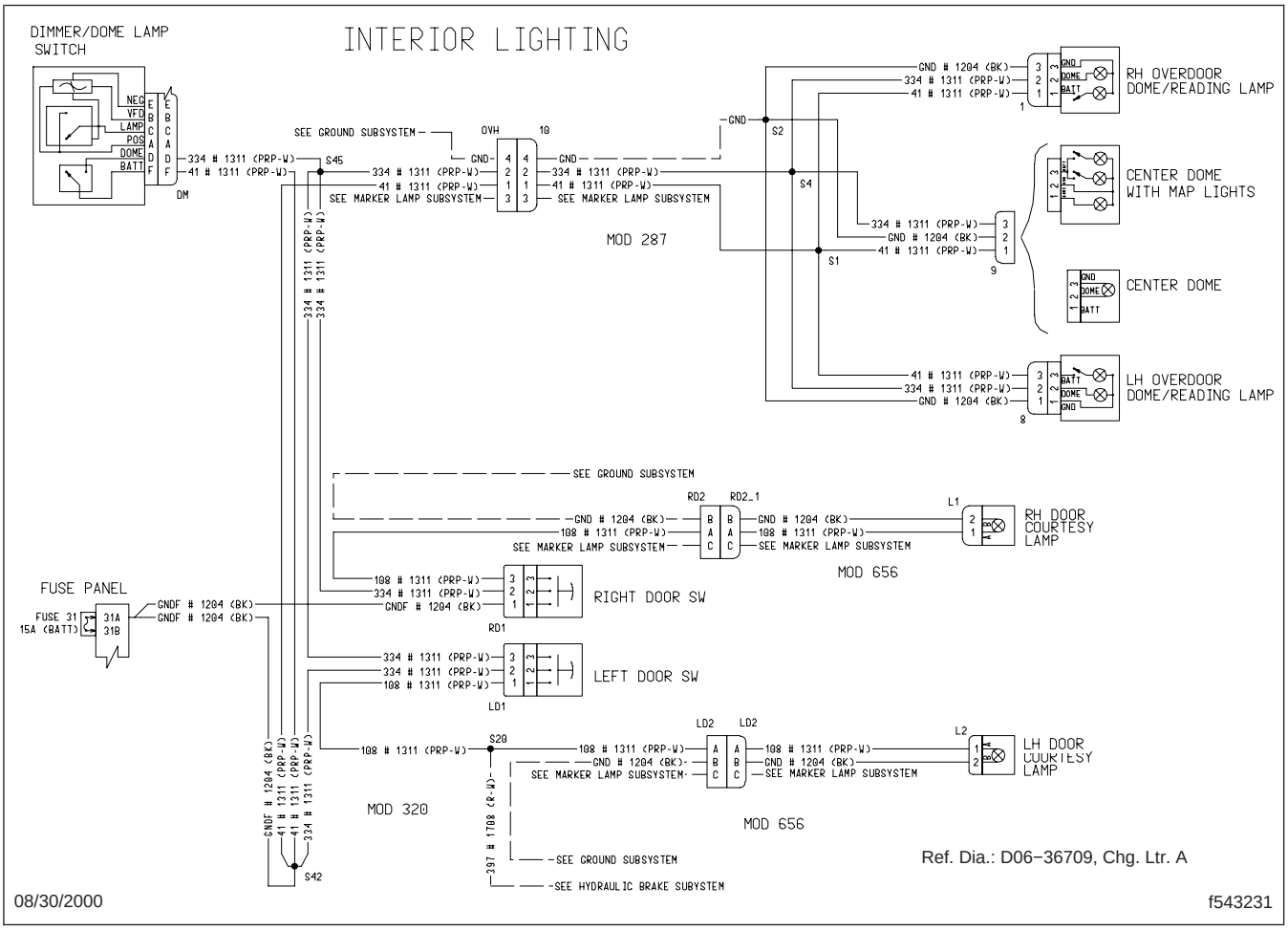


Fig. 10, Interior Lighting Wiring (full view)

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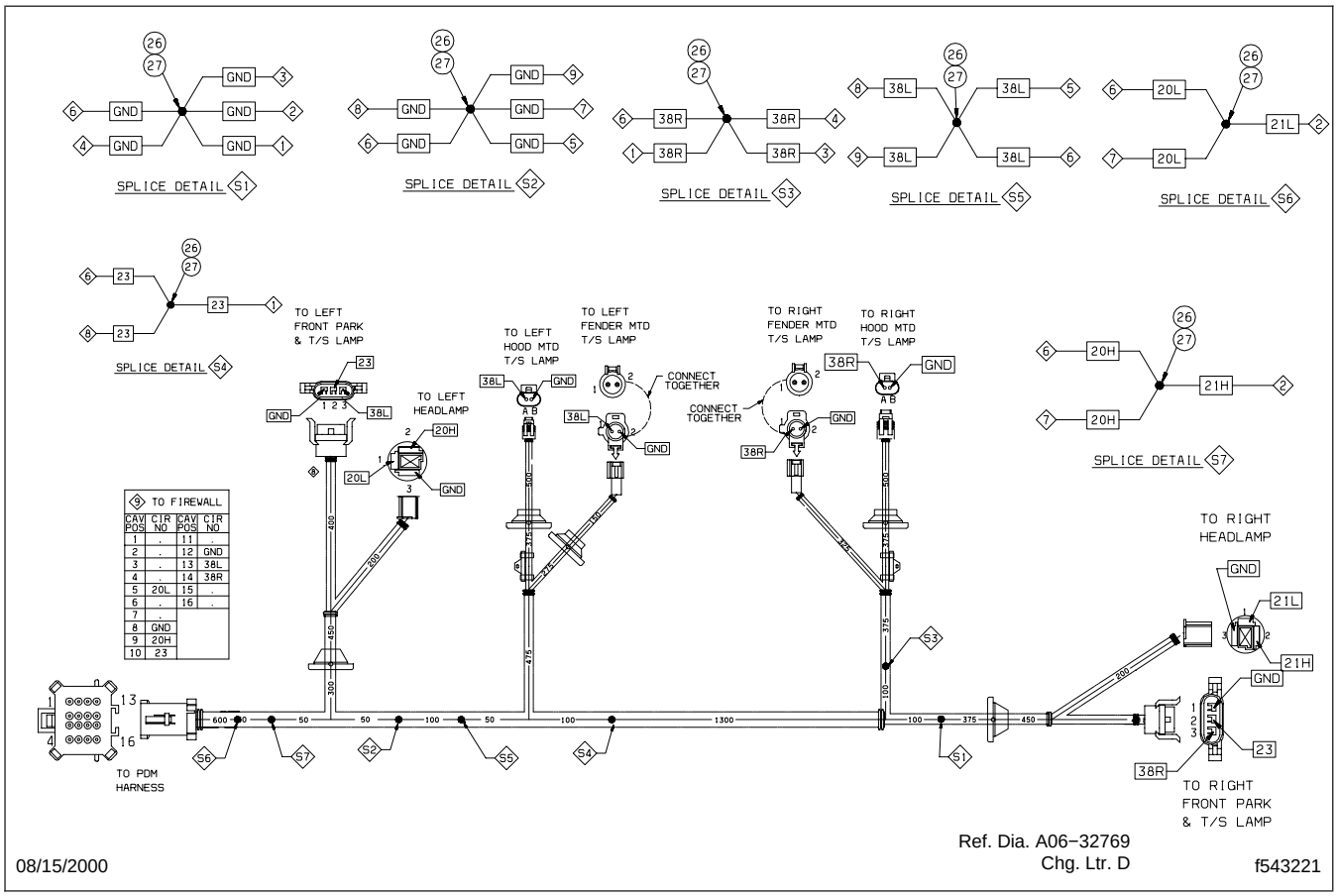


Fig. 11, Hood Wiring Harness (full view)

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Specifications

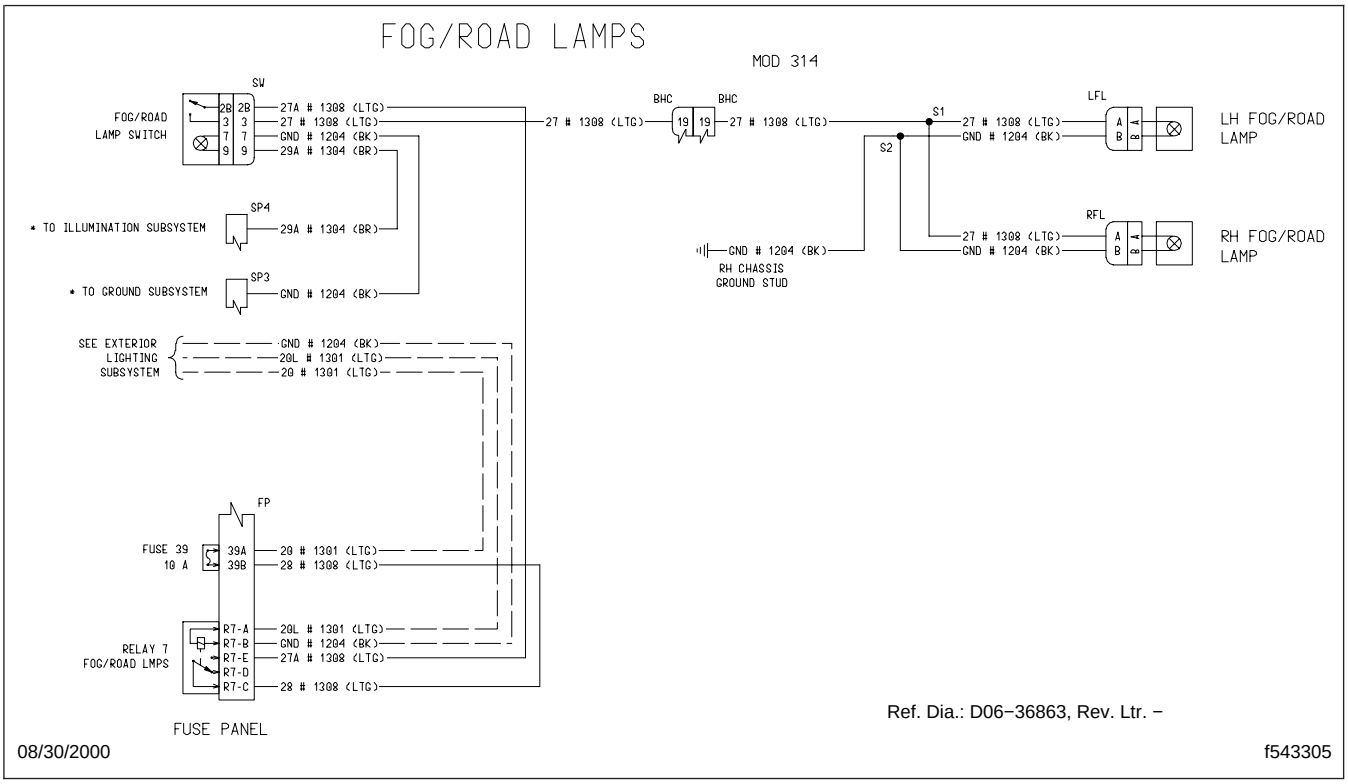


Fig. 12, Fog/Road Lights Wiring (full view)

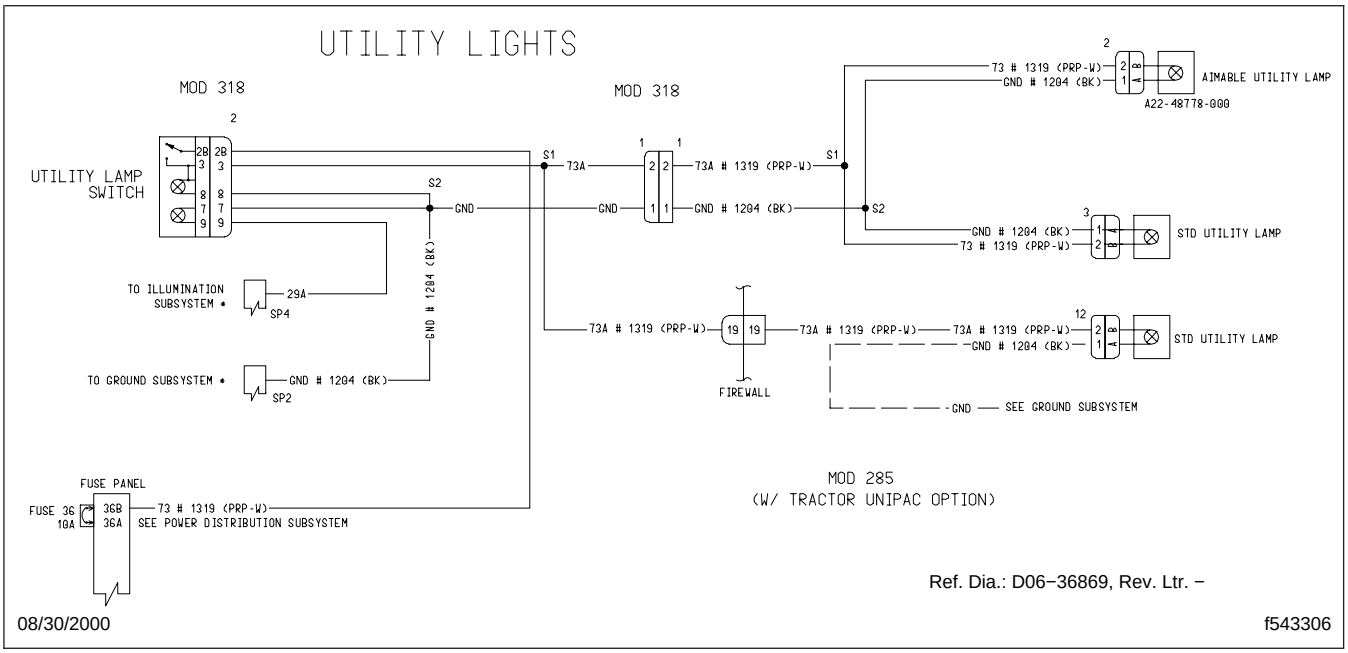


Fig. 13, Utility Lights Wiring (full view)

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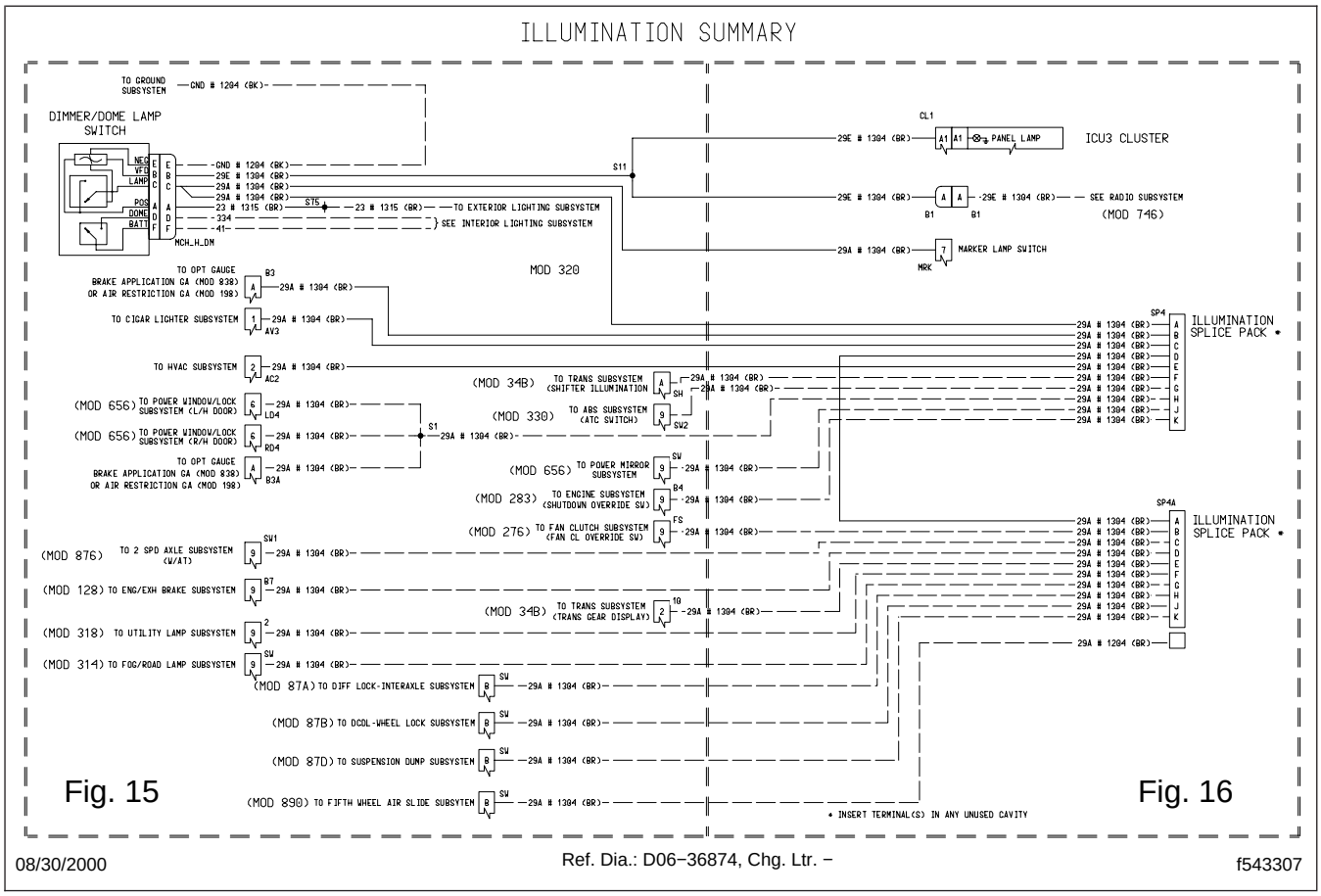


Fig. 14, Illumination Summary Wiring (full view)

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Specifications

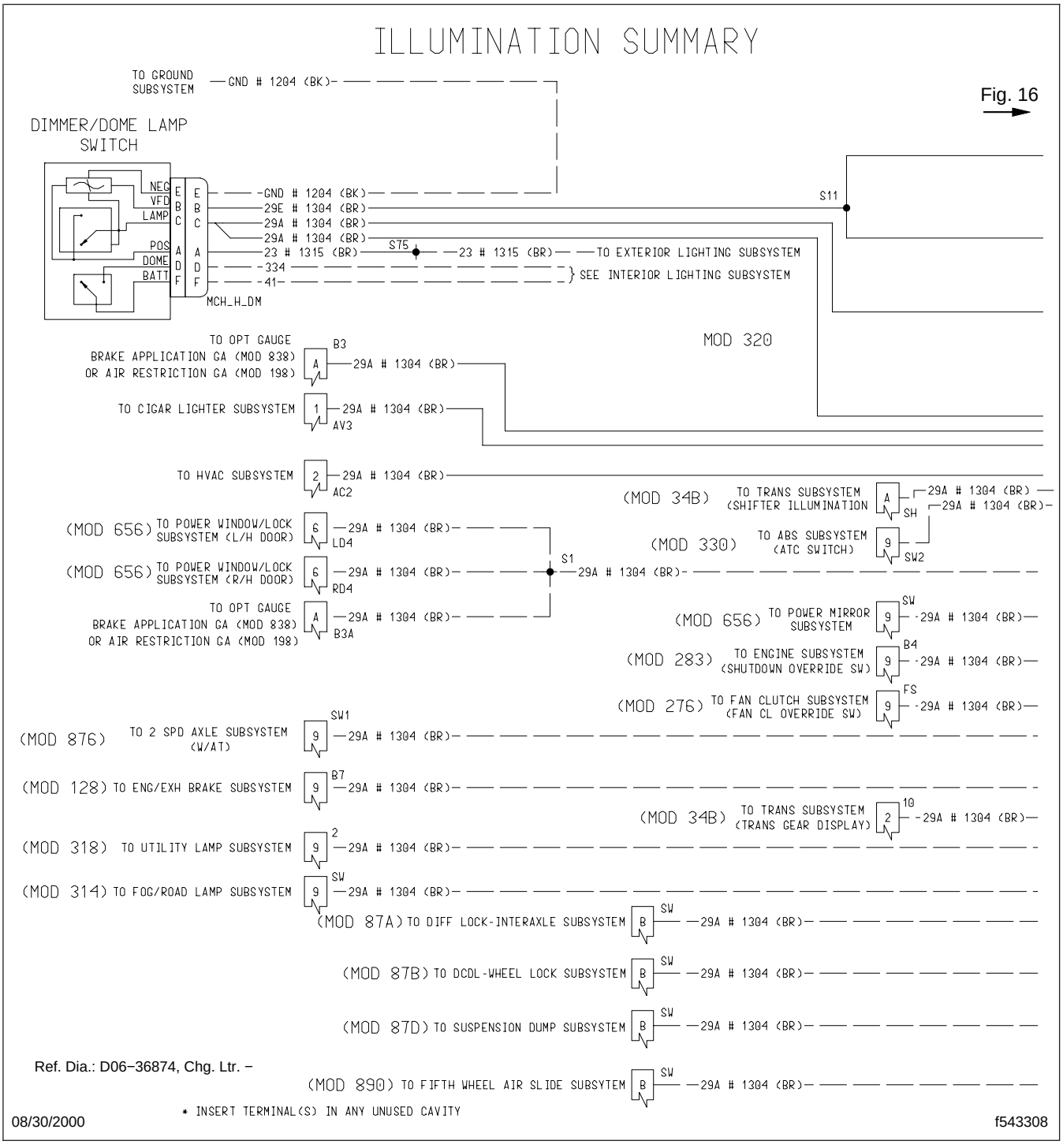


Fig. 15, Illumination Summary Wiring (partial view)

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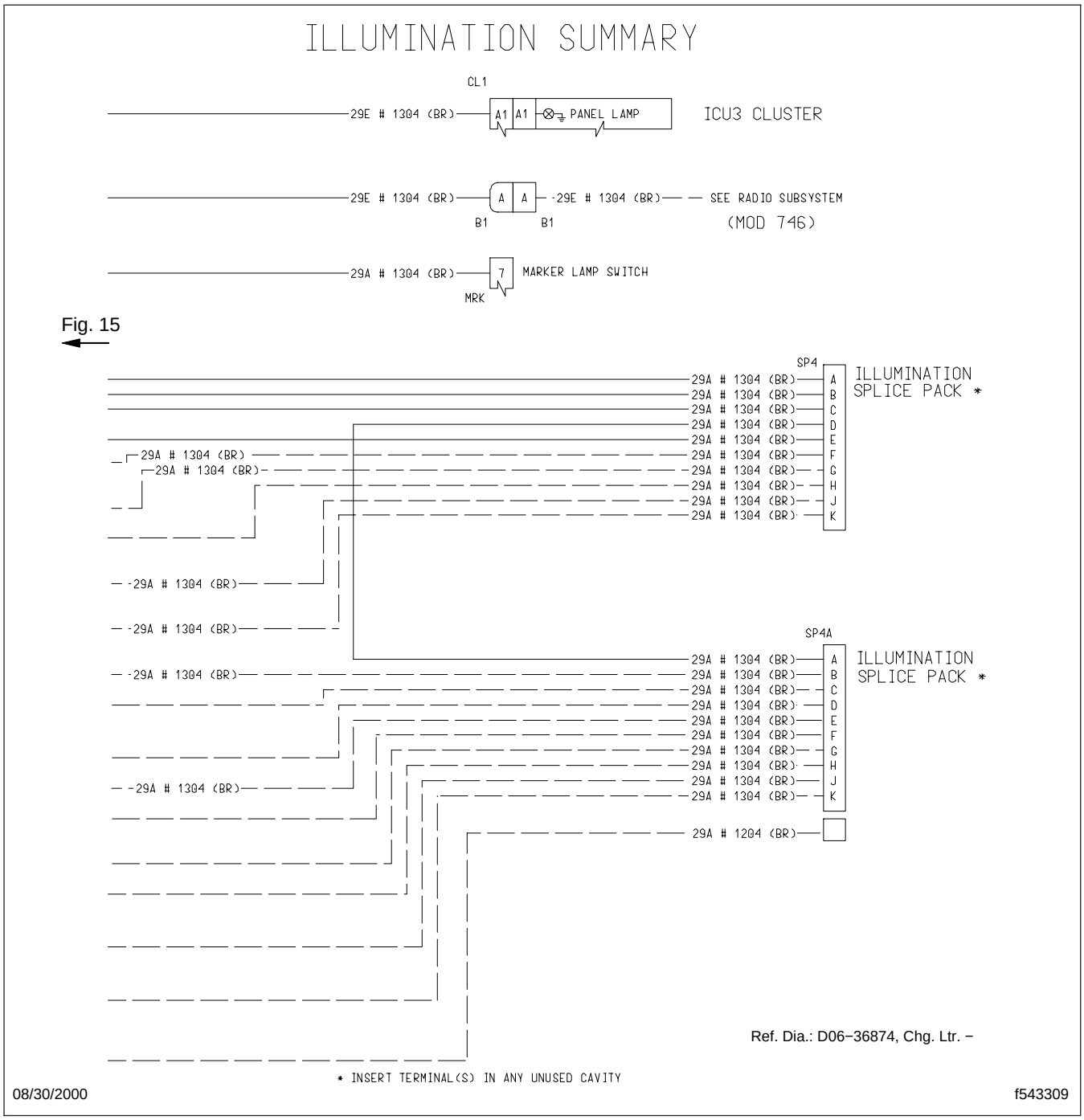
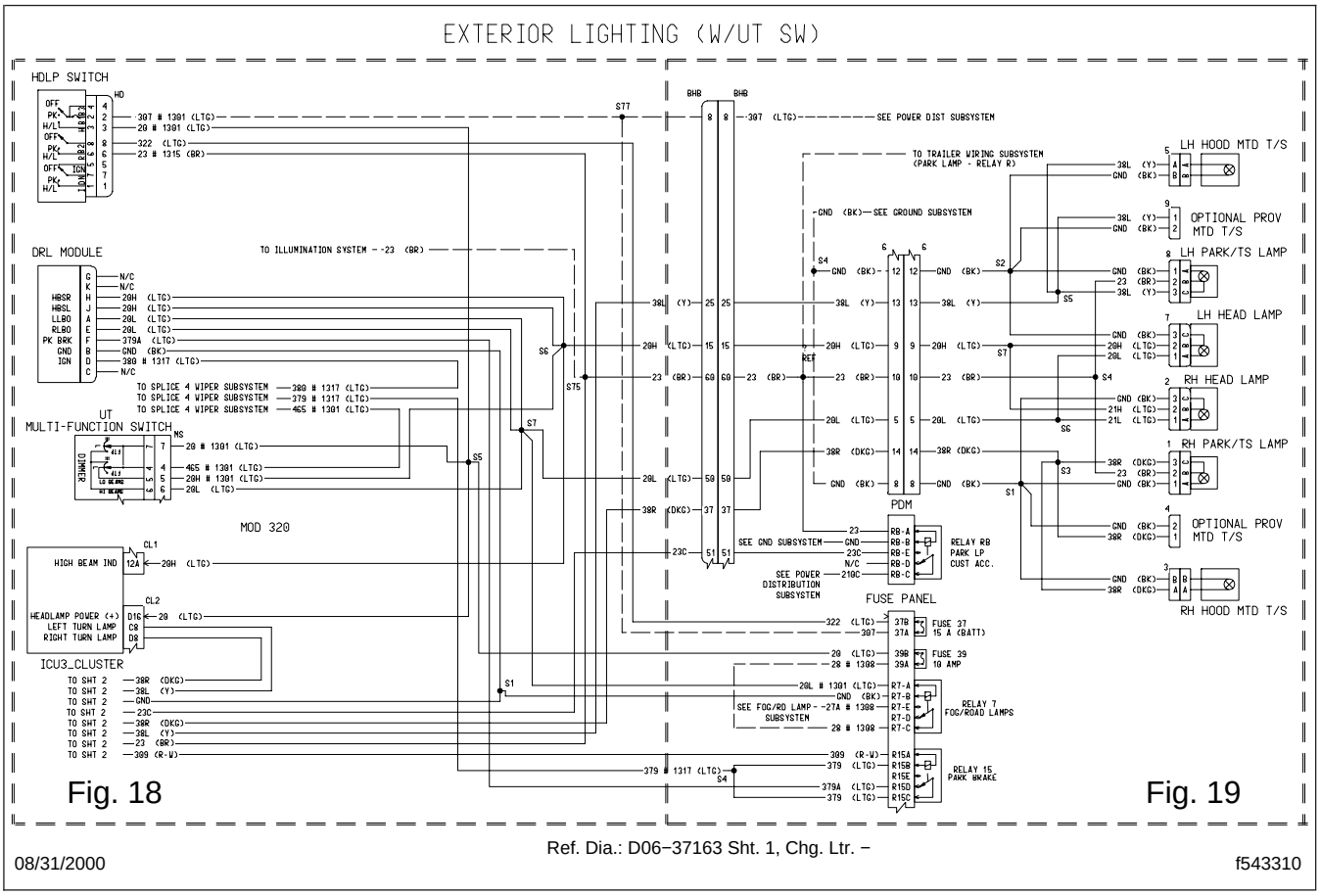


Fig. 16, Illumination Summary Wiring (partial view)

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Specifications



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Fig. 17, Exterior Lighting With United Technologies Switch Wiring, Sheet 1 (full view)

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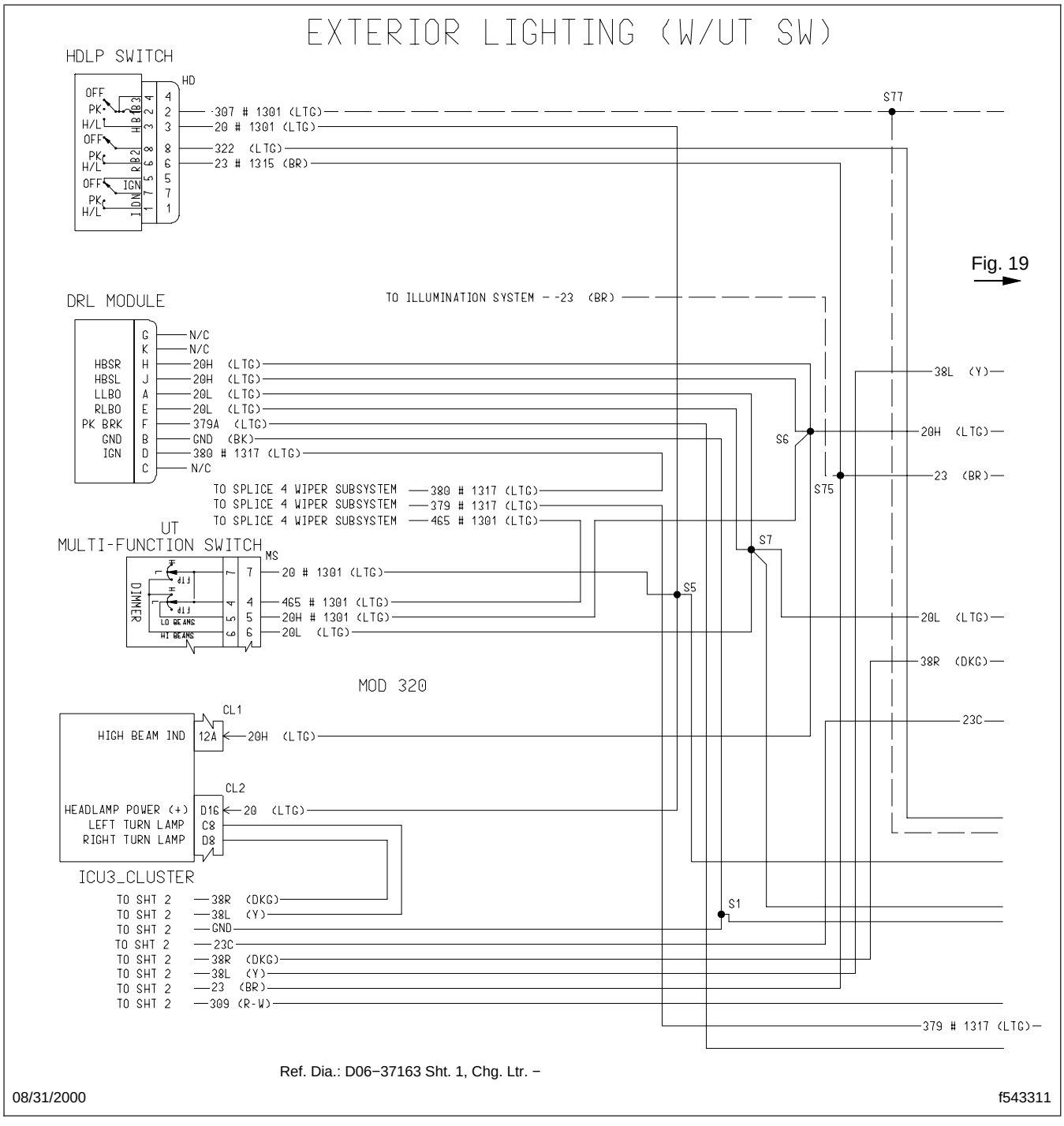


Fig. 18, Exterior Lighting With United Technologies Switch Wiring, Sheet 1 (partial view)

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Specifications

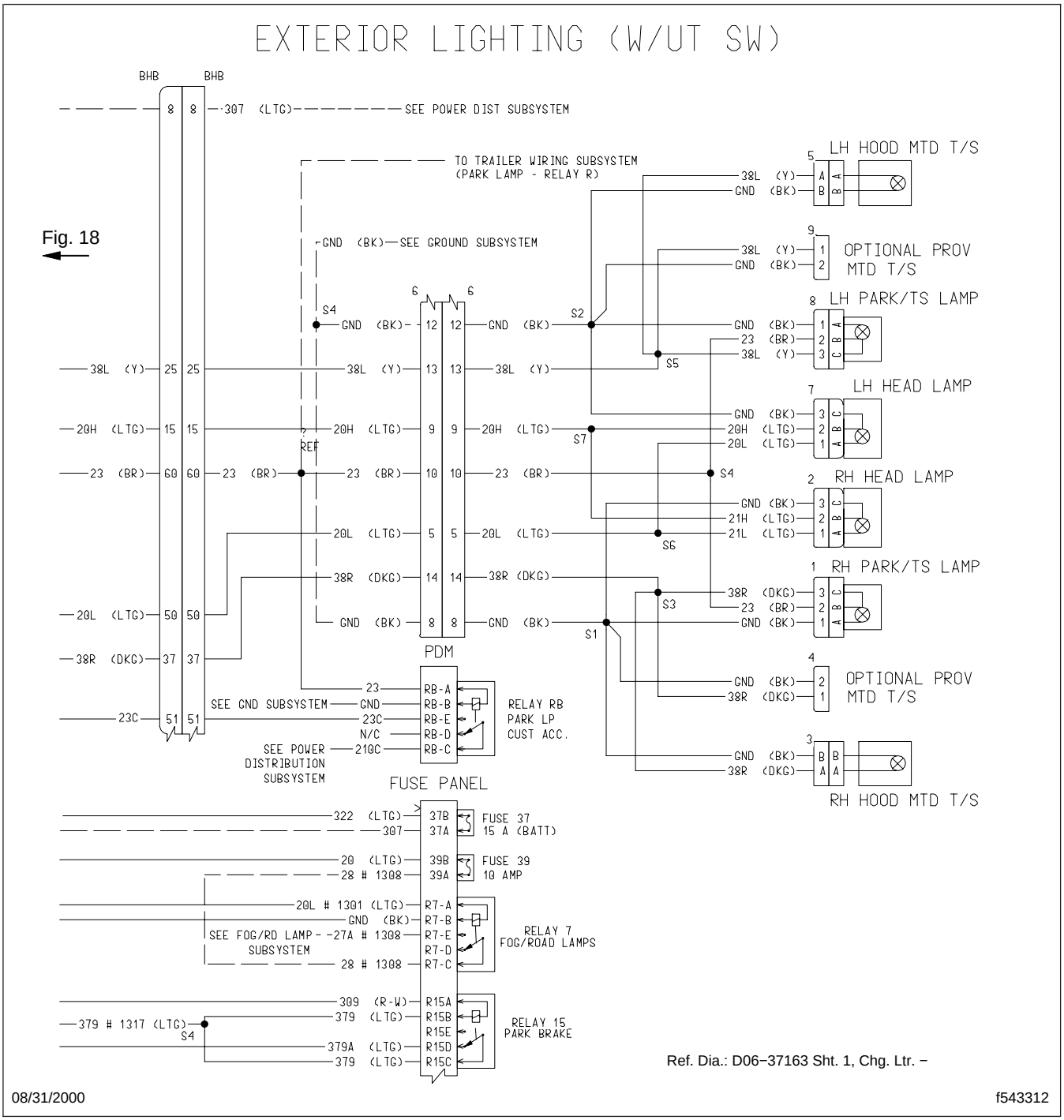


Fig. 19, Exterior Lighting With United Technologies Switch Wiring, Sheet 1 (partial view)

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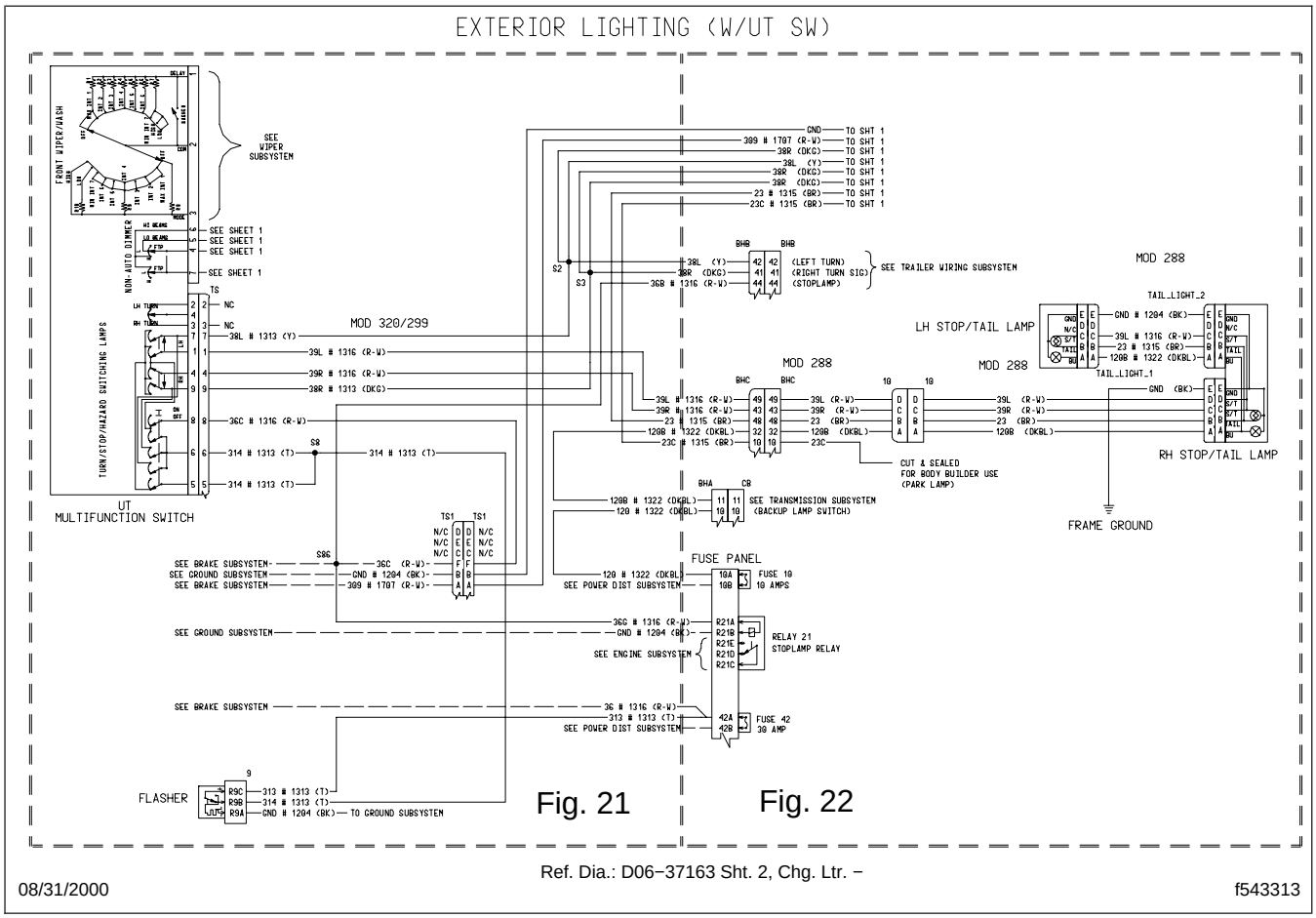


Fig. 20, Exterior Lighting With United Technologies Switch Wiring, Sheet 2 (full view)

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Specifications

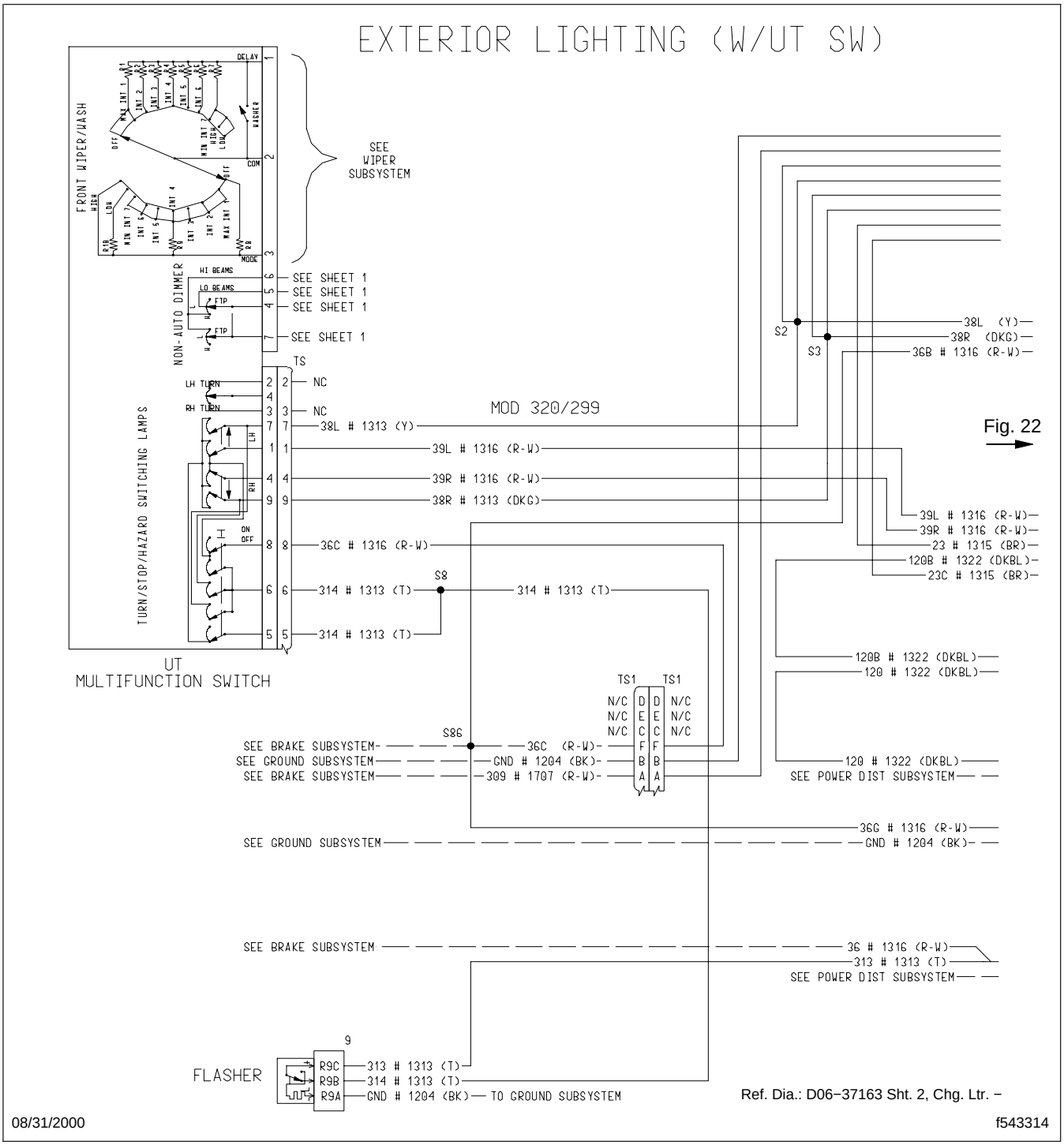


Fig. 21, Exterior Lighting With United Technologies Switch Wiring, Sheet 2 (partial view)

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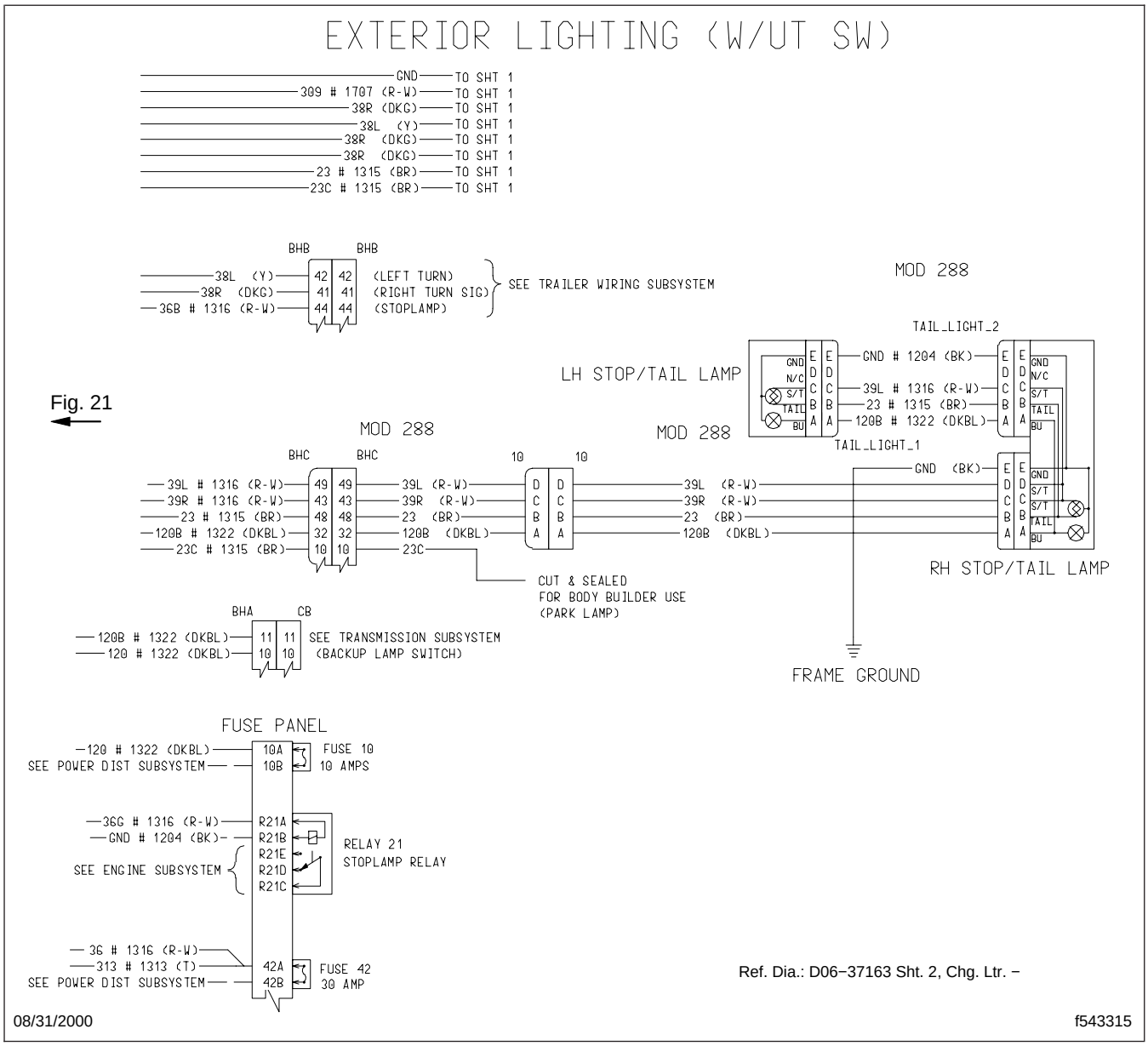


Fig. 21

Fig. 22, Exterior Lighting With United Technologies Switch Wiring, Sheet 2 (partial view)

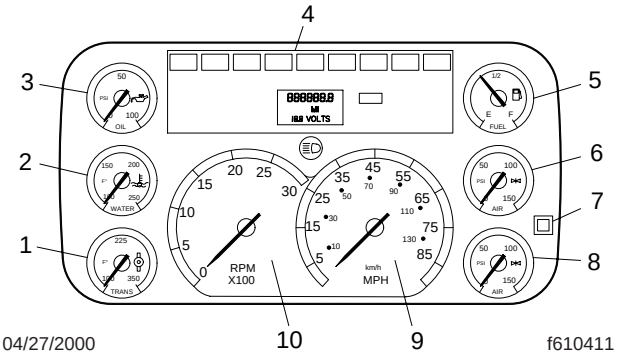
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General Information

INSTRUMENTATION CONTROL UNIT (ICU3)

The instrumentation control unit (ICU3) is a basic electronic dashboard that accepts input from the fuel level sensor, the transmission temperature sensor (if installed), and the J1587 datalink. The information is processed by a micro-computer and displayed on electronic gauges driven by stepper motors. Air gauges operate mechanically.

The speedometer and tachometer are large-faced electronic gauges located below the dash message center. See **Fig. 1**.



1. Transmission Fluid Temperature Gauge
2. Coolant Temperature Gauge
3. Engine Oil Pressure Gauge
4. Dash Message Center
5. Fuel Level Gauge
6. Primary Air Pressure Gauge
7. Optional Mode/Reset Push Button
8. Secondary Air Pressure Gauge
9. Speedometer
10. Tachometer

Fig. 1, ICU3 Gauge Layout (typical)

The other gauges are small-faced and located to either side of the speedometer and tachometer. The engine oil pressure, coolant temperature, transmission fluid temperature and fuel level gauges are electronic; the air pressure gauges are mechanical. The ICU3 can not drive gauges located on the auxiliary instrument panel.

A transmission fluid temperature gauge is required on vehicles with automatic transmissions.

The following items are replaceable:

- air pressure gauges
- light bulbs
- lens/mask assembly
- mode/reset button
- top row warning and indicator lenses
- back cover

Dash Message Center

The dash message center has two parts: a dash driver display screen and a set of 26 warning and indicator lights similar to those found on a conventional lightbar.

DASH DRIVER DISPLAY

The dash driver display screen is a 1-line by 7-character liquid crystal display (LCD) that is normally used to display the odometer reading. In addition, there is a separate voltmeter display underneath the odometer display.

The information that can be provided by the message center includes:

- Odometer readings;
- Trip miles;
- Trip engine hours;
- A listing of active faults.

With the optional Mode/Reset button, you can switch the odometer to display either miles or kilometers, invoke the trip odometer and trip engine hours, and call up diagnostic messages (active faults).

ODOMETER

The odometer is set to display in either miles or kilometers, depending on the primary scale of the speedometer. The legend, either "MI" or "KM," illuminates between the odometer and the volts display when the engine is running or the headlights are turned on.

The odometer is a seven-digit display with a decimal point, until the vehicle has traveled 999,999.9 miles or kilometers (km). At one million miles (km), the odometer rolls over to "1000000," without the decimal point, and can continue up to 9,999,999. The odometer only displays significant figures (no leading zeros).

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General Information

IMPORTANT: The odometer uses data supplied by the engine ECU to update its count. However, it keeps its own mileage (starting at zero) from when it was first installed. The ICU3 odometer will not match the engine ECU odometer if the engine has been operated with the ICU3 disconnected, during factory break-in or engine service, or if the ICU3 has been replaced.

WARNING AND INDICATOR LIGHTS

There are spaces on the dash message center for 26 warning and indicator lights. See **Fig. 2** for a typical installation.

There are four rows of lights. The lights in the top row are all optional and may be installed in any order, except for STOP ENGINE (Cummins engines only) and WHEEL SPIN that are typically installed at a fixed position:

NOTE: Positions 1 through 8 are ground-activated circuits. Position 2 can be activated with the ignition switch in the OFF position. Position 9 is power-activated.

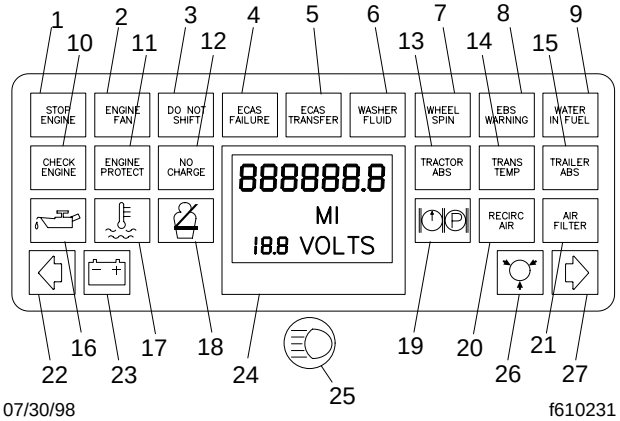
On the other three rows, the lights are installed at fixed positions. Some lights are optional; if an optional light is not requested, the position is blank (does not light up).

All light bulbs are replaceable in the field, including gauge light bulbs and warning/indicator light bulbs.

Buzzer

The buzzer sounds during the ignition sequence and whenever:

- The engine oil pressure falls below the preset level, which is 5 to 9 psi (35 to 60 kPa) on most engines;
- The coolant temperature rises above the preset level, which is 215°F (101°C) on Caterpillar™ engines, 220°F (104°C) on Cummins engines and 189°F (87°C) on MBE900 engines;
- The air pressure falls below the preset level of approximately 70 psi (483 kPa);
- The parking brake is set with the vehicle moving at a speed greater than 2 miles per hour (3 km/h).



1. Stop Engine Warning (Cummins engines only)
2. Engine Fan On Indicator (optional)
3. Do Not Shift Indicator (optional)
4. ECAS Failure Warning (optional)
5. ECAS Transfer Indicator (optional)
6. Low Washer Fluid Indicator (optional)
7. Wheel Spin Indicator (optional)
8. EBS Warning (optional)
9. Water In Fuel Indicator (optional)
10. Check Engine Indicator
11. Engine Protection Warning
12. Alternator No Charge Indicator (optional)
13. Tractor ABS Warning
14. Transmission Temperature Warning (optional)
15. Trailer ABS Warning (optional)
16. Low Engine Oil Pressure Warning
17. High Coolant Temperature Warning
18. Fasten Seat Belt Warning
19. Parking Brake On Warning
20. Recirculated Air Indicator
21. Air Restriction Indicator (optional)
22. Left Turn Signal
23. Low Battery Voltage Warning
24. Dash Driver Display Screen
25. High Beams On Indicator
26. Low Air Pressure Warning
27. Right Turn Signal

Fig. 2, ICU3 Dash Message Center

IGNITION SEQUENCE

NOTE: If the headlights are turned on, the screen displays the odometer and waits for the ignition to be turned on.

When the ignition is turned on, the ICU3 performs a self-test, looking for active faults. All the electronic gauges complete a full sweep of their dials, the warning and indicator lights light up and the buzzer

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sounds for 3 seconds. During the first half of the self-test, all segments of the driver dash display screen illuminate as follows: "888888.8." During the second half of the self-test, the software revision level is displayed.

NOTE: The engine and ABS warning lights go on during the ICU3 self-test, but they are not controlled by the ICU3. They are controlled by their own system electronic control unit (ECU).

If the ICU3 receives active fault codes from other devices, the screen displays a three-letter acronym and message identifier (MID), indicating the ECU or system that is not functioning properly. For a list of MIDs, see **Specifications 400**. Each active fault is displayed for 3 seconds, one after the other, until the parking brake is released or the ignition is turned off. Once the parking brake is released, the screen displays the odometer. If there are no active faults, the screen displays the odometer.

NOTE: If the ICU3 receives a message from an ECU that has not been pre-programmed into the ICU3's memory, it displays "SYS ###", where ### is replaced by the MID of the broadcasting device.

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Replacement

CAUTION

Electronic components of the ICU3 are vulnerable to damage from static electricity. If available, wear a wrist grounding strap connected to a ground in the cab or workbench. If a grounding strap is not available, touch a grounded component immediately before doing any work which could bring a tool or body part in contact with ICU3 circuitry.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries.

WARNING

All air pressure must be relieved from the air reservoirs before disconnecting any pneumatic lines or hoses from the air system. Failure to relieve air pressure could cause the lines to whip, resulting in personal injury.

3. Drain the air system.
4. Remove the driver side finish panel. For instructions, see **Section 60.07**.
5. Remove the ICU3 mounting fasteners. See **Fig. 1**.

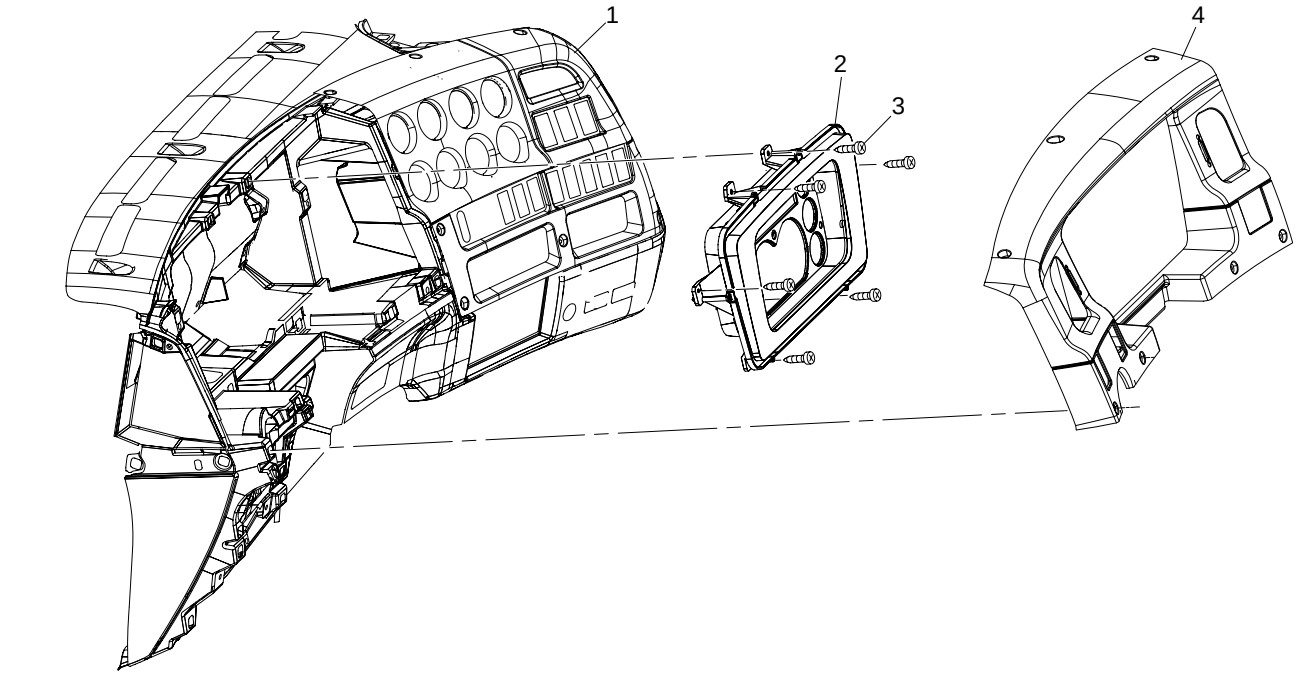
CAUTION

Do not forcibly pull the ICU3 from the dash. This may dislodge wires from the harness electrical connectors on the back of the ICU3 and damage the wires, the ICU3 or the dash.

6. Tilt the ICU3 away from the dash.
7. Disconnect the connectors from the back of the ICU3.
   - 7.1 Disconnect the two electrical connectors.
   - 7.2 Disconnect the air pressure lines from the brass fittings.
8. Remove the ICU3 from the vehicle.
9. Position the ICU3 on the dash.
10. Connect the connectors to the back of the ICU3.
    - 10.1 Connect the air pressure lines to the brass fittings.
    - 10.2 Connect the two electrical connectors.
11. Install the ICU3 mounting fasteners.
12. Install the driver side finish panel. For instructions, see **Section 60.07**.
13. Connect the batteries.
14. Turn on the ignition and test the operation of the ICU3.
15. Remove the chocks from the rear tires.

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Instrumentation Control Unit (ICU3) Replacement



1. Instrument Panel
2. Instrument Cluster
3. Fasteners
4. Driver Side Finish Panel

Fig. 1, Instrument Cluster Mounting

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Air Pressure Gauge Replacement

Replacement

CAUTION

Electronic components of the instrumentation control unit (ICU3) are vulnerable to damage from static electricity. If available, wear a wrist grounding strap connected to a ground in the cab or workbench. If a grounding strap is not available, touch a grounded component immediately before doing any work which could bring a tool or body part in contact with ICU3 circuitry.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries.

WARNING

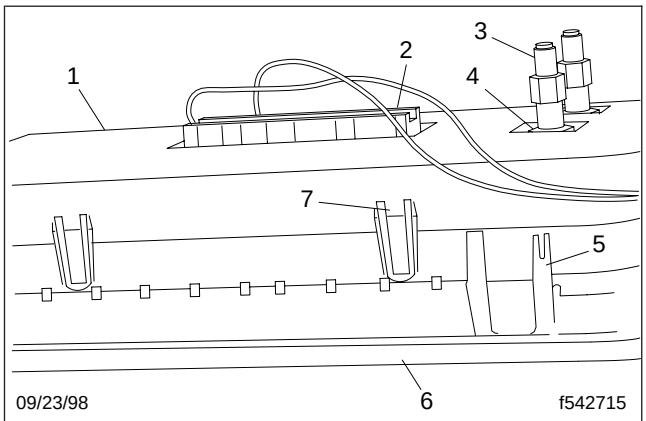
All air pressure must be relieved from the air reservoirs before disconnecting any pneumatic lines or hoses from the air system. Failure to relieve air pressure could cause the lines to whip, resulting in personal injury.

3. Drain the air system.
4. Remove the ICU3. For instructions, see **Subject 100**.

CAUTION

Use extreme care to avoid breaking the clips when prying them off the ICU3 housing. The clips are under tension and are easy to damage.

5. Using a thin-bladed screwdriver, very carefully pry the nine large white clips away from the sides of the ICU3 housing. It is helpful to use a small thin piece of metal, such as a spade terminal, to hold each clip away from the housing after it has been gently levered off its pawl. Remove the bezel from the ICU3 housing. See **Fig. 1**.
6. From the back of the ICU3 housing, remove the quick-disconnect fitting and nut from the threaded tube coming out the back of the air gauge.
7. Remove the air gauge from the ICU3.



1. ICU3 Housing
2. Electrical Connector
3. Quick-Disconnect Fitting
4. Nut
5. Bezel Clip (white)
6. Bezel
7. Back Cover Clip (black)

Fig. 1, Air Pressure Gauge Installation

8. Remove the air gauge fitting from the air gauge.
9. Install the air gauge fitting on the new air gauge.
10. Install the air gauge.
    - 10.1 Insert the gauge into the hole in the ICU3 housing.
    - 10.2 Tighten the nut on the threaded tube.
    - 10.3 Install the quick-disconnect fitting.
11. Position the bezel on the ICU3 housing. Fasten the nine white clips to the sides of the ICU3 housing.
12. Install the ICU3. For instructions, see **Subject 100**.
13. Connect the batteries.
14. Start the engine and verify the proper operation of the new gauge as the air pressure builds up.
15. Remove the chocks from the tires.

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Replacement

CAUTION

Electronic components of the instrumentation control unit (ICU3) are vulnerable to damage from static electricity. If available, wear a wrist grounding strap connected to a ground in the cab or workbench. If a grounding strap is not available, touch a grounded component immediately before doing any work which could bring a tool or body part in contact with ICU3 circuitry.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries.

WARNING

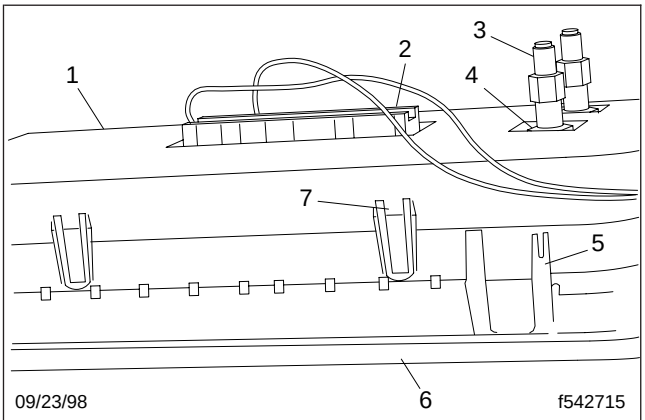
All air pressure must be relieved from the air reservoirs before disconnecting any pneumatic lines or hoses from the air system. Failure to relieve air pressure could cause the lines to whip, resulting in personal injury.

3. Drain the air system.
4. Remove the ICU3. For instructions, see **Subject 100**.

CAUTION

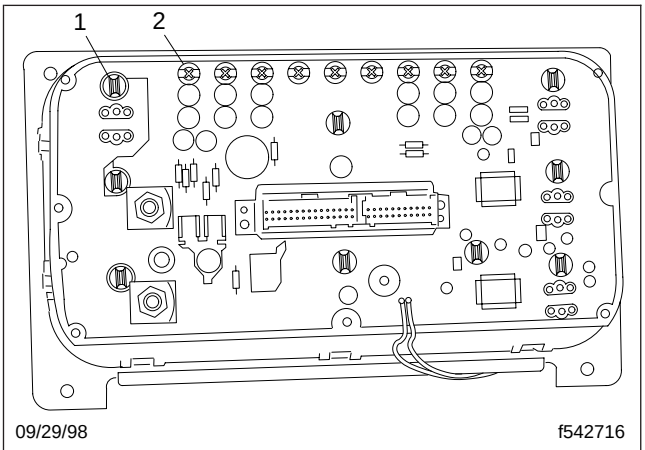
Use extreme care to avoid breaking the clips when prying them off the ICU3 housing. The clips are under tension and are easy to damage.

5. Pry off the four small black clips from the sides of the ICU3 housing. See **Fig. 1**.
6. Remove the two screws from the back of the housing, one on the middle of each side, and remove the back cover from the ICU3 housing.
7. Remove the burned out light bulb(s). See **Fig. 2**.
   - 7.1 To remove gauge light bulbs, twist the bulb base a quarter-turn counterclockwise and pull out.
   - 7.2 To remove warning/indicator light bulbs, use a small screwdriver to twist out the bulb base behind the affected light.



1. ICU3 Housing
2. Electrical Connector
3. Quick-Disconnect Fitting
4. Nut
5. Bezel Clip (white)
6. Bezel
7. Back Cover Clip (black)

Fig. 1, Back Cover Installation



1. Gauge Light Bulb Base
2. Warning and Indicator Light Bulb Base

Fig. 2, Light Bulb Installation

8. Install the new light bulb(s).
   - 8.1 To install gauge light bulbs, twist the bulb holder into the slot from which the old one was removed.
   - 8.2 To install warning/indicator light bulbs, insert the new bulb base into the proper slot and use a small screwdriver to tighten it.

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Light Bulb Replacement

NOTE: Light emitting diodes (LEDs) must be installed with correct polarity. Insert the LED into the socket, rotating and pushing gently until it touches the contacts. If it lights, push it the rest of the way into the socket. Otherwise, pull it out, rotate it a half-turn, and check for lighting again. If it still does not light, you need to push it further into the socket, the socket is not getting power, or you may have a bad LED.

9. Position the back cover on the ICU3 housing. Fasten the four black clips to the sides of the ICU3 housing.
10. Install the two screws on the back of the housing, one on the middle of each side.
11. Install the ICU3. For instructions, see **Subject 100**.
12. Connect the batteries.
13. Turn on the ignition. Check all bulbs for correct operation.
14. Remove the chocks from the tires.

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Fuel Level Gauge Diagnosis

The fuel level gauge is controlled by the ICU using a variable resistance input from the fuel level sending unit that is located in the fuel tank. The fuel level sending unit resistance varies linearly from 31±2Ω with a full tank to 247±3Ω when empty.

If the ICU3 is measuring a resistance greater than 284Ω between circuit 47 and ground, a fault will be set for fuel level circuit open. If the ICU3 is measuring less than 23.5Ω between circuit 47 and ground, a fault will be set for fuel level circuit shorted low. ServiceLink may be used to monitor for these faults. The gauge will read empty until the measurement from the sensor is between 284Ω and 23.5Ω. Refer to **Table 1** for the fuel level diagnostic procedure.

NOTE: If the fuel level sensor is below the minimum resistance (short to ground) or above the maximum (open), the fuel gauge will read empty. Shorting the fuel sensor wires will not drive the gauge to full scale.

Fuel Level Gauge Diagnosis

Step	Test Procedure	Test Result	Action
1	If a 100 ohm resistor is available, disconnect the fuel level sender connector and place the resistor across circuit 47 and ground in the wiring harness connector to simulate the fuel level sending unit. Turn the ignition to the ON position and observe the fuel gauge. If, after gauge initialization, the gauge points closely to the half tank mark, then the wiring and ICU are all operating correctly. Jump to Step 4 if there is no problem with the wiring and ICU. Does the fuel level gauge stay at empty even though there is fuel in the tank or is the complaint an inaccurate and intermittent reading? Note - turn the ignition to OFF and disconnect the batteries before continuing.	Stays at Empty	Go to Step 2.
		Inaccurate or Intermittent	Go to Step 4.
2	Disconnect the connector at the fuel level sender and measure the resistance of the sender. What is the resistance of the sender?	Greater than 284Ω or Less than 23.5Ω	Go to Step 4.
		Between 284Ω and 23.5Ω	Go to Step 3.
3	Connect the fuel level sender and disconnect the connectors on the back of the ICU. Measure the resistance in the vehicle wiring between circuit 47 in connector pin D1 and the ground circuit in connector pin D2. What is the resistance of the circuit?	Greater than 284Ω	Troubleshoot and repair an open circuit on either circuit 47 or the ground between the ICU connector and the fuel level sender.
		Between 284Ω and 23.5Ω	This is the valid resistance range. If the fuel tank is full and the resistance is close to 31Ω, replace the ICU. Otherwise no problem is indicated.
		Less than 23.5Ω	Troubleshoot and repair a short to ground on circuit 47 between the ICU connector and the fuel level sender.

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Troubleshooting

Fuel Level Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
4	Remove the fuel sending unit from the fuel tank. Connect an ohm meter to the pins at the fuel level sender connector. Slowly move the level of the float arm from full to empty. See **Fig. 1**. Does the resistance vary linearly from 31±2Ω to 247±3Ω?	Yes	Troubleshoot and repair for corrosion or an intermittent connection in the circuitry between the ICU and the fuel level sender.
		No	Replace the fuel level sending unit.

Table 1, Fuel Level Gauge Diagnosis

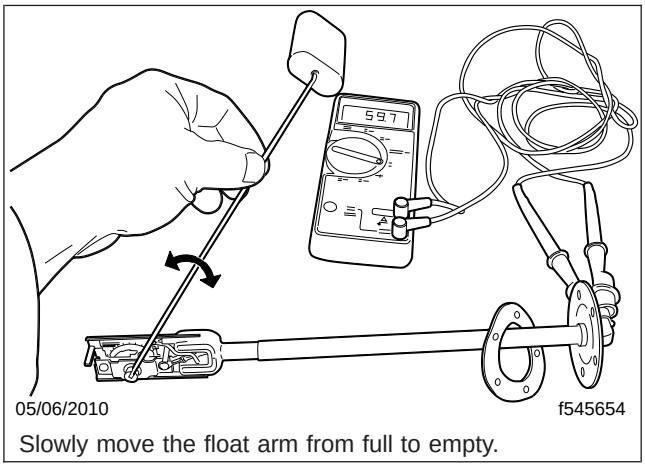


Fig. 1, Testing the Fuel Level Sending Unit

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See **Fig. 1** for the ICU3 cluster wiring.

See **Fig. 2** for the fuel level wiring.

See **Fig. 3** for the low coolant warning wiring.

See **Fig. 4** for the transmission temperature wiring.

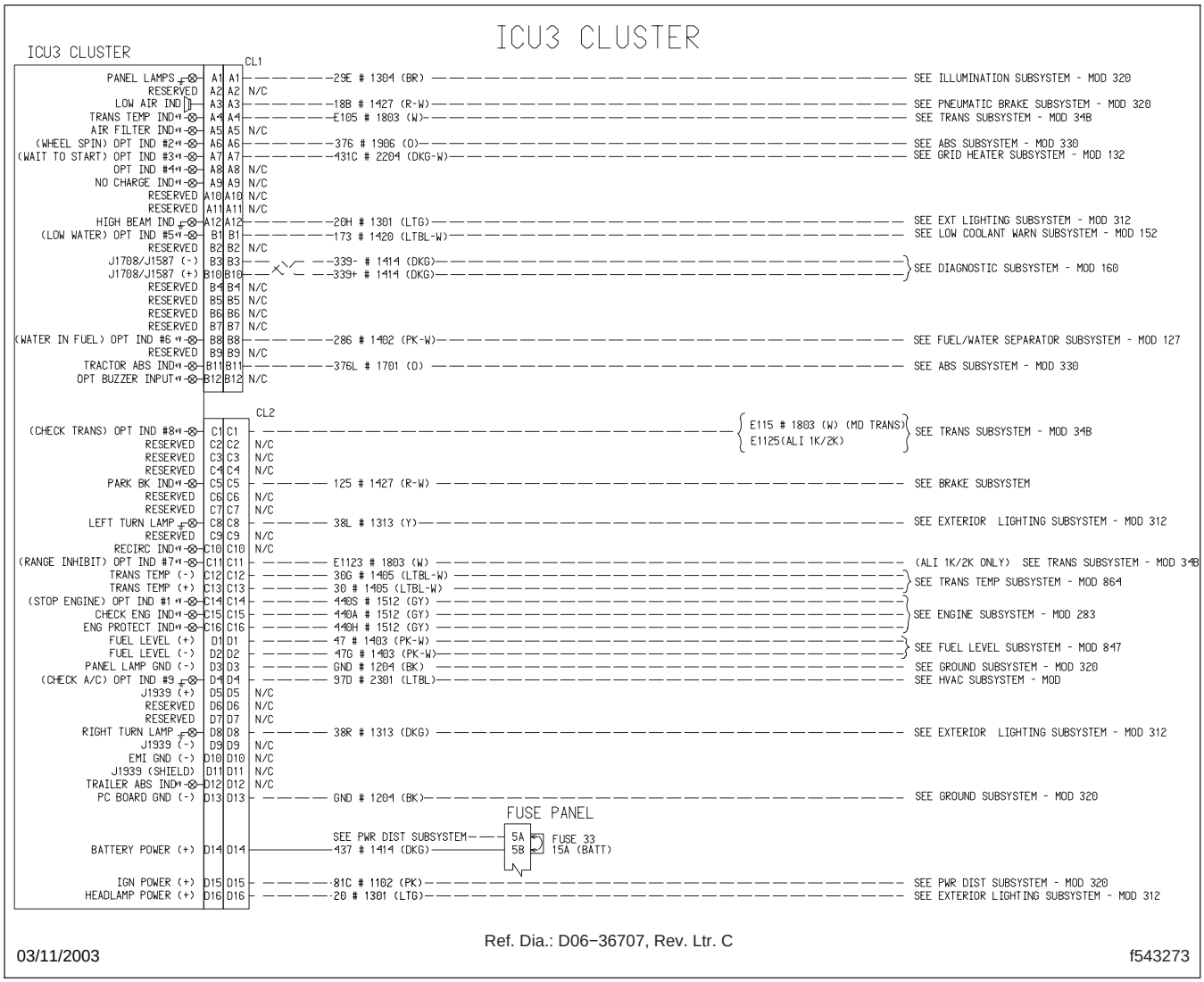


Fig. 1, ICU3 Cluster Wiring

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Specifications

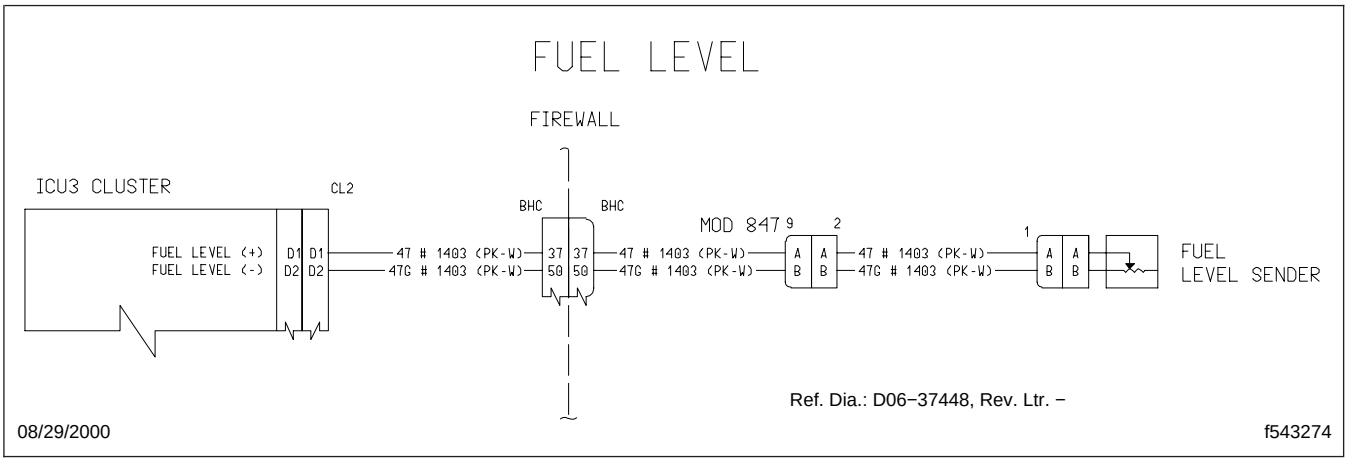


Fig. 2, Fuel Level Wiring

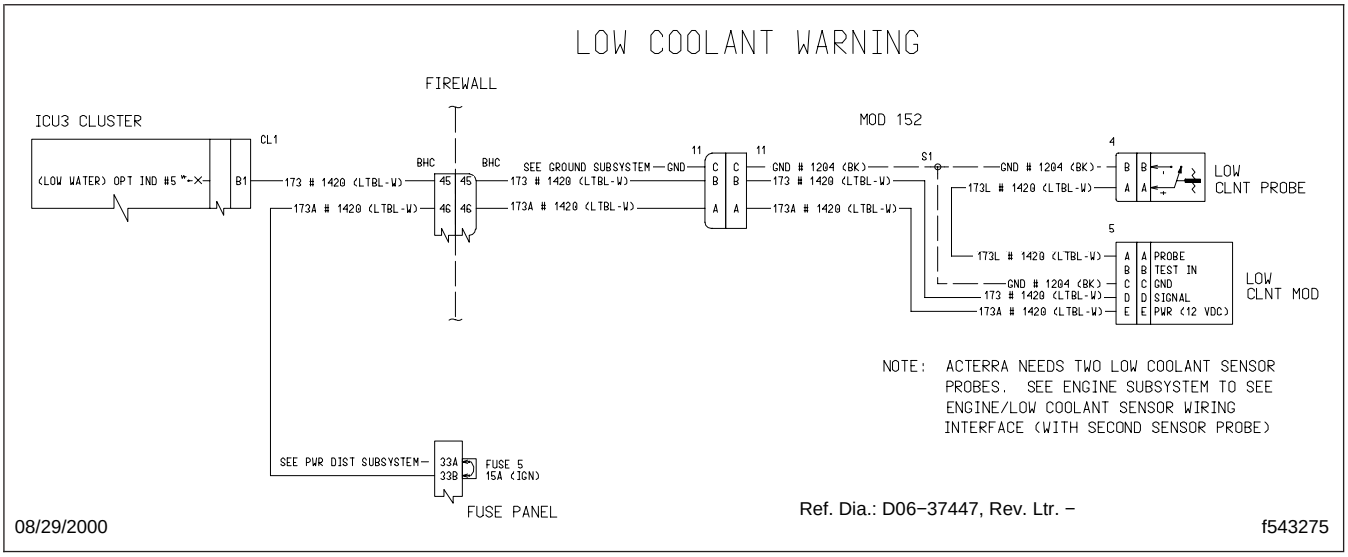


Fig. 3, Low Coolant Warning Wiring

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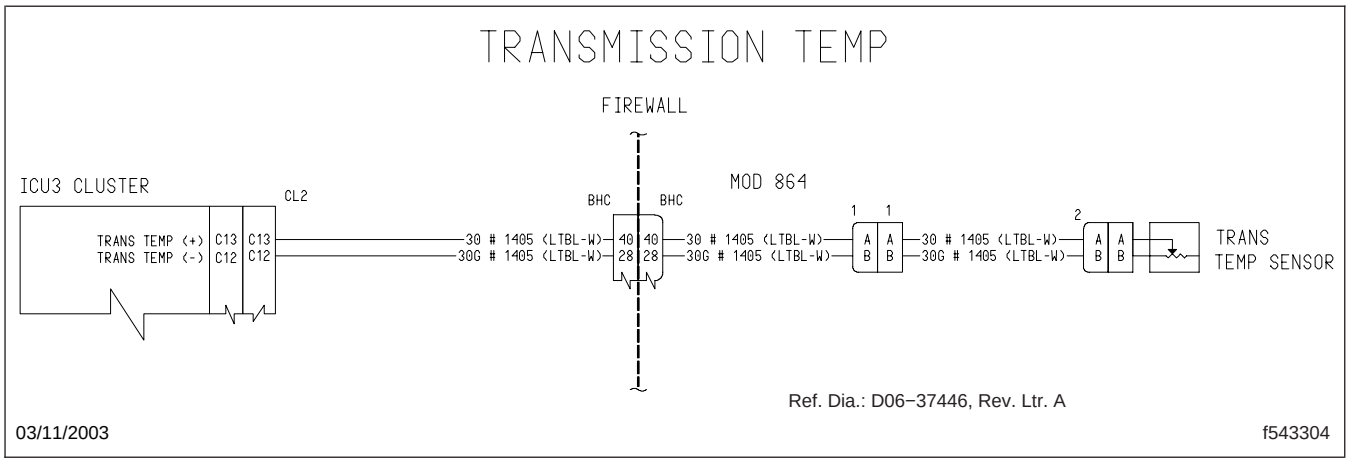


Fig. 4, Transmission Temperature Wiring

ICU3 Connector Pin Assignments		
Number	**Description**	**Wire**
A1	Panel Lights	29A
A3	Low Air Pressure Indicator	390
A4	Transmission Temperature Indicator	274
A5	Air Restriction Indicator	183A
A7	Do Not Shift Indicator	223
A9	No Charge Indicator	137
A12	High Beam Indicator	21B
B3	J1587 Databus –	M08
B10	J1587 Databus +	M27
C5	Parking Brake	394
C8	Left Turn Signal	60A
C12	Transmission Fluid Temperature Sender Return	30G
C13	Transmission Fluid Temperature Sender Feed	30
D1	Fuel Level Gauge Sender Feed	47
D2	Fuel Level Gauge Sender Return	47G
D3	Ground	GND
D8	Right Turn Signal	61A
D13	Ground	GND
D14	Battery Feed—Unswitched	339
D15	Ignition—Switched	81C
D16	Odometer Light (from headlight)	20L

Table 1, ICU3 Connector Pin Assignments

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Specifications

Message Identifiers (MIDs)		
MID	**Description**	**Text Message**
128	Engine Control Unit	ECU128
130	Transmission Control Unit	TCU130
136	Antilock Brake System (ABS)	ABS136
140	Instrumentation Control Unit	ICU140
223	Transmission Shift Unit	TSU223
###	Generic MID	SYS###

Table 2, Message Identifiers (MIDs)

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Mode/Reset Switch Functions

Use the following flow charts to cycle through the Mode/Reset switch functions and screens.

See **Fig. 1**, for Mode/Reset Switch Start Sequence.

See **Fig. 2**, for Mode/Reset Switch Trip Screens.

See **Fig. 3**, for Mode/Reset Switch Engine Miles and Service Screens.

See **Fig. 4**, for Mode/Reset Switch Fault Screens.

See **Fig. 5**, for Mode/Reset Switch Service Screens.

See **Fig. 6**, for Mode/Reset Switch Oil Level Screens.

See **Fig. 7**, for Mode/Reset Switch Reset and Toggle Screens.

Service Interval Tables

For service interval miles look-up values, see **Table 1**.

For service interval hours look-up values, see **Table 2**.

Service Interval Distance Settings		
Number	**Miles**	**Kilometers**
1	1000	1610
2	1500	2415
3	2000	3220
4	2500	4025
5	3000	4830
6	3500	5635
7	4000	6440
8	4500	7245
9	5000	8050
10	5500	8855
11	6000	9660
12	6500	10465
13	7000	11270
14	7500	12075
15	8000	12880
16	8500	13685
17	9000	14490
18	9500	15295
19	10000	16100
20	11000	17710
21	12000	19320
22	13000	20930
23	14000	22540
24	15000	24150
25	16000	25760
26	17000	27370
27	18000	28980
28	19000	30590
29	20000	32200
30	21000	33810
31	22000	35420
32	23000	37030
33	24000	38640
34	25000	40250

Table 1, Service Interval Distance Settings

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Mode/Reset Switch Functions

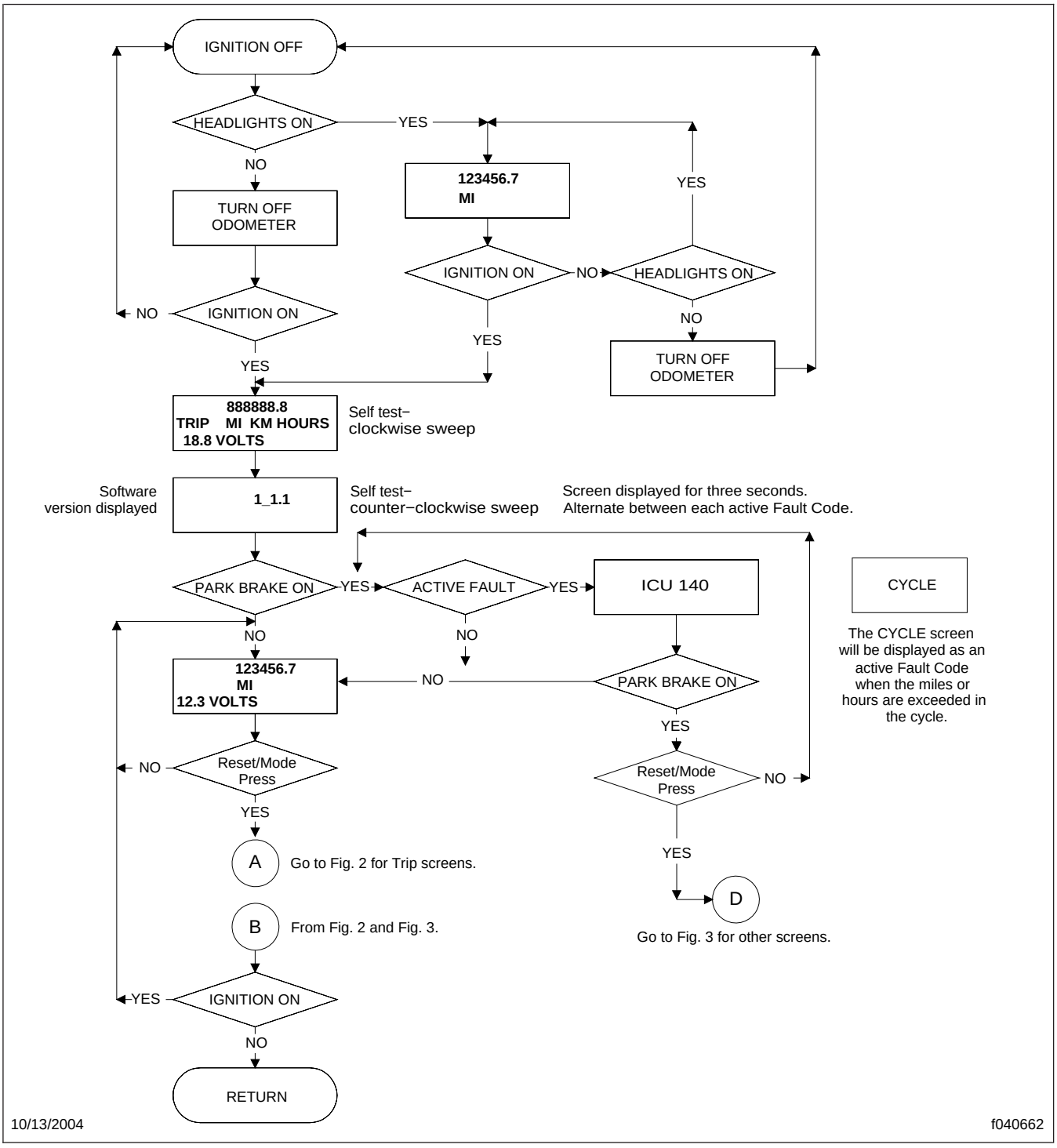


Fig. 1, Mode/Reset Switch Start Sequence

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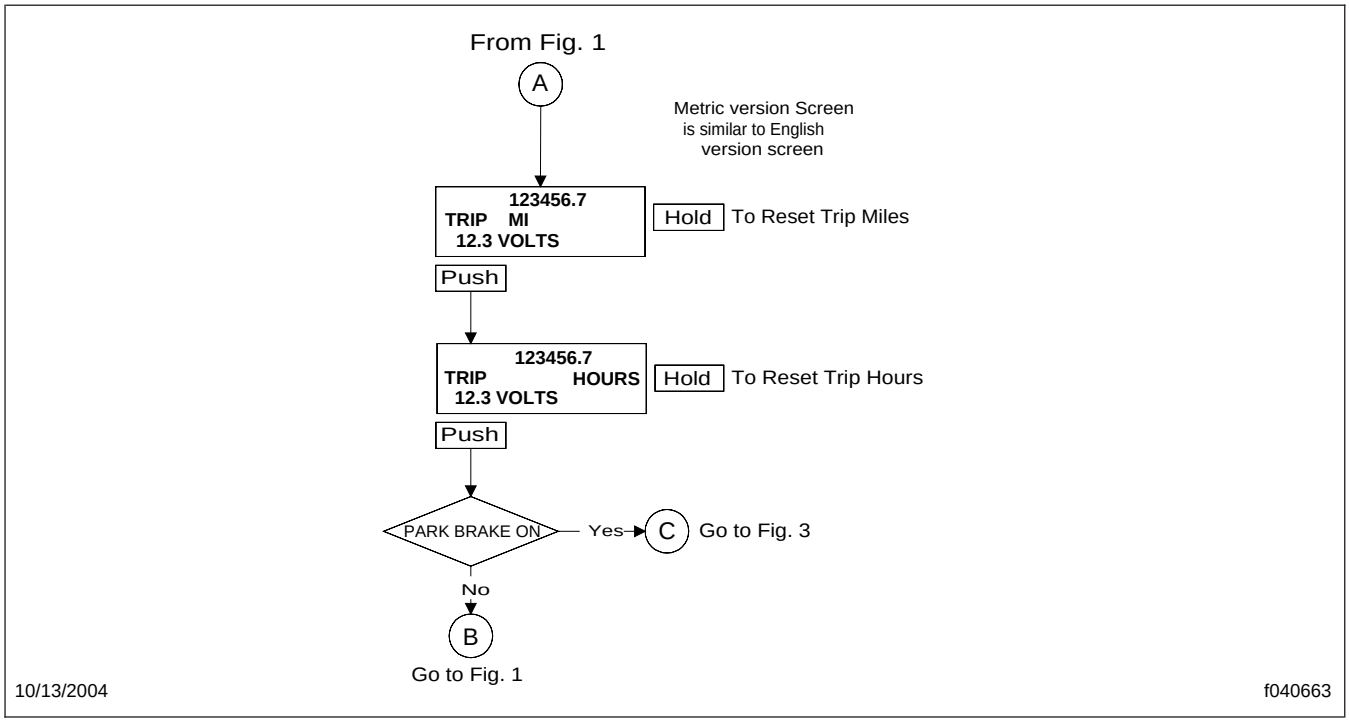


Fig. 2, Mode/Reset Switch Trip Screens

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Mode/Reset Switch Functions

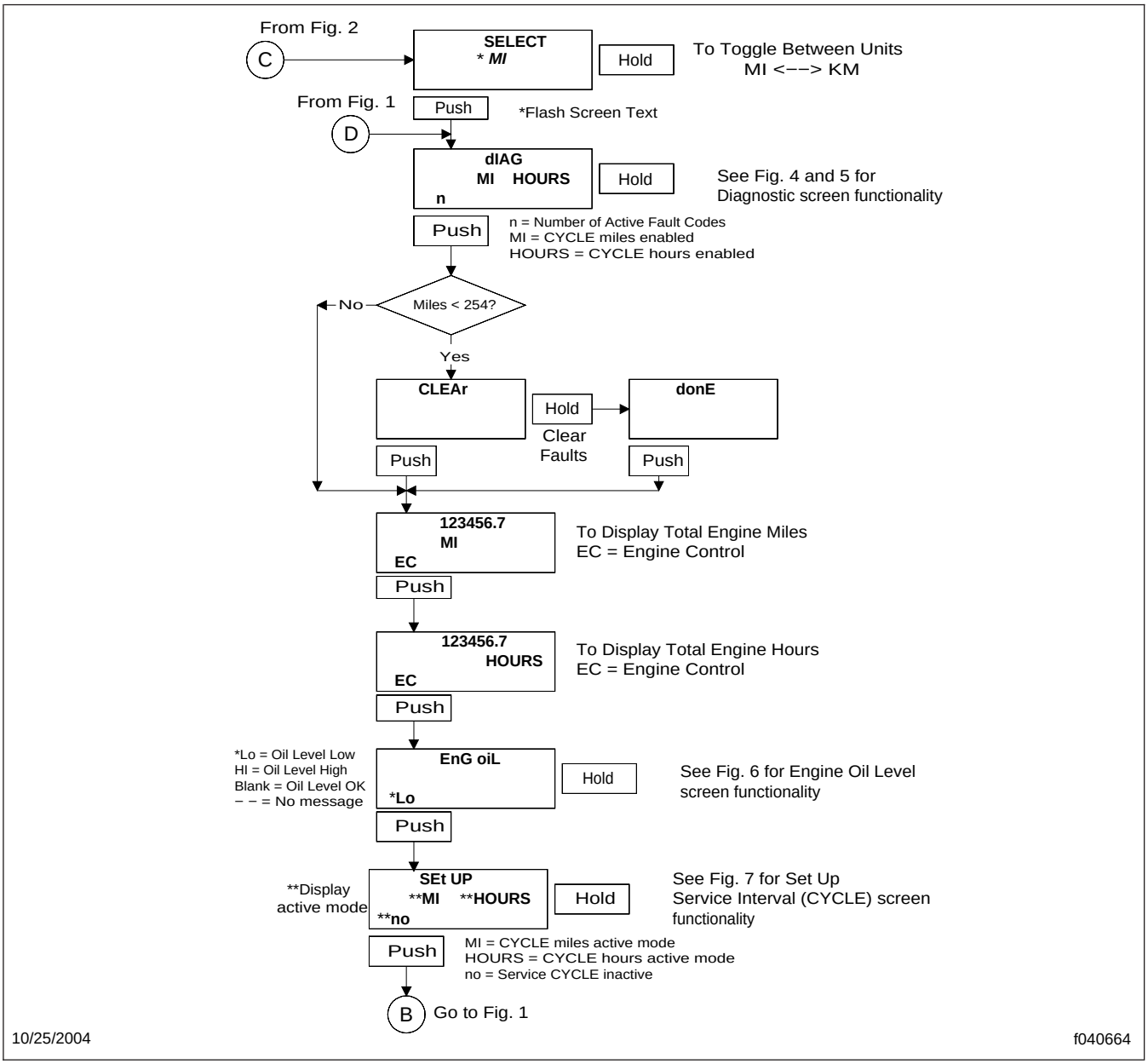


Fig. 3, Mode/Reset Switch Engine Miles and Service Screens

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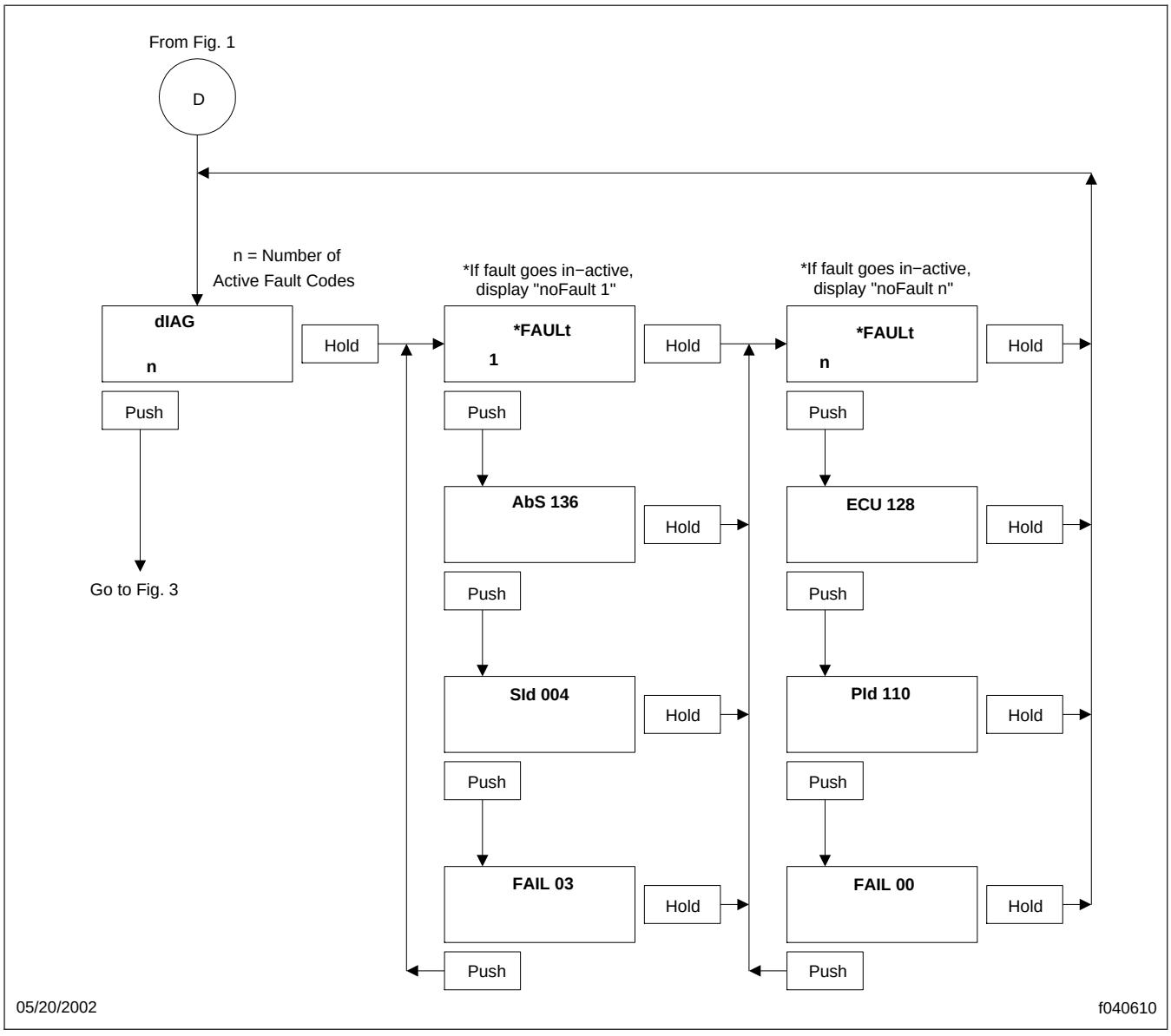


Fig. 4, Mode/Reset Switch Fault Screens

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Mode/Reset Switch Functions

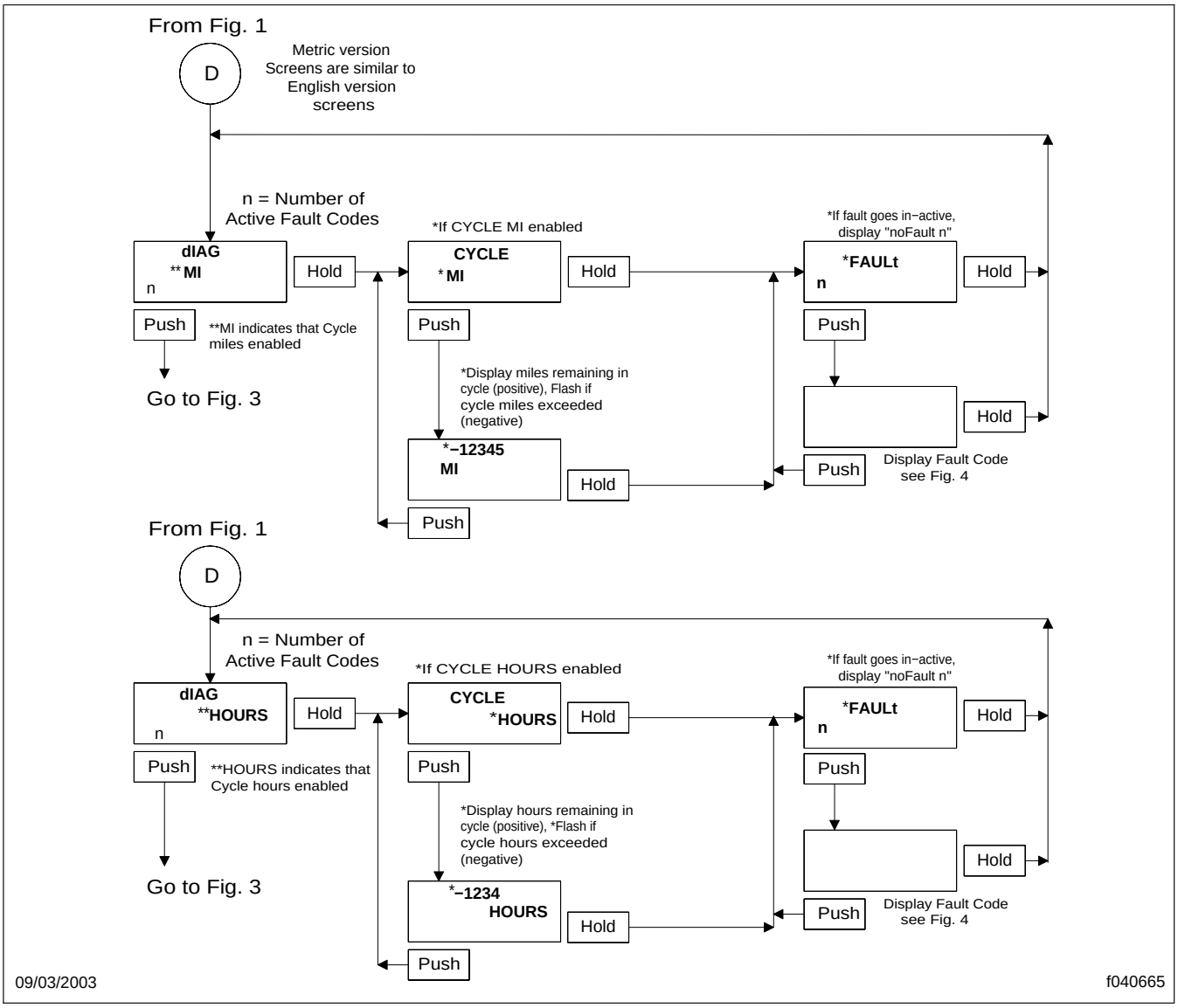


Fig. 5, Mode/Reset Switch Service Screens

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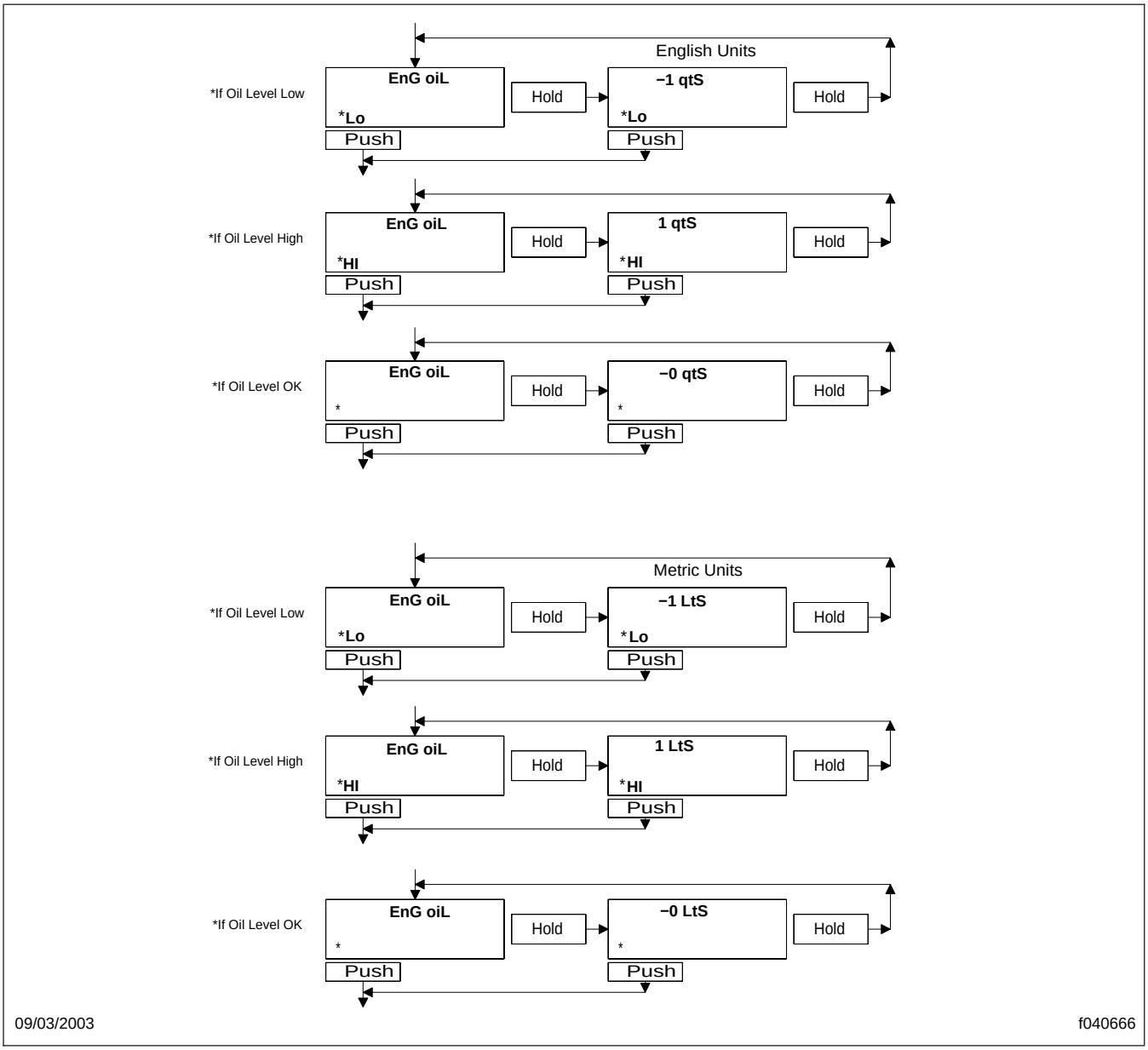


Fig. 6, Mode/Reset Switch Oil Level Screens

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Mode/Reset Switch Functions

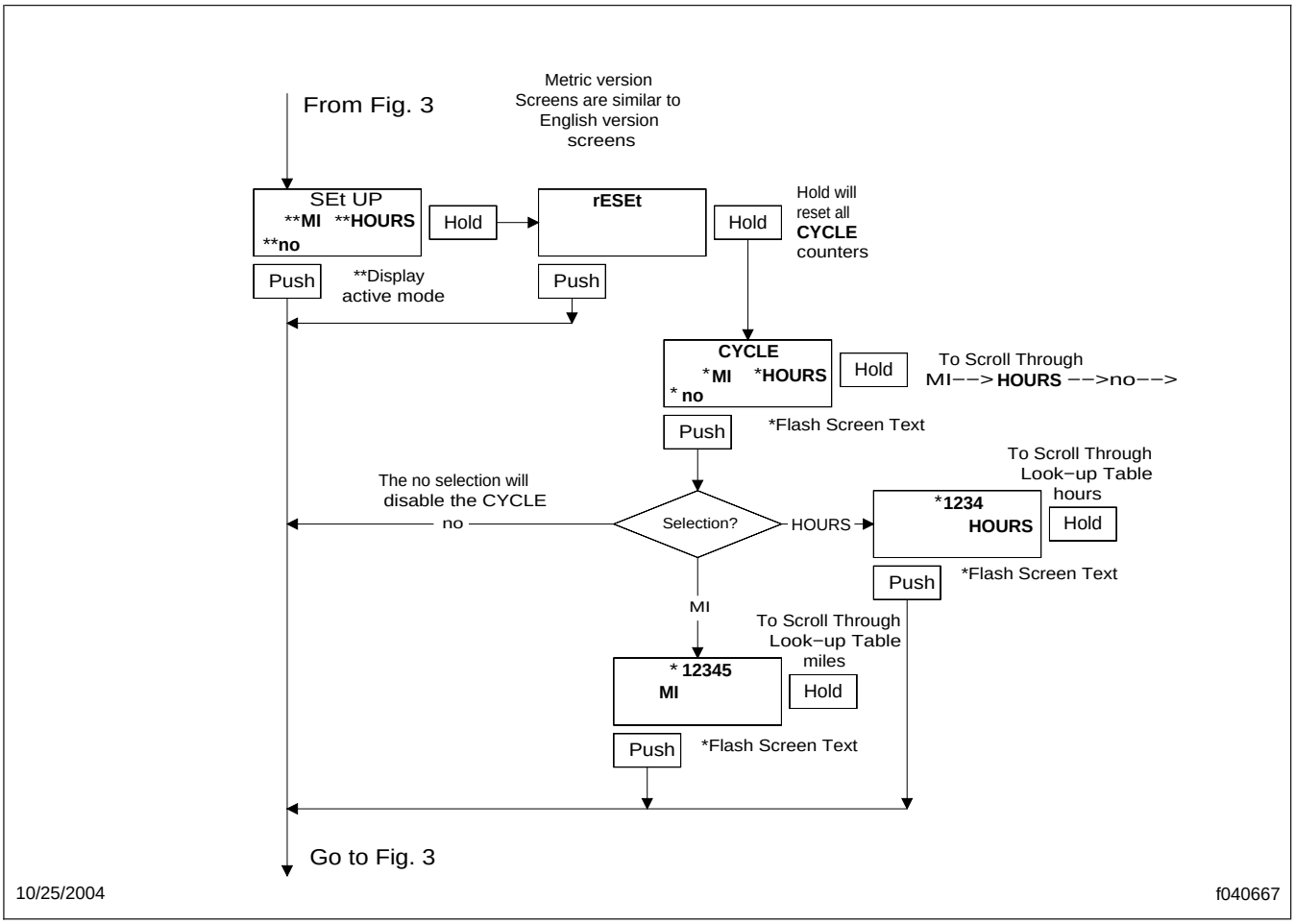


Fig. 7, Mode/Reset Switch Reset and Toggle Screens

Service Interval Hours Settings	
Number	**Hours**
1	50
2	75
3	100
4	125
5	150
6	175
7	200
8	225
9	250
10	300
11	350

Service Interval Hours Settings	
Number	**Hours**
12	400
13	450
14	500
15	550
16	600
17	650
18	700
19	750
20	800
21	850
22	900

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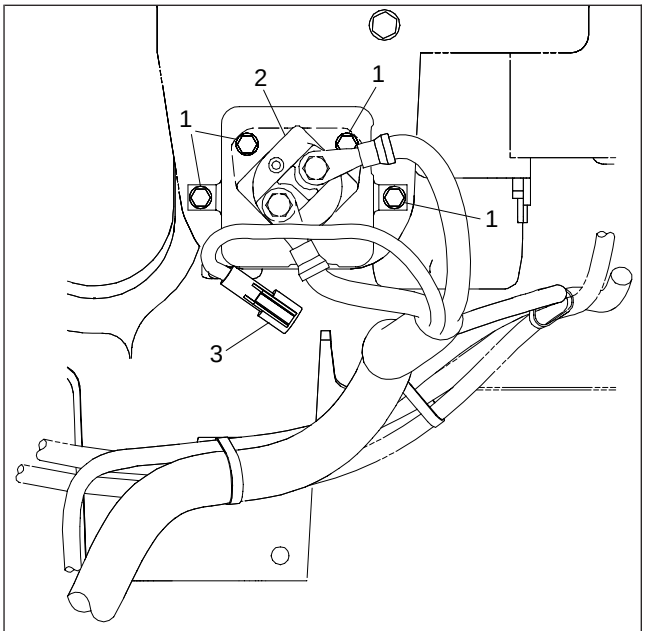
Service Interval Hours Settings	
Number	**Hours**
23	950
24	1000

Table 2, Service Interval Hours Settings

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General Information

All Acterra vehicles are equipped with a 12-volt starting system that includes an Essex magnetic switch. See **Fig. 1**. The magnetic switch acts as a relay to reduce the length of the high-current starting motor cables, and to make it unnecessary for the ignition switch to handle the high current.



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1. Hexhead Capscrew
2. Switch
3. Connector

Fig. 1, Essex Magnetic Switch

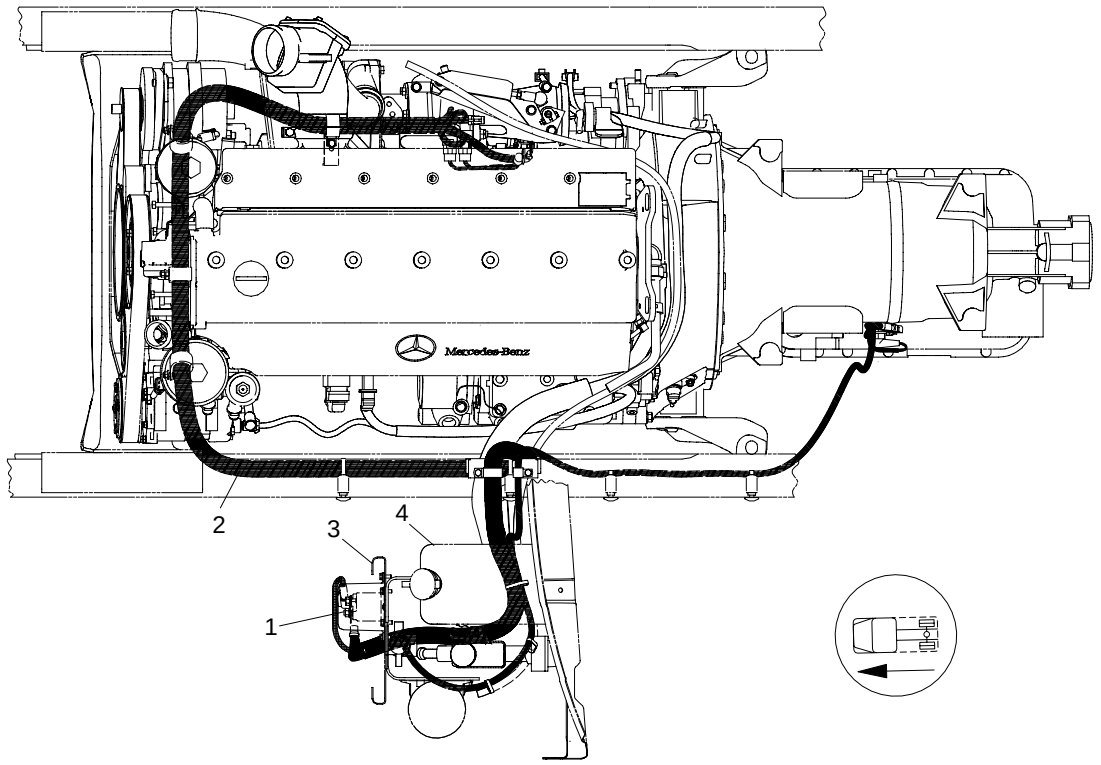
The magnetic switch consists of a pull-in coil wound around a hollow cylinder containing a movable core (plunger). A contact plate attaches to the end of the plunger's pushrod.

When the ignition key is turned to the start position, the pull-in coil is energized. The electromagnetic effect of the energized coil centers the plunger in the hollow cylinder. Plunger movement forces the contact plate against the battery and starter solenoid terminals of the switch, completing the high-current circuit between the batteries and the starter solenoid and starter motor. The starter solenoid remains activated and the starter motor cranks the engine as long as the ignition key is held in the start position. When the key is returned to the ignition position once the engine starts (or turned to the off position to allow the starter motor to cool after 30 seconds of cranking), the pull-in coil is de-energized. The magnetic switch's return spring forces the contact plate and plunger back to their rest positions, breaking the circuit to the starter motor.

The magnetic switch is mounted under the hood, on the left-side of the vehicle, below the windshield washer fluid reservoir. See **Fig. 2** or **Fig. 3**.

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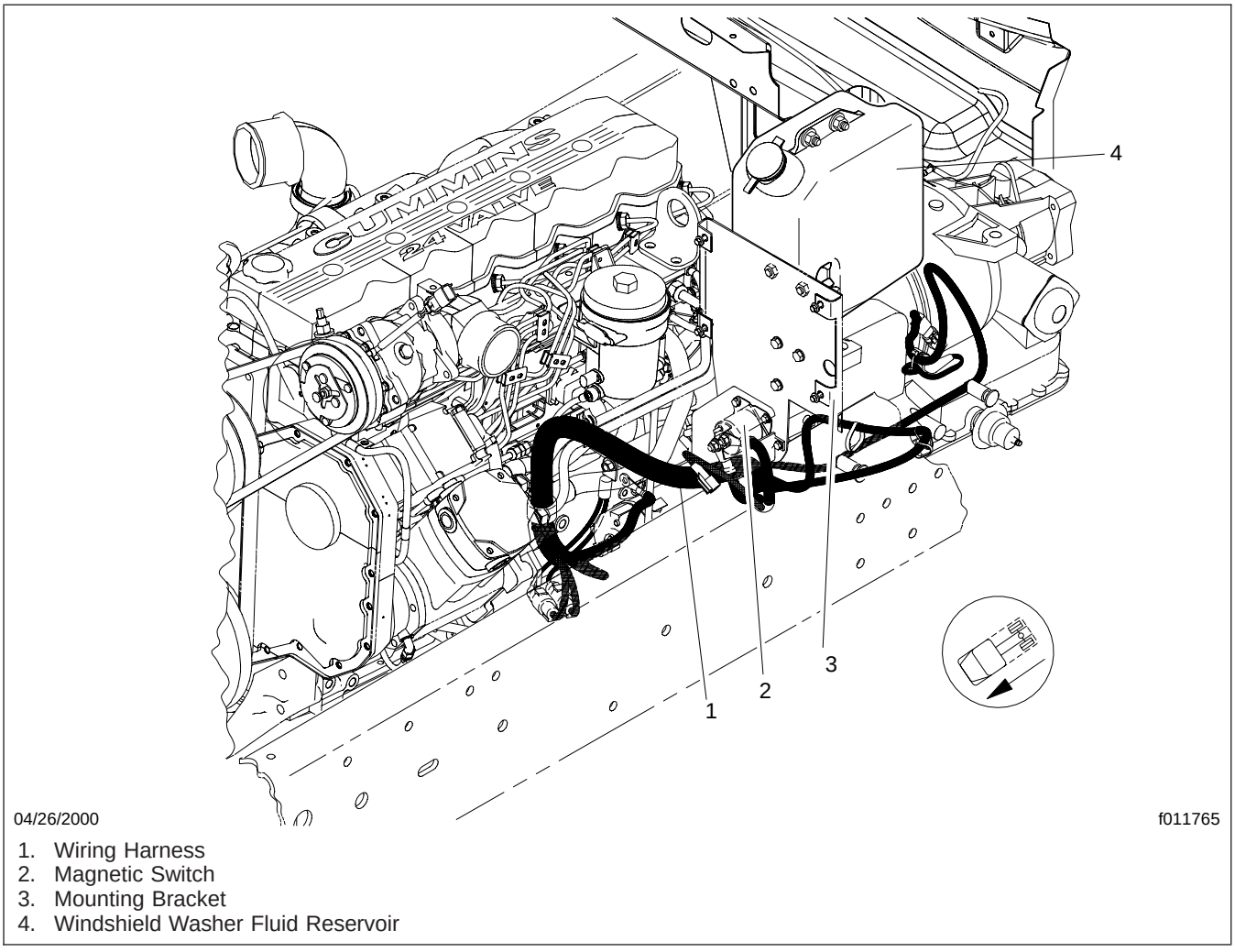
General Information



1. Magnetic Switch
2. Wiring Harness
3. Mounting Bracket
4. Windshield Washer Fluid Reservoir

Fig. 2, Magnetic Switch Installation, Mercedes-Benz MBE900 Engine

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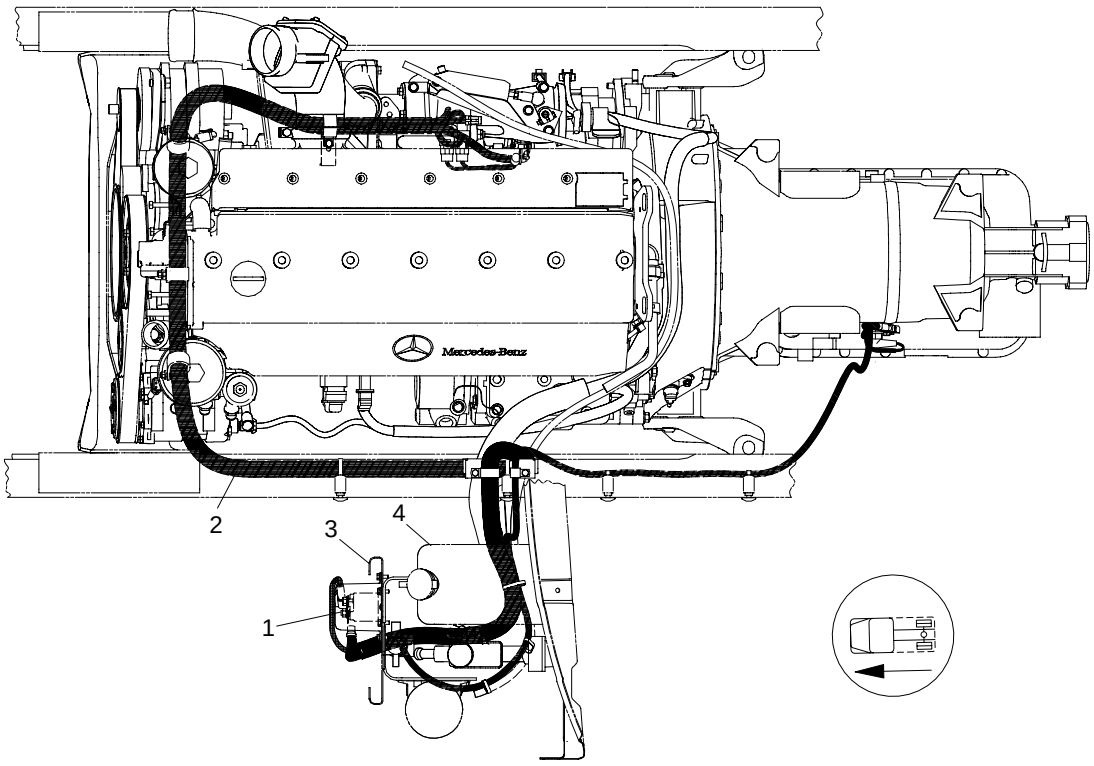


1. Wiring Harness
2. Magnetic Switch
3. Mounting Bracket
4. Windshield Washer Fluid Reservoir

Fig. 3, Magnetic Switch Installation, Cummins ISB Engine (Cummins ISC and Caterpillar 3126B similar)

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Replacement (See Fig. 1 or Fig. 2)



04/11/2000 f011764

1. Magnetic Switch
2. Wiring Harness
3. Mounting Bracket
4. Windshield Washer Fluid Reservoir

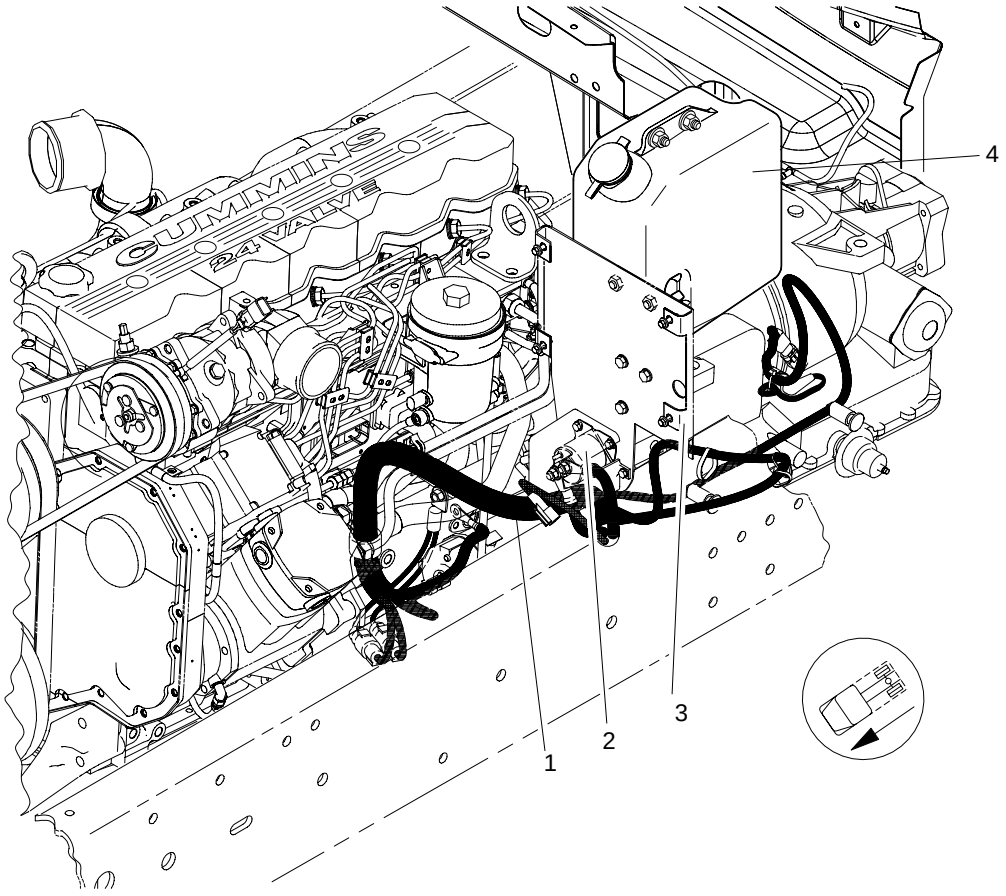
Fig. 1, Magnetic Switch Installation, Mercedes-Benz MBE900 Engine

IMPORTANT: The Essex magnetic switch is not repairable and cannot be disassembled. If the switch is not functioning correctly, replace it.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the ground cable from the batteries.
3. For later reference, mark the wires that are attached to the magnetic switch. Disconnect the wires.
4. Remove the two self-tapping screws that hold the magnetic switch in position. Remove the switch.
5. Install the new magnetic switch and tighten the screws.
6. Connect the wires to the magnetic switch. Tighten the nuts securely. Be sure to connect them as referenced above.
7. Spray the switch terminals and wiring ring terminals with dielectric red enamel spray sealer.
8. Connect the battery cable to the batteries. Tighten the nuts securely.
9. Remove the chocks from the rear tires.

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Magnetic Switch Replacement



04/26/2000 f011765

1. Wiring Harness
2. Magnetic Switch
3. Mounting Bracket
4. Windshield Washer Fluid Reservoir

Fig. 2, Magnetic Switch Installation, Cummins ISB Engine (Cummins ISC and Caterpillar 3126B similar)

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Wiring Diagram

See **Fig. 1** for a starting system wiring diagram.

See **Fig. 2** for the magnetic switch harness assembly.

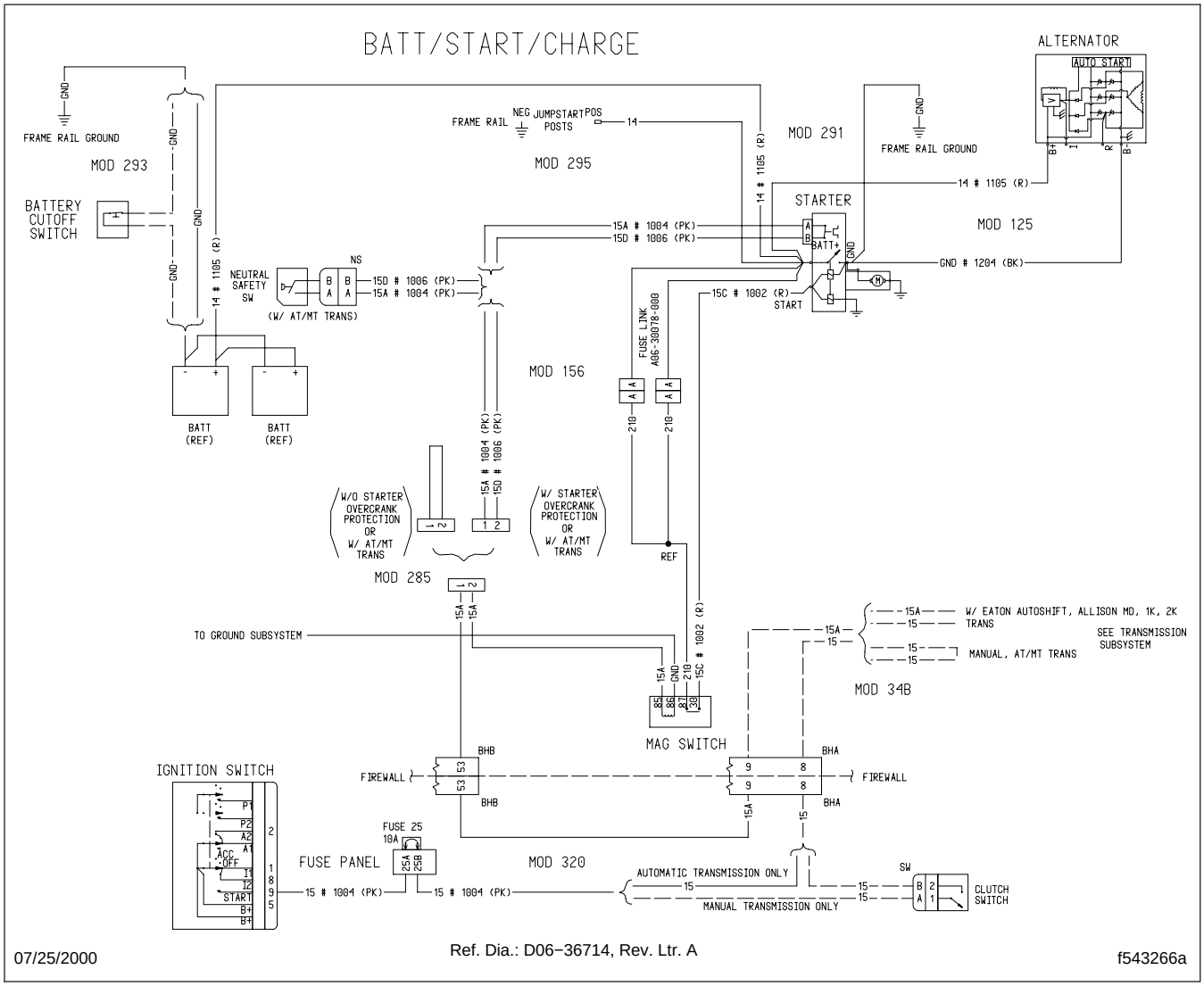


Fig. 1, Starting System Wiring Diagram

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Specifications

F/L CIR NO.	WIRE ITEM NO.	COLOR	SAE	FROM LOC	FROM TERM ITEM NO.	FROM SEAL INSL ITEM	FROM CONN CAV POS	TO LOC	TO TERM ITEM NO.	TO SEAL INSL ITEM	TO CONN CAV POS	APPROX LENGTH	CIRCUIT DESCRIPTION
210	16	RED	1101	S1	-	3	-	MSW	1	3	-	'A'	STARTER MAG SW SUPPLY
15C	6	BLK	1004	ST	4	2	-	MSW	1	2	-	'A'+250	STARTER SOLENOID CRANK
15A	8	PINK	1004	NS	15	-	A	MSW	11	-	1	2500	MAG SWITCH CONTROL
15D	8	PINK	1004	ST	13	-	B	MSW	11	-	2	'A'+250	MAG SWITCH CONTROL RETURN
15E	8	PINK	1004	ST	13	-	A	NS	15	-	B	A+2350	TRAN NS TO OCP BRIDGE
210A	17	RED	1101	S1	-	-	-	FL	20	-	-	250	STARTER MAG SW SUPPLY FUSE LINK 1
210B	17	RED	1101	S1	-	-	-	FL	20	-	-	250	STARTER MAG SW SUPPLY FUSE LINK 2

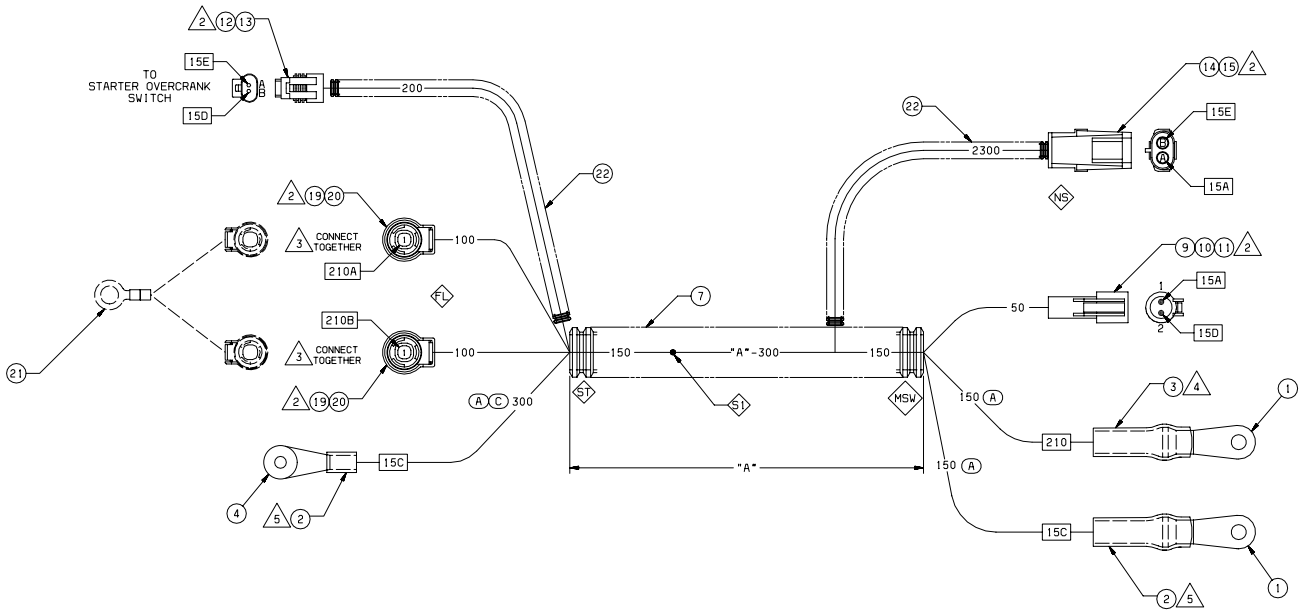


Fig. 2, Harness Assembly

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The following diagrams show the wiring circuits installed by Sterling. For detailed engine wiring, see the applicable Caterpillar manual.

See **Fig. 1** for a full view of Sheet 1 for Caterpillar 3126B engine wiring.

See **Fig. 2** and **Fig. 3** for partial views of Sheet 1.

See **Fig. 4** for a full view of Sheet 2 for Caterpillar 3126B engine wiring.

See **Fig. 5** and **Fig. 6** for partial views of Sheet 2.

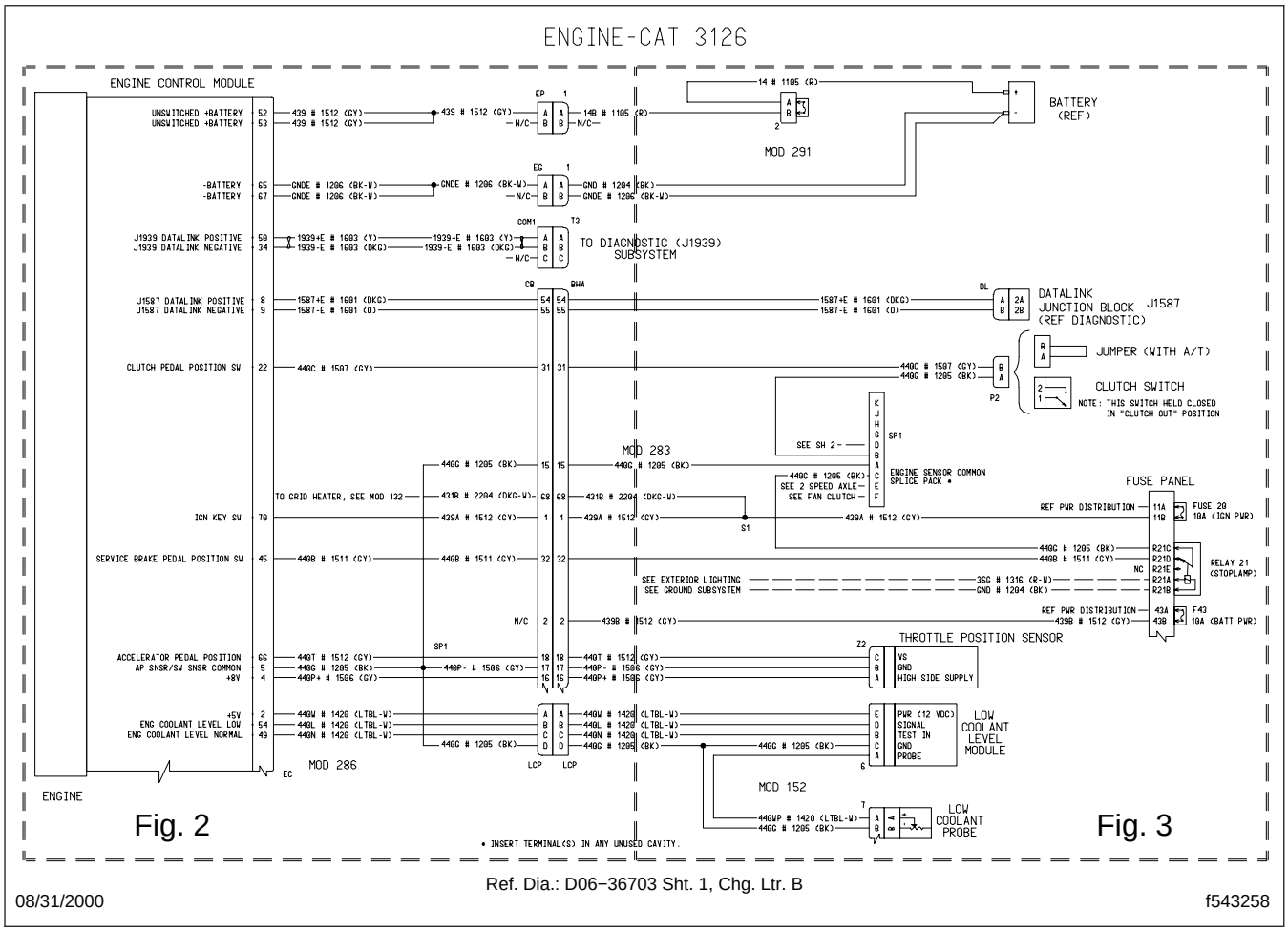


Fig. 1, Engine Wiring, Sheet 1 (full view)

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Specifications

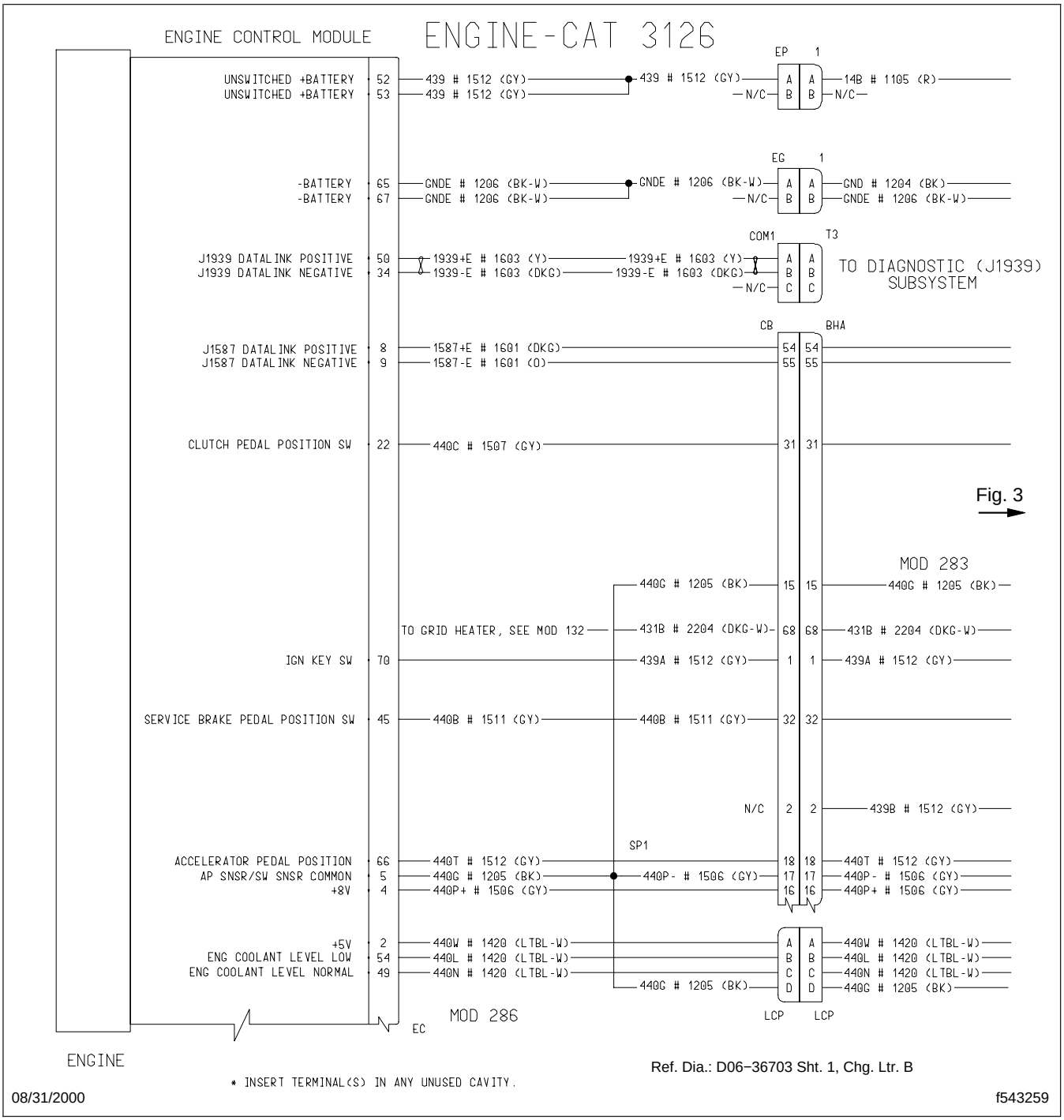


Fig. 2, Engine Wiring, Sheet 1 (partial view)

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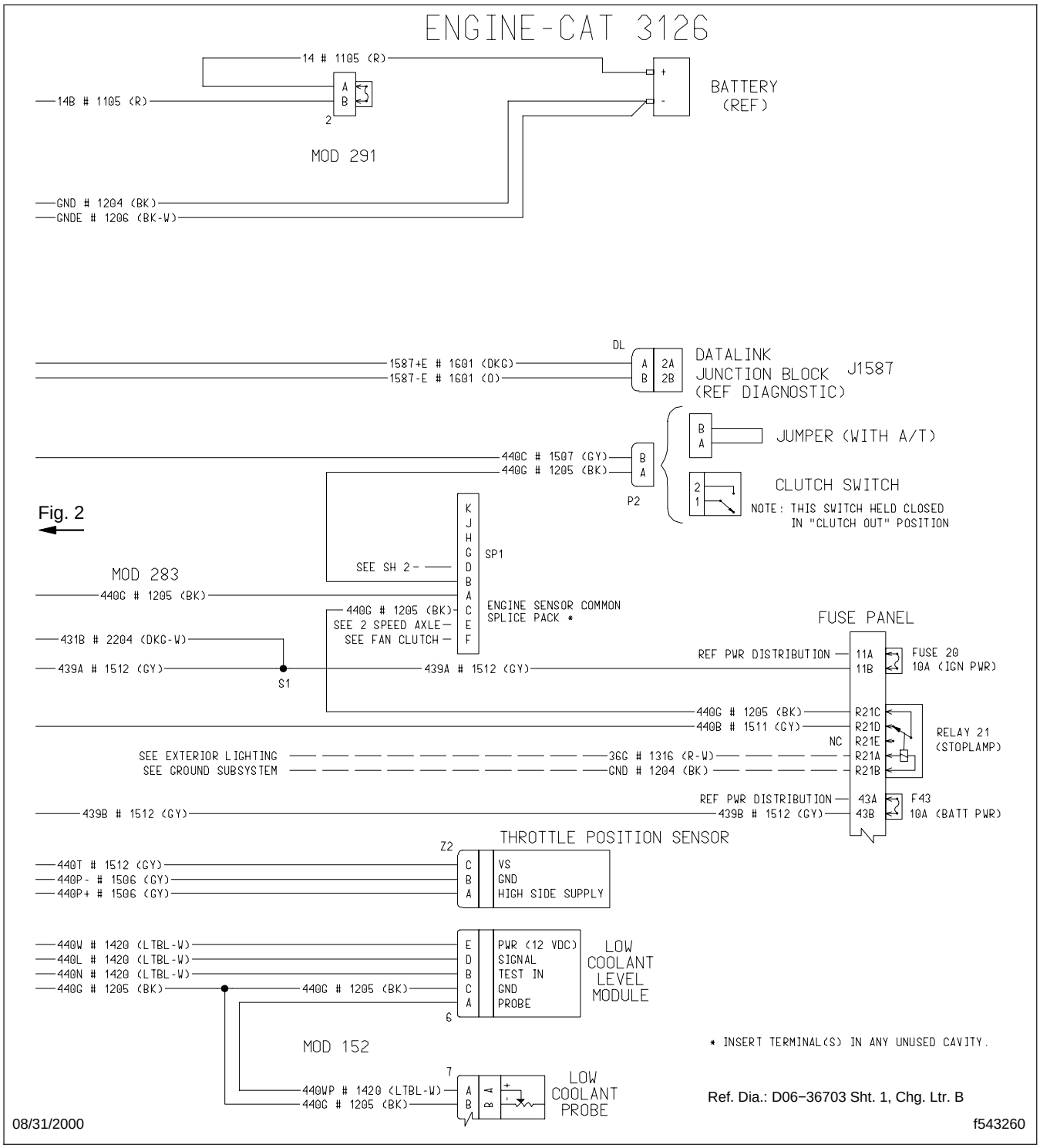
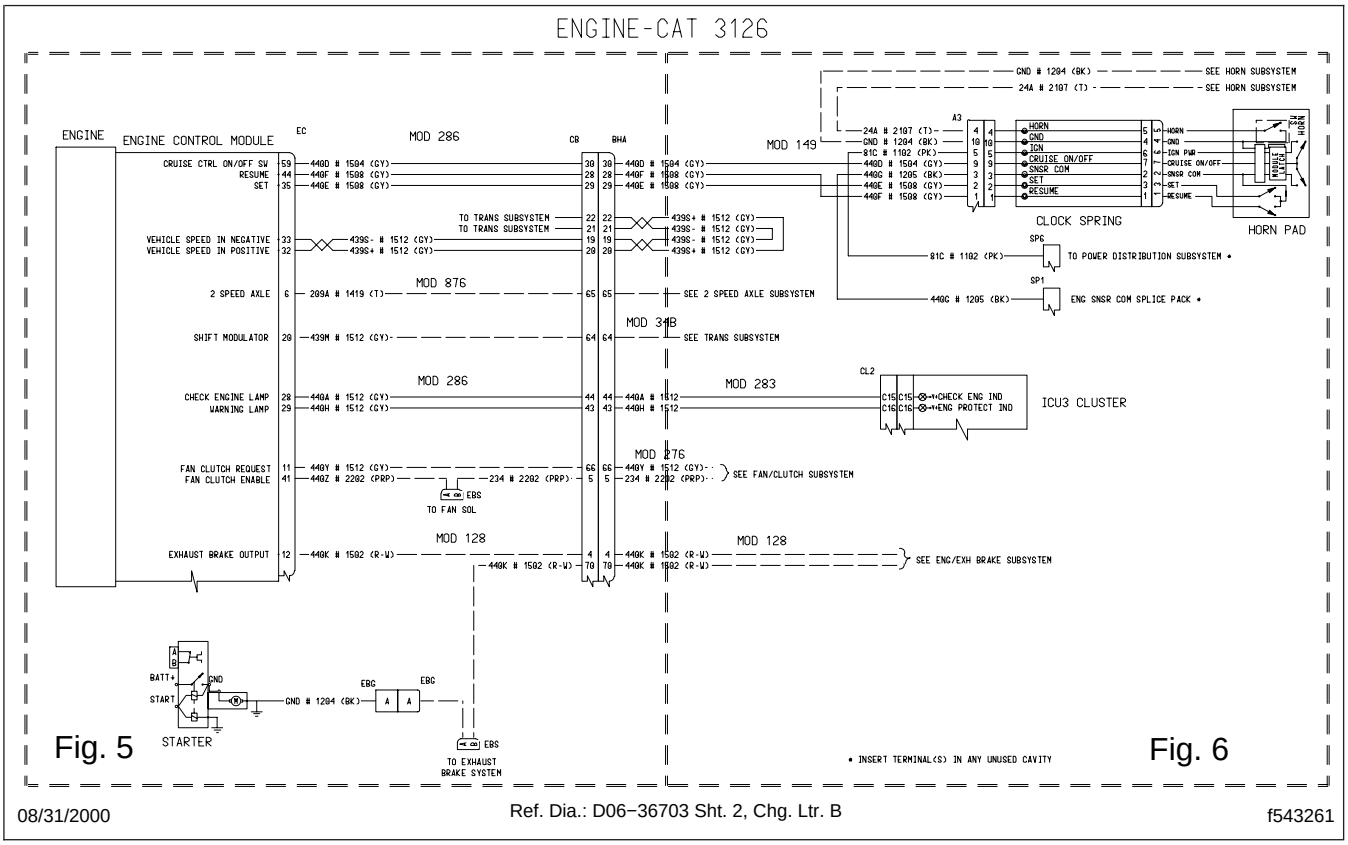


Fig. 3, Engine Wiring, Sheet 1 (partial view)

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Specifications



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Fig. 4, Engine Wiring, Sheet 2 (full view)

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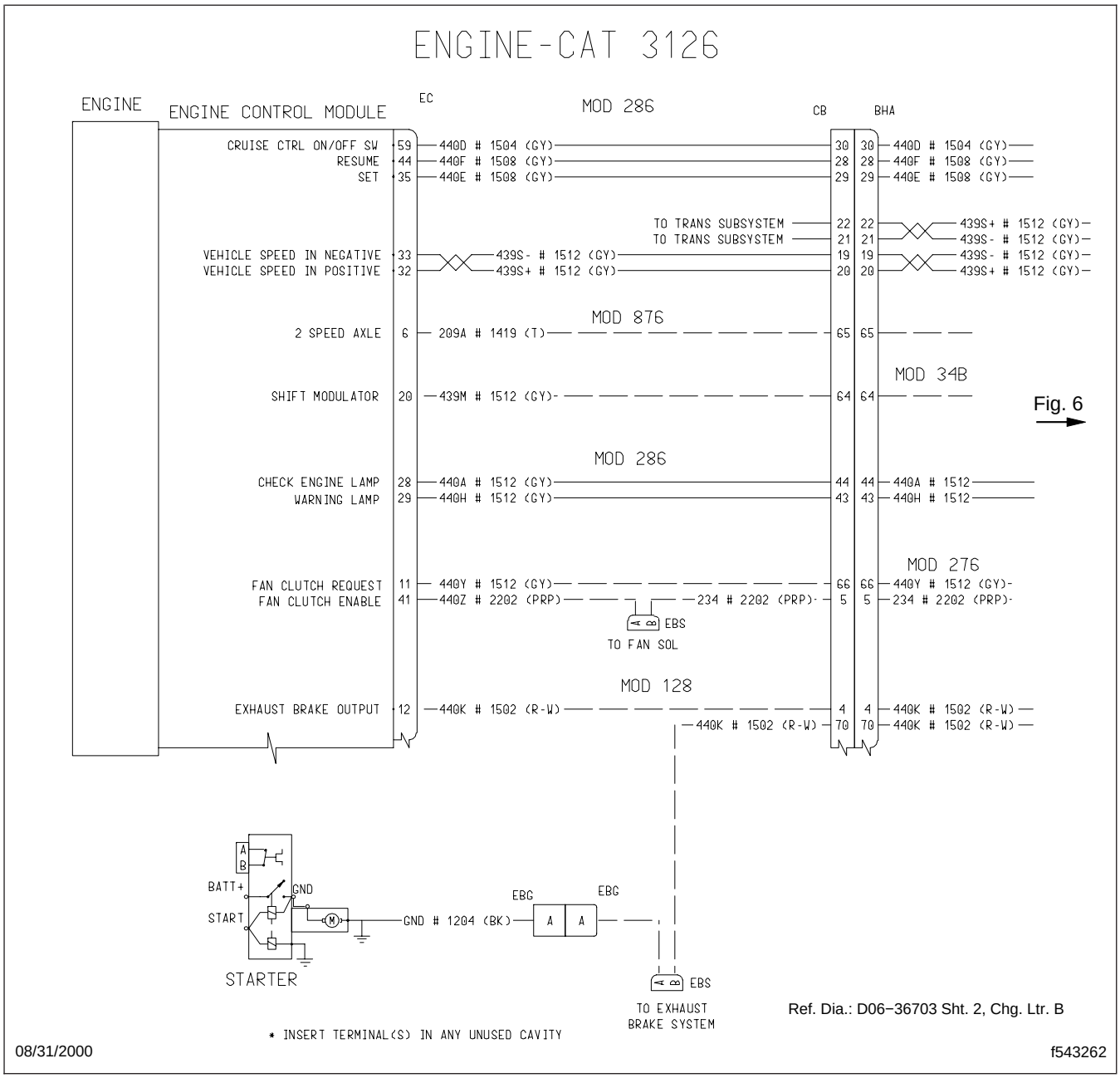


Fig. 5, Engine Wiring, Sheet 2 (partial view)

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Specifications

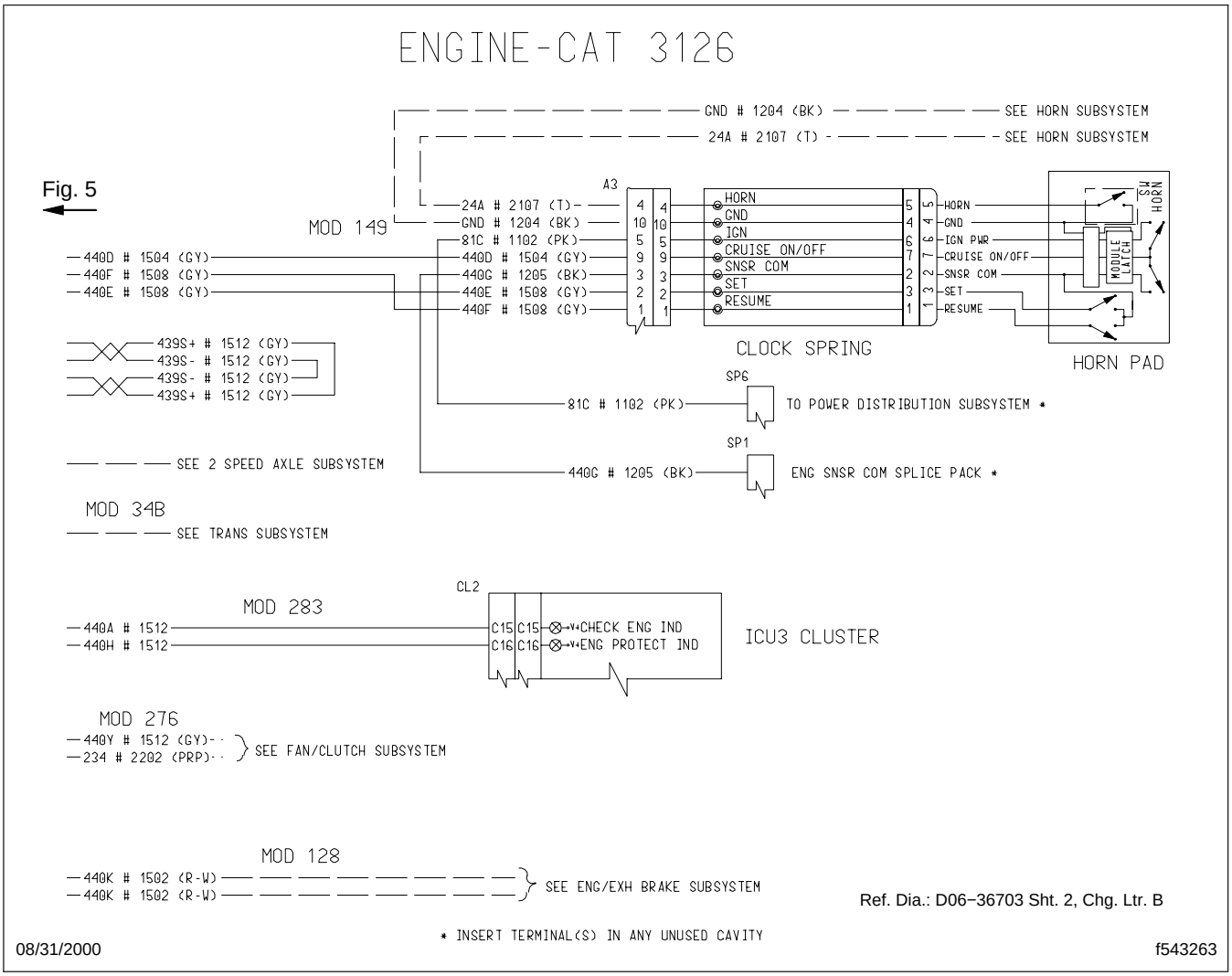


Fig. 6, Engine Wiring, Sheet 2 (partial view)

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The following diagrams show the wiring circuits installed by Sterling. For detailed engine wiring, see the applicable Cummins manual.

See **Fig. 1** for a full view of Sheet 1 for Cummins ISB/ISC engine wiring.

See **Fig. 2** and **Fig. 3** for partial views of Sheet 1.

See **Fig. 4** for a full view of Sheet 2 for Cummins ISB/ISC engine wiring.

See **Fig. 5** and **Fig. 6** for partial views of Sheet 2.

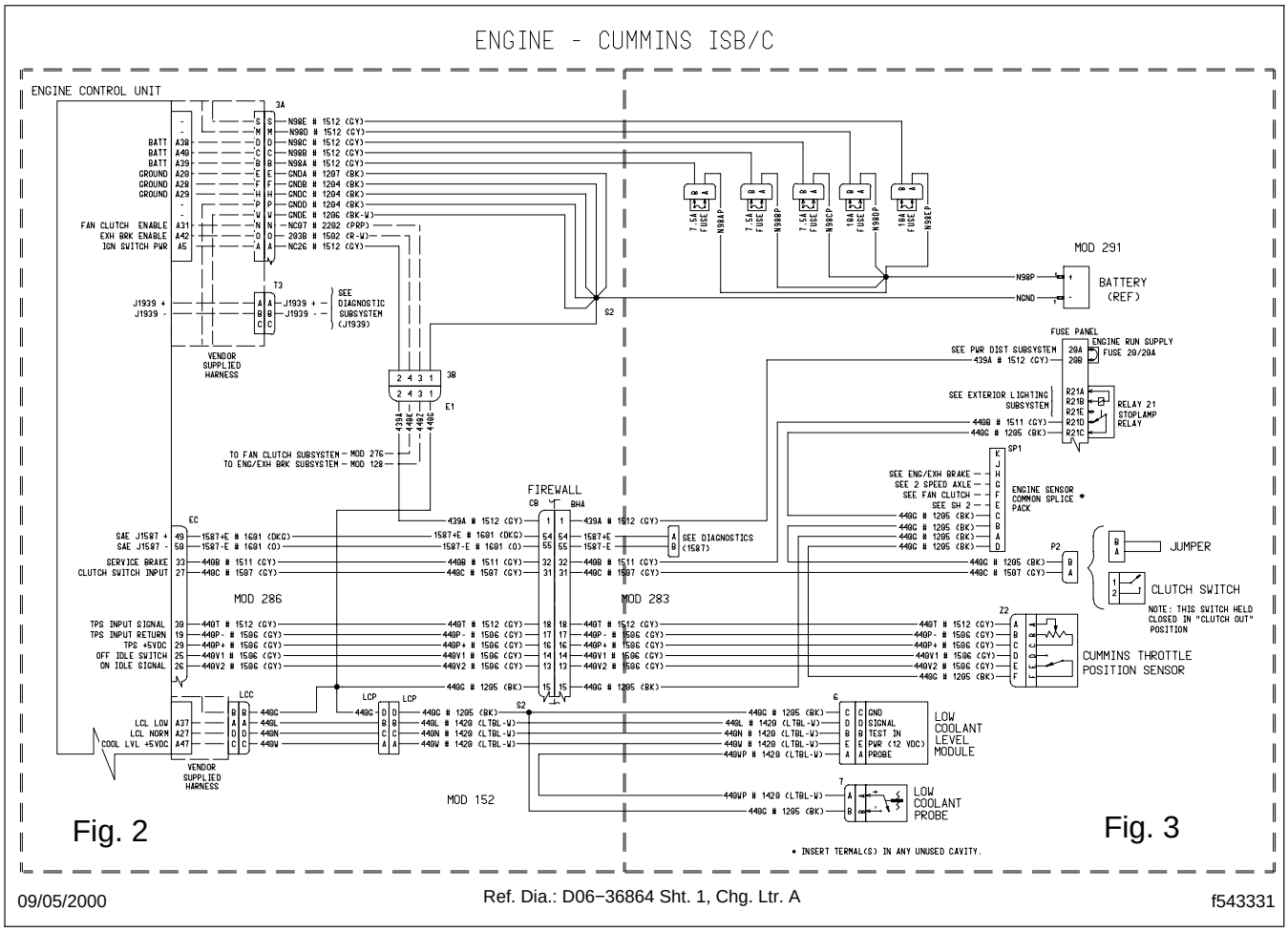


Fig. 1, Engine Wiring, Sheet 1 (full view)

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Specifications

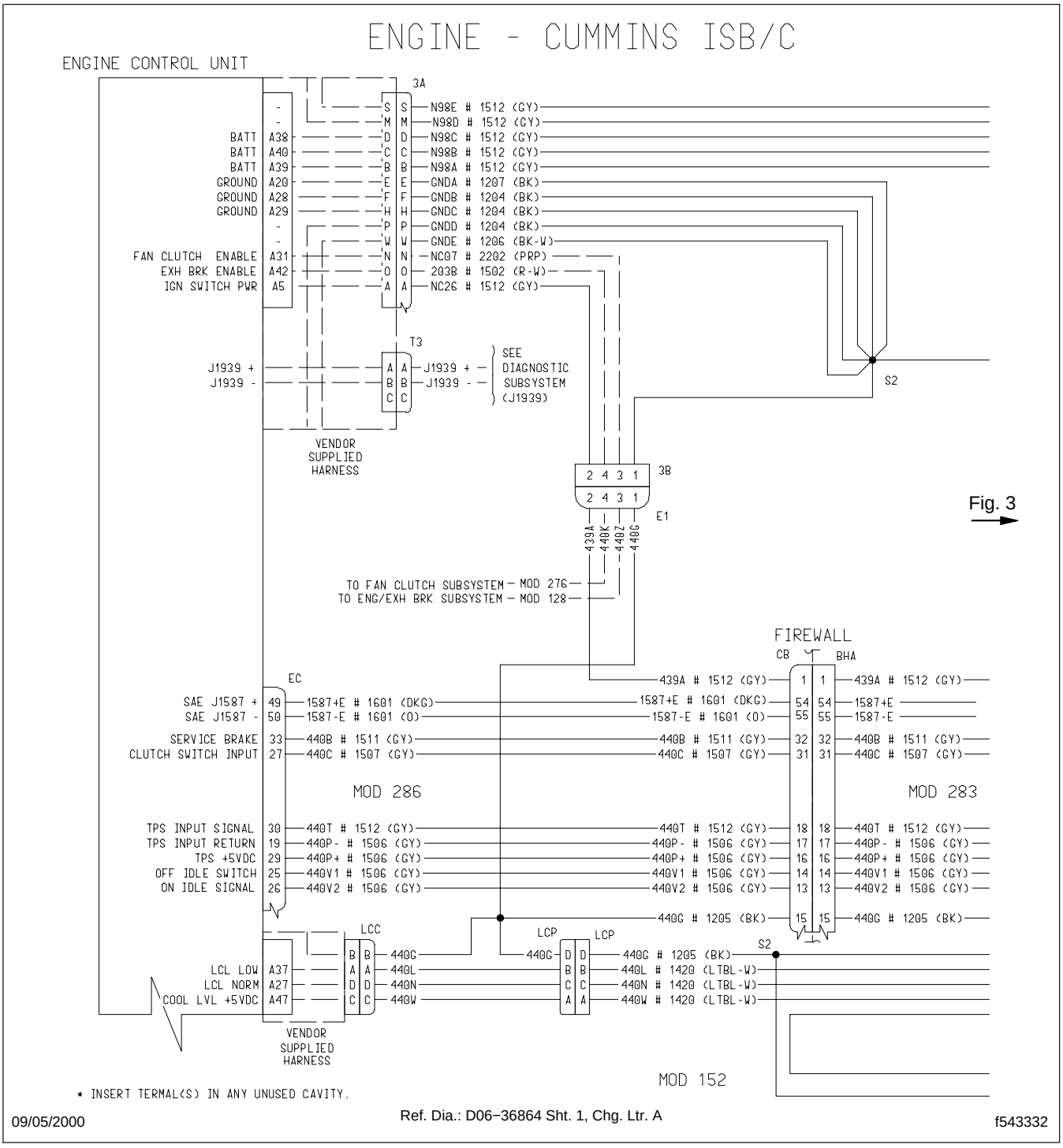


Fig. 2, Engine Wiring, Sheet 1 (partial view)

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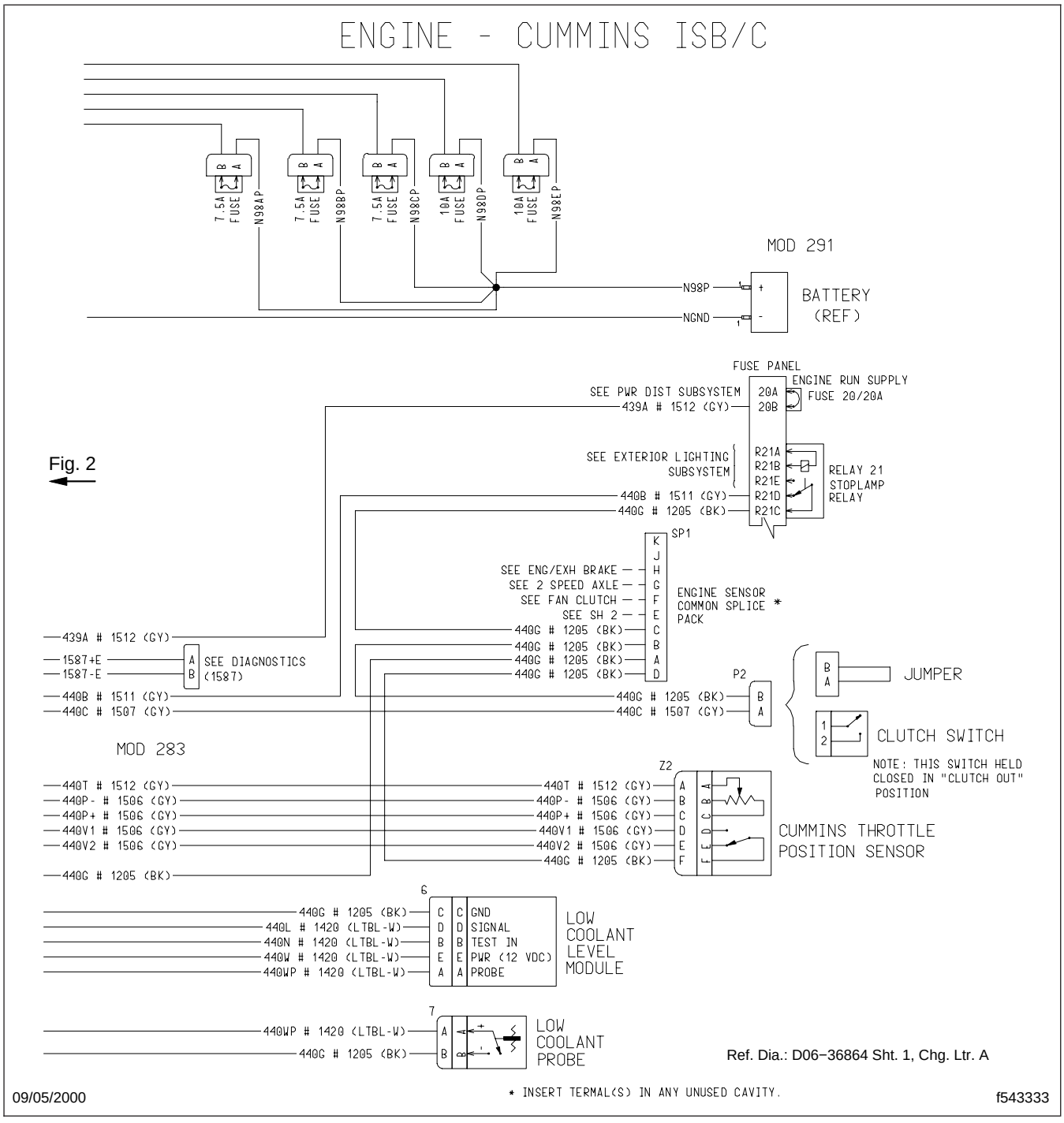


Fig. 2

Fig. 3, Engine Wiring, Sheet 1 (partial view)

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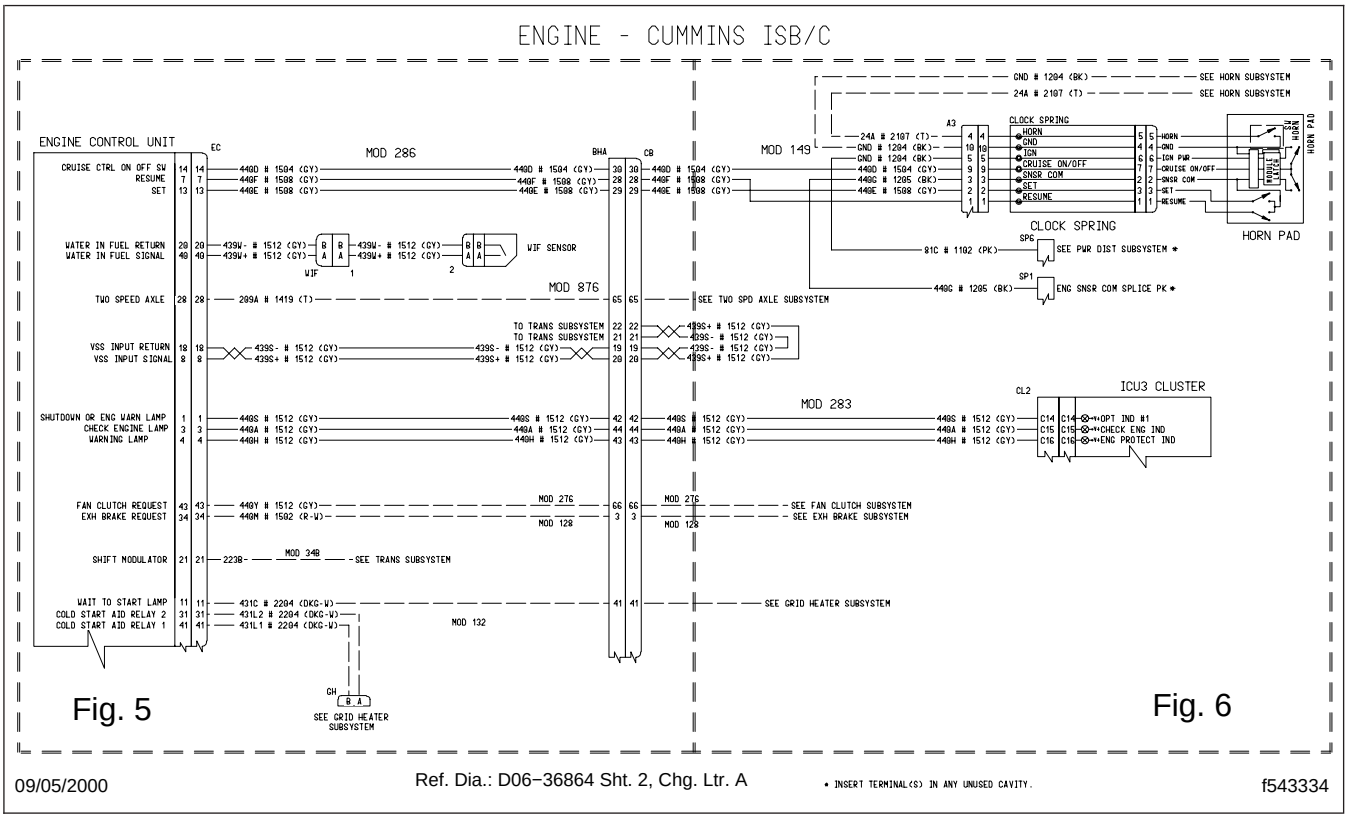


Fig. 4, Engine Wiring, Sheet 2 (full view)

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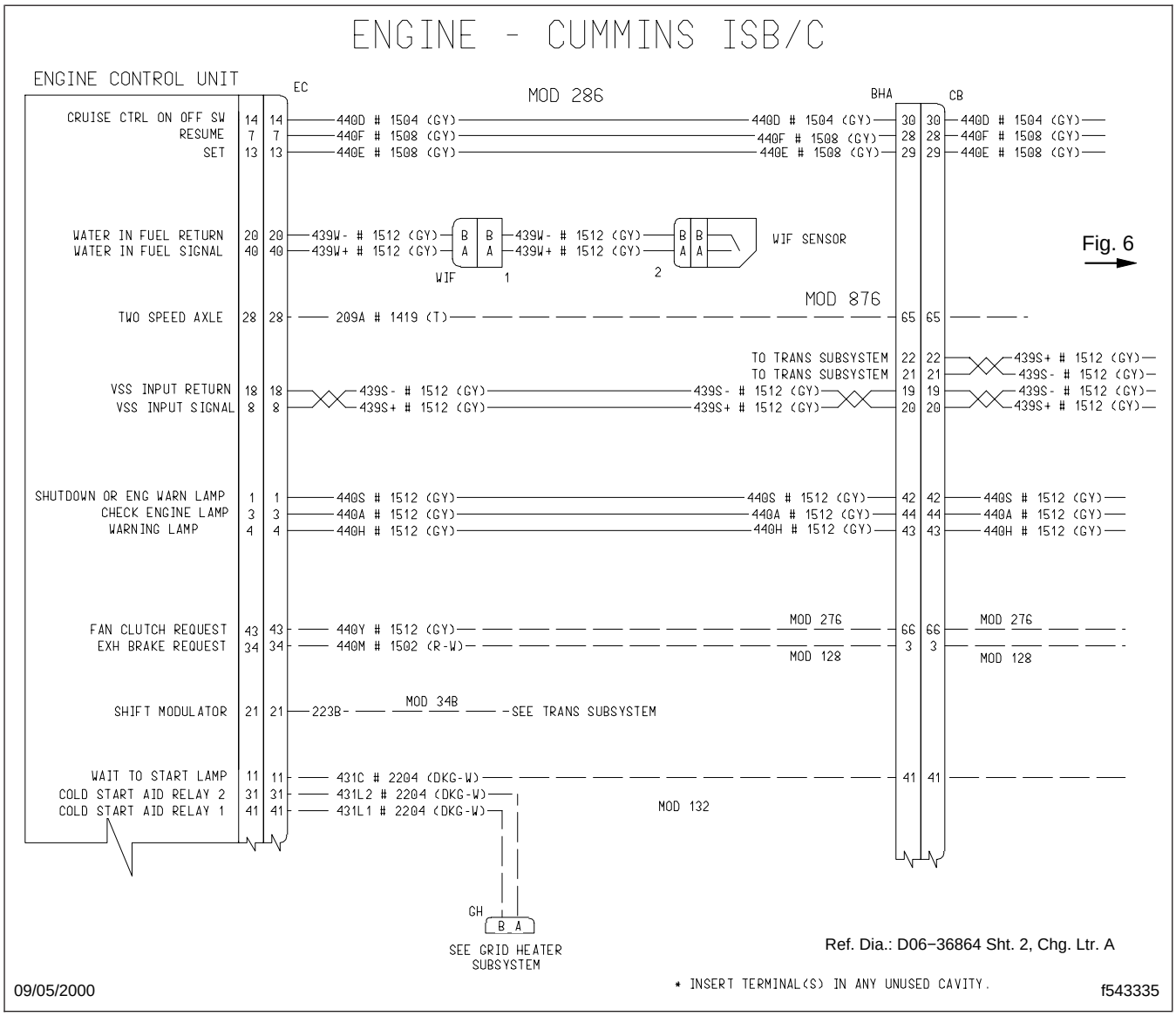


Fig. 5, Engine Wiring, Sheet 2 (partial view)

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Specifications

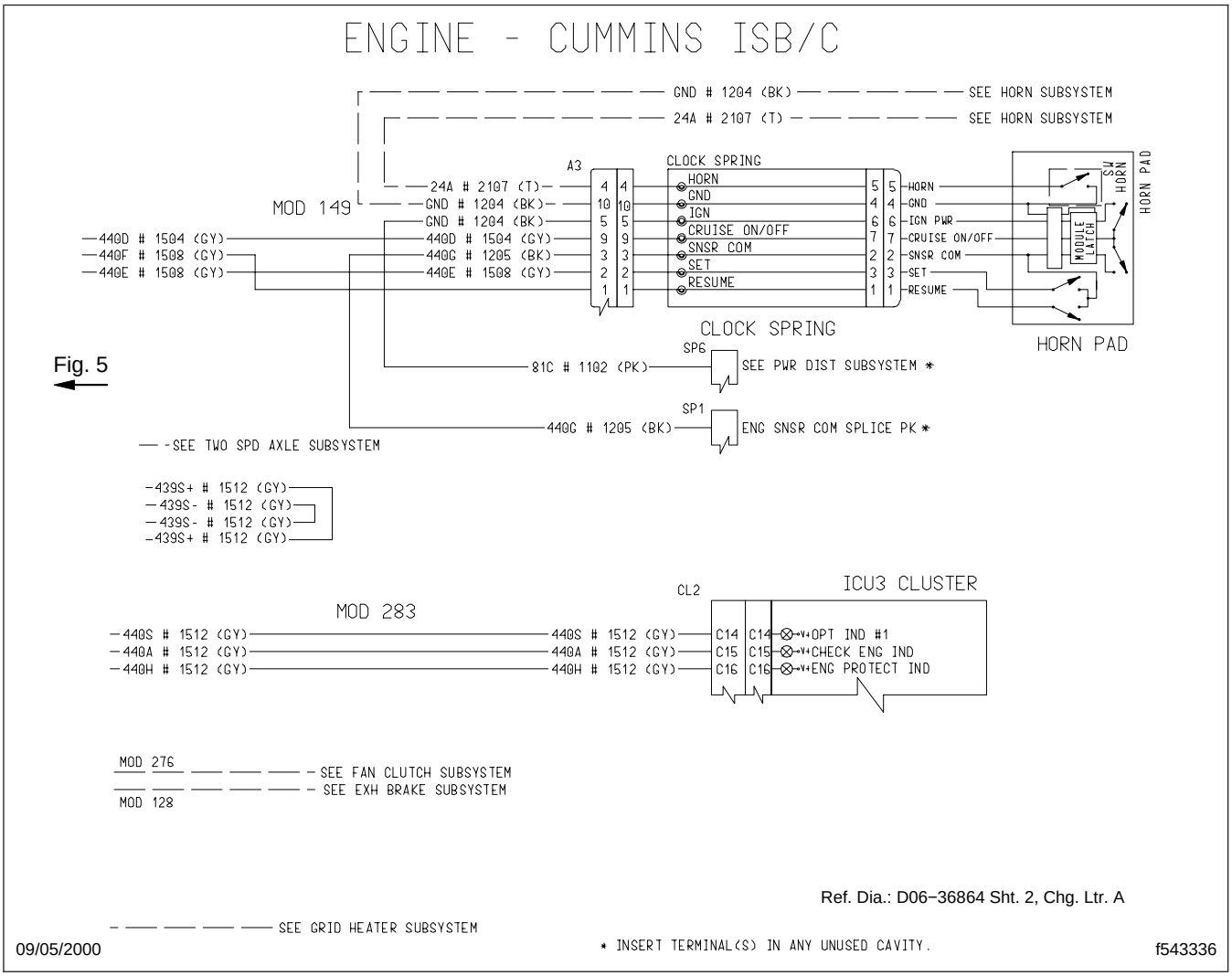


Fig. 6, Engine Wiring, Sheet 2 (partial view)

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General Information

A "datalink" is an electrical network that connects two or more computers to exchange data. The simplest datalink is a pair of wires between two computers. Freightliner uses datalinks to connect the Electronic Control Units (ECUs) for the electronically controlled vehicle systems with each other and with the Instrumentation Control Unit (ICU). A personal computer using Freightliner's ServiceLink diagnostic software can also be connected to the network via a datalink.

Datalink Systems

Different types of datalinks are used to connect certain ECUs. The vehicle may have any of the following datalinks:

J1587/J1708

J1587/J1708 is a low speed vehicle datalink that communicates information between the ECUs on the vehicle. The J1587 datalink is also referred to as J1708. See **Fig. 1**. J1708 refers to the SAE standard for the physical part of the datalink, such as the wiring and the electronic components. J1587 refers to the SAE standard for the messaging protocol that communicates on the J1708 network. In the context of vehicle repair, the terms J1708 and J1587 are used interchangeably.

The J1587 datalink uses a twisted pair of wires to reduce interference from digital messages being sent on the wires. Wire colors for the J1587 datalink are:

- Orange **J1587 Low**
- Green **J1587 High**

J1939

J1939 is a high-speed vehicle datalink that communicates information between ECUs on the vehicle. See **Fig. 2**.

Unlike the J1587 datalink, the J1939 datalink allows an ECU to broadcast requests as well as information. Examples of information that can be communicated on the J1939 datalink are:

- engine rotational speed;
- road speed;
- transmission tailshaft speed;
- engine retarder deactivation request;
- engine torque reduction request.

The J1939 datalink uses a twisted pair of wires to reduce interference from digital messages being sent on the wires. Wire colors for the J1939 datalink are:

- Yellow **J1939 High**
- Green **J1939 Low**

The back bone of the J1939 datalink is the section of the datalink that is between two terminating resistors. An ECU can be connected anywhere along the length of the backbone in between the terminating resistors. The wiring between the ECU and the J1939 backbone is called a circuit. The maximum distance of the terminating resistor is 3 feet from the last ECU or diagnostic connector.

The purpose of the terminating resistors is to minimize the reflection of data on the datalink which can cause J1939 messages to become partially or completely lost. Terminating resistors prevent this from occurring. Each terminating resistor is 120 Ohms, but the equivalent of two 120 Ohms resistors in parallel is 60 Ohms. With both resistors installed in the circuit, there should be 60 Ohms measured at any two points between **J1939 High** and **J1939 Low** in the circuit.

Each ECU is generally connected to the J1939 backbone using a tee connector or splice. See **Fig. 3**.

Making the Pinout Measurements Easier to See

The pins on the diagnostic connector may be difficult to see when testing. If the pins are difficult to see, use a Y-cable as an extension to the diagnostic connector to make test measurements easier. See **Fig. 4** for a drawing of the connector at the end of the Y-cable and the corresponding 9-pin diagnostic connector pins.

NOTE: Be sure to attach a meter with a proper jumper kit to prevent unintentional shorting to other pins and possible damage to ECUs.

The Roll Call

To check the readiness of the ECUs on the datalink, the ICU sends a signal to other ECUs and expects a response from each. This "Roll Call" procedure tells the ICU which ECUs are functioning correctly. When

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General Information

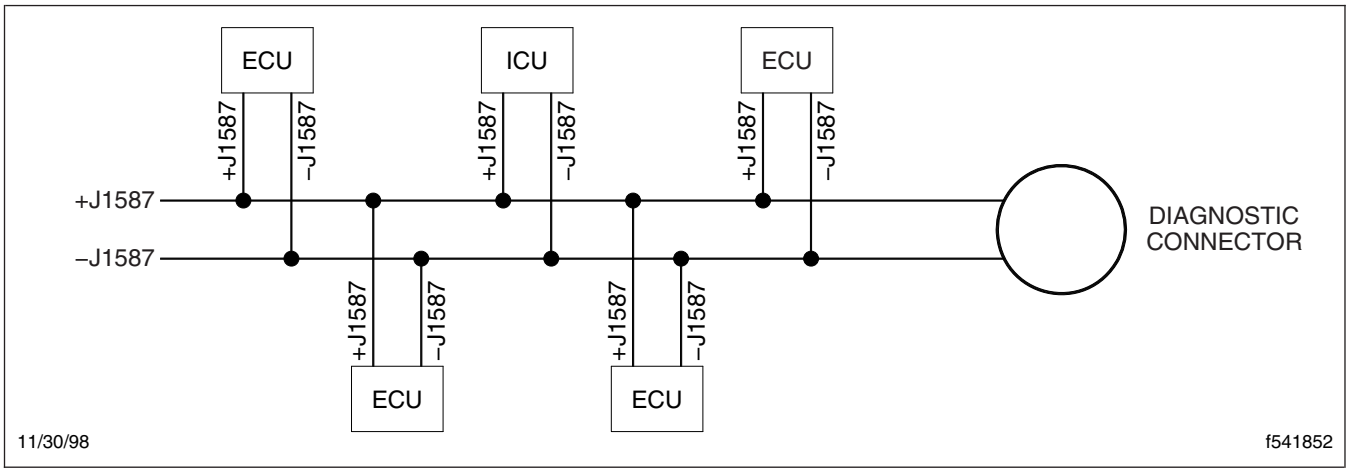


Fig. 1, J1587 Datalink

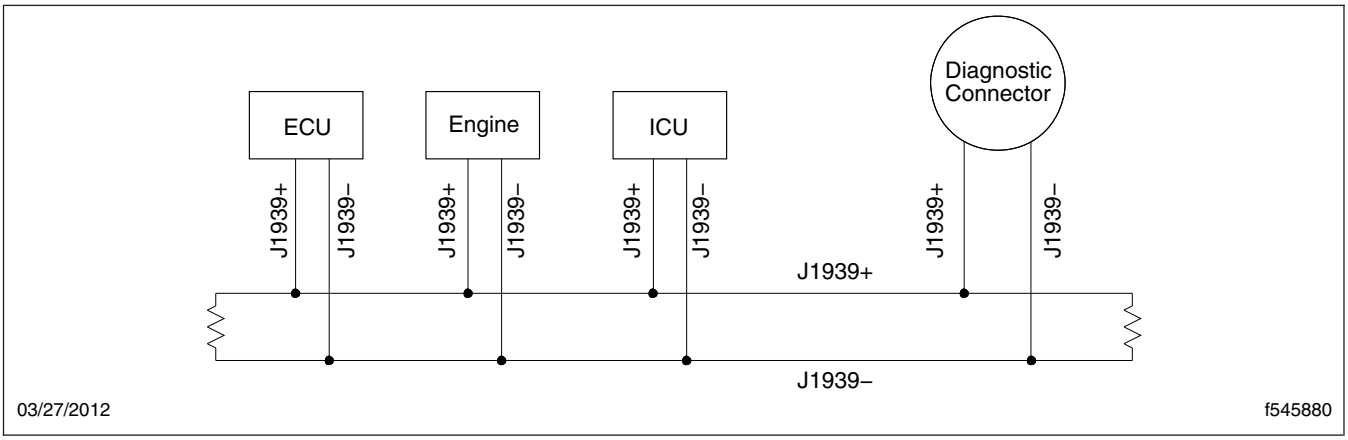


Fig. 2, J1939 Datalink

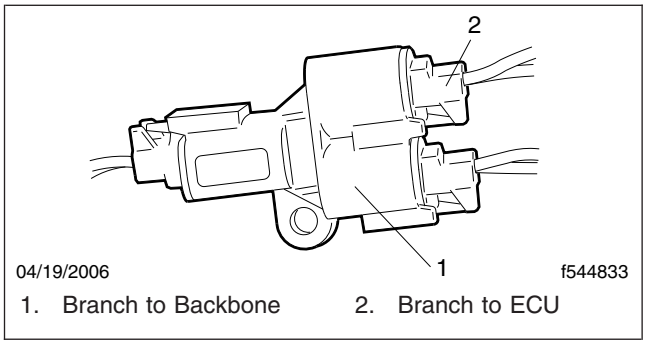


Fig. 3, J1939 Tee Connector

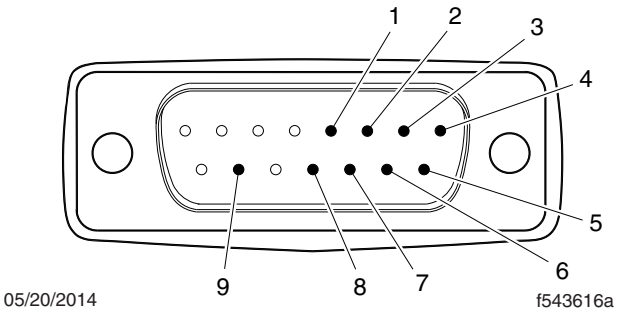
the list of functioning ECUs is compared against the parameter list of factory-installed ECUs that are supposed to respond, the technician can determine which ECUs or datalinks are bad.

If the ICU does not receive a signal on the datalink from one or more of the active ECUs, it displays a roll call fault. The roll call fault is displayed *only* on the dash driver display screen. It is not broadcast on the datalink; therefore, it cannot be read by Service-Link. However, Servicelink can be used to determine if an ECU is not responding because it polls all ECUs on the datalink when it first connects to the vehicle datalink.

Datalink Junction Blocks

For the J1587 datalink, the wires routed through the vehicle cab have two datalink junction blocks and two datalink connections. The ICU3 uses only one connection to the ICU.

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1. Pin H (Diagnostic CAN High)
2. Pin A
3. Pin E
4. Pin B
5. Pin F
6. Pin G
7. Pin C (J1939 High)
8. Pin D (J1939 Low)
9. Pin J (Diagnostic CAN Low)

Fig. 4, Y-Cable Pinouts

Locating J1939 Wiring Diagrams

The J1939 wiring diagram can be found in module 160. Other modules may also contain datalink wiring information. See **Table 1**.

Use PartsPro® to obtain drawing numbers for installation drawings, harness assembly drawings, and wiring diagrams applicable to the vehicle being worked on.

Component Module Locations	
Component	**Module Number**
General J1939 harness drawings, schematics, and installation drawings	160
Engine harness and installation drawings	283 and 286
Transmission harness and installation drawings	34A and 343
ABS harness and installation drawings	330, 332, and 333

Table 1, Component Module Locations

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Datalink Repairs

J1587 and J1922 Repairs

Use the same methods of repair for the twisted-pair datalink wiring as are used for the other wires on the vehicle. However, the datalink wires must be twisted at a rate of a minimum one turn per inch (25 mm) of length.

J1939 Repairs

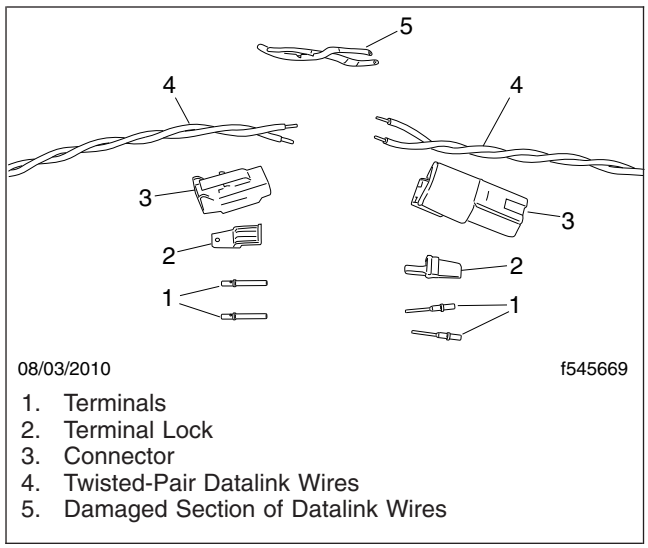
A special cable must be used for repairs to the J1939 datalink wiring. The two types of J1939 cable ("heavy" and "lite") can be spliced together as long as the pass-through connectors are the "heavy" type. The "lite" cable (because of its lower cost) is recommended for repairs on both types of J1939 cable. Refer to Appendix C of SAE J1939-11 for the special procedures for repairing the "heavy" J1939 datalink.

Parts

Twisted-pair datalink wires may be spliced using a mating connector set. See **Table 1** for a typical set of datalink connector parts.

Procedure

1. Cut out any damaged section of datalink wire, keeping the lengths of the two wires equal. See **Fig. 1** for an example of a damaged section of datalink wire that has been removed and the datalink prepared for repair.
2. Crimp the terminals onto the wires using the proper crimp tool.
3. Pull test the terminals by hand to ensure the crimp is mechanically solid.
4. Insert the terminated wires into the connector body and install the terminal lock. The protocol for J1939 is for the yellow wire to be in cavity 1 and the green wire to be in cavity 2. Note that the lock is installed while holding the wires in position. Test the installation. If the wires slipped back during the lock installation, they will pull out of the connector.
5. Make certain the wires are twisted as close to the entry point of the connector as possible. Plug the two connector halves together. See **Fig. 2**.



1. Terminals
2. Terminal Lock
3. Connector
4. Twisted-Pair Datalink Wires
5. Damaged Section of Datalink Wires

Fig. 1, Datalink Splice Parts

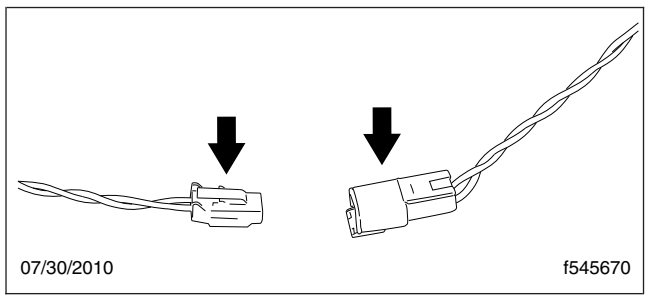


Fig. 2, Datalink Connectors

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Datalink Repairs

Datalink Connector Parts		
Description	**Part Number**	**Quantity**
Connector Body Plug	23-13148-204	1
Terminal Lock	23-13303-015	1
Terminals	23-13210-020	2
Connector Body Receptacle	23-13148-206	1
Terminal Lock	23-13303-013	1
Terminals	23-13210-030	2

Table 1, Datalink Connector Parts

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General Information

This Troubleshooting subject has three main parts:

- Troubleshooting Tables

  Use the Troubleshooting Tables to get ideas on what could be causing the problem and the possible remedies to that problem.

- Troubleshooting Procedures

  Follow the Troubleshooting Procedures section to isolate the areas that have faults and to know which tests to perform.

- Testing Procedures

  The Testing Procedures section has the individual tests and specifications needed to determine whether a part must be repaired or replaced.

NOTE: Be sure to attach a meter with a proper jumper kit to prevent unintentional shorting to other pins and possible damage to ECUs.

Troubleshooting Tables

Use the following troubleshooting tables to find remedies to possible causes of datalink problems.

Problem—Power-On Roll Call Reports Fault

Problem—Power-On Roll Call Reports Fault	
Possible Cause	**Remedy**
The ECU does not support roll call function (ICU1/2M only).	Reset the ECU parameter to disable roll call.
The datalink wiring has a fault.	Repair or replace the wiring.
Wrong power supply voltage or ground to ECU.	Replace the fuse or circuit breaker, charge the battery, the check connections.
The connector has a fault - (Pass-through, Branch, Diagnostic)	Repair or replace the wiring.
The ECU has a fault.	Replace the ECU.
The ICU has a fault.	Replace the ICU.
The terminating resistor for J1939 datalink is missing or has a fault.	Replace the terminating resistor.
The branch length is too long on J1939 datalink.	Shorten "lite" branch to less than 10 feet (3 m).
The battery is discharged or is bad.	Charge or replace the battery.

Problem—ServiceLink Will Not Connect

Problem—ServiceLink Will Not Connect	
Possible Cause	**Remedy**
ICU is older series that does not support roll call.	Use ICU for display of active fault codes only.
One or more ECUs has a fault.	Remove suspected ECUs one at a time until ServiceLink can be connected.
ServiceLink computer is not configured or connected correctly.	Check the computer settings, communication adaptor and cabling between the computer, communication adaptor, and diagnostic connector.
Connector types are different.	The J1939 datalink and new J1587 datalinks have 9-pin connectors. Connect an adapter or use the ICU for the diagnostics information display.
Battery is discharged, has a bad connection, or has a fault.	Charge, clean terminals, or replace battery.

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Troubleshooting

Problem—Missing Data on Datalink-Driven Gauges

Problem—Missing Data on Datalink-Driven Gauges *	
Possible Cause	**Remedy**
ICU or engine ECU is not communicating on datalink.	Test wiring and ICU or engine ECU.
Datalink wiring has a fault.	Test and repair wiring.
Connector or junction block has a fault.	Repair or replace connector.
Incorrect voltage to ECUs	Test datalink and vehicle wiring.

* Datalink-driven gauges include: engine oil pressure, coolant temperature, engine oil temperature, turbo air pressure, tachometer, speedometer

Troubleshooting Procedures

To find the part of the datalink system that is causing a problem, follow the Troubleshooting Procedures and refer to the appropriate Troubleshooting Tests for the test points and specifications. Perform the steps of the Troubleshooting Procedures in sequence until you locate the fault.

The seven steps to diagnosing a datalink problem are:

1. Determine which types of datalink are installed on the vehicle.

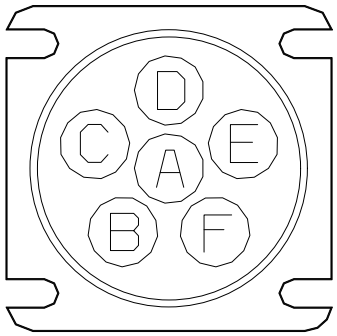
   1.1 Check the diagnostic connector. A 6-pin connector (or a 9-pin connector without pins C and D installed) is used for J1587 datalinks. See **Fig. 1** and **Fig. 2**. J1939 datalinks have pins C and D installed in the 9-pin diagnostics connector.

   1.2 Check the wires. J1939 cable has a heavy jacket. Note that some non-Freightliner ECUs have their J1587 wires inside a jacket as well. If all the wiring has a jacket, the datalink is a J1939 datalink.

   If the J1939 cable has a drain wire inside the shielding, it is a "heavy" cable. The J1939 "lite" cable (with no drain wire) can be spliced into a section of "heavy" cable.

   1.3 Determine whether a Cummins IS Series, Caterpillar CFE, or a Mercedes-Benz engine is installed with an ABS system that has traction control. These systems use a J1939 datalink.

   1.4 A J1939 datalink is used when an Eaton® Fuller® AutoShift transmission is installed. The WABCO EBS (brake-by-wire) system and certain Eaton VORAD EVT-300 systems also require J1939 datalinks. Certain other ECUs may require a J1939 datalink.



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1. Pin A (J1587 High)
2. Pin B (J1587 Low)
3. Pin C (12V+)
4. Pin D (Reserved)
5. Pin E (Ground)
6. Pin F (Reserved)

Fig. 1, J1587 6-Pin Diagnostics Connector

2. Determine which ECUs are not communicating with ServiceLink.

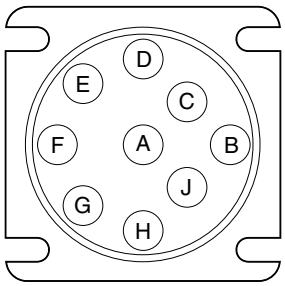
   2.1 Connect to the vehicle with ServiceLink

   2.2 Compare the ICU roll call list with ServiceLink ECU list.

   Note: Some ECUs cannot communicate with the ICU, but will appear on the ServiceLink parameter list. The ICU2L and ICU3 rollcall function is limited to the engine ECU and the ABS ECU.

   2.3 If an ECU is not communicating on the datalink, disconnect all the generic ECUs, one at a time, until no faults are displayed on the ICU screen or until ServiceLink

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NOTE: Pins C and D are not installed in the J1587 diagnostics connector.

1. Pin A Battery (Low)
2. Pin B Battery (High)
3. Pin C (J1939 High)
4. Pin D (J1939 Low)
5. Pin E (Shield)
6. Pin F (J1587 High)
7. Pin G (J1587 Low)
8. Pin H (Diagnostic CAN High)
9. Pin J (Diagnostic CAN LOW)

Fig. 2, J1939/J1587 9-Pin Diagnostics Connector

connects to the system. The last ECU to be disconnected before the successful ServiceLink connection is the one causing the problem.

3. Check the suspected ECU.
   - 3.1 Check the resistance and voltage at the ECU connectors. See **Testing the ECUs** in the datalink testing procedures section of this subject.
   - 3.2 Temporarily replace the ECU with an ECU known to be good. If the ICU (or ServiceLink) now lists that ECU, install a new ECU.
4. Check the wires and connectors from the ICU at the connector for the suspected faulty ECU. See **Testing the J1587 Datalink** or **Testing the J1939 Datalink** in the datalink testing procedures section of this subject.
   - 4.1 Check the power supply voltage.
   - 4.2 Check the data signal voltage.
   - 4.3 Check the continuity and resistance to ground. If the readings are outside the acceptable range and are found at several test points, suspect that the datalink has a fault.
5. Determine which branch includes the suspected faulty ECU. Find the connectors and junction blocks that are in series with the suspected faulty ECU.
6. Check the wiring between the branch connector and the ECU and the wiring from the ICU to the branch connector. See **Testing the J1587 Datalink** or **Testing the J1939 Datalink** in the datalink testing procedures section of this subject.
   - 6.1 Check power supply voltage.
   - 6.2 Check the data signal voltage.
   - 6.3 Check the continuity and resistance to ground.
7. Check the ICU. See **Testing the ICU** in the datalink testing procedures section of this subject.
   - 7.1 Check the voltages at the junction block to the ICU.
   - 7.2 Replace the ICU with an ICU known to be good.

Datalink Testing Procedures

The following procedures give the test points and specifications for checking the various types of datalinks, connectors, ECUs and ICUs. Refer to the datalink troubleshooting tables, and the datalink troubleshooting procedures, above, for information on when to test the particular parts of the datalink system.

Testing at the ECUs

1. Make sure that the vehicle battery is charged and the fuses and circuit breakers are good before testing the ECU connectors.
2. The keyswitch must be in the OFF position. Disconnect the ECU datalink circuit at the connector closest to the ECU. Turn the keyswitch to the ON position and check the voltage at the ECU harness connector. See **Table 1** for the acceptable results.
3. Connect the ECU to the datalink connector when the keyswitch is in the OFF position. Turn the keyswitch to the ON position for this test. Touch the probes of the digital multimeter (on the DC voltmeter scale) to the metal terminals of the ECU connector as shown in **Table 1** to test the ECU. Use the AC scale for the voltage tests if

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the multimeter will not display the rapidly changing DC voltage using the DC scale. If the test results are not within the range shown, replace the ECU and test again.

NOTE: Voltages in **Table 1** will be varying.

ECU Harness Voltage Tests		
J1587 aDatalink		
Meter (High) Probe	**Meter (Low) Probe**	**Acceptable Meter Reading (VDC)**
ECU Datalink High Terminal	ECU Datalink Low Terminal	1 to 4 VDC (1 to 3V on the AC Scale)
Battery Positive Post	ECU Datalink High Terminal	6 to 11 VDC *
	ECU Datalink – Terminal	9 to 13.5 VDC *
J1939 Datalink		
Diagnostics Pin C (J1939 High)	Diagnostics Pin D (J1939 Low)	.2 to 5 VDC (.1 to 4V on the AC Scale)
Diagnostics Pin B (BAT High)	Diagnostics Pin C	6 to 11 VDC*
	Diagnostics Pin D	9 to 13.5 VDC*

* If datalink wire connections are reversed, the results are reversed.

Table 1, ECU Harness Voltage Tests

Testing the J1587 Twisted-Pair Datalink

1. Make sure that all fuses and circuit breakers are in good condition.
2. Turn the keyswitch to the OFF position before disconnecting or connecting any part of the datalink system. Disconnect the J1587 connector for the datalink section you are testing.

IMPORTANT: Do NOT disconnect the datalink by disconnecting the engine, frontwall or chassis electrical connectors.

IMPORTANT: The batteries **MUST** be disconnected and the ignition must be **OFF** prior to any J1587 resistance tests. Failure to do so may result in inconclusive resistance measurements. The J1939 datalink is not completely inactive with only the ignition off. It may be active even if there appears to be no voltage on the the datalink.

3. Turn the keyswitch to the OFF position. Test the continuity of a J1587 twisted-wire pair by touching the red (positive) probe of a digital multimeter (set to the ohmmeter mode) to the **J1587 High** terminal of the connector. Connect the black (negative) probe to the J1587– wire terminal. See **Table 2** for the results.

   Check the datalink isolation to the vehicle ground by holding one ohmmeter probe on the **J1587 Low** wire and the other probe to a good ground. Perform this test again with the ohmmeter leads reversed. **Table 2** shows the acceptable resistances for these tests.

J1587 Resistance Tests		
Meter (High) Probe	**Meter (Low) Probe**	**Acceptable Meter Reading (Ohms)**
High	Low	1k to 30k Ohms
High	Vehicle Ground	More than 1k Ohms
Low	Vehicle Ground	More than 1k Ohms

Table 2, J1587 Resistance Tests

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4. Test the signal voltage on the J1587 twisted pair as shown in **Table 1**. The keyswitch must be in the ON position for the voltage tests. Use the AC scale for the voltage tests if your multimeter will not display the rapidly changing DC voltage using the DC scale.

NOTE: If any voltage reading is a steady 0 VDC or a steady 12 VDC, the ECU or datalink wiring has a fault.

Testing the J1939 Datalink

Use the following five basic steps in the order given to successfully locate J1939 datalink problems. Do not skip steps or tests unless directed to do so.

J1939 Resistance Test

This test checks whether or not both terminating resistors are installed, and ensures that there is a complete circuit from the diagnostic connector through the backbone loop. It does not ensure that branch circuits to each ECU are OK.

Tests in this subject are performed using a digital multimeter set to read ohms.

IMPORTANT: The batteries **MUST** be disconnected and the ignition must be **OFF** prior to any J1939 resistance tests. Failure to do so may result in inconclusive resistance measurements. The J1939 datalink is not completely inactive with only the ignition off. It may be active even if there appears to be no voltage on the the datalink.

1. Turn the ignition OFF and disconnect the batteries.
2. Connect the meter leads of a digital multimeter set to read ohms to pins C and D of the 9-pin diagnostic connector and measure the resistance.
3. Reconnect the batteries after the test is completed.

See **Table 3** for test results and possible causes.

J1939 Resistance Test	
Result	**Possible Cause**
60Ω ± 6Ω	The J1939 datalink backbone is intact and both terminating resistors are installed. Go to step 2.
120Ω ± 12Ω	Any of the following: • One of the terminating resistors is missing. • One of the terminating resistors is open. • The circuit may be open anywhere between the terminating resistors.
40Ω ± 4Ω	Three terminating resistors have been installed; one must be removed. There must be one terminating resistor at each end of the backbone for a total of two.
0Ω to 5Ω	**J1939 High** and **J1939 Low** have shorted together somewhere in the system.
Greater than 1000Ω	The most likely cause is an open circuit between the diagnostic connector and the J1939 backbone. It may also be that both terminating resistors are missing or open.
Any other readings	Any of the following: • Incorrect terminating resistor resistance. • Poor or corroded connections. • Short circuit to ground or an open circuit somewhere on the datalink. Go to step 2 to pinpoint the problem.

Table 3, J1939 Resistance Test

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ECU Communication Test

The following series of tests check for communication with each ECU connected to the J1939 datalink. If one fails to communicate, pinpoint whether the problem is wiring or an ECU. If all ECUs communicate as they should, J1939 is probably not the problem.

1. **Check whether each ECU connected to the J1939 datalink responds.**

   1.1 Connect the computer to the diagnostic connector.

   1.2 Start the J1939 Datalink Monitor template.

   NOTE: The template contains instructions on its use.

   1.3 Check whether each ECU that is supposed to be connected to the datalink responds. See **Table 4** for test results and possible causes.

Check whether each ECU connected to the J1939 datalink responds	
Result	**Possible Cause**
All ECUs respond	The J1939 datalink is probably not the problem.
One ECU fails to respond.	Go to step 2.
No ECUs respond	Possible explanations are: • The **J1939 High** and **J1939 Low** pinouts may be reversed at the diagnostic connector, or at any other connector in the system. Check their polarity. • There may be a problem with the PC to vehicle interface. • The entire datalink may be down due to a short to power or short to ground. Go to Step 3 to pinpoint the problem.

Table 4, Check Whether Each ECU Connected to the J1939 Datalink Responds

2. **Check the J1939 datalink wiring to the ECU that does not respond.**

   IMPORTANT: The batteries **MUST** be disconnected and the ignition must be **OFF** prior to any J1939 resistance tests.

   2.1 Turn the ignition OFF and disconnect the batteries.

   2.2 Locate the connector at the ECU in Step 2, Test 1 that did not respond and disconnect it.

   2.3 Locate the pins for **J1939 High** and **J1939 Low**. Refer to Freightliner or component supplier literature or wiring diagrams for the specific component.

   2.4 Check to make sure that **J1939 High** and **J1939 Low** polarity is correct at the component before proceeding. If not, this is the most likely problem.

   2.5 Using a digital multimeter set to read ohms, measure the resistance across the two J1939 datalink pins at the connector to the suspect ECU.

   2.6 Reconnect the batteries after the test is completed. See **Table 5** for test results and possible causes.

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Check the J1939 datalink wiring to the ECU that does not respond	
Result	**Possible Cause**
60Ω ± 6Ω	The datalink itself is probably not the problem. Make sure that any changeable J1939 parameters for this ECU are set correctly before proceeding. Also, make sure that there is power and ground to the suspect ECU. Go to **step 3** once the following have been confirmed: • J1939 parameters for the ECU (if they can be changed) are correct. • There is power and ground to the suspect ECU.
Not 60Ω ± 6Ω	There is a problem with the J1939 wiring between the ECU connector and its connection to the J1939 backbone. Repair as necessary.

Table 5, Check the J1939 Datalink Wiring to the ECU That Does Not Respond

3. **Install a test ECU to confirm the problem.**
   - 3.1 Install a test ECU and make sure that all J1939 parameters (if changeable) are set correctly.
   - 3.2 Using the J1939 Datalink Monitor template, check to see if every ECU that is supposed to be connected to the datalink responds. See **Table 6** for test results and possible causes.

Install a test ECU to confirm the problem	
Result	**Possible Cause**
All ECUs respond	The ECU was faulty and the test ECU confirmed this. Replace the ECU.
The ECU still does not respond.	The problem has not been confirmed. Carefully repeat all the diagnostics. If the ECU still does not respond, contact your District Service Manager or the ECU supplier directly for assistance.

Table 6, Install a Test ECU to Confirm the Problem

Test J1939 Voltage for Circuit Faults (Shorts to Power and Ground)

These tests check for shorts to power and shorts to ground on the J1939 datalink.

NOTE: All tests are performed using a digital multimeter set to read voltage.

NOTE: Before proceeding, verify that battery voltage (approximately +12 VDC) is available at pin B of the diagnostic connector. With the ignition ON, use a digital multimeter to test for voltage at pin B by placing the red (+) lead on pin B and the black (-) lead on a good chassis ground.

1. **Test J1939 High for shorts to power and ground.**
   - 1.1 Turn the ignition ON.
   - 1.2 Touch the red (+) lead to pin B (+12 VDC) and the black (-) lead to pin C (**J1939 High**) of the diagnostic connector. See **Table 7** for test results and possible causes.

Shorts to Power and Ground (J1939 High)	
Result	**Possible Cause**
0 VDC	**J1939 High** is shorted to power. Continue to the next test, "Pinpointing Short Circuits on the J1939 Datalink."

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Troubleshooting

Shorts to Power and Ground (J1939 High)	
Result	**Possible Cause**
12 VDC (battery voltage)	**J1939 High** is shorted to ground. Continue to the next test, "Pinpointing Short Circuits on the J1939 Datalink."
Any other reading	**J1939 High** is not shorted to power or ground. Go to step 2.

Table 7, Shorts to Power and Ground (J1939 High)

2. **Test J1939 Low for shorts to power and ground.**

   2.1 Turn the ignition ON.

   2.2 Touch the red (+) lead to pin B (+12 VDC) and the black (-) lead to pin D (**J1939 Low**) of the diagnostic connector. See **Table 8** for test results and possible causes.

Shorts to Power and Ground (J1939 Low)	
Result	**Possible Cause**
0 VDC	**J1939 Low** is shorted to power. Continue to the next test, "Pinpointing Short Circuits on the J1939 Datalink."
12 VDC (battery voltage)	**J1939 Low** is shorted to ground. Continue to the next test, "Pinpointing Short Circuits on the J1939 Datalink."
Any other reading	**J1939 Low** is not shorted to power or ground. There may be a problem with the vehicle to computer interface. The datalink itself appears to be OK.

Table 8, Shorts to Power and Ground (J1939 Low)

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Databus Quick Test

NOTE: All voltages in **Table 1**, except for BAT + and BAT – will be varying.

Databus Quick Test				
No.	**Test**	**Red Lead/Black Lead**	**Specification**	**Result**
Battery Connected – Ignition ON				
1	Bat+ to Bat-	Pin B to Pin A	Source Voltage (> 12.4)	
2	J1587+ to J1587–	Pin F to Pin G	1 – 5 VDC (0 – 4 VAC)	
3	Bat+ to J1587+	Pin B to Pin F	6 – 11 VDC	
4	Bat+ to J1587–	Pin B to Pin G	9 – 13.5 VDC	
5	J1939+ to J1939–	Pin C to Pin D	.2 – 5 VDC (.1 – 4 VAC)	
6	Bat+ to J1939+	Pin B to Pin C	6 – 11 VDC	
7	Bat+ to J1939–	Pin B to Pin D	9 – 13.5 VDC	
Ignition OFF – Battery Disconnected at Batteries – NOT Cab Load Disconnect Switch				
8	J1587+ to J1587–	Pin F to Pin G	1k – 30k Ohms	
9	J1587+ to Bat–	Pin F to Pin A	> 1k Ohms	
10	J1587- to Bat–	Pin G to Pin A	> 1k Ohms	
11	J1939+ to J1939–	Pin C to Pin D	55 – 65 Ohms	
12	J1939+ to Bat–	Pin C to Pin A	> 1k Ohms	
13	J1939- to Bat–	Pin D to Pin A	> 1k Ohms	
14	Terminating Resistors	—	110 – 130 ohms	

Table 1, Databus Quick Tests

NOTE: J1939 tests can also be performed on Diagnostic CAN High – Pin H, and Diagnostic CAN Low – Pin J for similar results.

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See **Fig. 1** for a full view of J1587 diagnostics wiring.

See **Fig. 2** and **Fig. 3** for partial views of J1587 diagnostics wiring.

See **Fig. 4** for a full view of J1939 diagnostics wiring with a Caterpillar™ or Cummins engine without the Eaton® AutoShift transmission.

See **Fig. 5** and **Fig. 6** for partial views of J1939 diagnostics wiring with a Caterpillar or Cummins engine without the Eaton AutoShift transmission.

See **Fig. 7** for a full view of J1939 diagnostics wiring with a Caterpillar or Cummins engine with the Eaton AutoShift transmission.

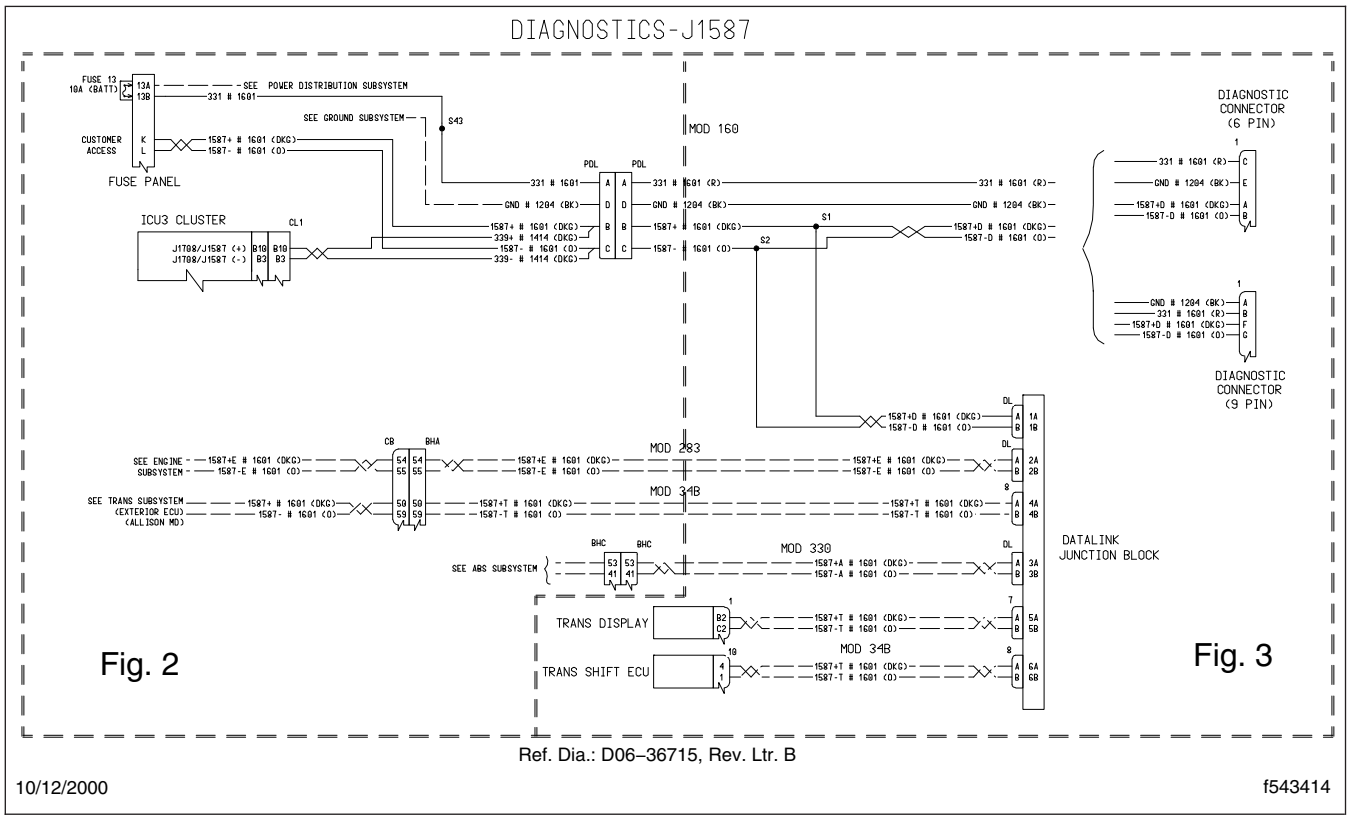
See **Fig. 8** and **Fig. 9** for partial views of J1939 diagnostics wiring with a Caterpillar or Cummins engine with the Eaton AutoShift transmission.

See **Fig. 10** for a full view of J1939 diagnostics wiring with the Mercedes-Benz MBE900 engine without the Allison electronic transmission.

See **Fig. 11** and **Fig. 12** for partial views of J1939 diagnostics wiring with the Mercedes-Benz MBE900 engine without the Allison electronic transmission.

See **Fig. 13** for a full view of J1939 diagnostics wiring with the Mercedes-Benz MBE900 engine with the Allison electronic transmission.

See **Fig. 14** and **Fig. 15** for partial views of J1939 diagnostics wiring with the Mercedes-Benz MBE900 engine with the Allison electronic transmission.



Ref. Dia.: D06–36715, Rev. Ltr. B

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Fig. 1, J1587 Diagnostics Wiring (full view)

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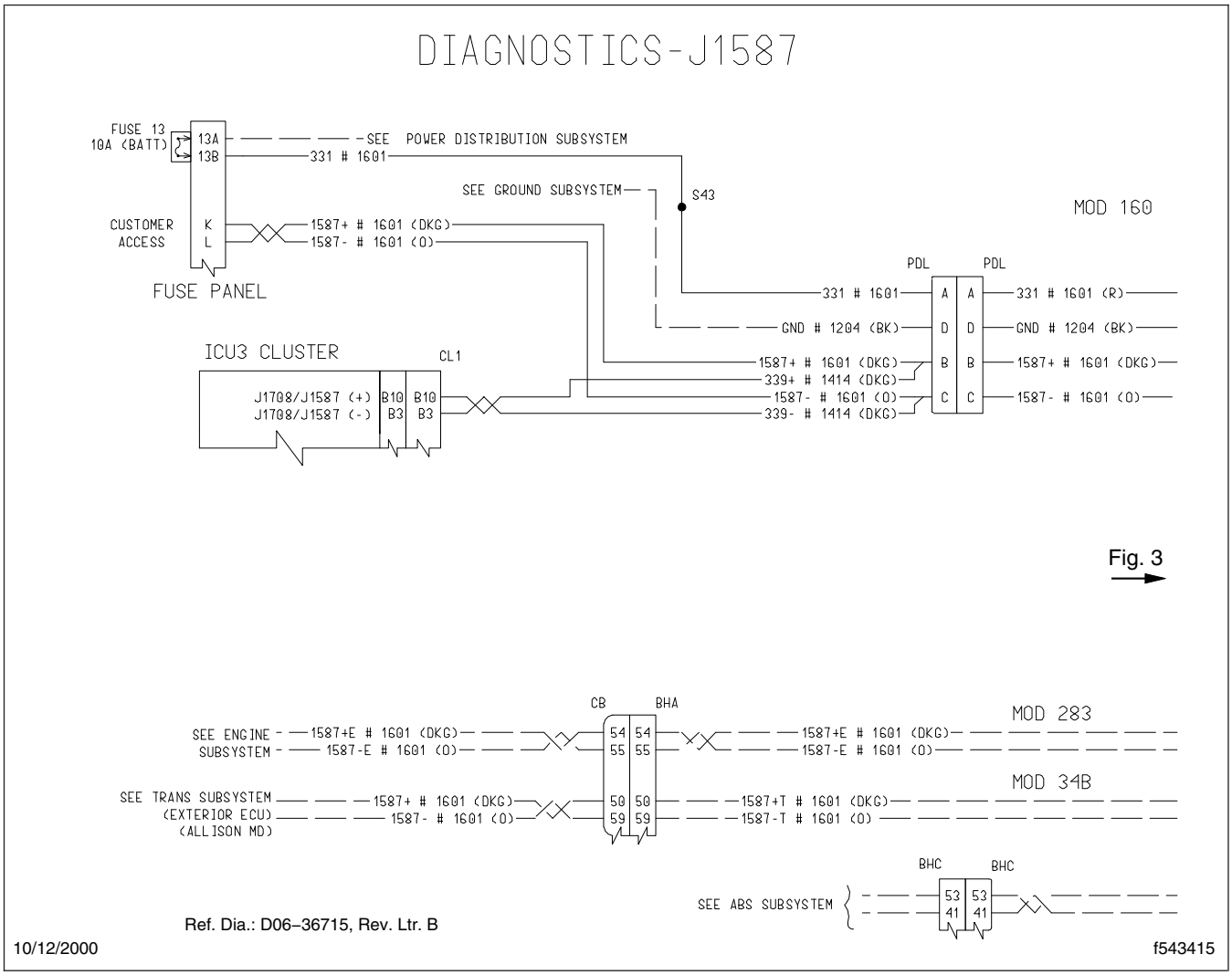


Fig. 2, J1587 Diagnostics Wiring (partial view)

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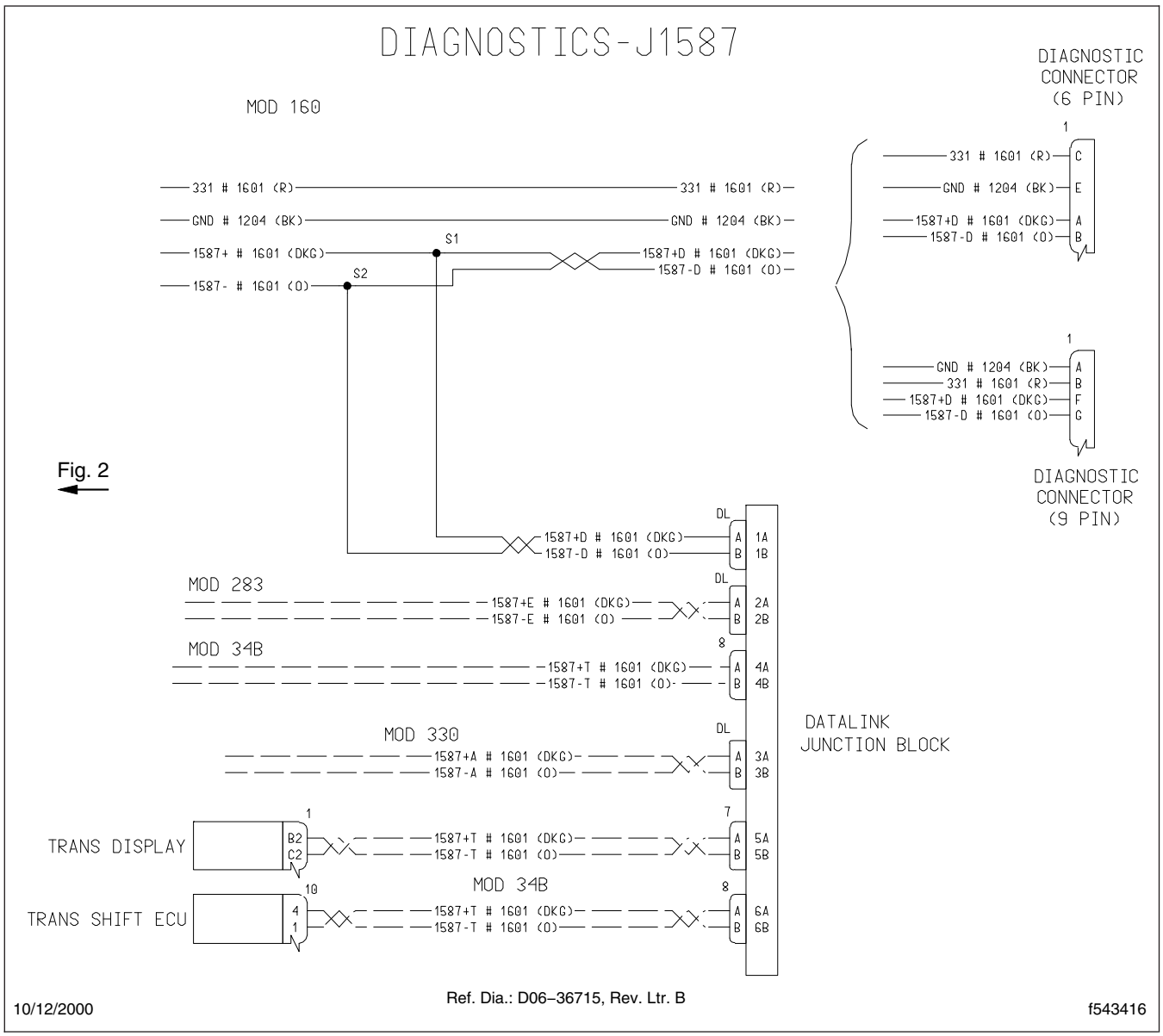
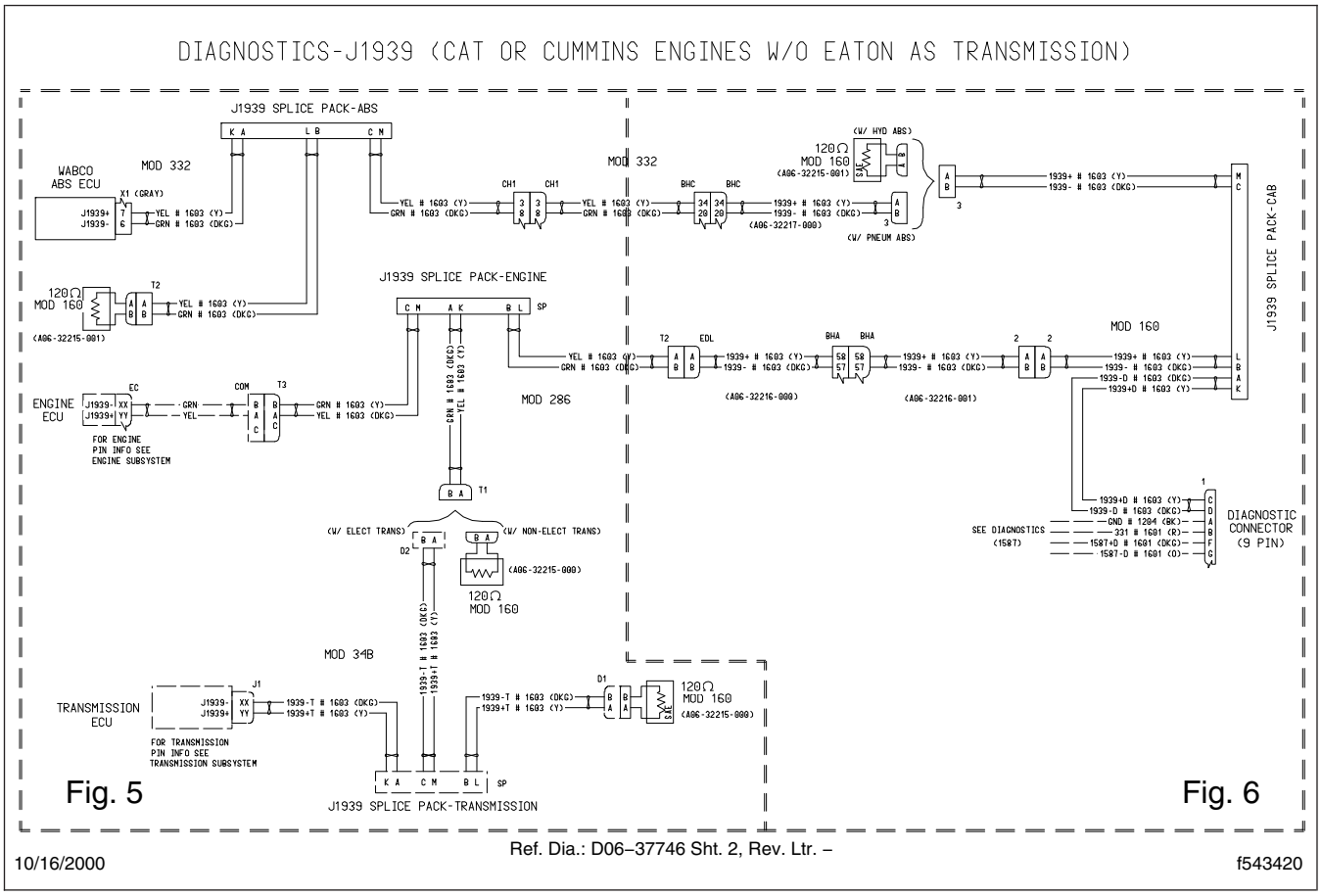


Fig. 3, J1587 Diagnostics Wiring (partial view)

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Fig. 4, J1939 Diagnostics Wiring With Caterpillar or Cummins Engine Without Eaton AutoShift Transmission (full view)

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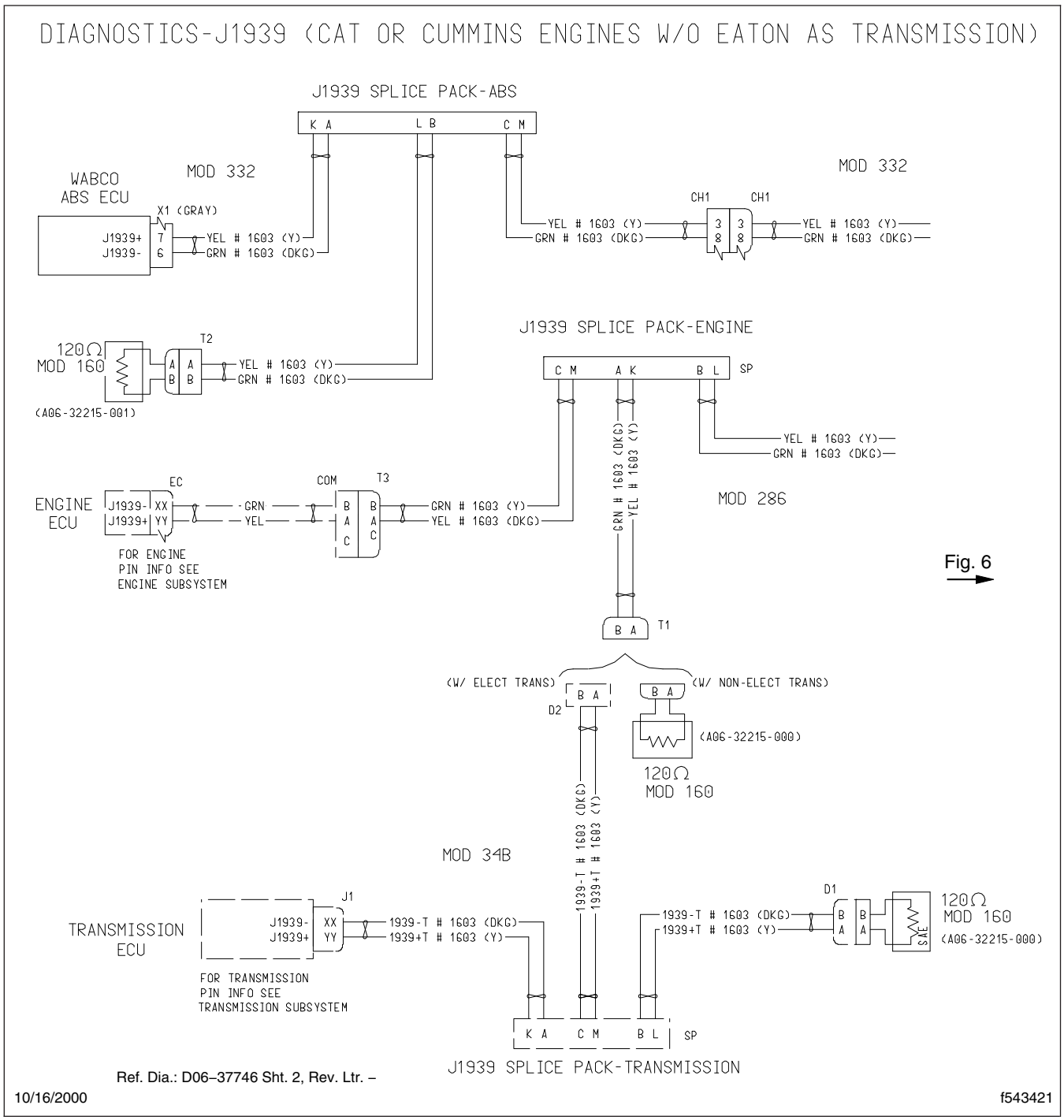


Fig. 5, J1939 Diagnostics Wiring With Caterpillar or Cummins Engine Without Eaton AutoShift Transmission (partial view)

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Specifications

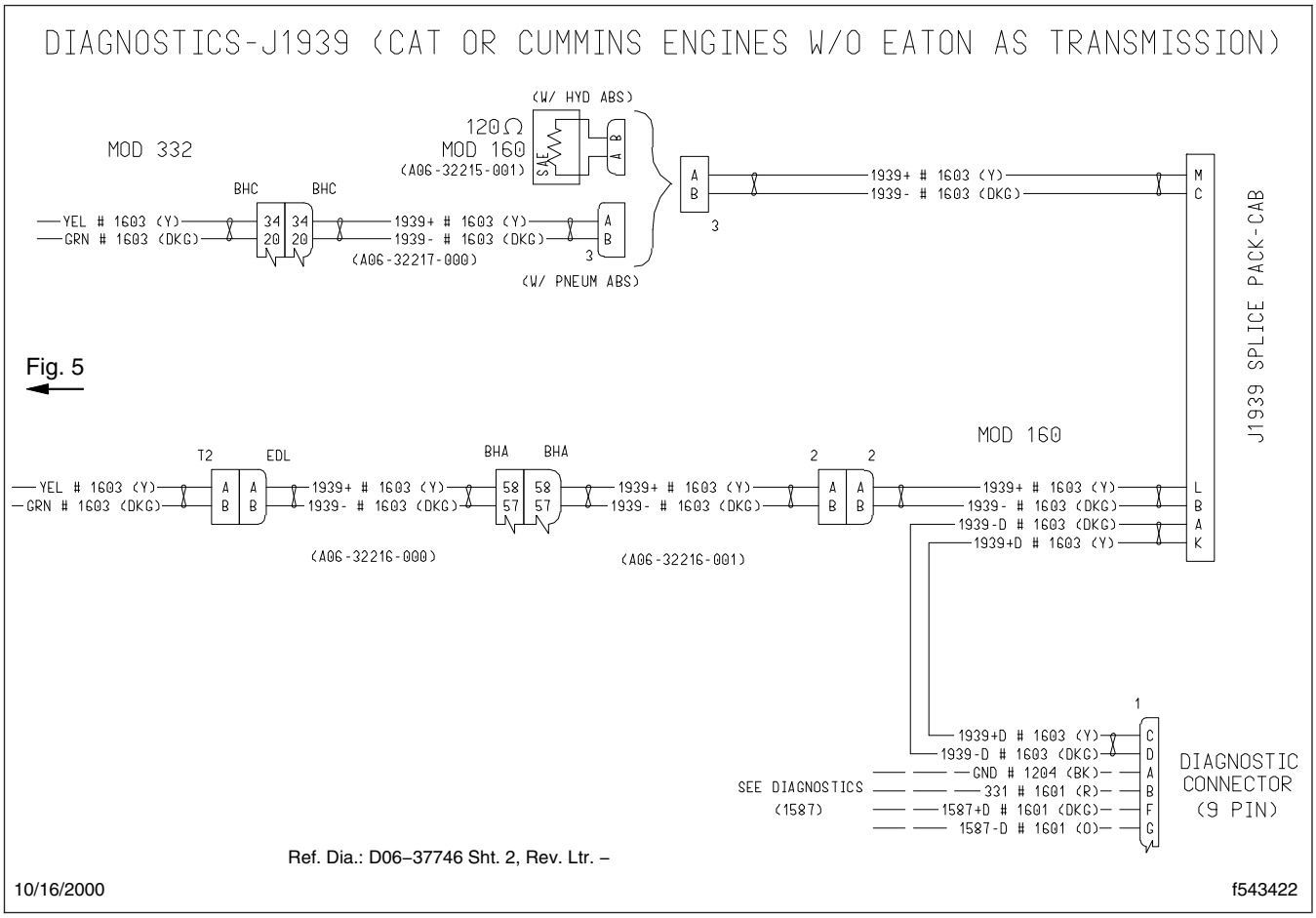


Fig. 6, J1939 Diagnostics Wiring With Caterpillar or Cummins Engine Without Eaton AutoShift Transmission (partial view)

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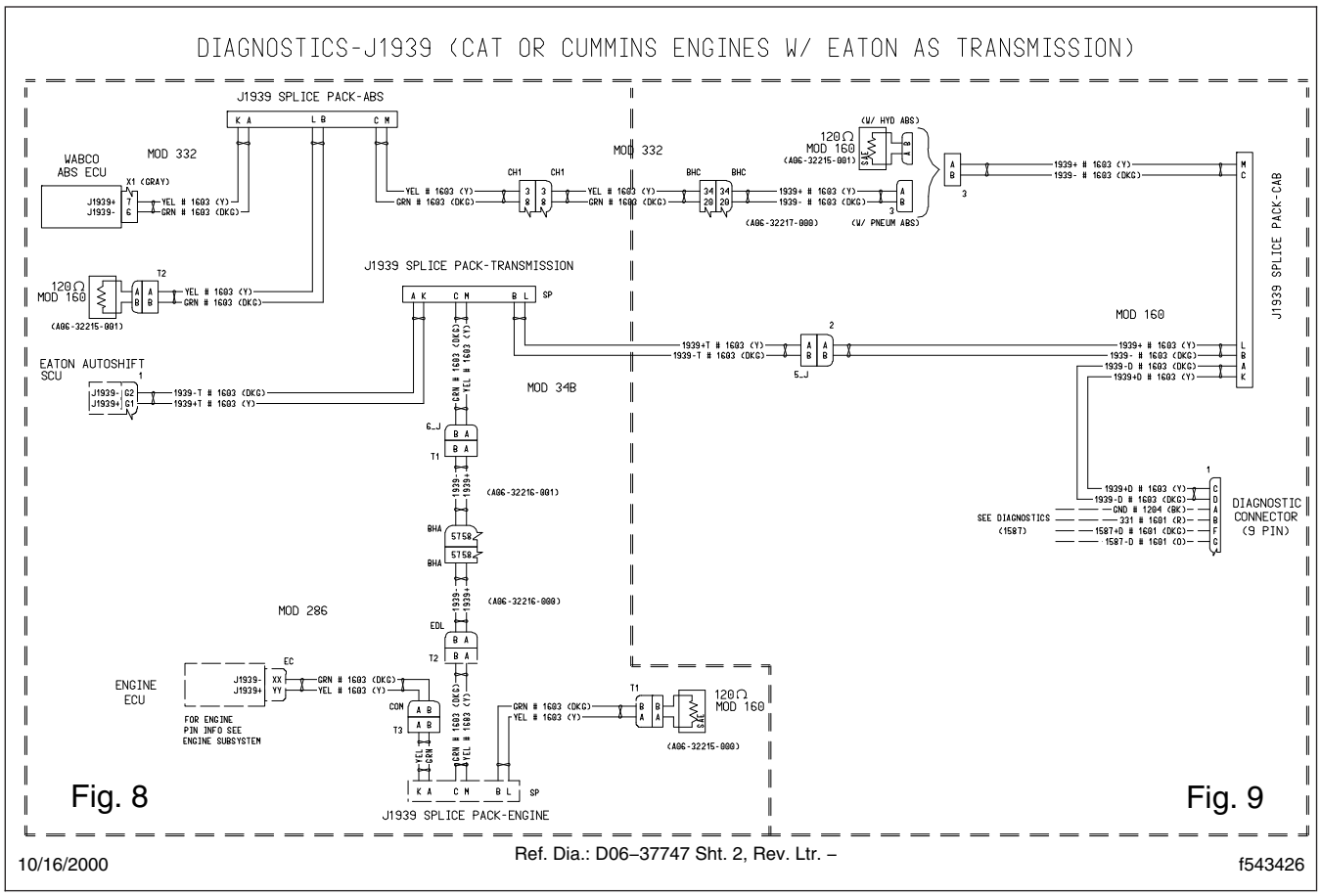


Fig. 7, J1939 Diagnostics Wiring With Caterpillar or Cummins Engine With Eaton AutoShift Transmission (full view)

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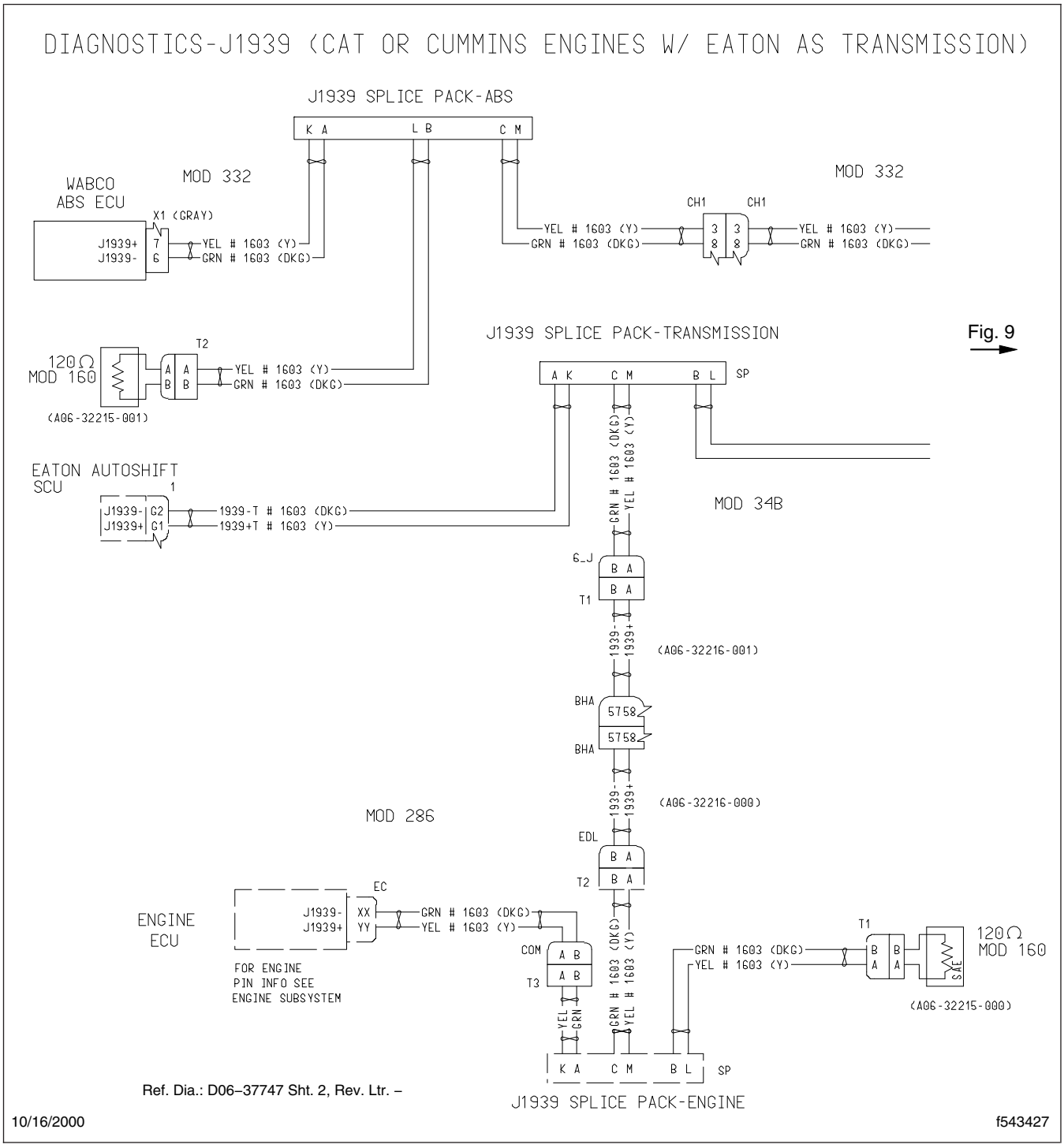


Fig. 8, J1939 Diagnostics Wiring With Caterpillar or Cummins Engine With Eaton AutoShift Transmission (partial view)

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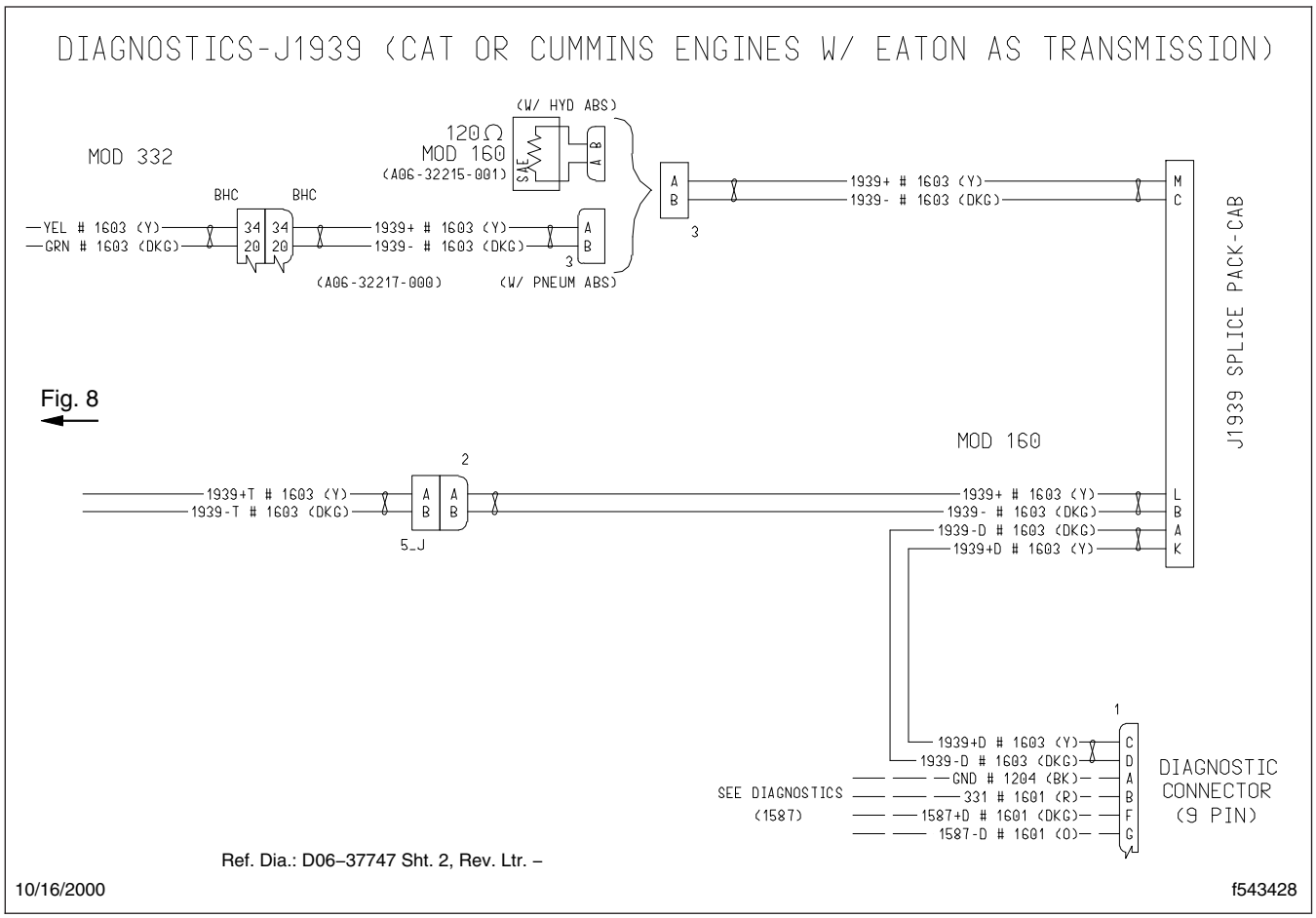


Fig. 9, J1939 Diagnostics Wiring With Caterpillar or Cummins Engine With Eaton AutoShift Transmission (partial view)

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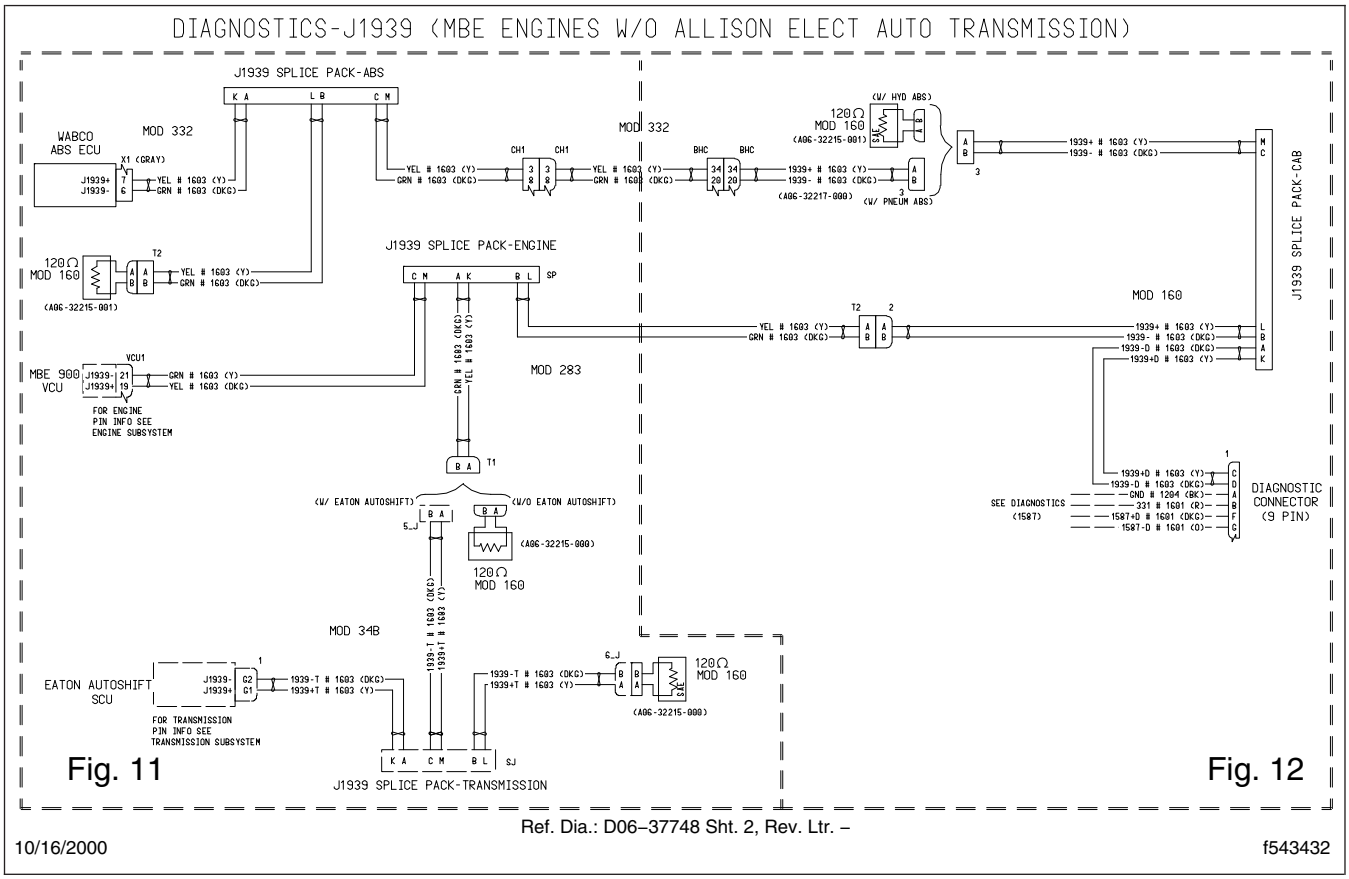


Fig. 10, J1939 Diagnostics Wiring With Mercedes-Benz MBE900 Engine Without Allison Electronic Transmission (full view)

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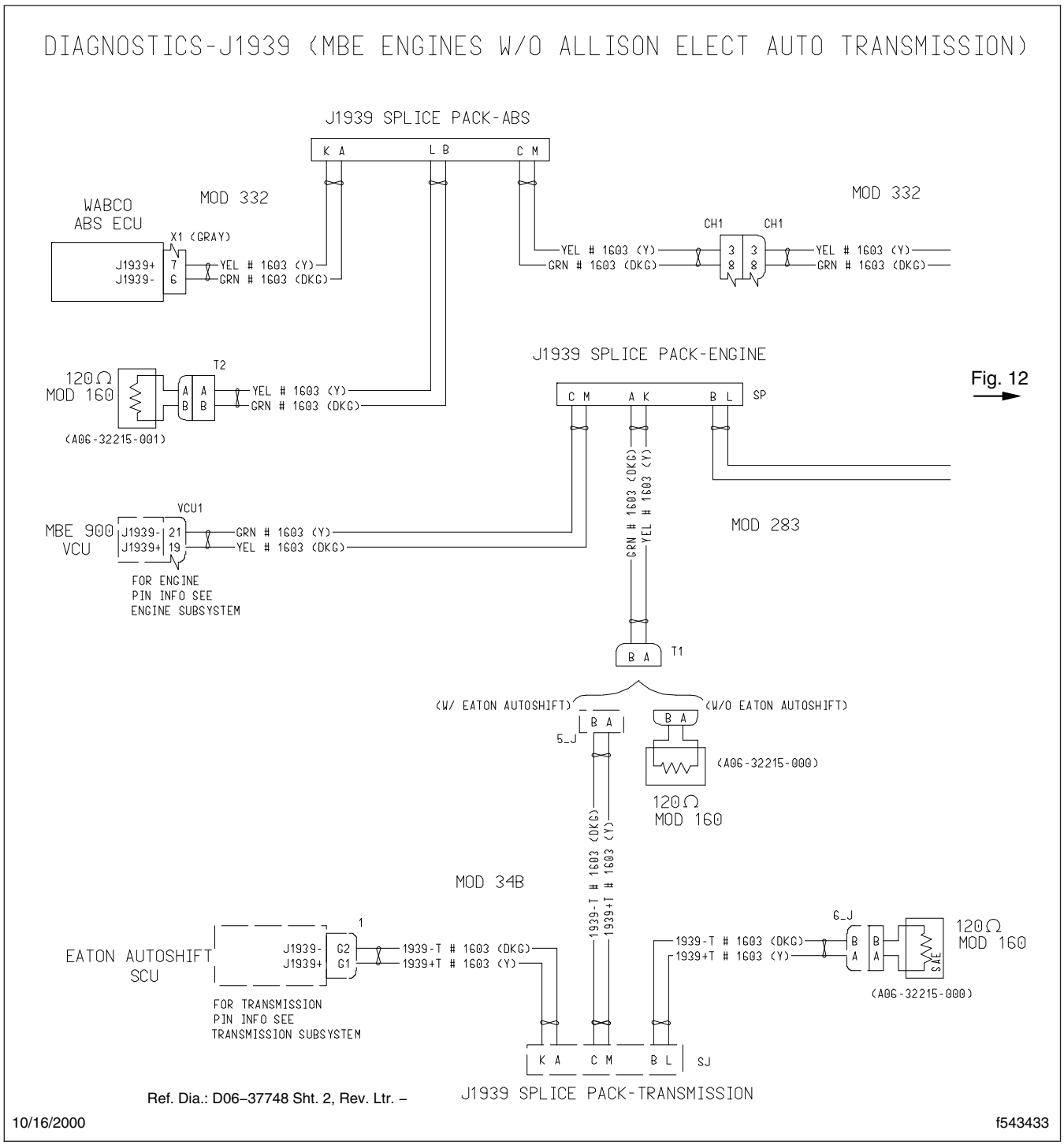


Fig. 11, J1939 Diagnostics Wiring With Mercedes-Benz MBE900 Engine Without Allison Electronic Transmission (partial view)

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Specifications

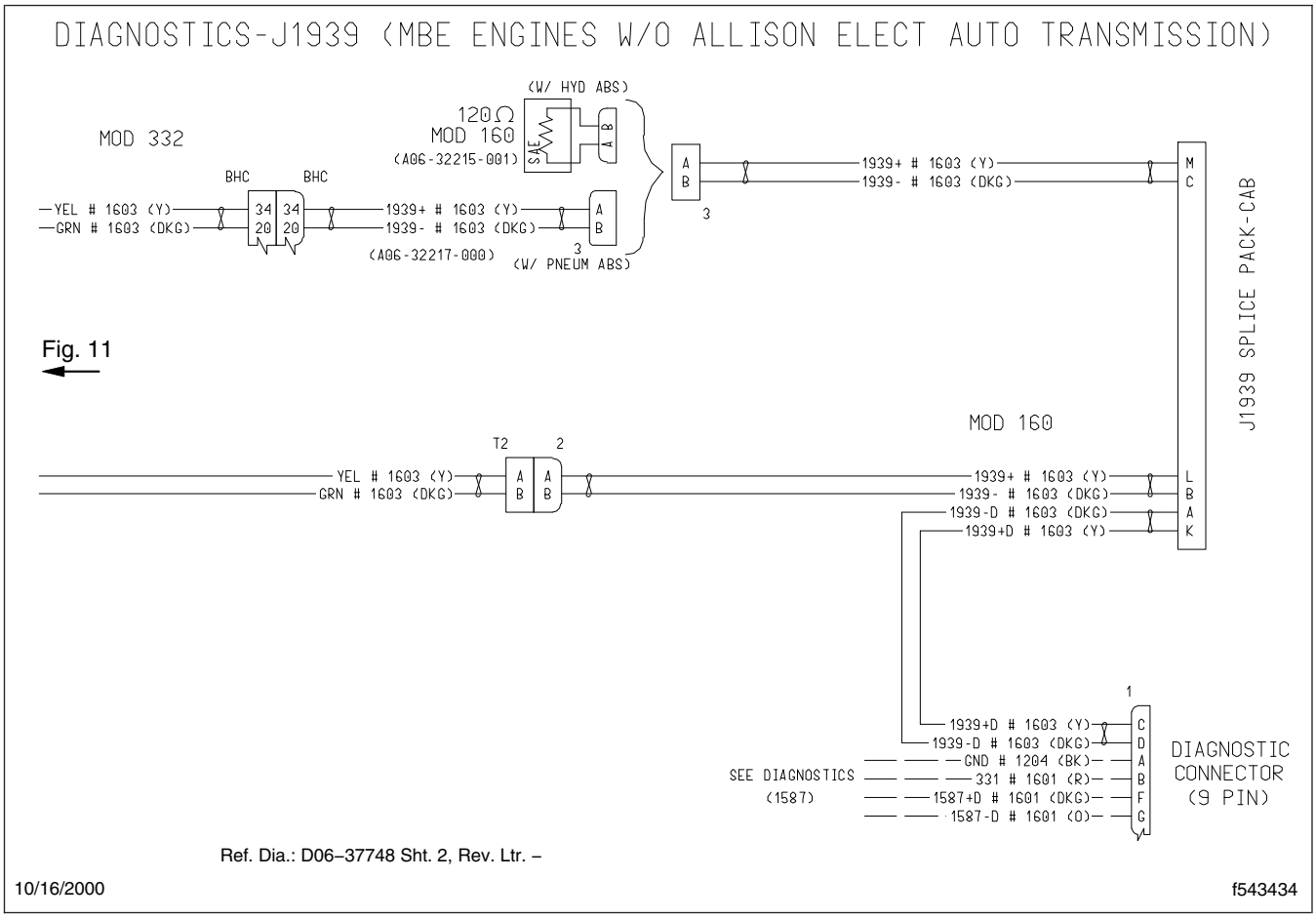


Fig. 12, J1939 Diagnostics Wiring With Mercedes-Benz MBE900 Engine Without Allison Electronic Transmission (partial view)

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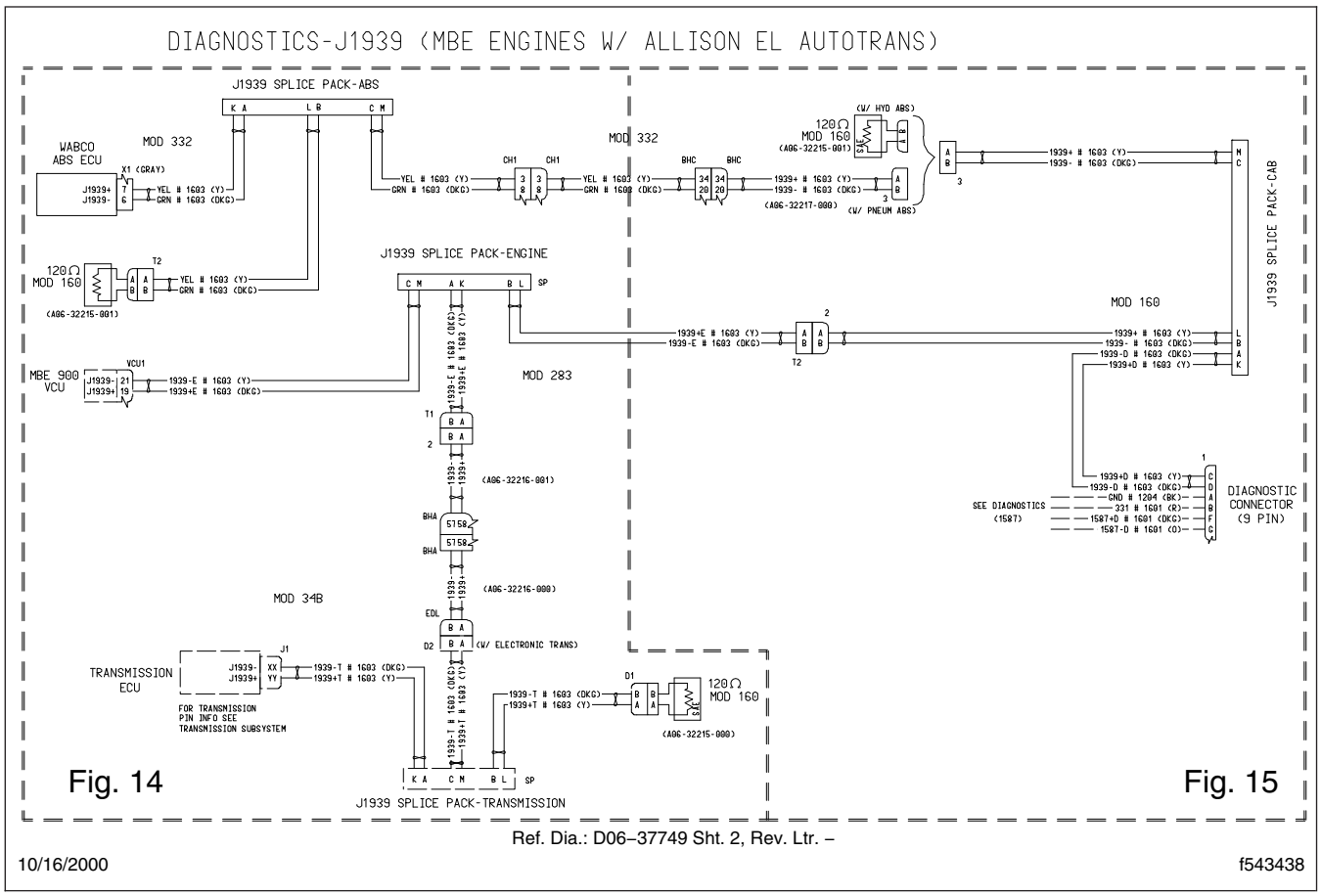


Fig. 13, J1939 Diagnostics Wiring With Mercedes-Benz MBE900 Engine With Allison Electronic Transmission (full view)

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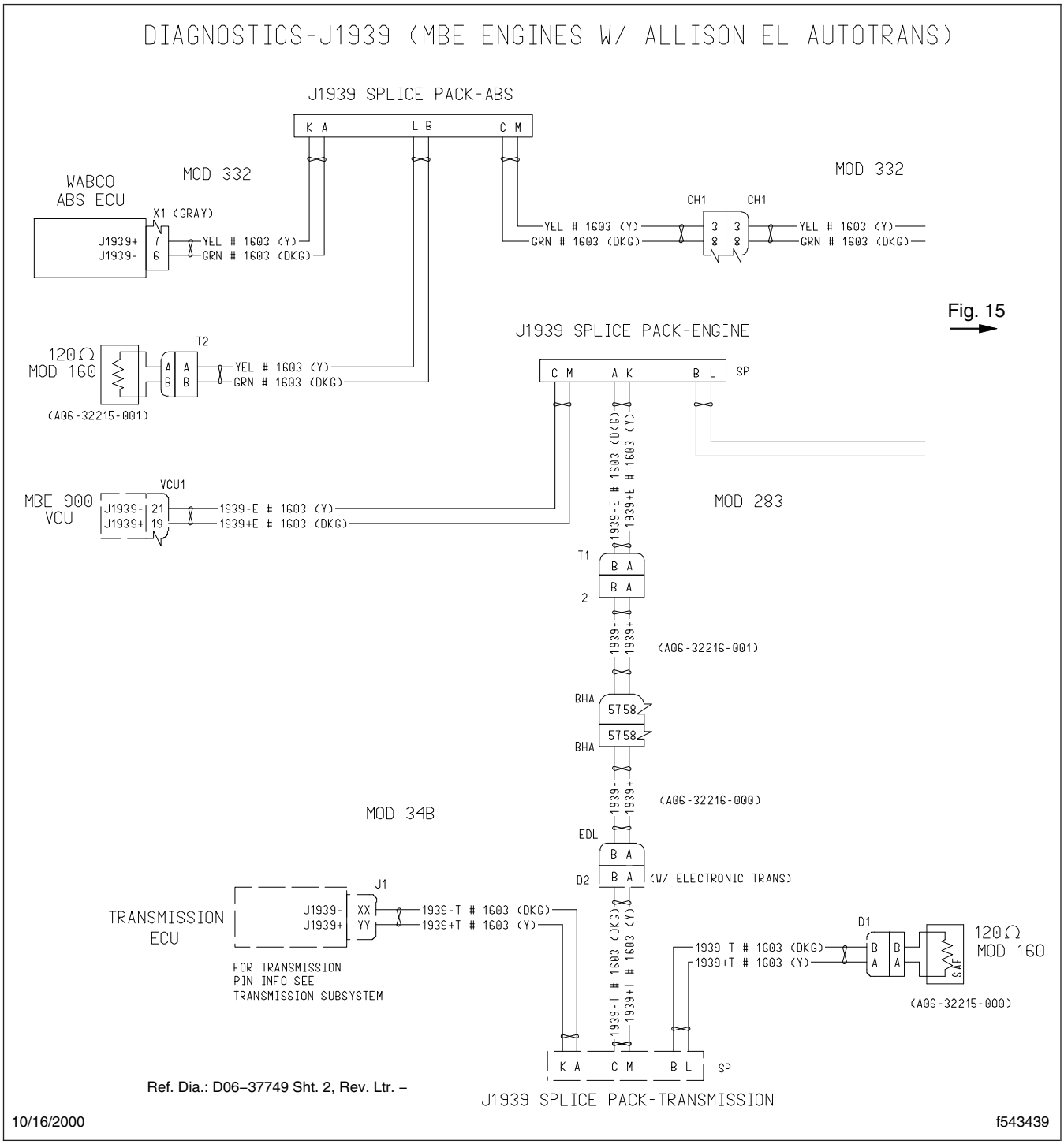


Fig. 14, J1939 Diagnostics Wiring With Mercedes-Benz MBE900 Engine With Allison Electronic Transmission (partial view)

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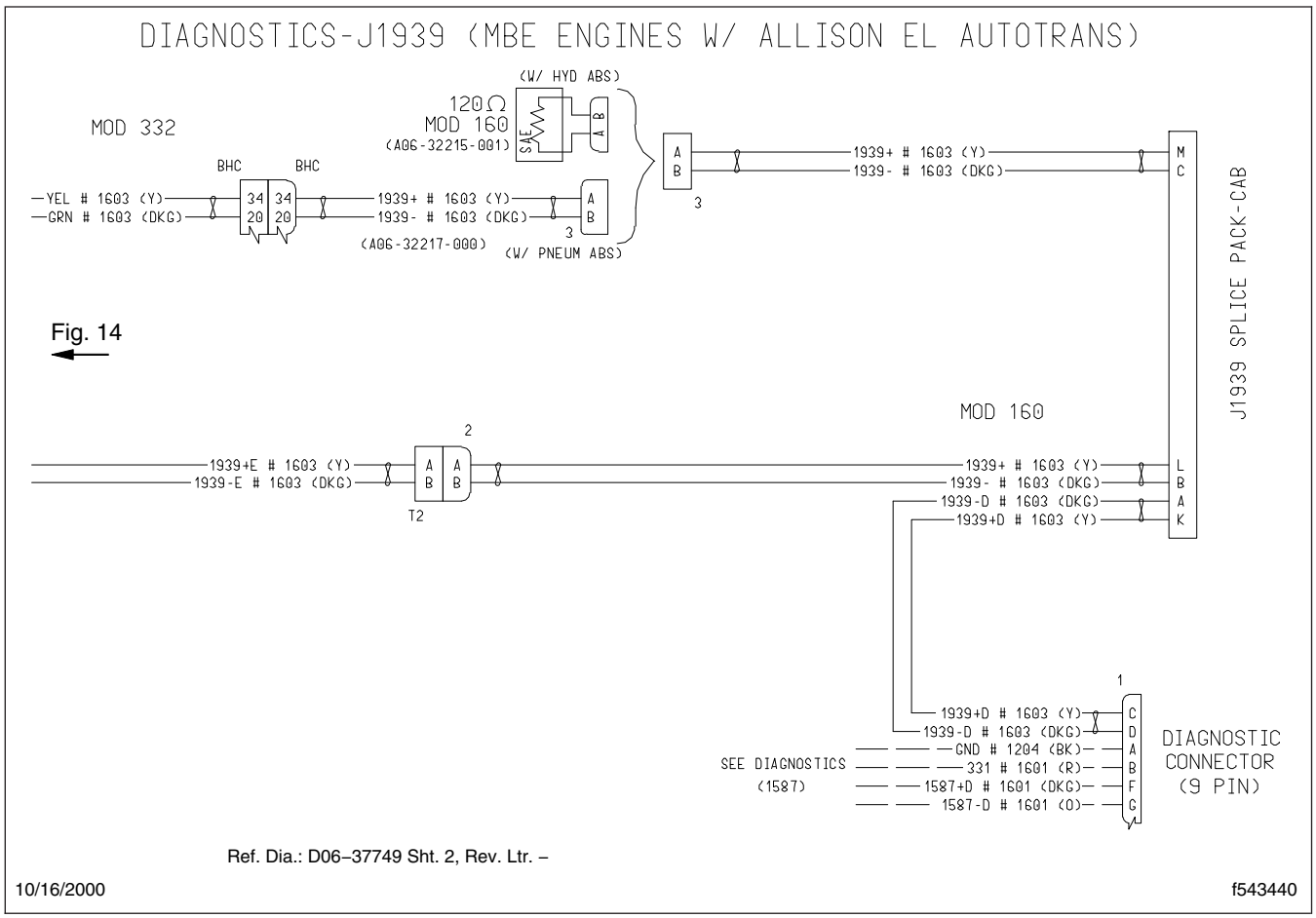


Fig. 15, J1939 Diagnostics Wiring With Mercedes-Benz MBE900 Engine With Allison Electronic Transmission (partial view)

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NGI Instrument Cluster

The optional AMETEK/Dixson Next Generation Instrumentation (NGI) gauge set is a full-featured individual gauge instrument cluster with a 21-telltale light bar. See **Fig. 1**. The individual gauges receive their signal over a serial data link driven by a processor, referred to as the SCU, located in the speedometer. The SCU receives and processes inputs from SAE J1587 data link, sensors, and discrete inputs for driving the various gauges and telltales. The individual gauges have stepper motor movements with Light Emitting Diode (LED) backlighting. All of the electronic gauges have LED-lit telltales. The light bar has 14 fixed positions, using LEDs to light the telltales, and seven optional telltales, six lit with replaceable incandescent bulbs for color flexibility, and one lit with an amber LED. The vehicle odometer is displayed using a Liquid Crystal Display (LCD) located in the speedometer. A collection of stand-alone mechanical and electrical gauges completes the NGI instrumentation package. The speedometer and tachometer are five-inch diameter data-buss driven gauges. All other gauges are approximately 2-inch diameter, data buss driven, and have a red LED-lit telltale except the fuel gauge, which is driven by the sensor in the fuel tank, and the air pressure gauges, which are mechanically driven. A transmission fluid temperature gauge is required on vehicles with automatic transmissions.

Driver's Message Center

The driver's message center has two parts; a 21 telltale light bar located in the top center of the instrument cluster, and a one-row, seven-character liquid crystal display (LCD) located on the speedometer.

Light Bar

The light bar has three rows of seven warning lights. See **Fig. 2**. The seven telltales on the top row of the light bar will vary depending on the vehicle configuration and customer preference. The two lower rows contain the 14 standard telltales shown in **Table 1**.

NGI Light Bar Standard Telltales	
Light	**LED Color**
Left Turn Signal	Green
Check Engine	Amber
Engine Protection	Red
Fasten Seat Belt Symbol	Red
High Beam Headlamps.	Blue
Tractor ABS (Antilock Brake System)	Amber
Parking/Emergency Brake	Red
Air Intake Filter Restriction	Amber
Right Turn Signal	Green
Trailer ABS	Amber
Water in Fuel	Amber
Intake Heater	Amber
Check A/C	Amber
Low Air	Red

Table 1, NGI Light Bar Standard Telltales

Message Center

The NGI message center, **Fig. 3** is a one-row, seven-character liquid crystal display (LCD) located on the speedometer that displays the following information:

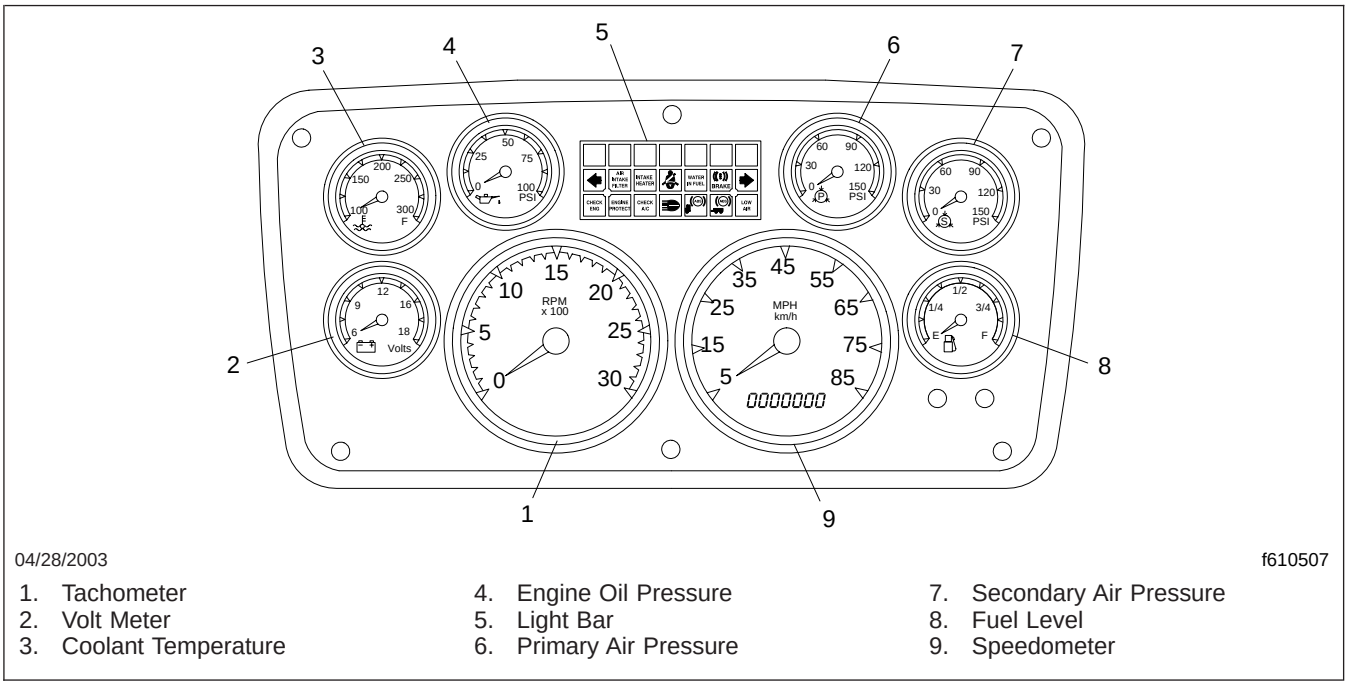
- Odometer
- Trip Odometers (two)
- Engine Hour Meter
- System Diagnostic Menu
- NGI-specific warning messages

Below the LCD there are five indicators along lower section of LCD, HR, MI, KM, TRIP, and a bell icon (not used at this time). **MI** or **KM** coincide with the primary scale of the speedometer when mileage is being displayed. The other icons display mode settings.

The odometer, hour meter, and trip odometers are primary screens. When a primary screen is displayed for 3 seconds or more it becomes the default screen. The default screen is displayed at ignition and will remain so until manually adjusted using the Mode and Set buttons.

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General Information



1. Tachometer
2. Volt Meter
3. Coolant Temperature
4. Engine Oil Pressure
5. Light Bar
6. Primary Air Pressure
7. Secondary Air Pressure
8. Fuel Level
9. Speedometer

Fig. 1, NGI Instrument Cluster

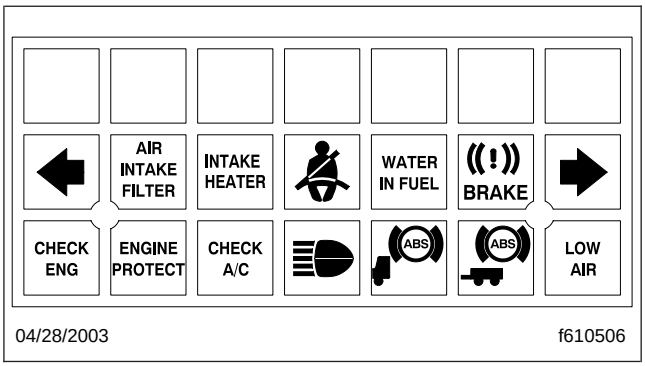


Fig. 2, NGI Light Bar

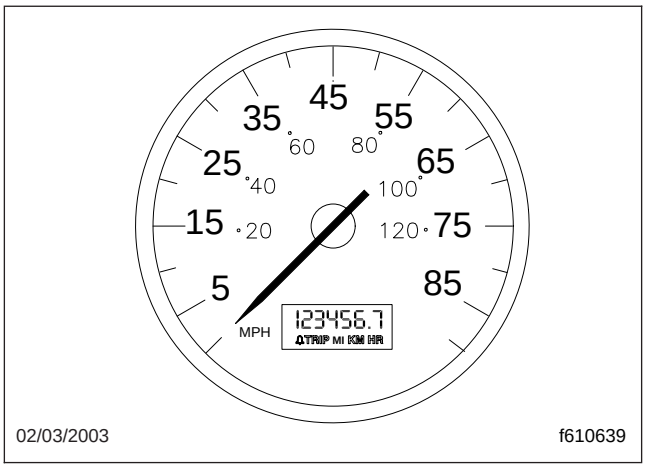


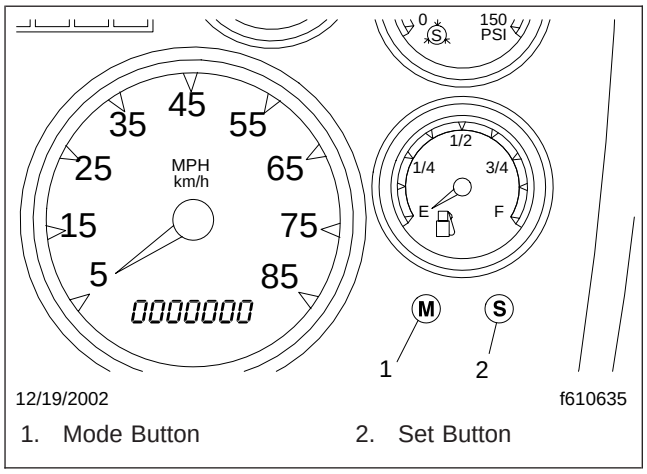
Fig. 3, Message Center

Mode and Set Buttons

The Mode and Set buttons are located in the lower right corner of the instrument cluster. See **Fig. 4**. Pressing the Mode button cycles through the various functions. Pressing the Set button selects the desired function. See **Fig. 5**. In the Odometer mode, the Set button toggles to MI or KM. In the Trip 1 and 2 Odometer modes, the Set button resets the Trip meter to zero. In the Engine hours mode, total engine hours are displayed. This is not resetable. In the System mode, the Set button initiates the System Diagnostics test and will display any warning messages that are present in the system. To run the system diagnostics, the following conditions must be met:

- Ignition on
- Park brake set
- Road speed below 2 mph
- Engine RPM at or below 1000

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1. Mode Button
2. Set Button

Fig. 4, Mode and Set Buttons

- No low air pressure warning in effect

Buzzer

The buzzer sounds during the ignition sequence and whenever:

- The engine oil pressure falls below the preset level, which is 5 to 9 psi (35 to 60 kPa) on most engines;
- The coolant temperature rises above the preset level, which is 215°F (101°C) on Caterpillar engines, 220°F (104°C) on Cummins engines and 189°F (87°C) on MBE900 engines;
- The air pressure falls below the preset level of approximately 70 psi (483 kPa);
- The parking brake is set with the vehicle moving at a speed greater than 2 miles per hour (3 km/h).

Ignition Sequence

NOTE: If the headlights are turned on, the screen displays the odometer and waits for the ignition to be turned on.

When the ignition is turned on, the SCU performs a self-test, looking for active faults. All the electronic gauges complete a full sweep of their dials, the warning and indicator lights light up and the buzzer sounds for 3 seconds. During the first half of the self-test, all segments of the driver dash display screen illuminate as follows: "888888.8." During the second half of the self-test, the software revision level is displayed.

NOTE: The engine and ABS warning lights go on during the SCU self-test, but they are not controlled by the SCU. They are controlled by their own system electronic control unit (ECU).

If the SCU receives active fault codes from other devices, the screen displays a three-letter acronym and message identifier (MID), indicating the ECU or system that is not functioning properly. For a list of MIDs, see **Specifications, 400**. Each active fault is displayed for 3 seconds, one after the other, until the parking brake is released or the ignition is turned off. Once the parking brake is released, the screen displays the odometer. If there are no active faults, the screen displays the odometer.

NOTE: If the SCU receives a message from an ECU that has not been pre-programmed into the SCU memory, it displays "SYS ###", where ### is replaced by the MID of the broadcasting device.

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General Information

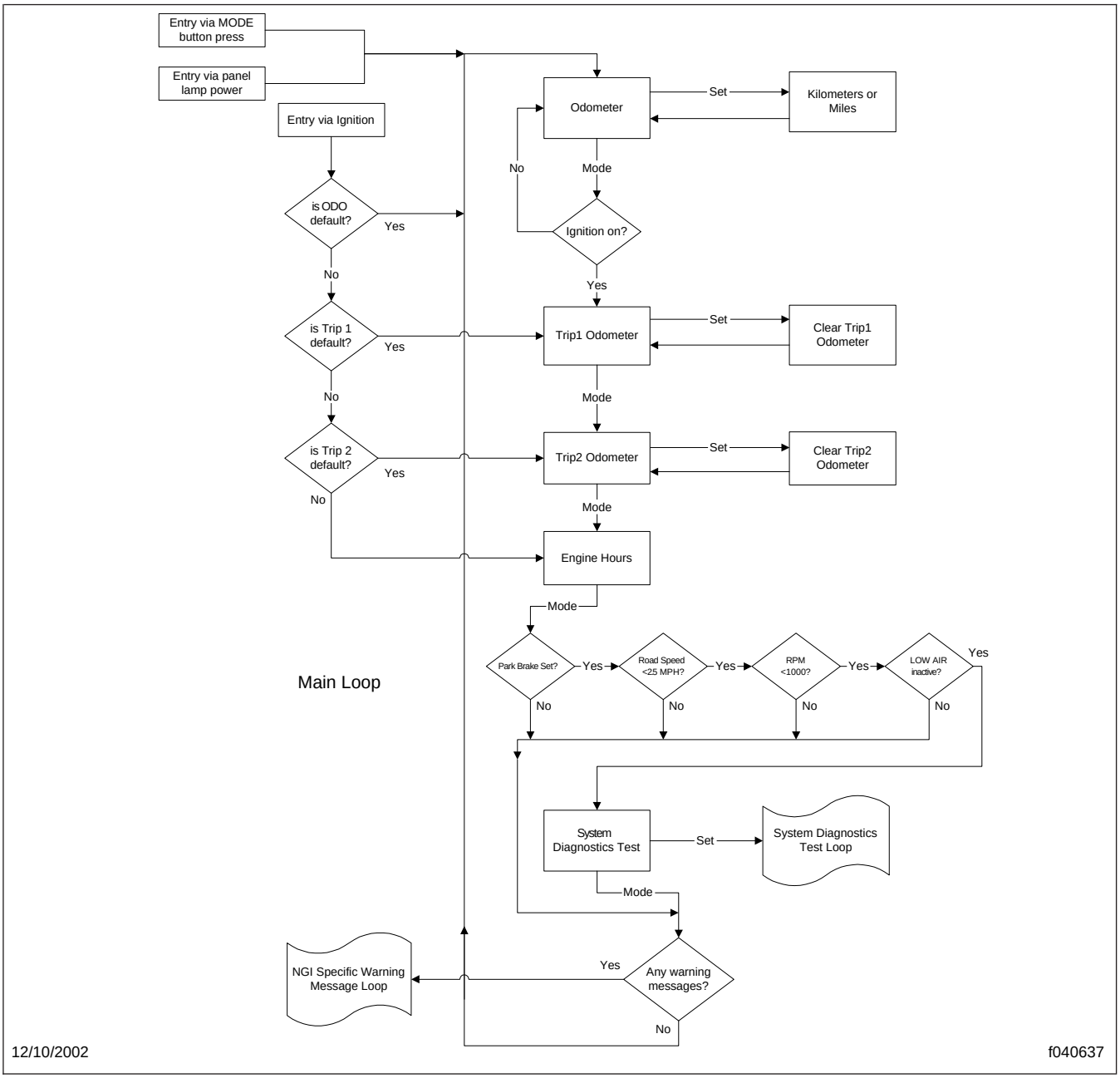


Fig. 5, State Diagram for LCD Display

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Instrument Cluster Removal and Installation

NOTE: The NGI instrument cluster is designed for easy access. It is no longer necessary to disassemble the entire dash to service the gauges.

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries.

⚠ WARNING

All air pressure must be relieved from the air reservoirs before disconnecting any pneumatic lines or hoses from the air system. Failure to relieve air pressure could cause the lines to whip, resulting in personal injury.

3. Drain the air system.
4. Loosen the six quarter-turn Torx-head fasteners around the edge of the instrument cluster. See **Fig. 1**.

⚠ CAUTION

Do not forcibly pull the instrument cluster from the dash. This may dislodge wires from the harness electrical connectors on the back of the instrument cluster and damage the wires, the instrument cluster or the dash.

5. Tilt the instrument cluster away from the dash.
6. Disconnect the connectors from the back of the instrument cluster.
   - 6.1 Disconnect the two electrical connectors (E3 & E6) from the back of the speedometer.
   - 6.2 Disconnect the air pressure lines from the primary and secondary air pressure gauges; see Section 42.05, Subject 110.
7. Remove the instrument cluster from the dash.

Installation

1. Position the instrument cluster in front of the dash opening.
2. Connect the connectors from the back of the instrument cluster.
   - 2.1 Connect the two electrical connectors (E3 & E6) to the back of the speedometer. See **Fig. 2**.
   - 2.2 Connect the air pressure lines to the primary and secondary air pressure gauges; see Section 42.05, Subject 110.
3. Pressurize the air system.
4. Check for air leaks.
5. Position the instrument cluster in the opening in the dash.
6. Fasten the six quarter-turn Torx-head fasteners.
7. Connect the batteries.
8. Remove the chocks.

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Instrument Cluster Removal and Installation

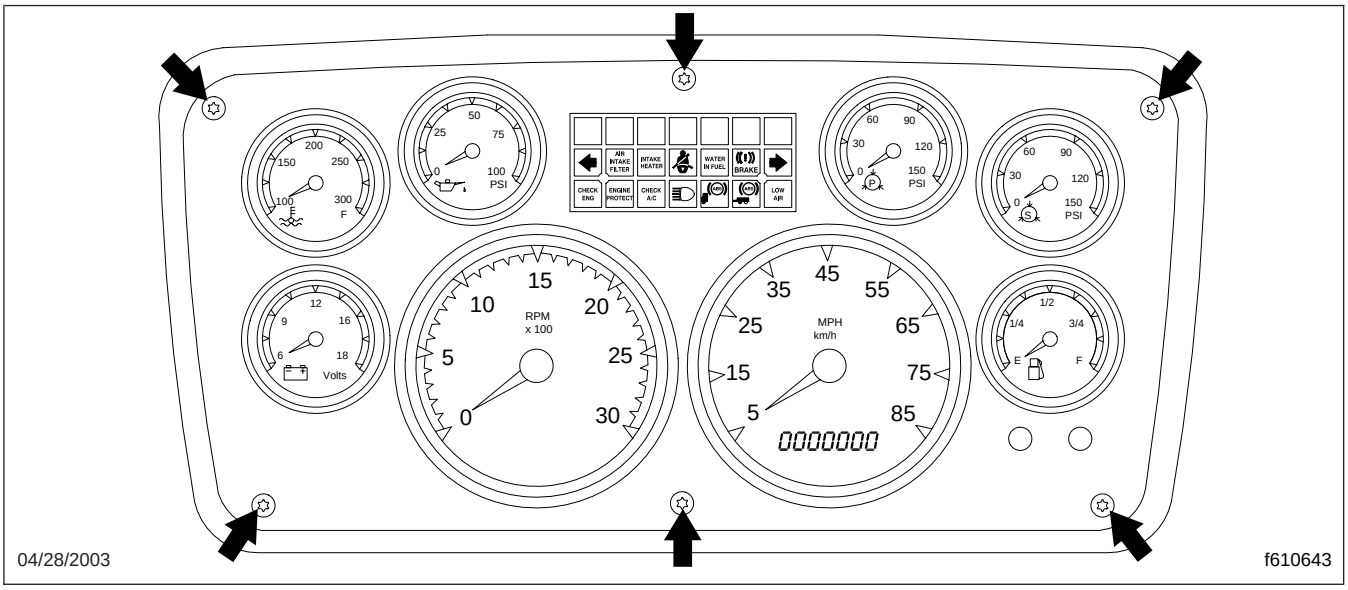


Fig. 1, Instrument Cluster Fasteners

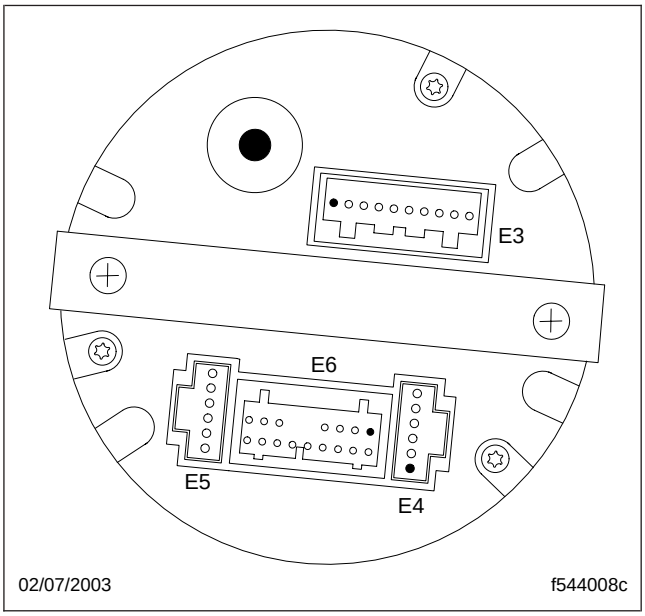


Fig. 2, Speedometer Electrical Connectors

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NOTE: The instrument cluster need not be completely removed from the vehicle to remove and replace individual gauges. However, if removing the cluster is preferred, refer to **Subject 100** for complete procedure.

Large Face Gauges

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries.

⚠ WARNING

All air pressure must be relieved from the air reservoirs before disconnecting any pneumatic lines or hoses from the air system. Failure to relieve air pressure could cause the lines to whip, resulting in personal injury.

3. Drain the air system if air gauges are to be disconnected.

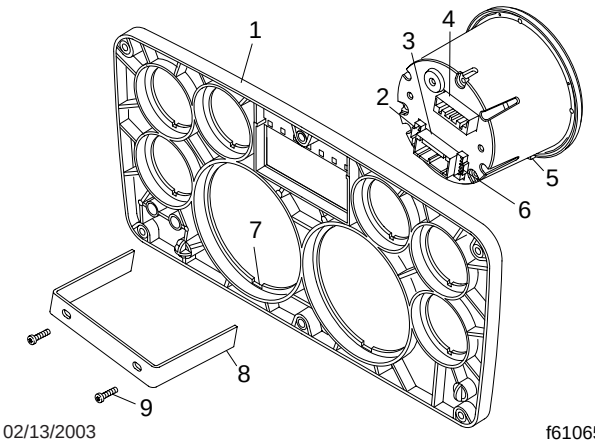
⚠ CAUTION

Do not forcibly pull the instrument cluster from the dash. This may dislodge wires from the harness electrical connectors on the back of the instrument cluster and damage the wires, the instrument cluster or the dash.

4. Access the back of the instrument cluster. Refer to **Subject 100** for the instrument cluster removal and installation procedure.
5. Disconnect the wire connectors from the back of the gauge to be removed. See **Fig. 1**. There are four connectors on the speedometer and two on the tachometer.
6. Remove the two screws from the U-clamp.
7. Slide the gauge out through the front of the Instrument panel.

Installation

1. Slide the gauge into position from the front of the instrument panel. Make sure the locating pin on the bottom of the gauge near the bezel fits into the notch in the gauge mounting hole.



1. Instrument Panel
2. NGI Buss, E5
3. Analog or Switched Inputs, E6
4. A/N Display, E3
5. Alignment Tab
6. NGI Buss, E4
7. Alignment Notch
8. U-clamp
9. Mounting Screw

Fig. 1, Installation, Large Face Gauges (speedometer)

2. Position the U-clamp and install the retaining screws.
3. Connect the wire connectors to the back of the gauge.
4. Install the instrument cluster. Refer to **Subject 100**.
5. Connect the batteries.
6. Remove the chocks.

Small Face Gauges

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries.

⚠ WARNING

All air pressure must be relieved from the air reservoirs before disconnecting any pneumatic lines or hoses from the air system. Failure to relieve

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Gauge Removal and Installation

air pressure could cause the lines to whip, resulting in personal injury.

3. Drain the air system if air gauges are to be disconnected.

⚠ CAUTION

Do not forcibly pull the instrument cluster from the dash. This may dislodge wires from the harness electrical connectors on the back of the instrument cluster and damage the wires, the instrument cluster or the dash.

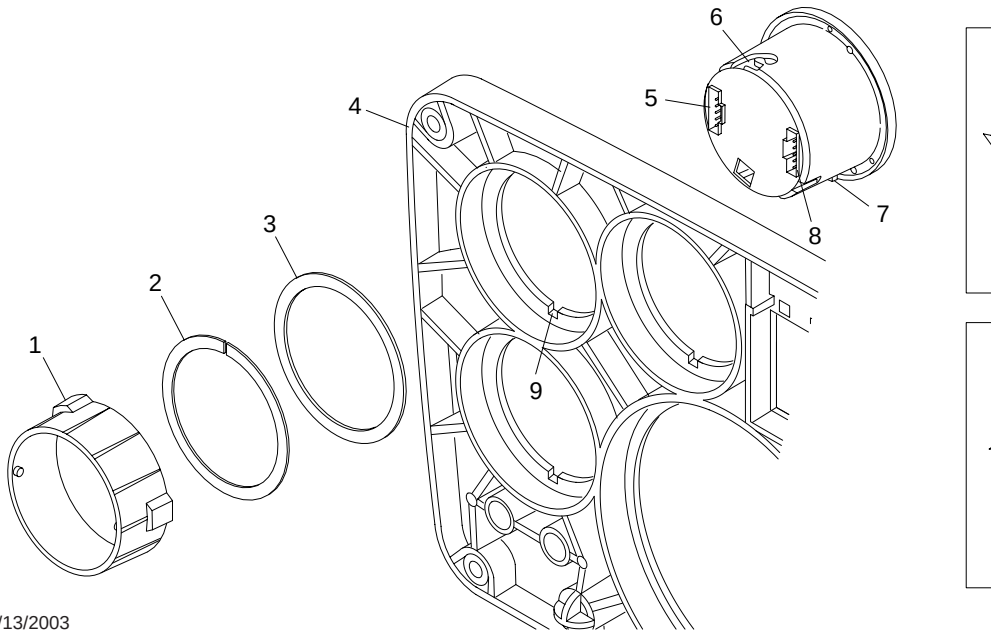
4. Access the back of the instrument cluster. Refer to **Subject 100** for the instrument cluster removal and installation procedure.
5. Disconnect the wire connectors from the back of the gauge to be removed.
6. If an air pressure gauge is to be removed, disconnect the air pressure lines from the press-to-release fitting on the gauge back; see **Section 42.05**, Subject 110.
7. While holding the front of the gauge, press and turn the clamp ring counterclockwise about 1/16-inch until it releases. See **Fig. 2** for exploded view of gauge installation.
8. Remove the clamp ring, flat shim, and wave shim from the back of the gauge.
9. Slide the gauge out through the front of the cluster panel.

Installation

1. Slide the gauge into position from the front of the cluster panel. Make sure the locating pin on the bottom of the gauge near the bezel fits into the notch in the gauge mounting hole.
2. Put the wave shim, flat shim, and clamp ring on the back of the gauge.
3. While holding the front of the gauge in position, press and turn the clamp ring clockwise about 1/16-inch until it locks into place.
4. Connect the wire connectors to the back of the gauge.
5. If applicable, connect the air pressure lines to the press to release fitting on the back air pressure gauge. For the correct procedure, see **Section 42.05**, Subject 110.
6. Pressurize the air system and check for leaks.
7. Install the instrument cluster. Refer to **Subject 100**.
8. Connect the batteries.
9. Remove the chocks.

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Gauge Removal and Installation



A. Remove
B. Install
1. Clamp Ring
2. Flat Shim
3. Wave Shim
4. Instrument Panel
5. NGI Buss, E1
6. Cutout
7. Alignment Tab
8. NGI Buss, E2
9. Alignment Notch
10. Lock Tabs

Fig. 2, Installation, Small Face Gauges

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Light Bar Removal and Installation

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires.
2. Disconnect the batteries.
3. Loosen the six quarter-turn Torx-head fasteners around the edge of the instrument cluster. See **Fig. 1**.

CAUTION

Do not forcibly pull the instrument cluster from the dash. This may dislodge wires from the harness electrical connectors on the back of the instrument cluster and damage the wires, the instrument cluster or the dash.

4. Tilt the instrument cluster out of the dash opening.
5. Depress the locking tabs and disconnect the electrical connectors from the rear of the light bar.
6. Remove the four T-10 Torx screws holding the light bar to the panel. See **Fig. 2**.
7. Remove the light bar from the mounting panel.

Installation

1. Position the light bar into the mounting panel.
2. Install the four T-10 Torx retaining screws.
3. Connect the electrical connectors to the rear of the light bar.
4. Position the instrument cluster back in the dash opening.
5. Fasten the six quarter-turn Torx-head fasteners.
6. Connect the batteries.
7. Remove the chocks.

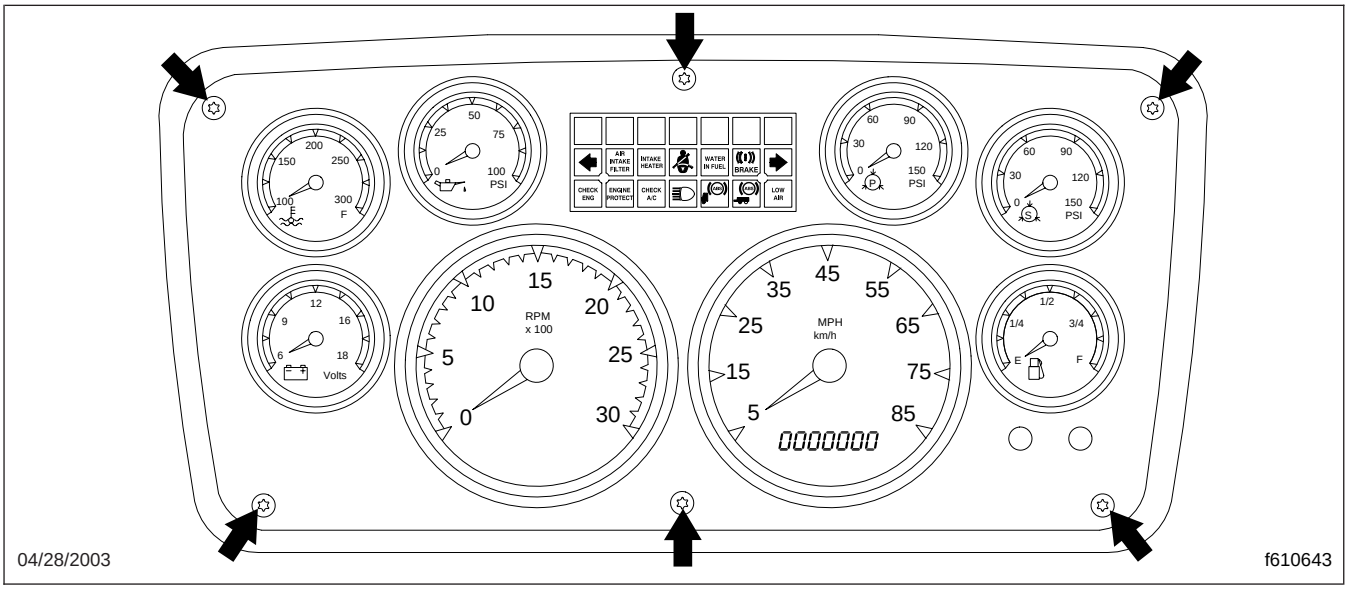


Fig. 1, Instrument Cluster Fasteners

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Light Bar Removal and Installation

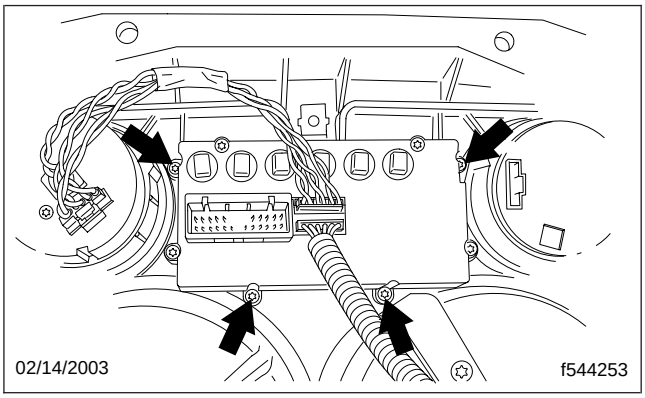


Fig. 2, Light Bar Mounting Screws

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Terms, Abbreviations, and Definitions

Terms, Abbreviations, and Definitions are listed below for your convenience.

- **ECU** - Electronic Control Unit
- **GC** - In the flow charts, a connector that is mounted on a gauge or other system component.
- **HC** - In the flow charts, a connector that is part of the vehicle's wiring harness.
- **LED** - Light-Emitting Diode
- **NGI** - Next Generation Instrumentation
- **SCU** - System Control Unit (Speedometer)

Mode and Set Switch Functions

Use the following flow charts to cycle through the Mode/Reset switch functions and screens when instructed to do so in the diagnostic flow charts.

See **Fig. 1** for Main Loop function flow chart.

See **Fig. 2** for Warning Message Loop function flow chart.

See **Fig. 3** for System Diagnostics Test Loop function flow chart.

See **Fig. 4** for Manual Mode Test Loop function flow chart.

See **Fig. 5** for Alpha Display Main Loop function flow chart.

Troubleshooting

For troubleshooting procedures, see tables 1 through 7 later in this subject.

Flow Chart Information

Troubleshooting flow charts begin with fig. 6. See Tables 1 through 7 to determine which troubleshooting flow chart to use. The black box(es) in each flow chart is the starting point for that chart. Follow the instructions in each box. The path to the next box depends upon how you answered the question in the previous box (i.e. "yes" or "no"). As you work your way through the chart you will eventually come to a box containing **bold type**. This represents the end of the flow chart. If you reach this box and your problem is still present, call the AMETEK Dixson Product Support Department for additional assistance at (800) 205-7710.

In the flow charts, "HC" refers to the connector on the wiring harness and "GC" refers to the connector on the gauge or lightbar.

Using the Automatic Mode Test Procedure

NOTE: Use this procedure when instructed to do so in the diagnostic flowcharts.

1. Using the mode switch, scroll until **DIAGTST** is displayed.
2. Press the set switch to enter the test mode.
3. Press the mode switch to scroll between **AUTO**, **MANUAL**, and **EXIT**.
4. When **AUTO** is displayed press the set switch to start the auto test.

NOTE: Light bar telltales will stay on if the condition that lights them is true.

5. The gauges, Check Engine light, and light bar will begin to cycle in the following manner with a corresponding message in the alphanumeric display. Verify that the gauges and light bar telltales function as follows:
    - **MIN** – All gauge pointers go to zero scale. All warning LEDs and all light bar telltales are off.
    - **MID** – All gauge pointers go to mid-scale. All warning LEDs are off, the Check Engine light is on, and every other telltale in the light bar is on.
    - **MAX** – All gauge pointers go to full-scale. All warning LEDs are off, the Check Engine light is off, and the light bar telltales change states.
    - **LED** – All gauge pointers go to zero-scale. All warning LEDs are on and only the Neutral, Park Brake and PTO telltales in the light bar are on.

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Troubleshooting

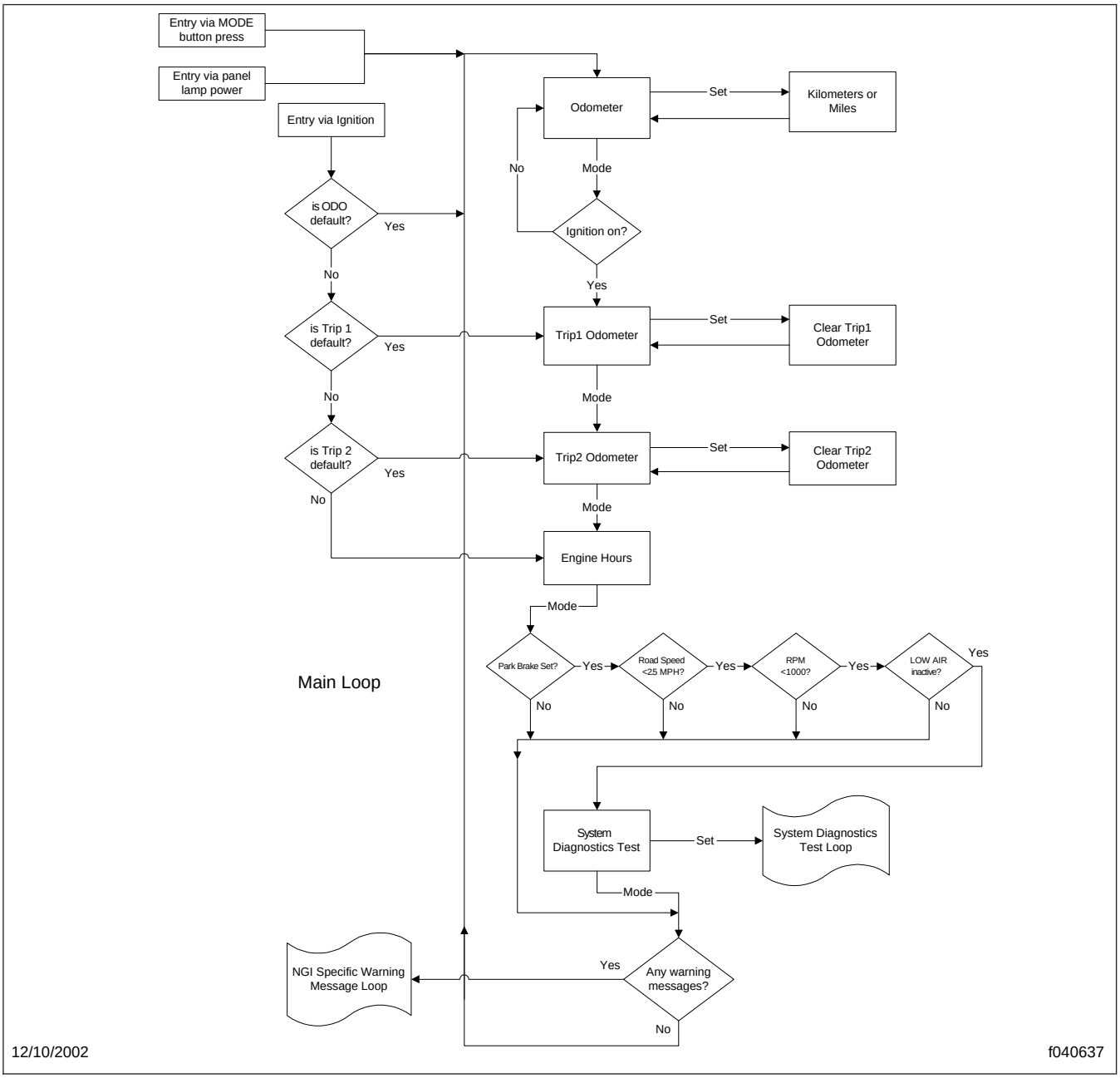


Fig. 1, Main Loop

6. All gauges, warning LEDs, and telltales must function as described.
7. When the test is complete push the set or mode switch to stop the test.
8. Use the mode switch to scroll until **EXIT** appears.

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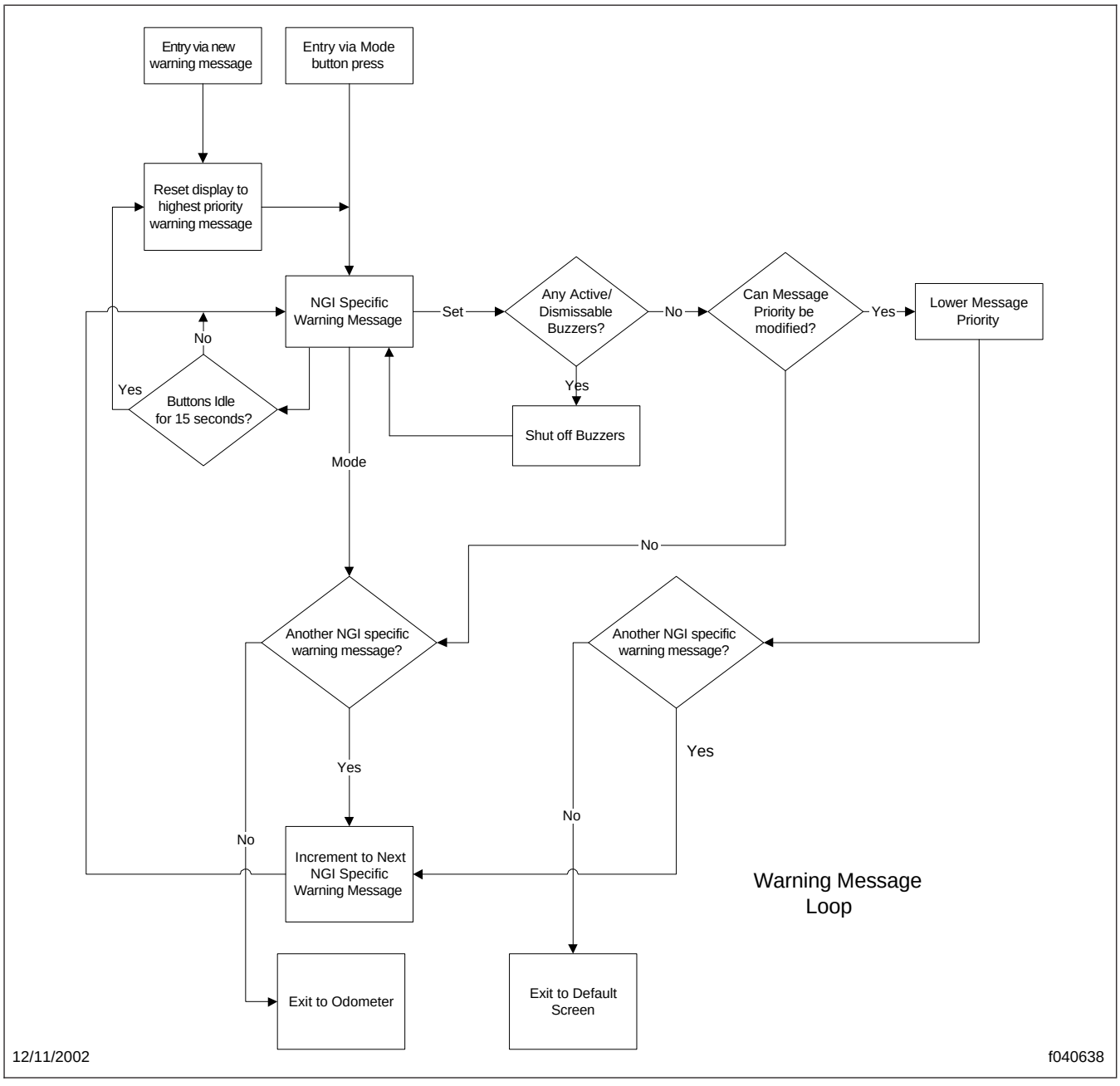


Fig. 2, Warning Message Loop

Using the Manual Mode Test Procedure

NOTE: Use this procedure when instructed to do so in the diagnostic flowcharts.

1. Using the mode switch scroll until **DIAGTST** is displayed.
2. Push the set switch to return to normal operation.
3. Press the set switch to enter the test mode.

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Troubleshooting

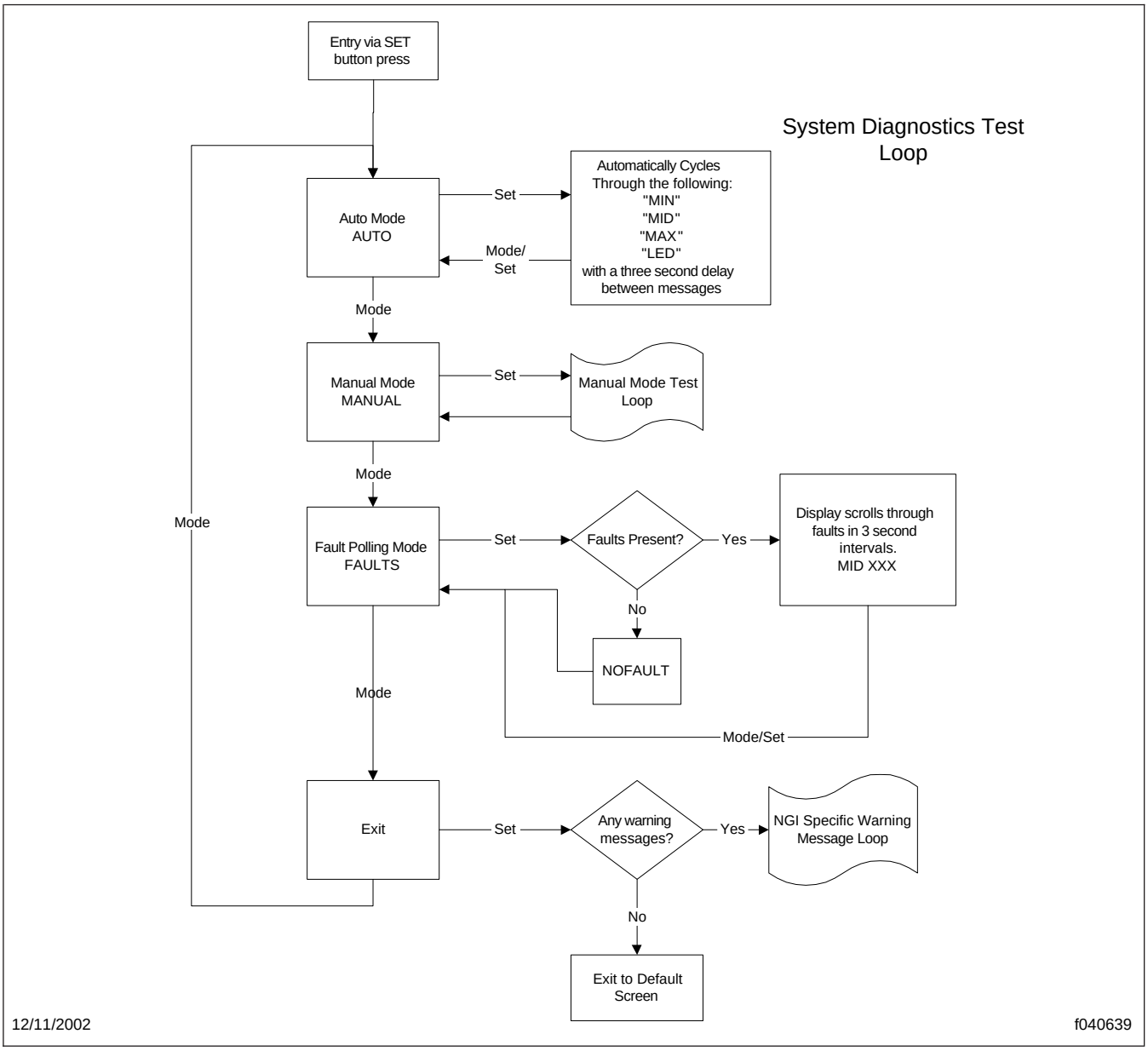


Fig. 3, System Diagnostics Test Loop

4. Press the mode switch to scroll between **AUTO**, **Manual**, and **EXIT**.
5. When **MANUAL** is displayed press the set switch.
6. To test a gauge:
   - 6.1 Press the mode switch to scroll through the menu until the name of the gauge you wish to test is displayed.
   - 6.2 Press the set switch to enable the test for the selected gauge.
   - 6.3 Verify the gauge or light bar telltale behaves as follows:

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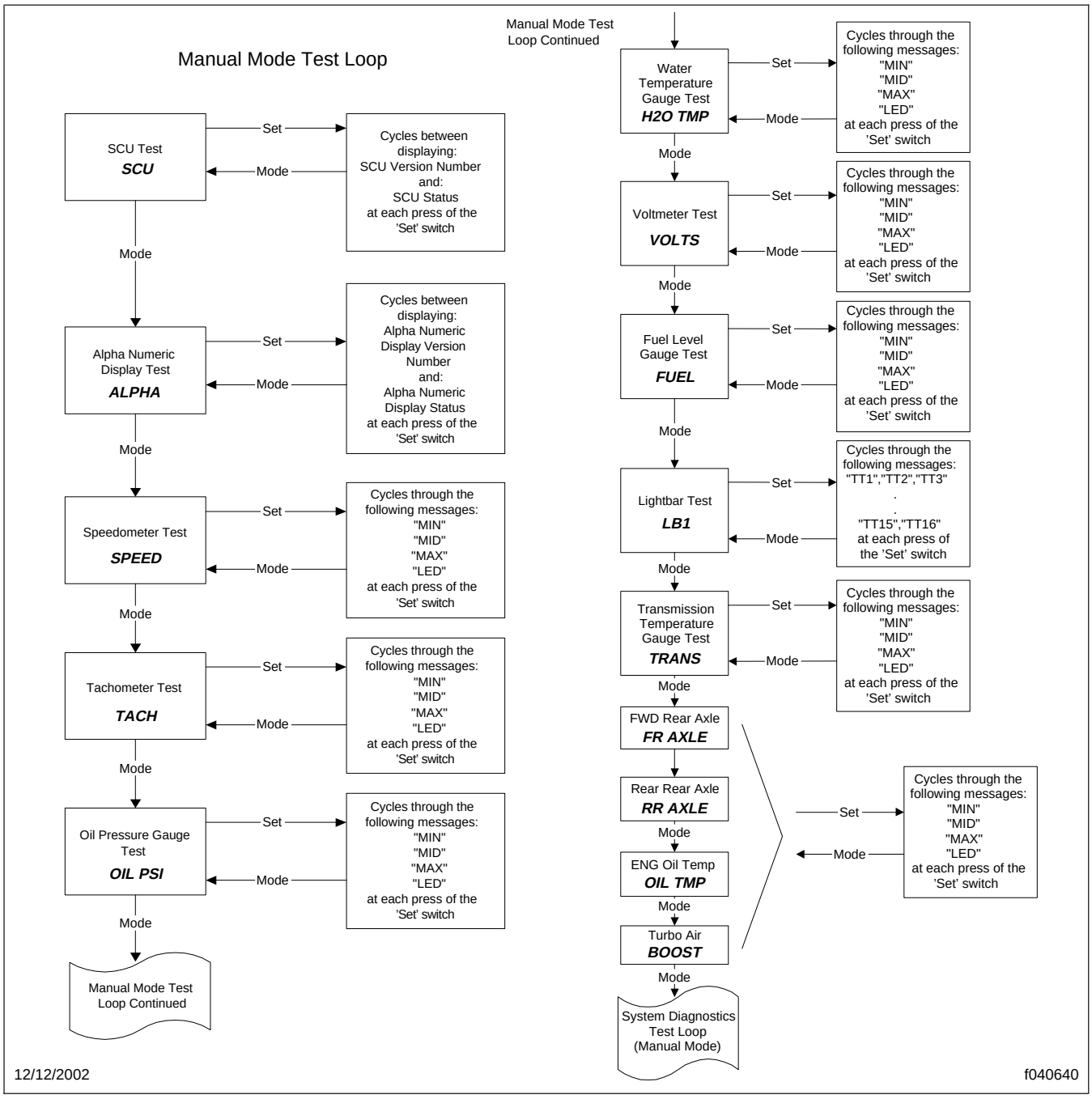


Fig. 4, Manual Mode Test Loop

- **MIN** – The gauge pointer goes to the zero scale and its warning LED is off.
- **MID** – The gauge pointer goes to mid-scale and its warning LED is off.
- **MAX** – The gauge pointer goes to full scale and its warning LED is off.

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Troubleshooting

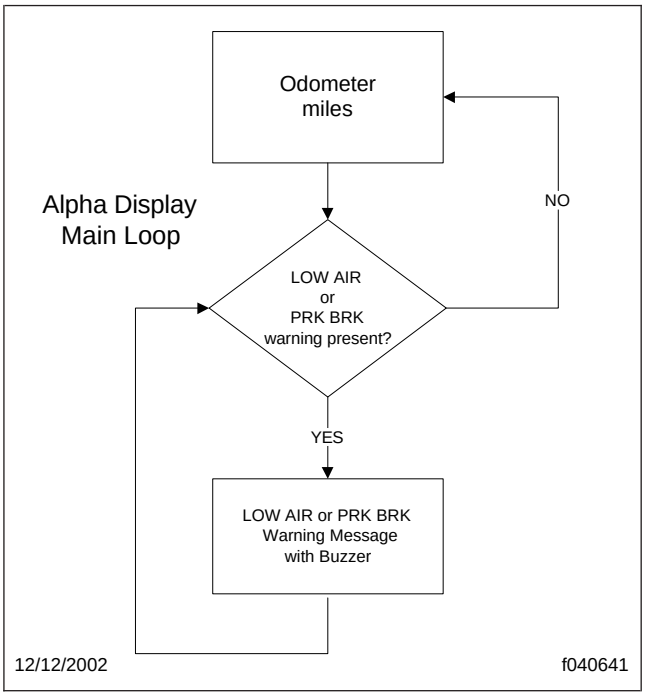


Fig. 5, Alpha Display Main Loop

- **LED** – The gauge pointer goes to the zero scale and its warning LED is on.

6.4 Press the set switch again to cycle through each test. You must continue pressing the set switch to cycle through the test.

6.5 Press the mode switch to exit the gauge test.

7. To test the light bar or one of its telltales:

7.1 When **MANUAL** is displayed press the set switch.

7.2 Press the mode switch until **LB1** is displayed.

7.3 Press the set switch to cycle through **TT1** to **TT16**. The location of the telltales T1 through T15 will be shown in the display. TT16 will turn the **CHECK ENGINE** light on.

7.4 Verify the correct light is on as indicated in the alphanumeric display.

7.5 Press the mode switch to exit the light bar test.

8. To exit the manual mode:

8.1 Continue pressing the mode switch to scroll through the menu until **EXIT** appears.

8.2 Press the set switch to exit the manual mode and return to normal operation.

Diagnostic Procedures

When troubleshooting the instrumentation, switch the ignition on and observe all the gauges during the initialization period. Locate the general symptom in **Table 1**, then follow the instructions.

NOTE: See **Subject 400** for instrumentation connector locations and pin identification.

Warning Messages

Warning messages are listed in **Table 8**. Read the message and determine what condition is causing it.

Should **NO DATA** be displayed, go to **Table 2** (Problem With Speedometer).

If you suspect the alarm condition is false and a problem does not really exist, then follow the gauge accuracy troubleshooting procedures for that gauge by going to **Table 3** (Problem With J1587 Driven Gauge).

General Symptoms	
Problem	**Remedy**
Problem with speedometer or alphanumeric display.	See **Table 2**.
Problem with 2-inch gauge or tachometer.	See **Table 3** or **Table 4**.
Problem with air pressure gauges.	See **Table 5**.

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General Symptoms	
Problem	**Remedy**
Problem with light bar telltales.	See **Table 6** and **Table 7**.
Problem with Check Engine light.	
Problem with left or right turn indicator.	See **Table 7**.
Problem with high beam indicator.	See **Table 7**.
Warning message displayed.	See **Table 8**.
No audible warning when warning message displayed.	Replace the speedometer.

Table 1, General Symptoms

Problem With Speedometer			
Problem	**Initialization results***	**Possible Cause**	**Remedy**
LCD is dead and speedometer pointer does not move to initialization point.	Fail	No power from battery or ignition switch; defective speedometer.	See **Fig. 6**.
Speedometer pointer does not move to its initialization point.	Fail	Defective speedometer.	Replace speedometer.
Speedometer pointer goes to and stays at minimum or full scale.	Pass	Engine ECU out of range.	See **Fig. 7**.
Speedometer pointer stays at minimum scale (LCD may read **NO DATA**).	Pass	No data from Engine ECU; NGI bus problem; defective speedometer.	
Inaccurate speed indication.	Pass	Problem with Engine ECU; defective speedometer.	See **Fig. 15**
NO DATA displayed. All other components function properly.	Pass	Defective speedometer.	Replace speedometer.
Select/mode buttons not functioning.	Pass	Defective speedometer.	Replace speedometer.
LCD is dead but speedometer pointer does move to initialization point.	Fail	Defective speedometer.	Replace speedometer.
LCD is missing segments.	Fail	Defective speedometer.	Replace speedometer.
LCD backlighting not working.	Pass	Defective speedometer.	Replace speedometer.
No odometer or engine hours display.	Pass	Engine ECU not sending data; defective speedometer.	See **Fig. 8**.
Odometer or engine hour display not advancing.	Pass	Engine ECU not sending data; defective speedometer.	See **Fig. 8**.
Cannot reset trip odometer.	Pass	Defective speedometer.	Replace speedometer.
No backlighting.	Pass	Power or ground problem.	See **Fig. 9**.

* When ignition is first turned on, each gauge pointer should sweep below minimum scale and the LED should be lit, then the pointer should return to minimum scale. *This does not apply to the air pressure gauges.*

Table 2, Problem With Speedometer

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Troubleshooting

Problems with J1587 Driven Gauges: Tachometer, Coolant Temperature, Oil Pressure, Voltmeter, Engine Oil Temperature, Turbo Boost			
Symptom	**Initialization Results**	**Probable Cause**	**Remedy**
Dead. Gauge pointer does not move and LED does not light.	Fail	NGI Power missing; power not getting to speedometer or gauge; defective speedometer or gauge.	See **Fig. 6**.
Gauge pointer moves correctly but LED does not light.	Fail	Defective gauge.	Replace gauge.
LED lights, but gauge pointer does not position correctly.	Fail	Defective gauge.	Replace gauge.
Gauge pointer goes to zero and LED flashes slowly.*	Pass	Open or shorted NGI bus; defective gauge or speedometer; data not on J1587 databus.	See **Fig. 10**.
Gauge inaccurate.	Pass	Engine ECU; defective sensor, speedometer.	See **Fig. 15**.
No backlighting.	Pass	Backlight power or ground problem.	See **Fig. 9**.

* Slowly means one flash per second.

Table 3, Problem With J1587 Driven Gauge

Problems with Sensor Driven Gauges: Fuel Level, Trans Oil Temperature, Axle Temperature (front and rear)			
Symptom	**Initialization Results**	**Probable Cause**	**Remedy**
Dead. Gauge pointer does not move and LED does not light.	Fail	NGI Power missing; power not getting to speedometer or gauge; defective speedometer or gauge.	See **Fig. 6**.
Gauge pointer moves correctly but LED does not light.	Fail	Defective gauge.	Replace gauge.
LED lights, but gauge pointer does not position correctly.	Fail	Defective gauge.	Replace gauge.
Gauge pointer goes to zero and LED flashes slowly.	Pass	Open or shorted NGI bus; defective gauge or speedometer.	See **Fig. 10**.
Fuel Gauge Only: Gauge pointer goes to minimum scale and LED may be lit.	Pass	Faulty sensor; open or shorted sensor wiring leading to instrumentation.	See **Fig. 16**
Transmission and Axle Temperature Gauges Only: Gauge pointer goes to minimum scale, or pointer goes to maximum scale and the LED is lit.	Pass	Faulty sensor; open or shorted sensor wiring leading to instrumentation.	See **Fig. 13**
Gauge inaccurate.	Pass	Defective sensor	Fuel level gauge: see **Fig. 16** All others: see **Fig. 13**

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Problems with Sensor Driven Gauges: Fuel Level, Trans Oil Temperature, Axle Temperature (front and rear)			
Symptom	**Initialization Results**	**Probable Cause**	**Remedy**
No backlighting.	Pass	Backlight power or ground problem.	See **Fig. 9**.

Table 4, Problems with Sensor Driven Gauges

Problems with Air Pressure Gauges: Primary and Secondary Air Pressure, Service Brake Application			
Symptom	**Initialization Results**	**Probable Cause**	**Remedy**
Dead. Gauge pointer does not move.	N/A	Defective gauge; no air pressure reaching gauge.	See **Fig. 14**.
Gauge inaccurate.	N/A	Defective gauge.	See **Fig. 14**.
No backlighting.	N/A	Backlight power or ground problem.	See **Fig. 9**.

Table 5, Problems with Air Pressure Gauges

Problem With Light Bar During Initialization		
Problem	**Probable Cause**	**Remedy**
Only some telltales turn on. Fasten seatbelt telltale does not turn on. NOTE: Bulb checks for discrete input telltales (hard wired) are controlled by the ECU they are connected to.	Light bar faulty.	Replace light bar.
No telltales turn on.	No power or ground to light bar.	See **Fig. 17**

Table 6, Problem With Light Bar During Initialization

Problem With Light Bar During Operation	
Problem	**Remedy**
Optional Telltale #1 always/never on.	See **Fig. 18**.
Low Coolant telltale always/never on.	See **Fig. 18**.
Engine Protection telltale always/never on.	See **Fig. 18**.
Water in fuel telltale always/never on.	See **Fig. 18**.
Air Intake Filter telltale always/never on.	See **Fig. 18**.
Low Air telltale always/never on.	See **Fig. 22**.
Tractor ABS, telltales always/never on.	Check wiring and ABS ECUs. If OK, replace lightbar.
Trailer ABS, telltales always/never on.	
Check engine light always/never on.	See **Fig. 18**.
Optional Telltale #2 through #7 always/never on.	See **Fig. 19**.
Right/Left Turn Signal always/never on.	See **Fig. 20**.
Check A/C telltale always/never on.	See **Fig. 20**.

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Troubleshooting

Problem With Light Bar During Operation	
Problem	**Remedy**
High Beam Indicator telltale always/never on.	See **Fig. 20**.
Fasten Seat Belt telltale always/never on.	See **Fig. 21**.

Table 7, Problem With Light Bar During Operation

Warning Messages	
Warning Message	**Probable Cause**
LOW AIR	Air pressure low
PRK BRK	Air tank #2 low
LOW OIL	Engine oil pressure low
H2OTMP	Coolant temperature high
No Data	See **Table 2**.

Table 8, Warning Messages

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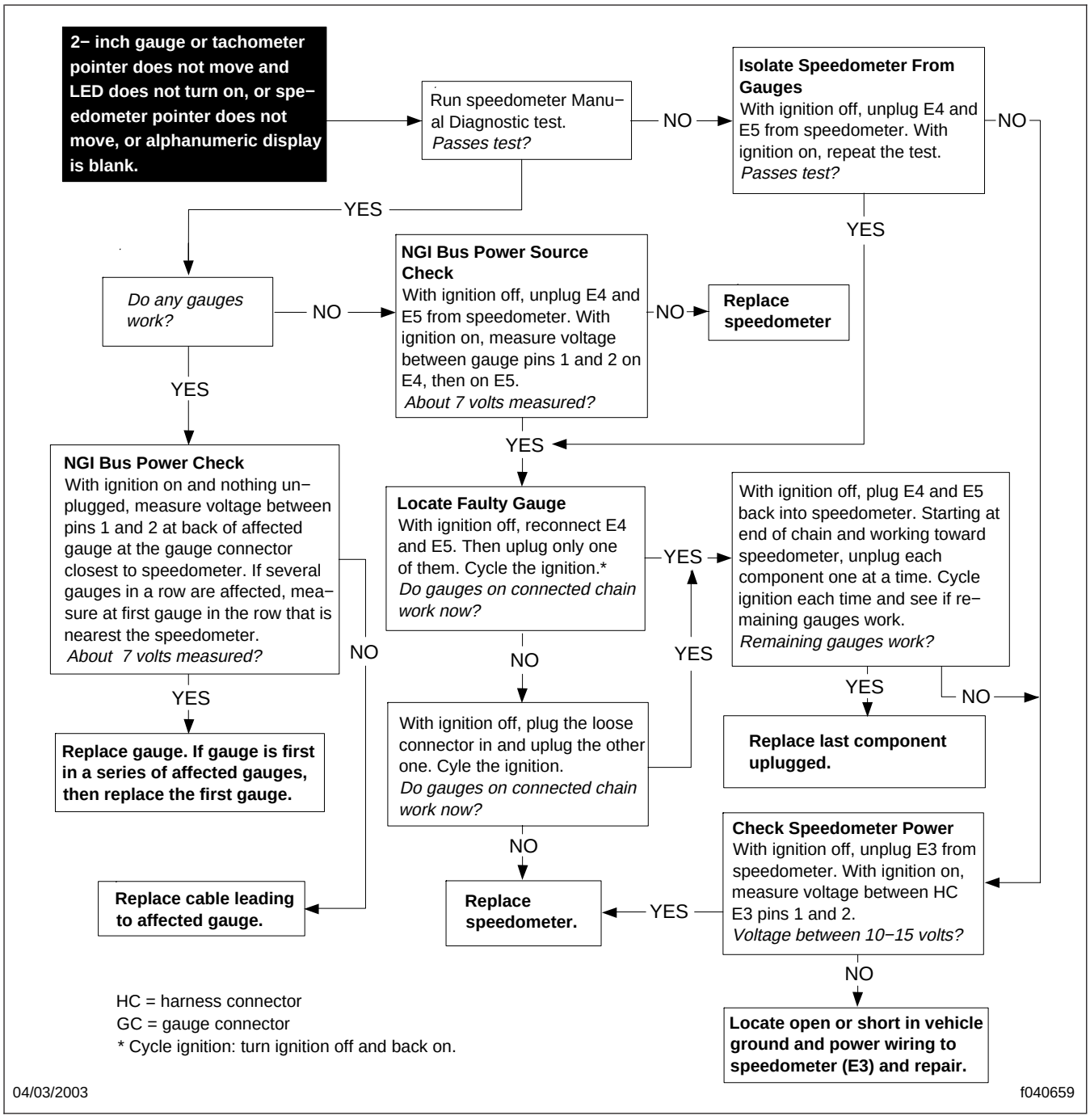


Fig. 6, Gauge Appears Dead

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Troubleshooting

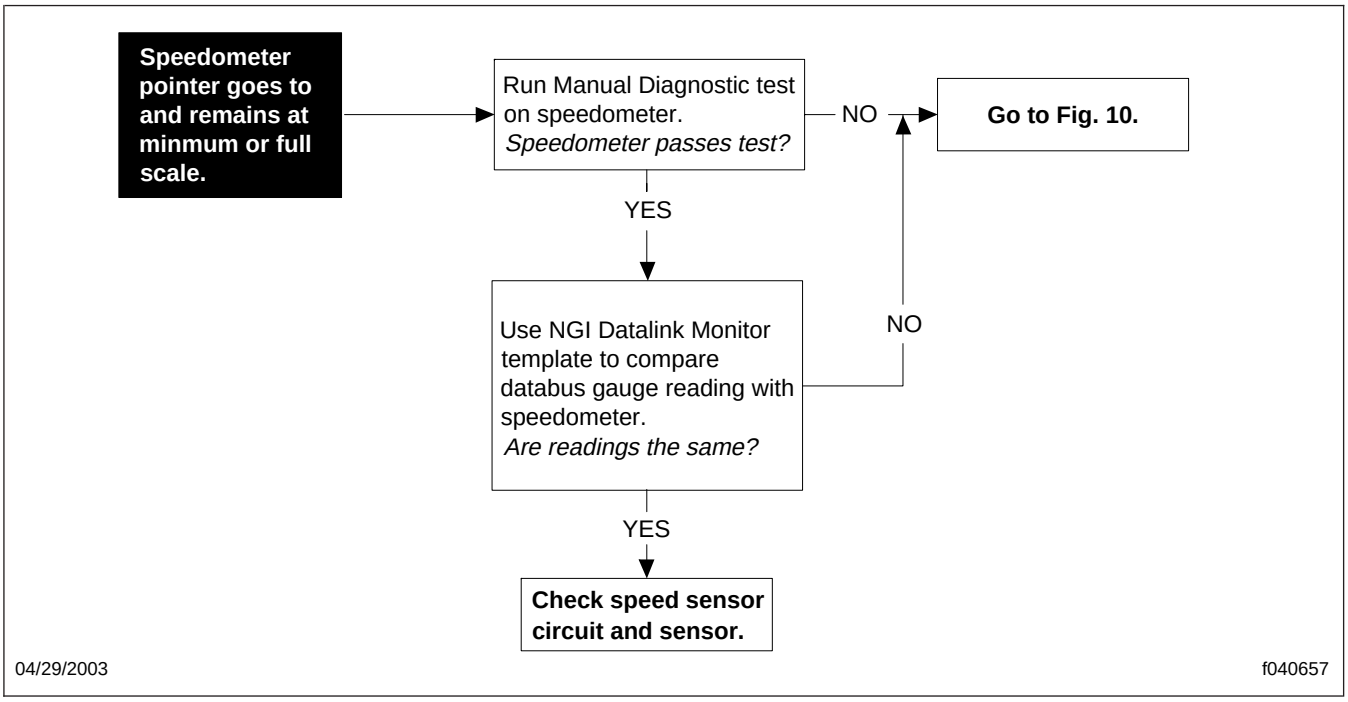


Fig. 7, No Speed Indication

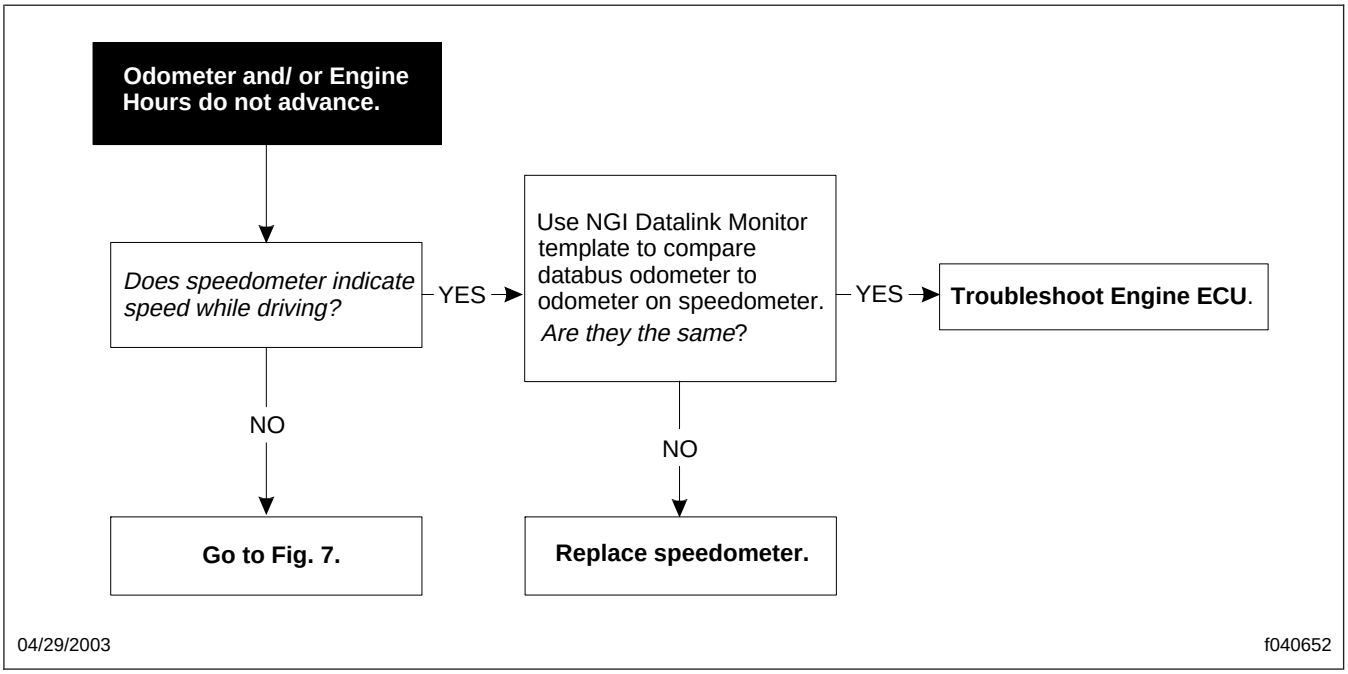


Fig. 8, Problem With Odometer or Engine Hourmeter

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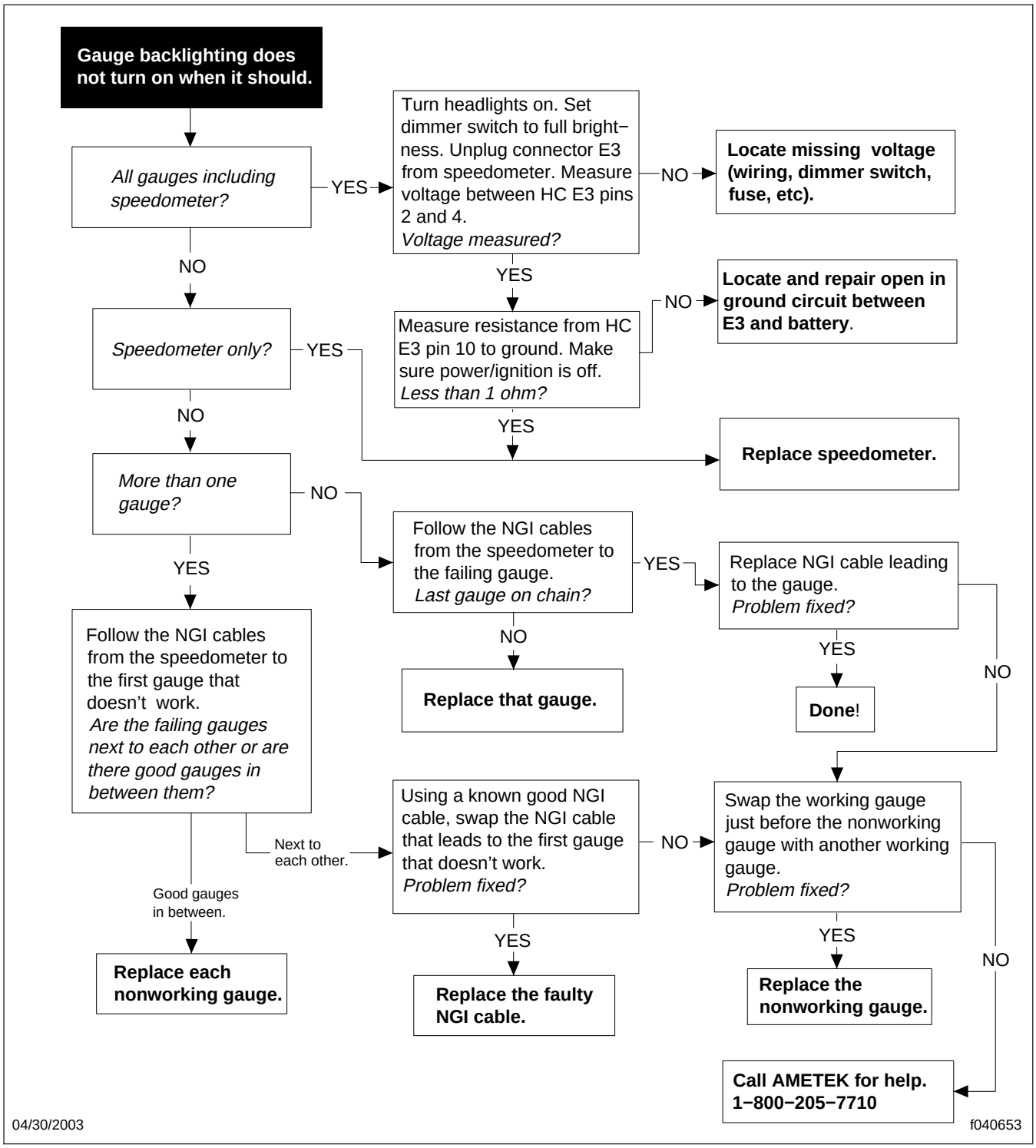


Fig. 9, Backlighting Problems

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Troubleshooting

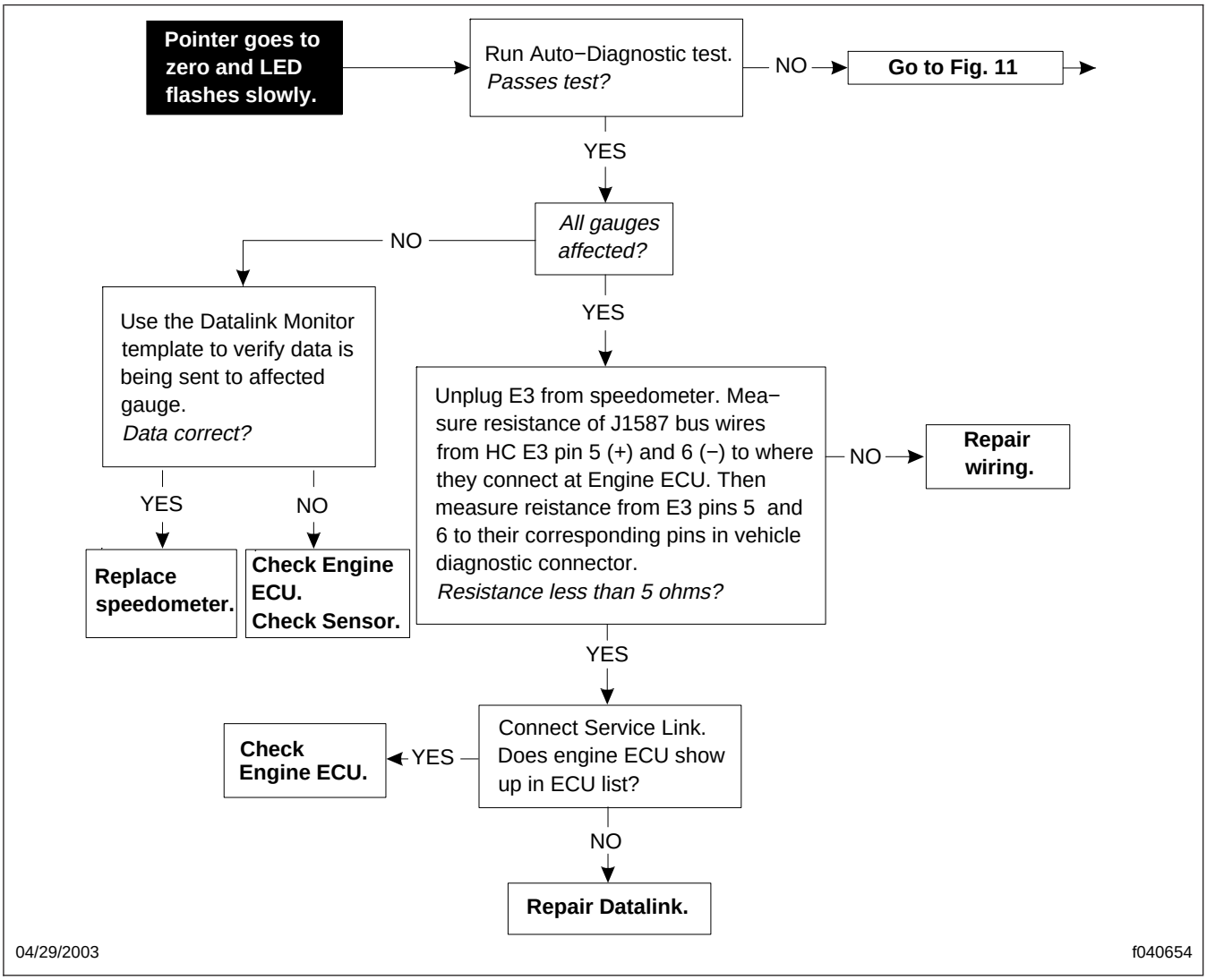


Fig. 10, Slow Flashing LED

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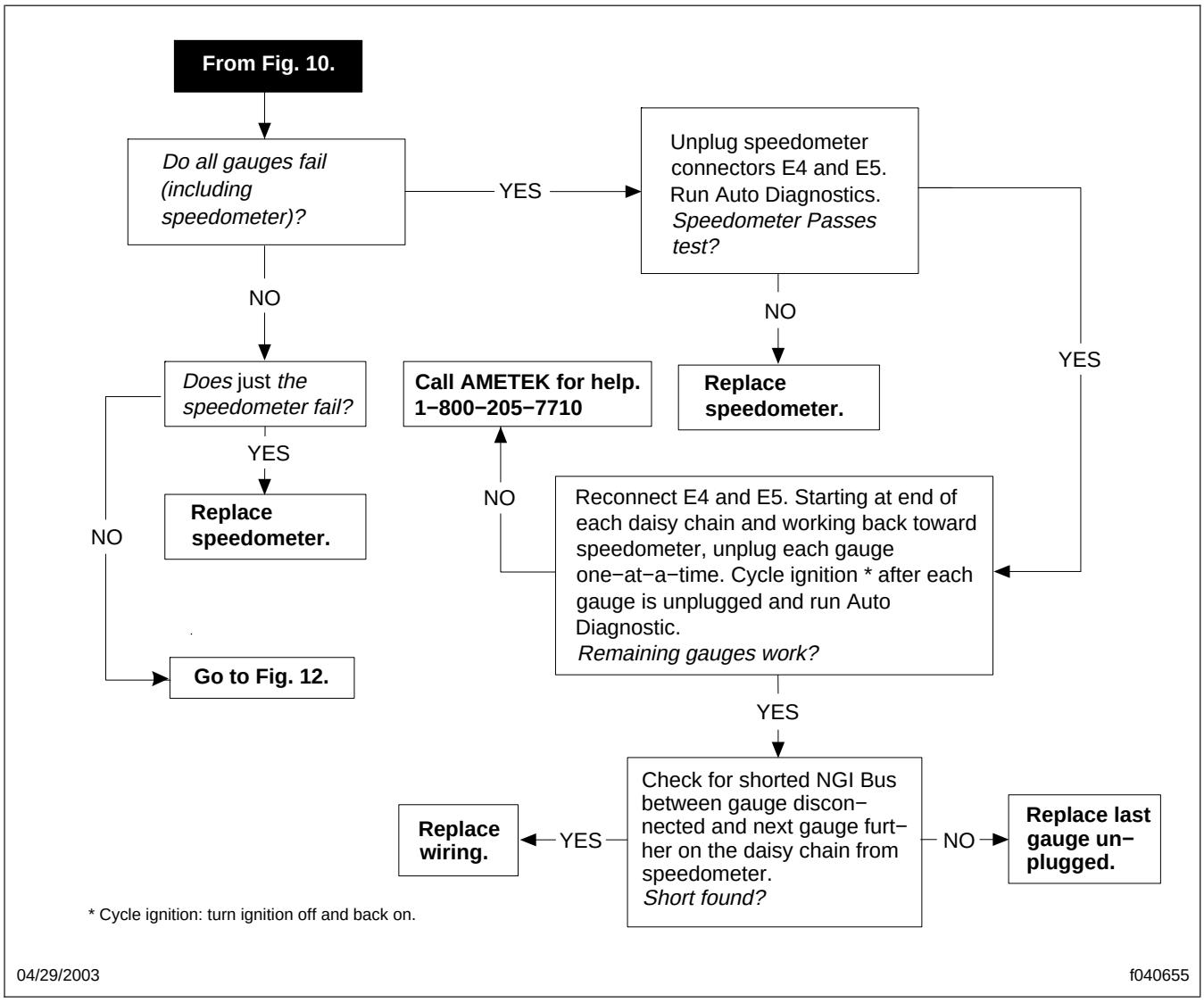


Fig. 11, Slow Flashing LED (part 2)

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Troubleshooting

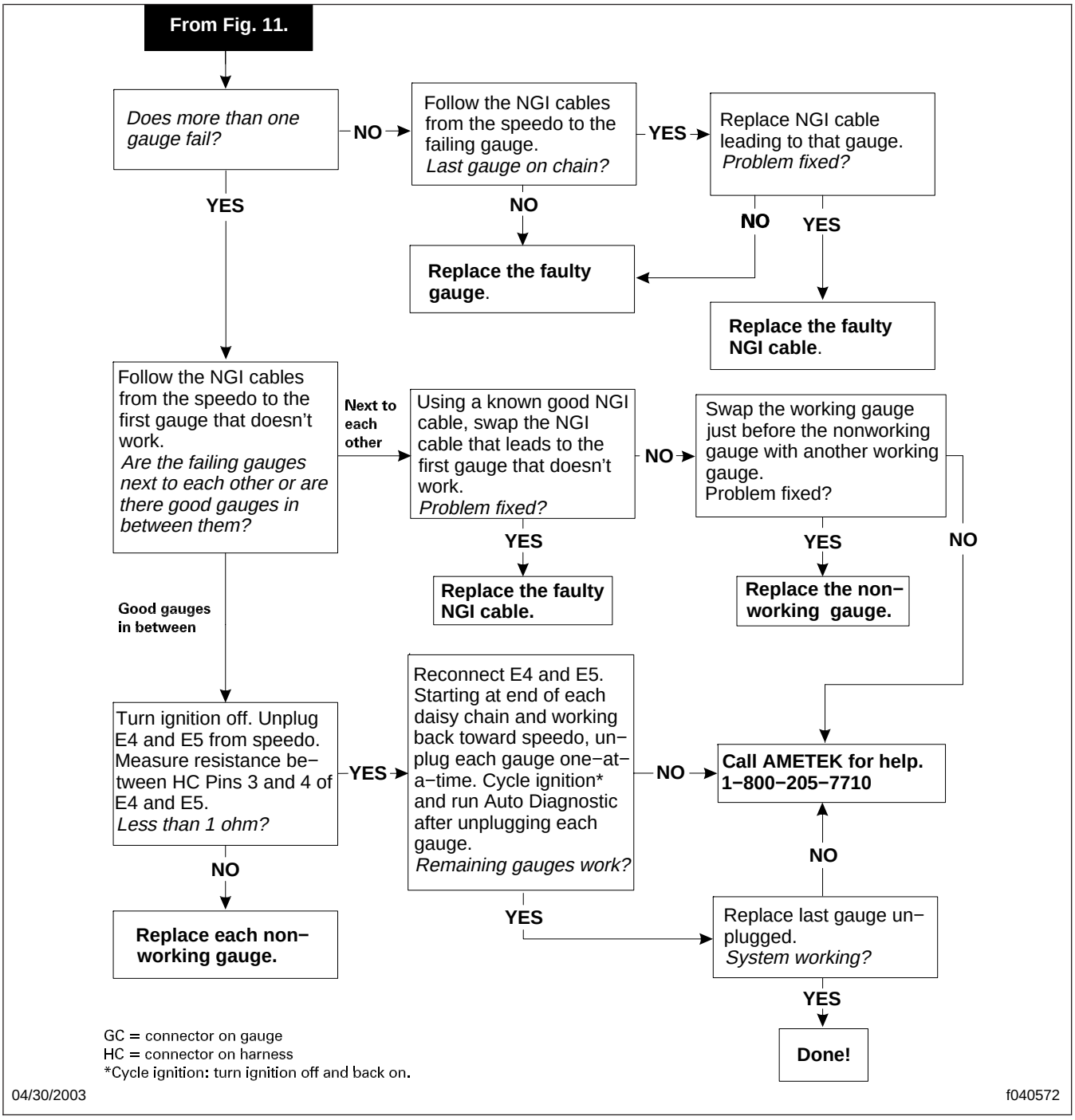


Fig. 12, Slow Flashing LED (part 3)

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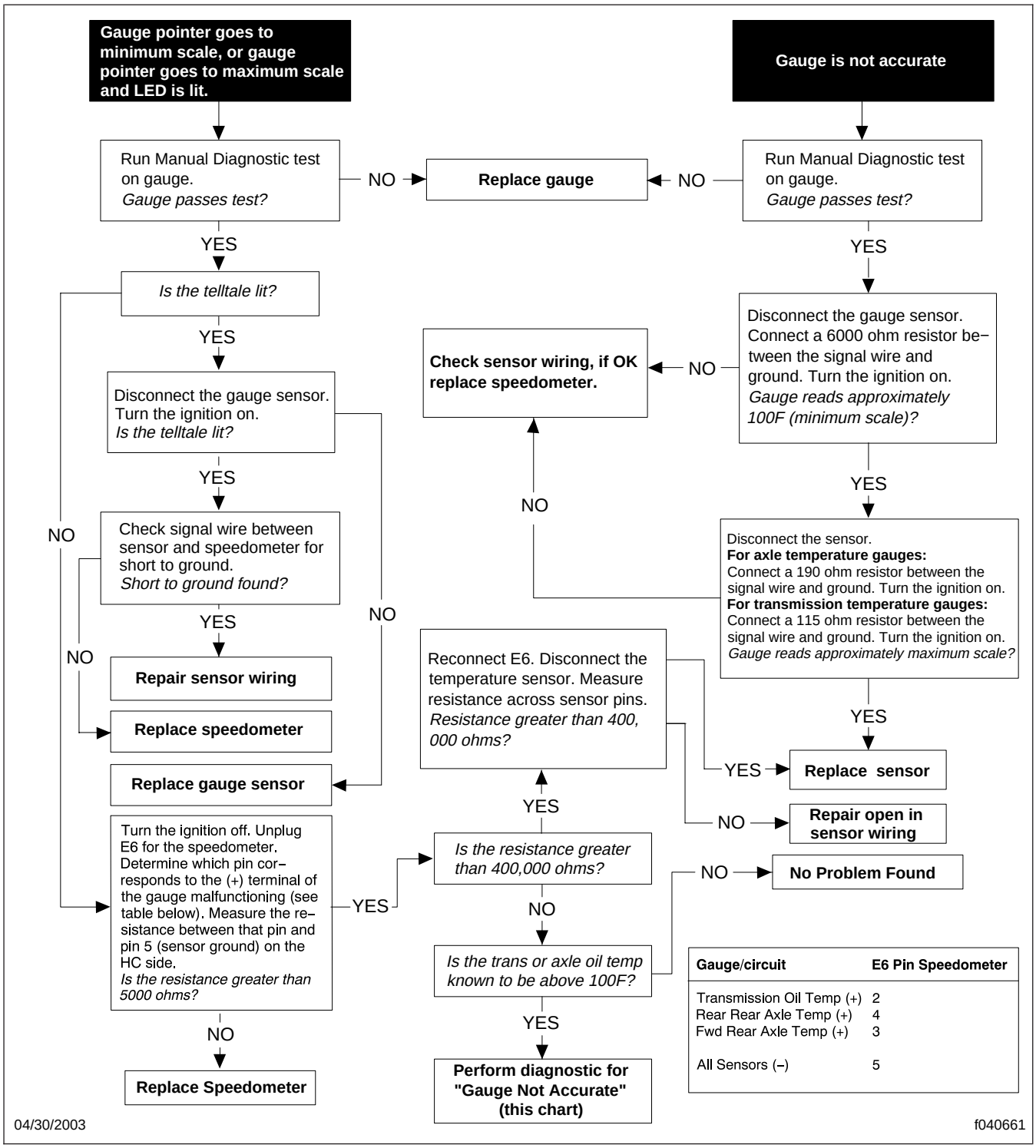


Fig. 13, Sensor Driven Gauge Problem (except fuel level gauge)

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Troubleshooting

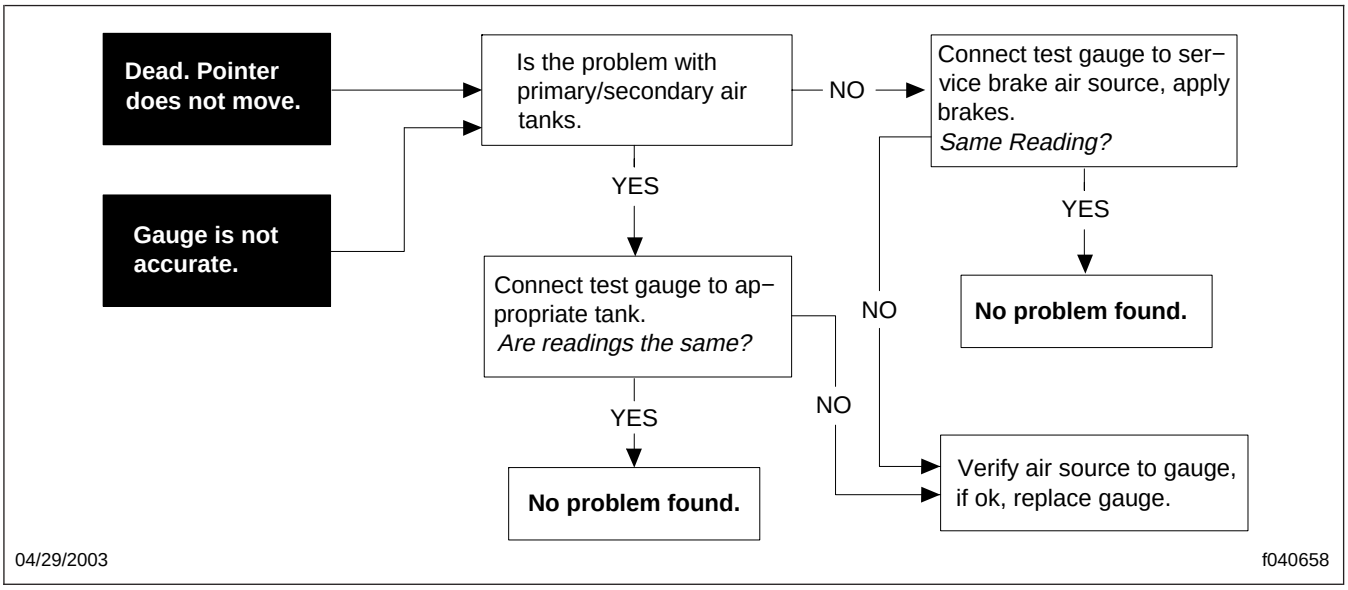


Fig. 14, Air Pressure Gauge Problem

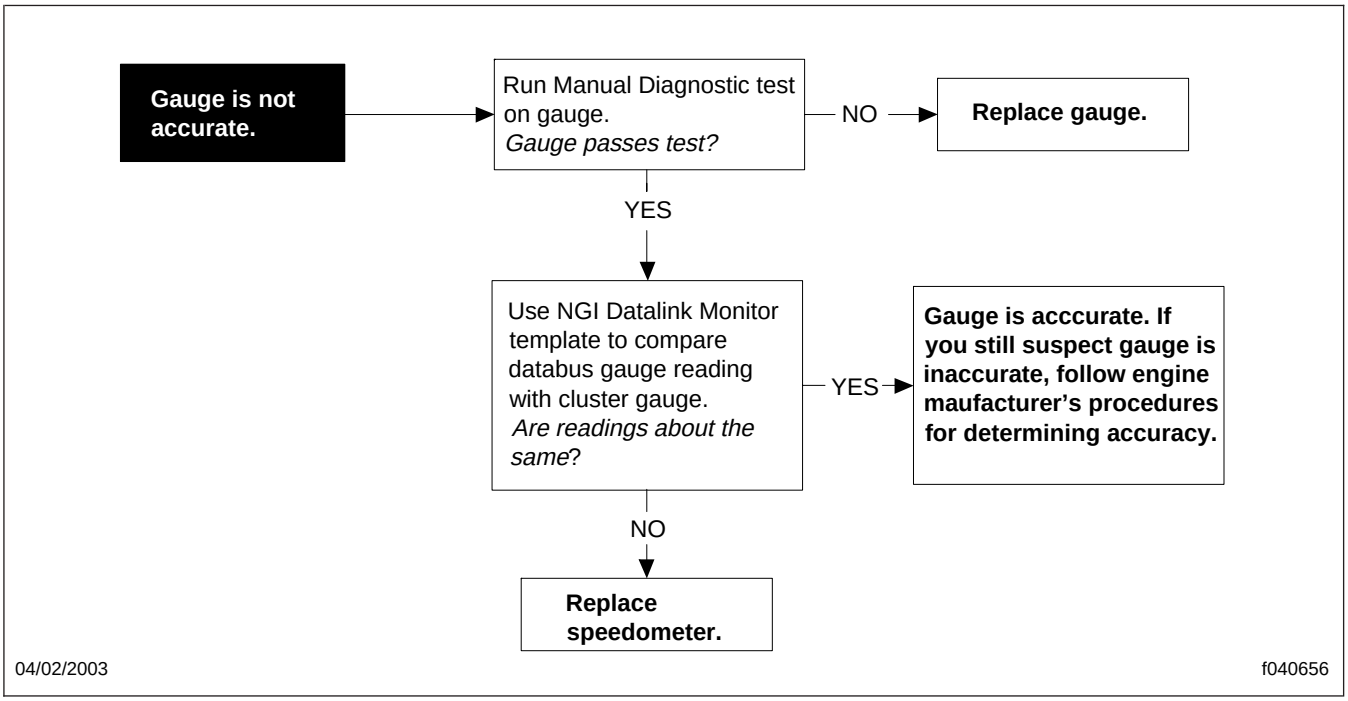


Fig. 15, Gauge Inaccurate

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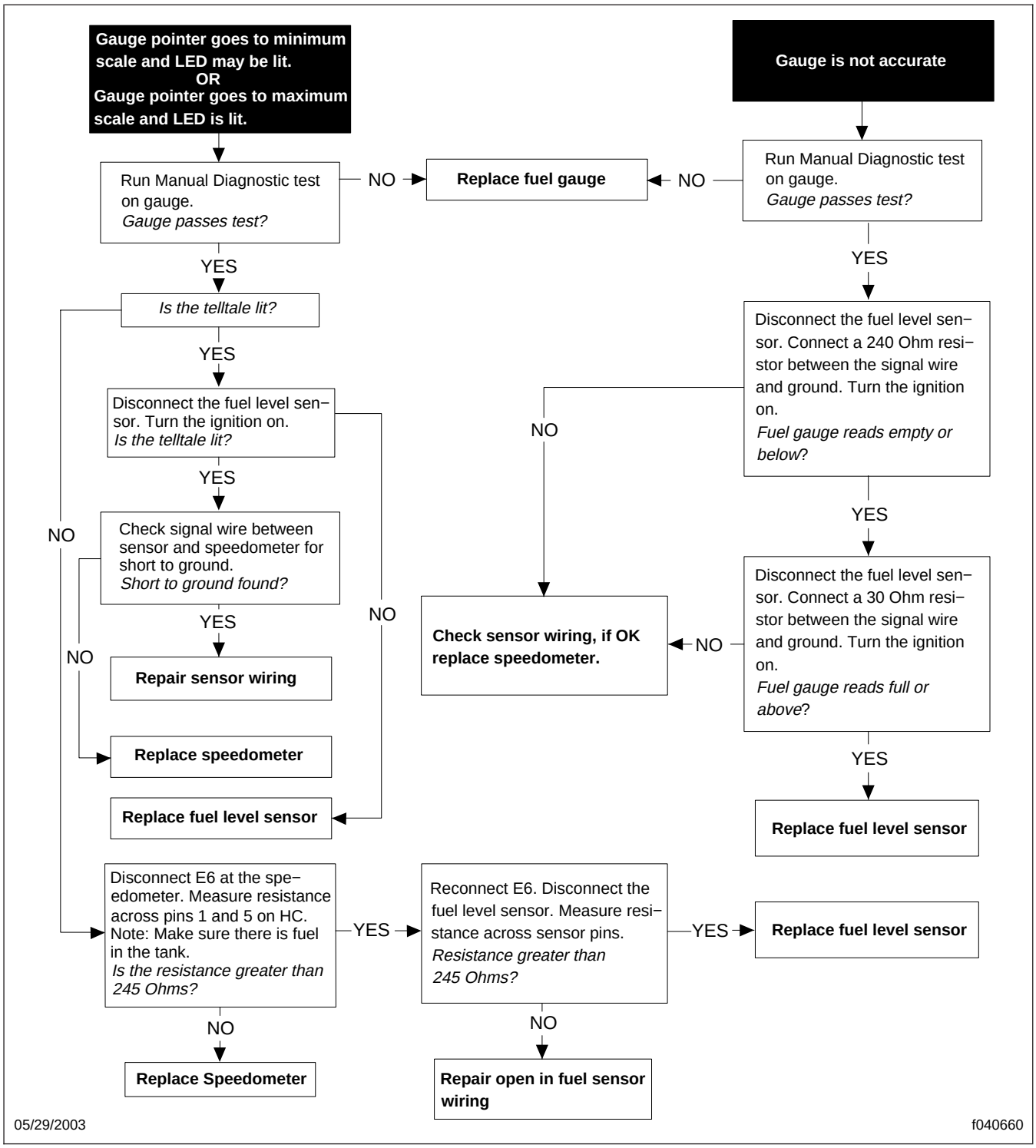


Fig. 16, Fuel Level Gauge Problem

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Troubleshooting

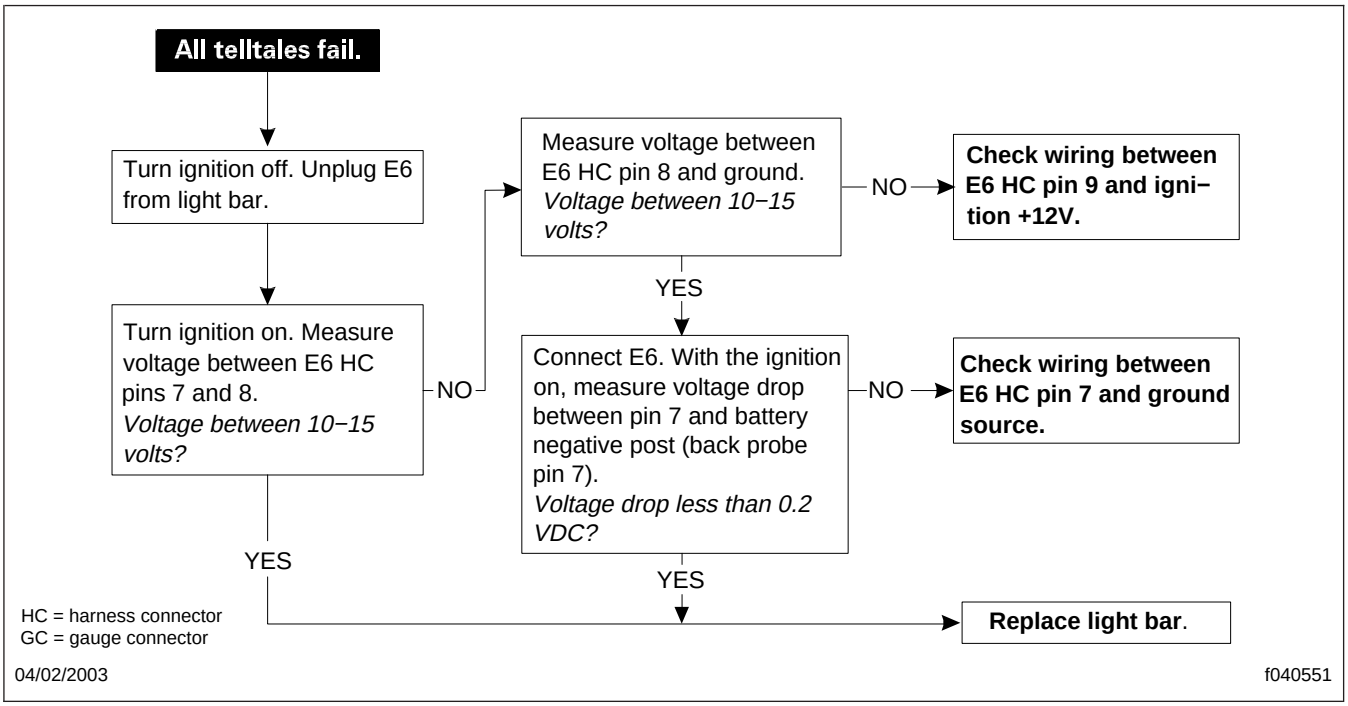


Fig. 17, No Telltales Turn On

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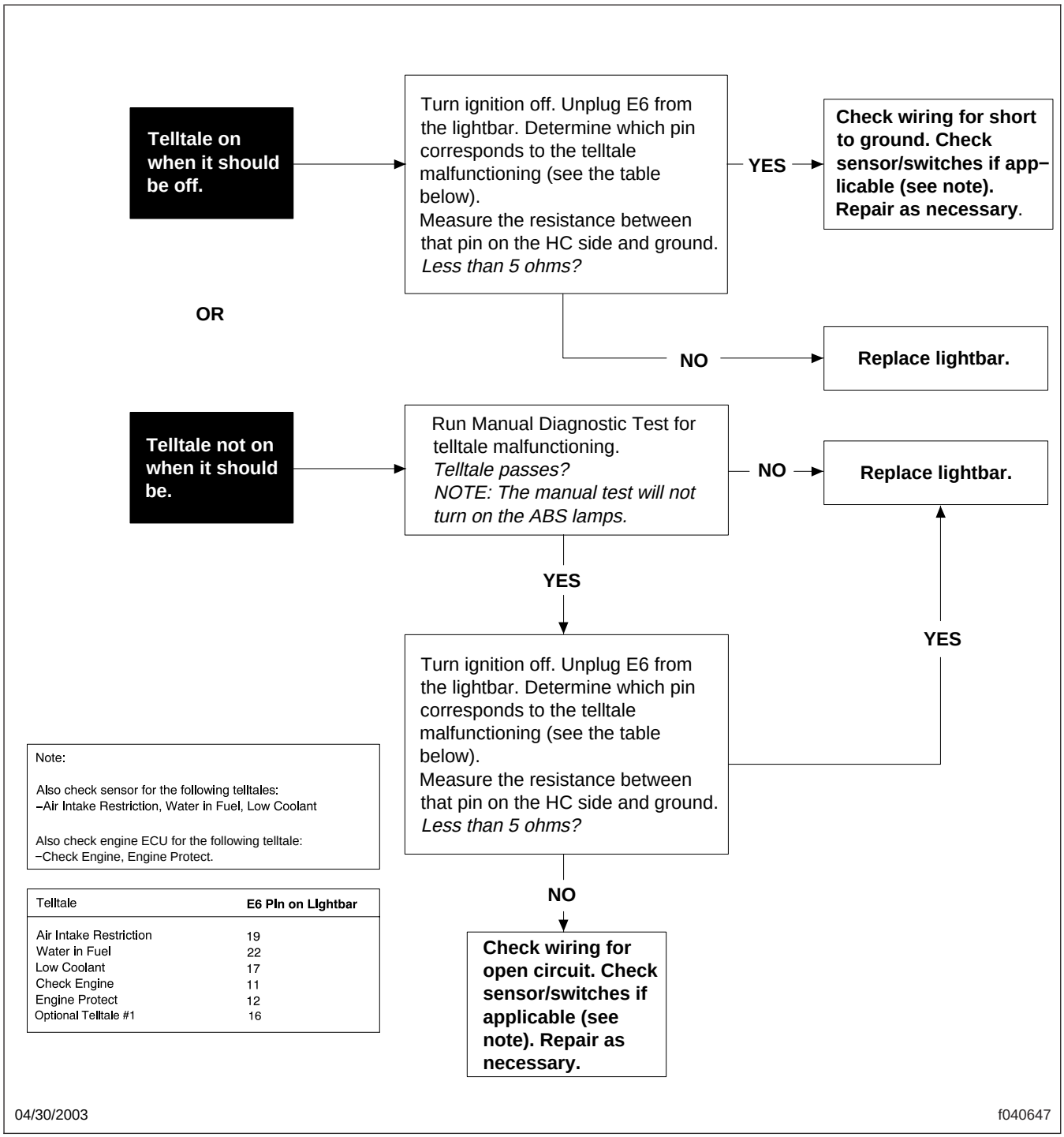


Fig. 18, Ground Activated Telltales Wired Directly to the Lightbar Always/Never On (except tractor and trailer ABS)

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Troubleshooting

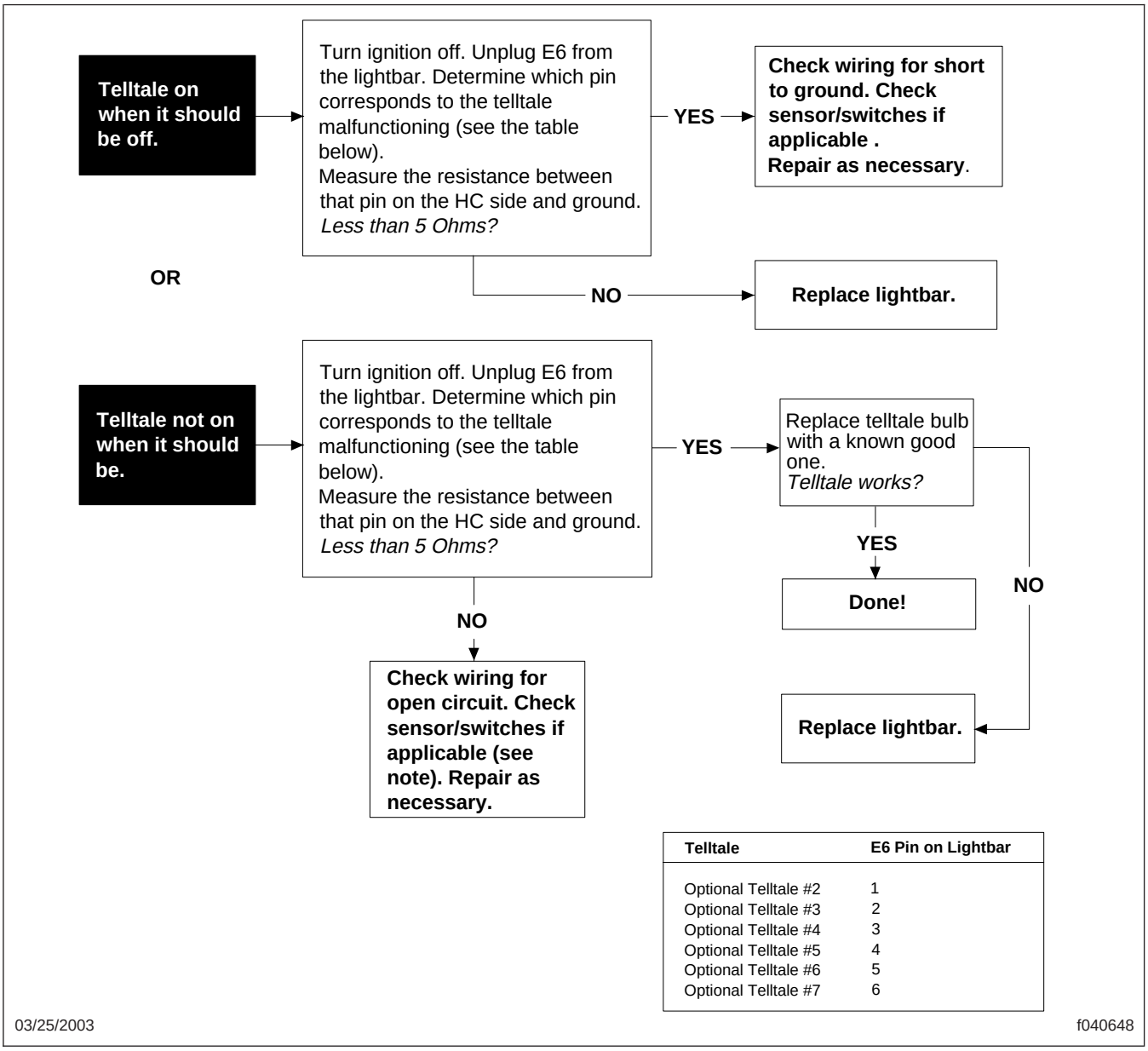


Fig. 19, Ground Activated Telltales Wired Directly to the Lightbar, Non-LED Optional Telltales Number 2 through 7 Always/Never On

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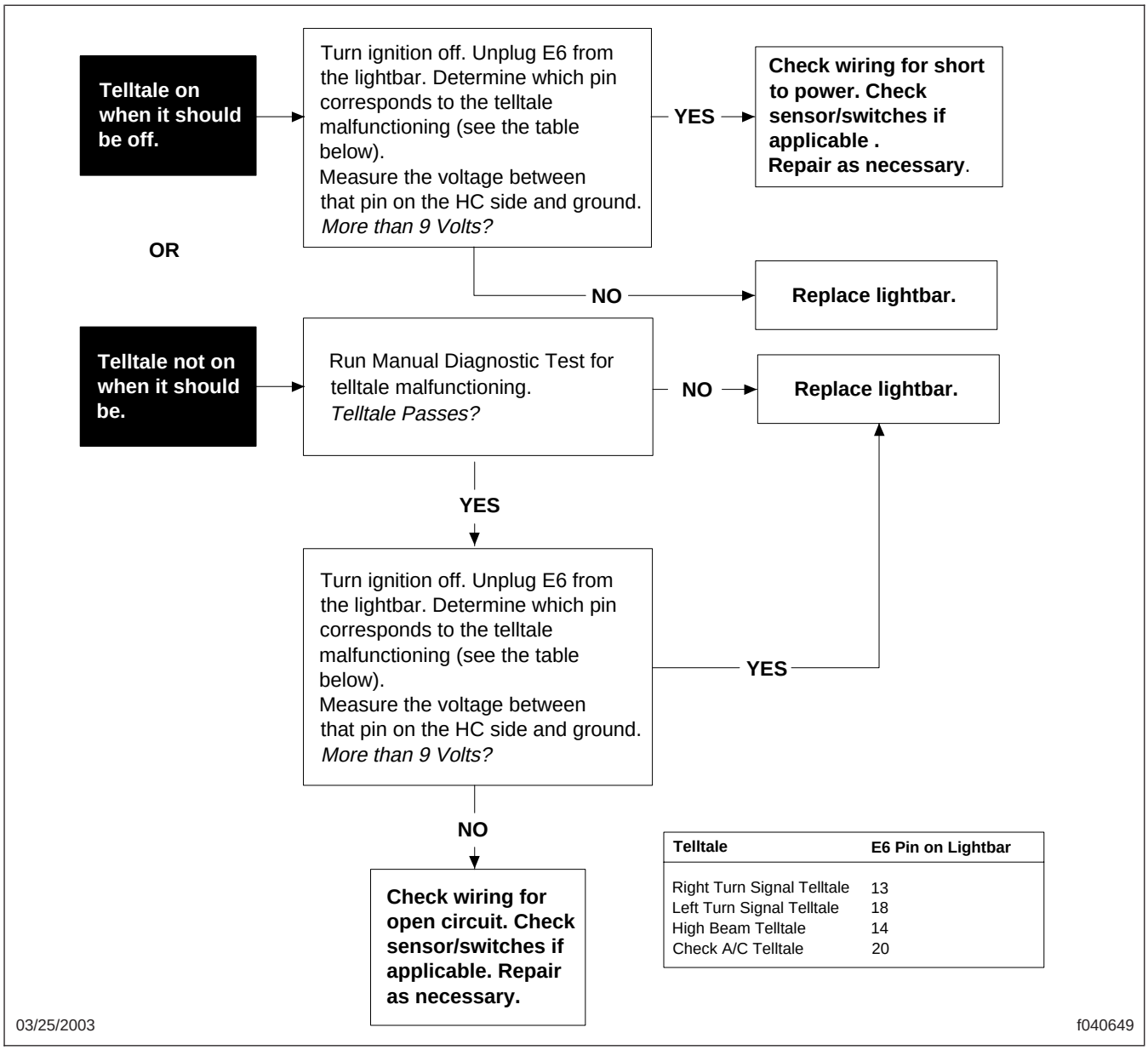


Fig. 20, Power Activated Telltales Wired Directly to the Lightbar Always/Never On

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Troubleshooting

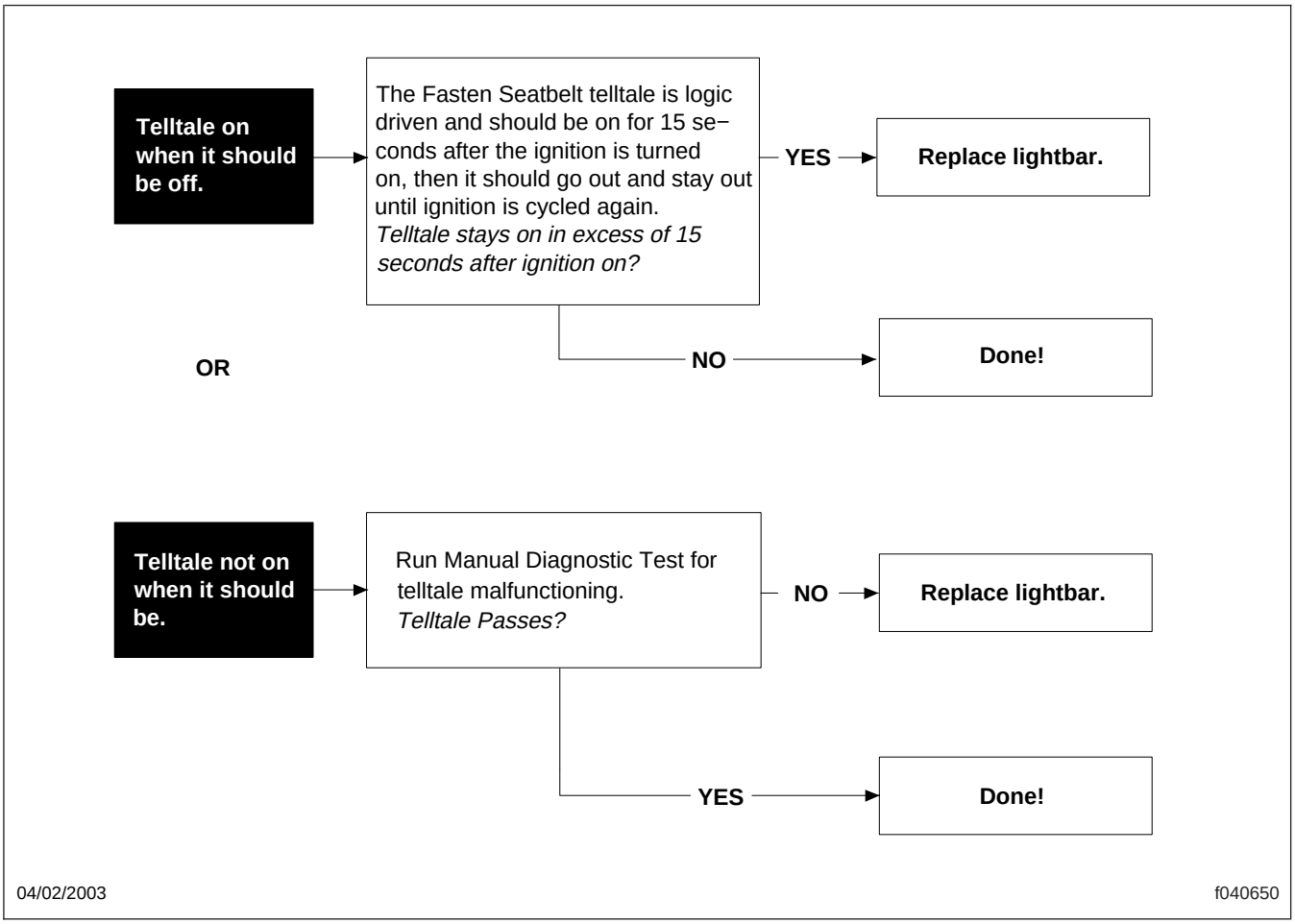


Fig. 21, Fasten Seatbelt Telltale Always/Never On

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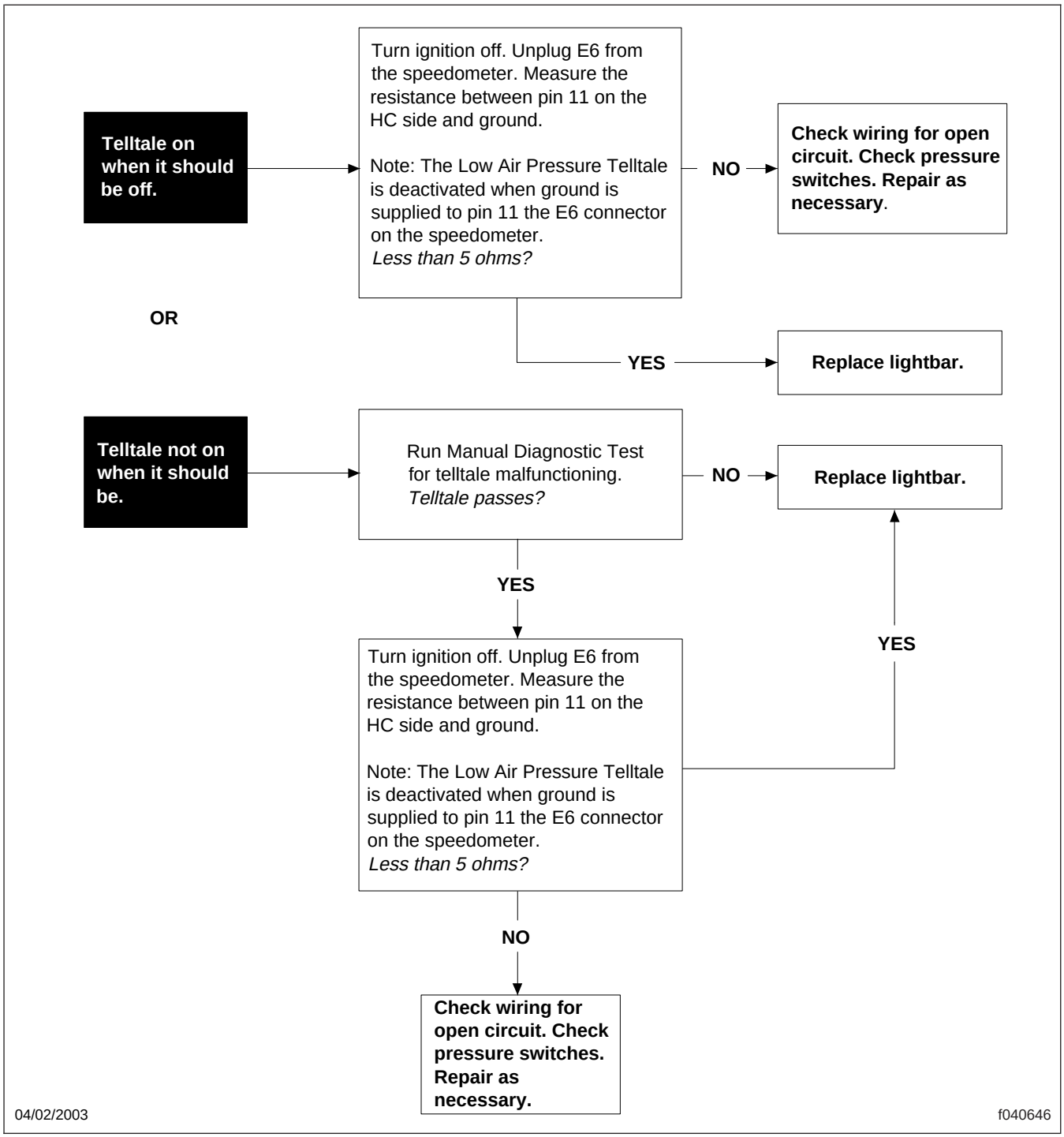
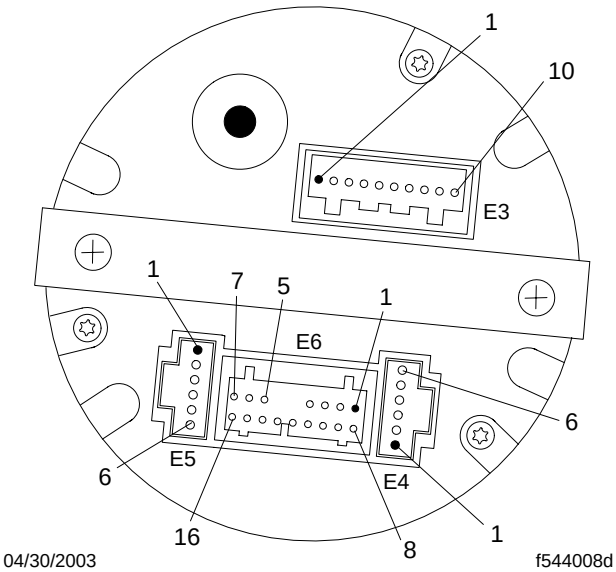


Fig. 22, Low Air Telltale Always/Never On

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See **Fig. 1** for speedometer connector locations.



NOTE: E4 and E5 are internally connected in parallel.

Fig. 1, Speedometer Connectors

Speedometer Connector E3	
Cavity	**Circuit Description**
Pin 1	Battery +
Pin 2	Battery Ground
Pin 3	Ignition +
Pin 4	Backlight Power (from PWM dimmer switch)
Pin 5	J1587 Bus +
Pin 6	J1587 Bus -
Pin 7	Not Used
Pin 8	Not Used
Pin 9	Not Used
Pin 10	Backlight Ground

Table 1, Speedometer Connector E3 Pin Identification

Speedometer Connector E6 (Analog and Switched Inputs)	
Cavity	**Circuit Description**
Pin 1	Fuel Level Sensor +
Pin 2	Transmission Oil Temperature Sensor +
Pin 3	Fwd Rear Axle Temperature Sensor +

Speedometer Connector E6 (Analog and Switched Inputs)	
Cavity	**Circuit Description**
Pin 4	Rear Rear Axle Temperature Sensor +
Pin 5	Sensor Ground
Pin 6	Not Used
Pin 7	Not Used
Pin 8	Not Used
Pin 9	Not Used
Pin 10	No Charge Telltale
Pin 11	Low Air Buzzer/Lamp (ground to turn off)
Pin 12	Park Brake Telltale
Pin 13	External Buzzer Input
Pin 14	Not Used
Pin 15	Transmission Temperature Telltale
Pin 16	Not Used

Table 2, Speedometer Connector E6 Pin Identification

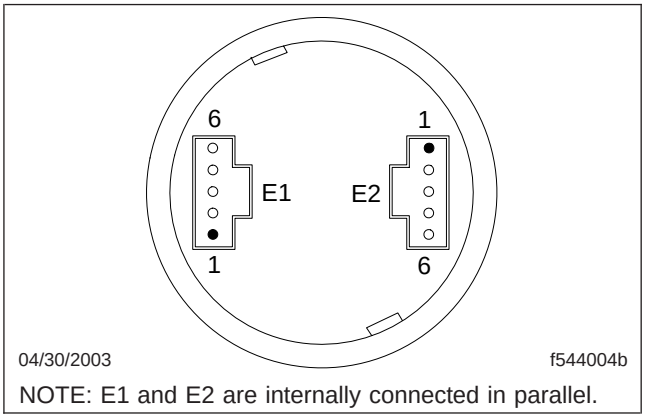
Speedometer Connector E4 and E5 (NGI Bus)	
Cavity	**Circuit Description**
Pin 1	NGI Power (+ 7.6VDC)
Pin 2	NGI Ground
Pin 3	NGI Bus Positive (+)
Pin 4	NGI Bus Negative (-)
Pin 5	Backlight Ground
Pin 6	Backlight Power

Table 3, Speedometer Connectors E4 and E5 Pin Identification

See **Fig. 2** for two-inch gauge connector locations.

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Specifications



NOTE: E1 and E2 are internally connected in parallel.

Fig. 2, Two-Inch Gauge Connectors

Two-Inch Gauge Connectors E1 and E2 (NGI BUS)	
Cavity	**Circuit Description**
Pin 1	NGI Power (+ 7.6VDC)
Pin 2	NGI Ground
Pin 3	NGI Bus Positive (+)
Pin 4	NGI Bus Negative (-)
Pin 5	Backlight Ground
Pin 6	Backlight Power

Table 4, Two-Inch Gauge Connectors E1 and E2 Pin Identification

See **Fig. 3** for lightbar connector locations.

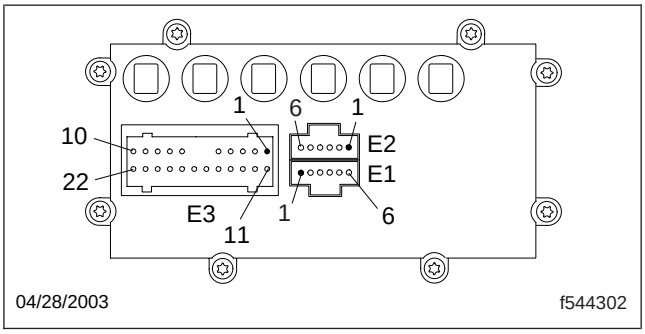


Fig. 3, Light Bar Connectors

Light Bar Connector E3 Pin Identification		
Cavity Pin #	**Function**	**Activation**
1	Optional Telltale #2	Ground (ignition OFF)

Light Bar Connector E3 Pin Identification		
Cavity Pin #	**Function**	**Activation**
2	Optional Telltale #3	Ground
3	Optional Telltale #4	Ground
4	Optional Telltale #5	Ground
5	Optional Telltale #6	Ground
6	Optional Telltale #7	Ground
7	Lightbar Ground	N/A
8	Lightbar + 12V (ignition)	N/A
9	Not Used	N/A
10	Not Used	N/A
11	Check Engine Telltale	Ground
12	Engine Protection Telltale	Ground
13	Right Turn Signal	+12V
14	High Beam Telltale	+12V
15	Trailer ABS Telltale	Ground
16	Optional Telltale #1	Ground
17	Intake Heater	Ground
18	Left Turn Signal	+12V
19	Air Filter Restriction Telltale	Ground
20	Low Air	Ground
21	Tractor ABS Telltale	Ground
22	Park Brake	Ground

Table 5, Light Bar Connector E3 Pin Identification

Light Bar Connectors E1 and E2 (NGI BUS)	
Cavity	**Circuit Description**
Pin 1	NGI Power (+ 7.6VDC)
Pin 2	NGI Ground
Pin 3	NGI Bus Positive (+)
Pin 4	NGI Bus Negative (-)
Pin 5	Backlight Ground
Pin 6	Backlight Power

Table 6, Lightbar Connectors E1 and E2 Pin Identification

See **Fig. 4** for the Packard dash harness to instrument cluster connectors.

See **Fig. 5** for the NGI Interface Schematic.

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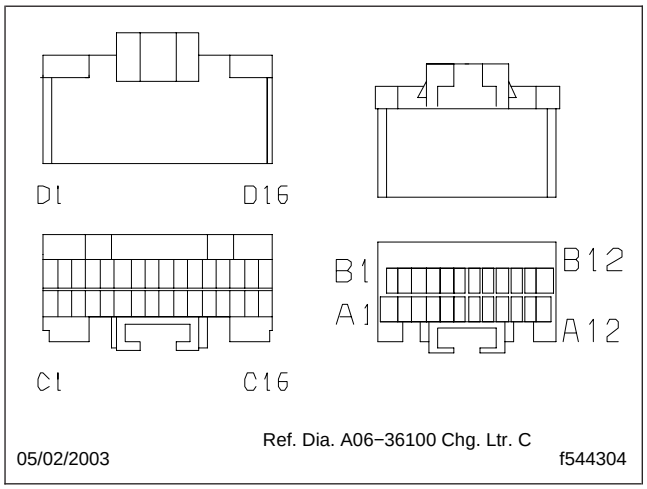


Fig. 4, Packard Connectors, Dash Harness to Instrument Cluster (dash side shown)

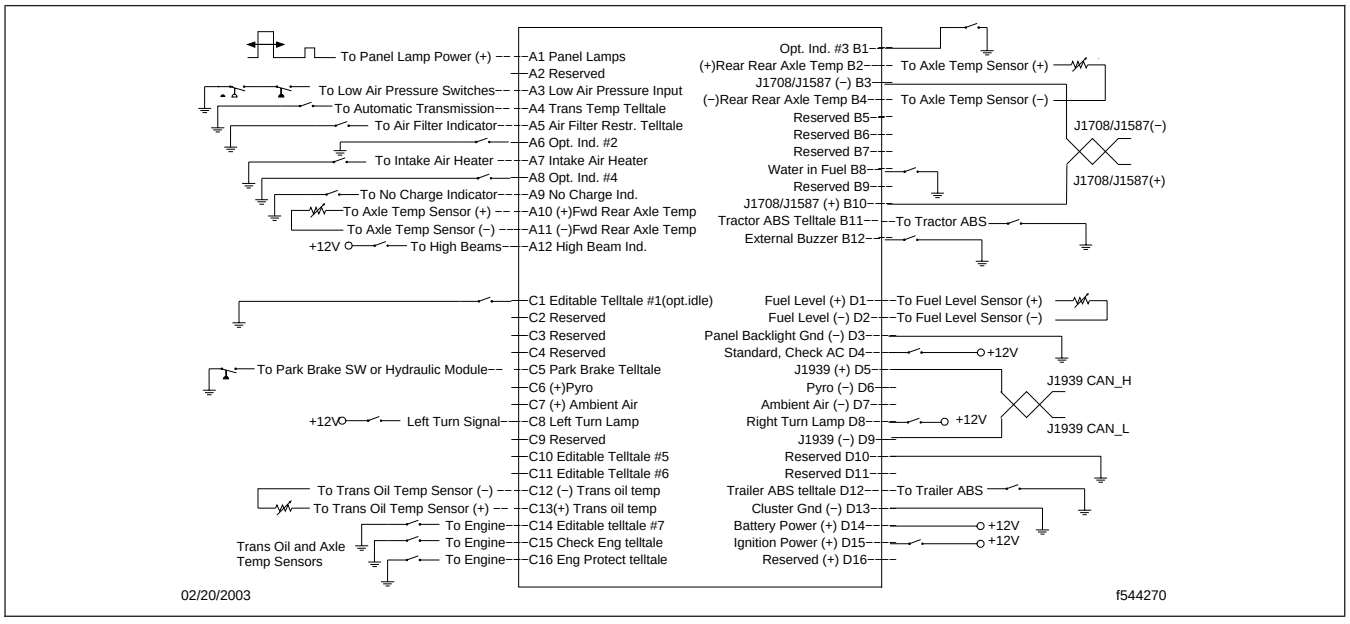


Fig. 5, NGI Interface Schematic

NGI Cluster to Vehicle Interface Connector Pinouts		
Pin	**Designation**	**Description**
A 1	(+) Panel Lamps	Panel backlight power from pulse width modulator (PWM) dimmer switch.
A 2	Reserved	N/A
A 3	Low Air Pressure Input	Closed (ground) turns off buzzer and lamp. Open (float) turns on buzzer and lamp.

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Specifications

NGI Cluster to Vehicle Interface Connector Pinouts		
Pin	**Designation**	**Description**
A 4	Trans Temp Telltale	Ground activated telltale.
A 5	Air Filter Restr. Telltale	Ground activated telltale.
A 6	Opt. Ind. #2	Optional ground activated telltale (ignition off).
A 7	Intake Air Heater	Ground activated telltale. (standard)
A 8	Opt. Ind. #4	Optional ground activated telltale.
A 9	No Charge Ind.	Optional Ground activated telltale.
A 10	(+) Fwd Rear Axle Temp	High side of variable resistance sensor.
A 11	(-) Fwd Rear Axle Temp	Low side of variable resistance sensor. Connected to signal ground.
A 12	High Beam Ind.	12V activated telltale.
B 1	Opt. Ind. #3	Optional ground activated telltale.
B 2	(+) Rear Rear Axle Temp	High side of variable resistance sensor. (Optional)
B 3	J1708/J1587 (-)	J1587 (-)
B 4	(-) Rear Rear Axle Temp	Low side of variable resistance sensor, connected to signal ground. (Optional)
B 5	Reserved	N/A
B 6	Reserved	N/A
B 7	Reserved	N/A
B 8	Water in Fuel	Ground activated telltale.
B 9	Reserved	N/A
B 10	J1708/J1587 (+)	J1587 (+)
B 11	Tractor ABS Telltale	Ground activated telltale.
B 12	External Buzzer	Ground activated, warning enabled.
C 1	Editable Telltale #1 (opt. idle)	Ground activated telltale. (Opt. Idle has highest priority)
C 2	Reserved	N/A
C 3	Reserved	N/A
C 4	Reserved	N/A
C 5	Park Brake Telltale	N/C switch = brake on (input grounded); sw open = brake off (input floating).
C 6	(+) Pyro	High side of pyrometer amplifier output. (reserved)
C 7	(+) Ambient Air	High side of variable resistance thermistor. (reserved)
C 8	Left Turn Lamp	12V activated telltale.
C 9	Reserved	N/A
C 10	Editable Telltale #5	Optional ground activated telltale.
C 11	Editable Telltale #6	Optional ground activated telltale.
C 12	(-) Tran Oil Temp	Low side of variable resistance sensor.

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NGI Cluster to Vehicle Interface Connector Pinouts		
Pin	**Designation**	**Description**
C 13	(+) Tran Oil Temp	High side of variable resistance sensor.
C 14	Editable Telltale #7	Optional ground activated telltale.
C 15	Check Eng Telltale	Ground activated telltale.
C 16	Engine Protection Telltale	Ground activated telltale.
D 1	Fuel Level (+)	High side of variable resistance fuel level sensor.
D 2	Fuel Level (-)	Low side of variable resistance fuel level sensor.
D 3	(-) Panel Backlight Ground	Ground for panel backlight.
D 4	Standard, Check A/C	12V activated telltale.
D 5	J1939 (+)	Not used
D 6	Pyro (-)	Low side of pyrometer amplifier output.
D 7	Ambient Air (-)	Low side of variable resistance thermistor.
D 8	Right Turn Telltale	12 V and micro activated telltale.
D 9	J1939 (-)	Not used.
D 10	Reserved	N/A
D 11	Reserved	N/A
D 12	Trailer ABS Telltale	Ground activated telltale.
D 13	Cluster Ground (-)	Ground for NGI Cluster.
D 14	Battery Power(+)	Constant 12V to cluster.
D 15	Ignition Power (+)	Ignition switched + 12V to cluster.
D 16	Reserved	N/A

Table 7, Connector Pin-out

Telltale Drive Functionality						
Telltale	**Drive**	**Connection**	**Active State**	**Location**	**Cleaning Current**	**Vehicle Interface PIN #**
Left Turn Signal	Discrete	Lightbar	High	Std. Lightbar	No	C8
Right Turn Signal	Discrete	Lightbar	High	Std. Lightbar	No	D8
Check Engine	Discrete	Lightbar	Low	Std. Lightbar	Yes	C15
Engine Protect	Discrete	Lightbar	Low	Std. Lightbar	Yes	C16
Fasten Seat Belt	Logic	N/A	N/A	Std. Lightbar	N/A	N/A
High Beam	Discrete	Lightbar	High	Std. Lightbar	No	A12
Tractor ABS	Discrete	Lightbar	Low	Std. Lightbar	Yes	B11
Trailer ABS	Discrete	Lightbar	Low	Std. Lightbar	Yes	D12
Parking Brake	Discrete	SCU and Lightbar	Low	Std. Lightbar	Yes	C5

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Specifications

Telltale Drive Functionality						
Telltale	**Drive**	**Connection**	**Active State**	**Location**	**Cleaning Current**	**Vehicle Interface PIN #**
Air Intake Restriction	Discrete	Lightbar	Low	Std. Lightbar	Yes	A5
Water in Fuel	Discrete	SCU	Low	Std. Lightbar	Yes	B8
Intake Heater	Discrete	Lightbar	Low	Std. Lightbar	Yes	A7
Check A/C	Discrete	SCU	High	Std. Lightbar	No	D4
Low Air Pressure	Discrete	SCU and Lightbar	Low	Std. Lightbar	Yes	A3
High Coolant Temp	Data Bus	N/A	N/A	Gauge	N/A	N/A
Low Oil Pressure	Data Bus	N/A	N/A	Gauge	N/A	N/A
Low Voltage	Data Bus	N/A	N/A	Gauge	N/A	N/A
No Charge	Discrete	SCU	Low	Gauge	N/A	A9
Trans Temp	Discrete	SCU	Low	Gauge	No	A4
Opt. #1 Editable (Amber LED)	Discrete	Lightbar	Low	Opt. Lightbar	Yes	C1
Opt. #2 Editable (Bulb)	Discrete	Lightbar	Low	Opt. Lightbar	Yes	A6
Opt. #3 Editable (Bulb)	Discrete	Lightbar	Low	Opt. Lightbar	Yes	B1
Opt. #4 Editable (Bulb)	Discrete	Lightbar	Low	Opt. Lightbar	Yes	A8
Opt. #5 Editable (Bulb)	Discrete	Lightbar	Low	Opt. Lightbar	Yes	C10
Opt. #6 Editable (Bulb)	Discrete	Lightbar	Low	Opt. Lightbar	Yes	C11
Opt. #7 Editable (Bulb)	Discrete	Lightbar	Low	Opt. Lightbar	Yes	C14
Opt. Data Bus Gauges per Sec 1.2.3	Data Bus	N/A	N/A	Gauge	N/A	N/A
Opt. Sensor Gauges per Sec 1.2.3	SCU	N/A	N/A	Gauge	N/A	N/A

Table 8, Telltale Drive Functionality

Stewart Warner Fuel Sensor Resistance Values			
Meter Indication	**Resistance: ohms**		
	Minimum	**Nominal**	**Maximum**
Empty Stop	244.0	246.50	249.0
Empty	232.0	235.60	239.2
1/8		193.80	
1/4	149.6	152.10	154.5
3/8		127.50	
1/2	102.5	103.00	103.5
5/8		85.00	
3/4	66.2	67.00	67.8
7/8		48.50	

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Stewart Warner Fuel Sensor Resistance Values			
Meter Indication	Resistance: ohms		
	Minimum	Nominal	Maximum
Full	29.4	30.00	30.6

Table 9, Stewart Warner Fuel Sensor Resistance Values

High-Stat Oil Temperature Sensor Resistance Values				
Temp °F	Temp °C	Resistance: ohms		
		Minimum	Nominal	Maximum
-40	-40	291,490	336,600	381,710
-4	-20	85,850	97,120	108,390
14	-10	49,250	55,340	61,430
32	0	29,330	32,660	35,990
50	10	17,990	19,900	21,810
68	20	11,370	12,490	13,610
77	25	9,120	10,000	10,880
86	30	7,370	8,060	8,750
104	40	4,900	5,325	5,750
122	50	3,330	3,605	3,880
140	60	2,310	2,490	2,670
158	70	1,630	1,750	1,870
176	80	1,170	1,255	1,340
194	90	860	915	970
212	100	640	680	720
230	110	480	510	540
248	120	370	390	410
266	130	282	300	318
284	140	219	234	249
302	150	170	185	200
311	155	150	165	180
320	160	130	145	160
329	165	115	130	145
338	170	105	120	135
347	175	90	105	120
356	180	80	95	110

Table 10, High-Stat Oil Temperature Sensor Resistance Values

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Specifications

Lightbar Schematic (pins are on vehicle interface connectors)						
Pin C1 Opt 1 LED	Pin A6 Opt 2 Incandescent	Pin B1 Opt 3 Incandescent	Pin A8 Opt 4 Incandescent	Pin C10 Opt 5 Incandescent	Pin C11 Opt 6 Incandescent	Pin C14 Opt 7 Incandescent
Pin C8 Left Turn	Pin A5 Air Filter	Pin A7 Intake Heater	Fasten Seatbelt	Pin B8 Water in Fuel	Pin C5 Park Brake	Pin B8 Right turn
Pin C15 Check Engine	Pin C16 Engine Protect	Pin D4 Check A/C	Pin A12 High Beam	Pin B11 Tractor ABS	Pin D12 Trailer ABS	Pin A3 Low Air Pressure

Table 11, Lightbar Schematic

Message Identifiers (MIDs)		
MID	**Description**	**Text Message**
128	Engine Control Unit	ECU128
130	Transmission Control Unit	TCU130
136	Antilock Brake System (ABS)	ABS136
140	Instrumentation Control Unit	ICU140
223	Transmission Shift Unit	TSU223
###	Generic MID	SYS###

Table 12, Message Identifiers (MIDs)

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General Information

The intake air restriction indicator indicates how much air filter capacity has been used and how much remains. The indicator registers the actual maximum restriction of the filter element when the engine is operating at full load. The indicator retains the reading so that the remaining capacity can be read after the engine is shut down.

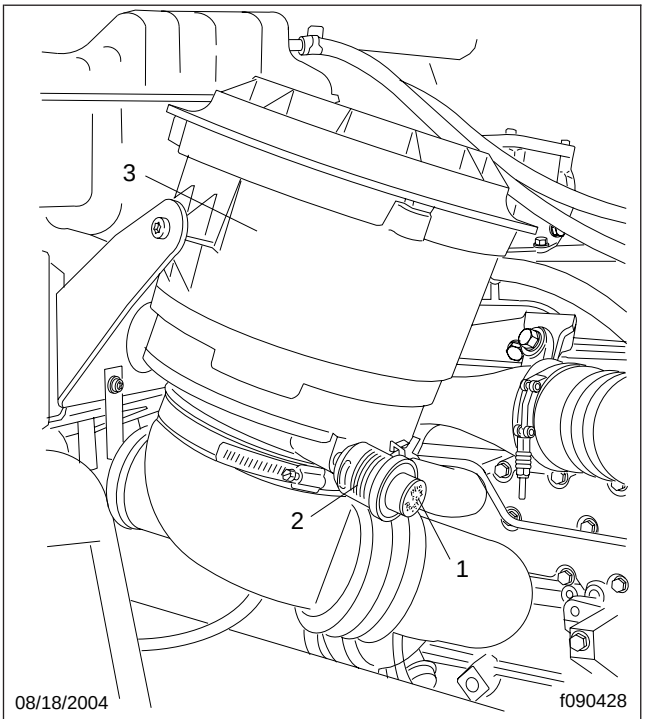
The intake air restriction indicator is mounted under the hood on the intake air piping, or in the cab on the dash panel. See **Fig. 1** and **Fig. 2**.

Do not open the air cleaner assembly until the indicator registers maximum restriction. When maximum restriction occurs, the air cleaner element needs to be serviced.

The intake air restriction indicator and the fitting may become plugged with moisture or engine vapors, possibly causing an incorrect reading. For troubleshooting procedures, see **Troubleshooting 300**.

An optional amber warning indicator is available and is displayed on the ICU3, defined as "Air Filter Restriction."

NOTE: Most engine degreasers are harmful to the polycarbonate (Lexan) plastic that is used in the intake air restriction indicator. When cleaning the engine or other components, avoid getting degreaser on the indicator.



1. Reset Button
2. Intake Air Restriction Indicator
3. Air Cleaner Assembly

Fig. 1, Intake Air Restriction Indicator Mounted Under the Hood

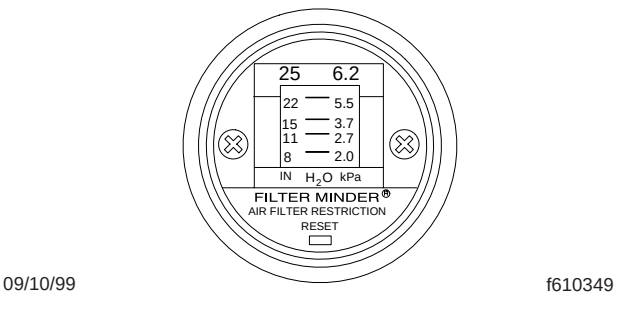


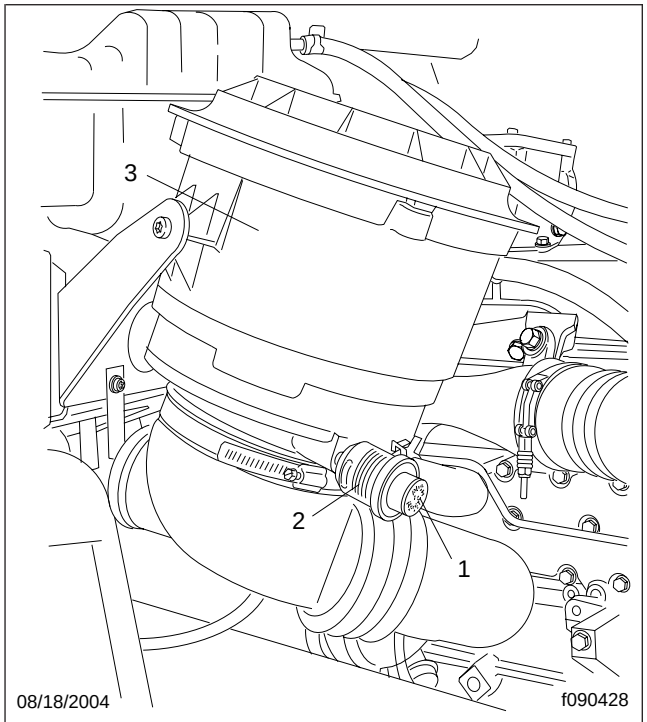
Fig. 2, Intake Air Restriction Indicator Mounted in the Cab

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Intake Air Restriction Indicator Mounted Under the Hood

Removal

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Using a wrench, remove the intake air restriction indicator from the intake air piping. See **Fig. 1**.



1. Reset Button
2. Intake Air Restriction Indicator
3. Air Cleaner Assembly

Fig. 1, Intake Air Restriction Indicator Mounted Under the Hood

Installation

1. Install the indicator on the intake air piping.
2. Close the hood and remove the chocks from the tires.

Intake Air Restriction Indicator Mounted in the Cab

Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Remove the necessary dash panels to access the intake air restriction indicator. For instructions, see **Section 60.07, Subject 100**.
3. Remove the electrical connector from the indicator. See **Fig. 2**.

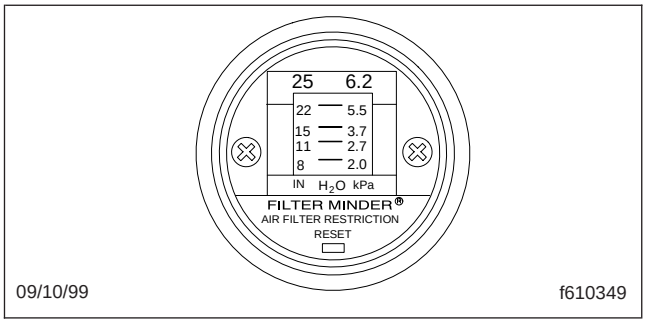


Fig. 2, Intake Air Restriction Indicator Mounted in the Cab

4. Remove the air line from the indicator.
5. Remove the screws that attach the indicator to the dash, and remove the indicator.
6. Using screws, attach a new indicator to the dash.
7. Attach the air line to the indicator.
8. Attach the electrical connector to the indicator.
9. Install the dash panels. For instructions, see **Section 60.07, Subject 100**.
10. Remove the chocks from the tires.

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Troubleshooting Tables

Problem—No Restriction Reading

Problem—No Restriction Reading	
Possible Cause	**Remedy**
The gauge leaks.	Remove the air restriction gauge. Apply a vacuum to the gauge until the yellow indicator reaches the red line. With your thumb on the mounting fitting, close the end of the gauge airtight. Hold in the reset button. The yellow indicator will drop slightly and then not move unless the gauge has a leak. If the gauge is functioning properly, install it and press the reset button. If the yellow indicator continues to move, replace the air restriction gauge. Repeat the troubleshooting procedure to verify that the new gauge does not leak. When the gauge is functioning properly, install it and press the reset button.
The air cleaner or intake pipe fitting is plugged.	Remove the obstruction.
Engine airflow is too low to generate a reading.	Turbocharged engines must be at full load to pull full engine airflow. Restrictions can be simulated by gradually closing off air intake. If there is still no restriction reading, check for leaks in the gauge or vacuum hose, as appropriate, and take corrective action.
The safety filter, if equipped, is plugged.	Do not clean the safety filter. Replace it with a new one.

Problem—High Restriction Readings

Problem—High Restriction Readings	
Possible Cause	**Remedy**
The element is plugged.	Anytime a high restriction is noted, it should be verified by resetting the restriction indicator and checking it again after several hundred miles of normal operation. Install a new filter element.
The intake screens or ducts are plugged.	Check the system upstream from the air restriction gauge and remove any debris. Check for damage or improper installation, and take necessary corrective action.
Heavy snow or rain.	Temporary high restriction can occur during a rain or snow storm and disappear after drying out. Anytime a high restriction is noted, it should be verified by resetting the restriction indicator and checking it again after several hundred miles of normal operation.

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Windshield Glass Removal and Installation

Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Open the hood.
3. Remove the windshield wipers. For instructions, see **Group 82**.
4. Remove the cowl-mounted antenna mast, if equipped.
5. Close the hood.
6. Remove the exterior visor, if equipped.

⚠ WARNING

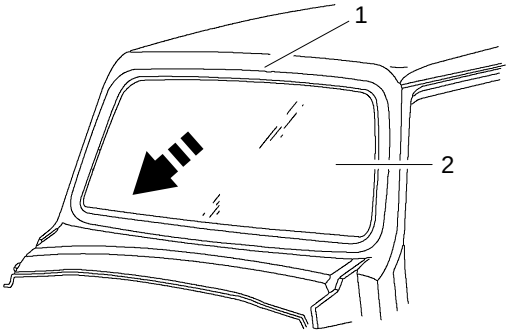
Wear protective gloves and safety glasses when replacing windshield glass. Gloves will protect your hands from sharp edges, and allow a better grip. Failure to wear gloves and safety glasses when handling glass could result in injury to hands or eyes.

NOTE: An assistant is necessary to remove the windshield glass.

7. Remove the windshield glass.
   - 7.1 Starting at the top and using a hook tool, lift the edge of the weatherstrip over the lip of the pinch weld from inside the vehicle.
   - 7.2 Push outward from inside the vehicle to remove the windshield glass.
8. Remove the weatherstrip from the glass. See **Fig. 1**.

Installation

1. Using a clean cloth and water, remove any foreign material from the glass and weatherstrip. The weatherstrip must be replaced if it is cracked or weather damaged.
2. Install the weatherstrip on the glass.
3. Insert a draw cord in the pinch weld opening of the weatherstrip. Overlap the cord 18 inches (457 mm) at the lower center of the glass. See **Fig. 2**.



1. Weatherstrip
2. Windshield Glass

Fig. 1, Windshield Glass

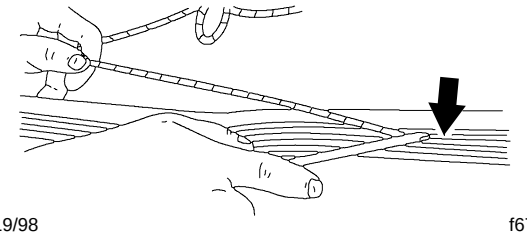


Fig. 2, Draw Cord in Pinch Weld Opening

4. Tape the ends of the cord to the inside of the glass.
5. Lubricate the weatherstrip with water.

IMPORTANT: Any scratches through the paint in the pinch weld area must be repainted or sealed prior to reinstalling the windshield. The pinch weld can rust and possibly bleed from under the seal if it is not repaired.

NOTE: An assistant is necessary to install the windshield glass.

6. Place the windshield back into the pinch weld making sure the bottom of the pinch weld lip falls into the weatherstrip. See **Fig. 1**.
7. From outside the vehicle, slide a plastic stick around the outer edge of the weatherstrip until the weatherstrip is resting on the pinch weld.
8. Apply pressure to the outside of the windshield and pull the cord from the inside to pull the lip of the weatherstrip over the pinch weld.

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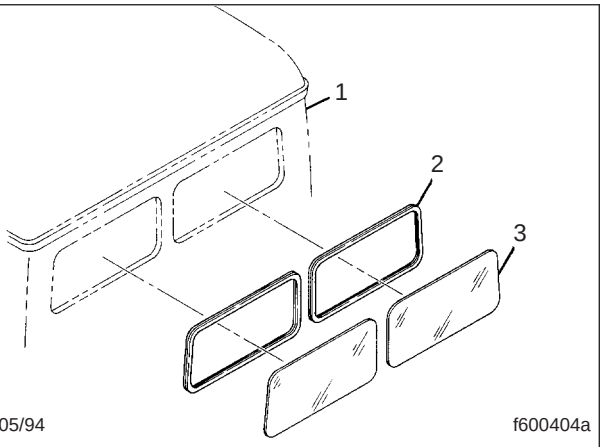
Windshield Glass Removal and Installation

9. Water test the installation for leaks. If leaks exist, apply 3M Windshield Sealer (or an equivalent) where required.
10. Clean the glass and surrounding areas.
11. Open the hood.
12. Install the antenna mast.
13. Install the windshield wipers. For instructions, see **Group 82**.
14. Close the hood.
15. Remove the chocks from the tires.

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Rear Window Removal and Installation

Removal (See Fig. 1)



1. Cab
2. Weather Seal Retainer
3. Window Glass

Fig. 1, Rear Window Installation

CAUTION

When replacing a broken rear window, it is very important to find the cause of the glass breakage, and correct the condition before installing a new window. A small obstruction or high spot somewhere around the window opening may break the replacement glass, especially when it is exposed to high winds, pressure, temperature extremes, and vehicle motion.

1. Disconnect the batteries.
2. Use tape and paper around the window opening and outside surfaces to protect the paint finish and cab interior. Before removing the window, mark the weather-seal retainer and opening with the location of the break at the edge of the window.

WARNING

Wear protective gloves and safety glasses when replacing windshield glass. Gloves will protect your hands from sharp edges, and allow a better grip. Failure to wear gloves and safety glasses when handling glass could result in injury to hands or eyes.

3. Install vacuum cups on the window, and have an assistant secure the window before removal.
4. Loosen the lip of the weather-seal retainer from the flange along the top and at the sides by applying firm, controlled pressure to the edge of the glass. At the same time, use a putty knife to lift the retainer over the window opening flange. Remove the window glass.

Installation

CAUTION

When handling the window glass, use care not to nick or splinter the edges of the glass. Chipped edges could cause future breaks.

IMPORTANT: Two people are required to install rear window glass.

1. Remove the sealant from the window opening flange.
2. Check for the following conditions at the previously marked point of fracture on the window opening flange:
   - chipped edges on the glass
   - high spots or obstructions in the window opening flange
   - high spots or obstructions in the weather-seal retainer
3. Correct any areas on the window opening that need to be fixed.
4. With the window supported and centered in the opening, check the relationship of the glass to the opening.
5. Mark any areas on the flange to be fixed. Remove the glass, and fix the flange as necessary.
6. Install the retainer on the glass.
7. Install a 1/8-inch (3-mm) nylon cord around the edge of the retainer, leaving a loop at the top and loose ends at the bottom. See **Fig. 2**.
8. Apply a lubricant to the retainer to ease installation.
9. Place the window and retainer assembly in the opening.

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Rear Window Removal and Installation

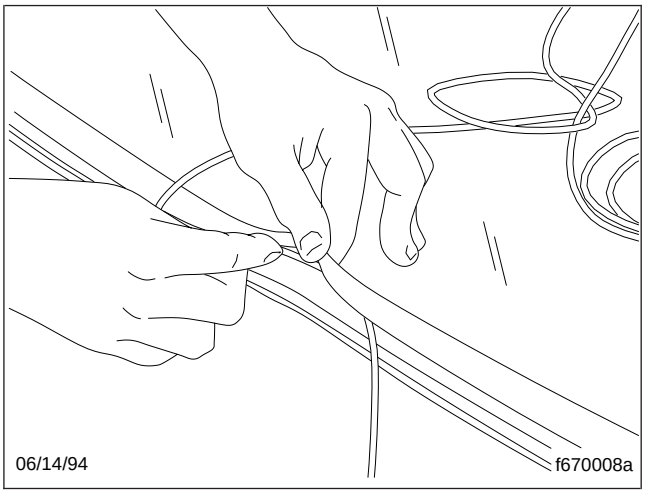


Fig. 2, Nylon Cord Installation

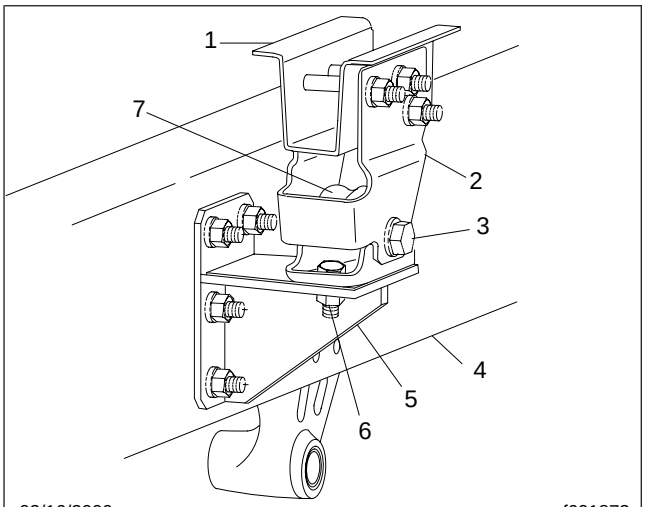
IMPORTANT: Use care not to tear the cab upholstery when pulling on the cord.

10. With one person lightly pushing in on the window, have another person pull on the loose ends of the cord until each is within 2 inches (51 mm) of its respective upper corner.
11. Pull on the loop until the cord is within 2 inches (51 mm) of the upper corners.
12. Finish seating the corners by pulling both ends of the cord at the same time at each corner. This will position the upper corner.
13. Be sure the window and retainer are correctly positioned in relation to each other.
14. Connect the batteries.
15. Remove the chocks from the tires.

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Front Cab Mount Replacement

Replacement (See Fig. 1)



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1. Cab Mount
2. Bracket
3. Isolator Thru-Bolt
4. Frame Rail
5. Frame-Mounted Bracket
6. Isolator Mounting Bolt
7. Isolator

Fig. 1, Front Cab Mount

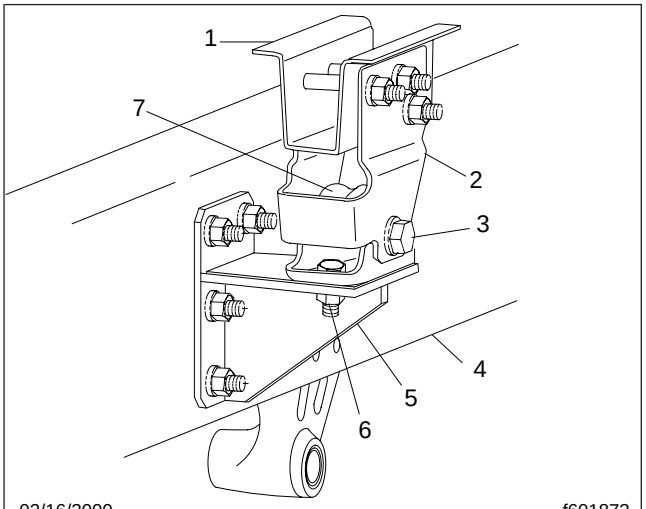
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the wing nuts from the engine splash panel on the right side of the vehicle. Remove the splash panel.
3. Remove the cab front quarter panel to provide access to the front cab mount.
4. Raise the cab enough to take the weight of the cab off of the mount. Support the front of the cab.
5. Remove the nuts, bolts and washers connecting the mount to the cab.
6. Remove the nuts, bolts and washers connecting the mount to the frame rail.
7. Remove the mount.
8. Remove the isolator thru-bolt and the isolator mounting bolts.
9. Remove the isolator.
10. Position the new isolator and install the isolator mounting bolts. Tighten 60 to 80 lbf·ft (81 to 108 N·m).
11. Position the mount under the cab.
12. Install the nuts, bolts and washers connecting the mount to the frame rail.
13. Install the nuts, bolts and washers connecting the mount to the cab.
14. Lower the front of the cab.
15. Install the isolator thru-bolt.
16. Install the quarter panel.
17. Install the engine splash panel.
18. Remove the chocks from the rear tires.

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Front Cab Mount Isolator Replacement

Replacement

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the wing nuts from the engine splash panel on the right side of the vehicle. Remove the splash panel. See **Fig. 1**.



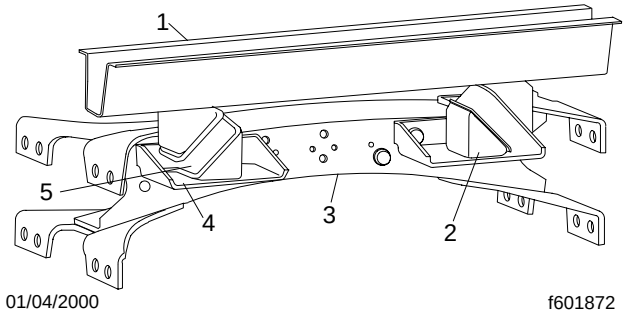
1. Cab Mount
2. Bracket
3. Isolator Thru-Bolt
4. Frame Rail
5. Frame-Mounted Bracket
6. Isolator Mounting Bolt
7. Isolator

Fig. 1, Front Cab Mount

3. Remove the cab front quarter panel to provide access to the front cab mount.
4. Raise the cab enough to take the weight of the cab off of the mount. Support the front of the cab.
5. Remove the isolator thru-bolt and the isolator mounting bolts.
6. Remove the isolator.
7. Position the new isolator and install the isolator mounting bolts. Tighten 60 to 80 lbf·ft (81 to 108 N·m).
8. Lower the front of the cab.
9. Install the isolator thru-bolt.
10. Install the quarter panel.
11. Install the engine splash panel.
12. Remove the chocks from the rear tires.

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Replacement (See Fig. 1)



1. Cab
2. Rear Cab Mount
3. Crossmember
4. Crossmember-Mounted Bracket
5. Isolator

Fig. 1, Rear Cab Mount

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. From inside the cab, remove the four bolts attaching the center console (if equipped) to the cab floor to provide working room in the cab. Remove the center console.
3. Remove the four bolts attaching the air system unit housing cover to the cab floor. Remove the cover.
4. Remove the four bolts attaching the air system unit to the cab floor. Remove the unit.
5. Untuck the carpeting, if equipped.
6. Remove the four bolts attaching the access plate to the rear cab floor. Remove the access plate.
7. Push aside the rubber cover and remove the nut and washer attaching the cab to the top of the cab mount.
8. From under the cab, remove the nut and washer attaching the bottom of the cab mount to the crossmember-mounted bracket.
9. Raise the cab enough to take the weight of the cab off of the mount.

NOTE: If only removing one mount, remove the nut and washer from under the cab for the opposite mount to allow the cab to be raised enough to remove the mount.

10. Remove the mount.
11. Position the mount under the cab.
12. Lower the cab.
13. From under the cab, install the nut and washer attaching the cab mount to the crossmember-mounted bracket. If removed, install the nut and washer on the opposite mount.
14. From inside the cab, install the nut and washer attaching the cab to the top of the cab mount.
15. Position the access plate and install the four bolts attaching the access plate to the rear cab floor.
16. Tuck-in the carpeting, if equipped.
17. Position the air system unit and install the four bolts attaching the air system unit to the cab floor.
18. Position the cover and install the four bolts attaching the air system unit housing cover to the cab floor.
19. Position the center console and install the four bolts attaching the center console to the cab floor.
20. Remove the chocks from the rear tires.

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West Coast Mirror Replacement

Replacement

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries.
3. Remove the door grab handle.
4. Remove the door trim finish panel.
5. Remove the inner watershield.
6. Disconnect the electrical connector. See **Fig. 1**.

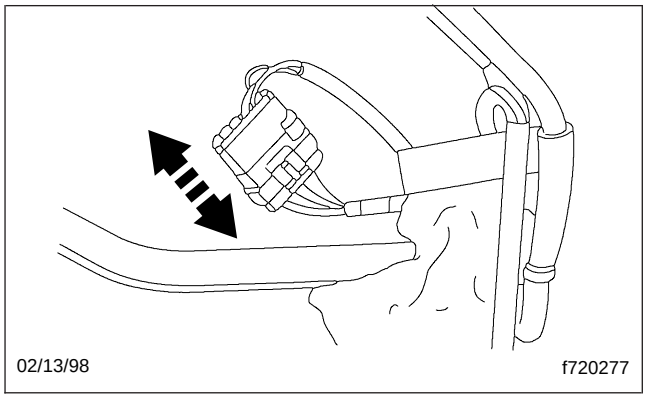


Fig. 1, Mirror Electrical Connector

7. Remove the rubber grommet from the mirror bracket. See **Fig. 2**.

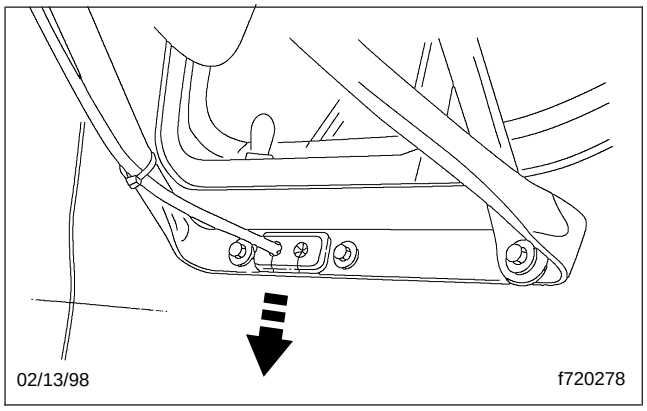


Fig. 2, Mirror Bracket Wire Grommet

8. Remove the wire harness from the door. See **Fig. 3**.
9. Cut the cable wraps on the mirror bracket. See **Fig. 4**.

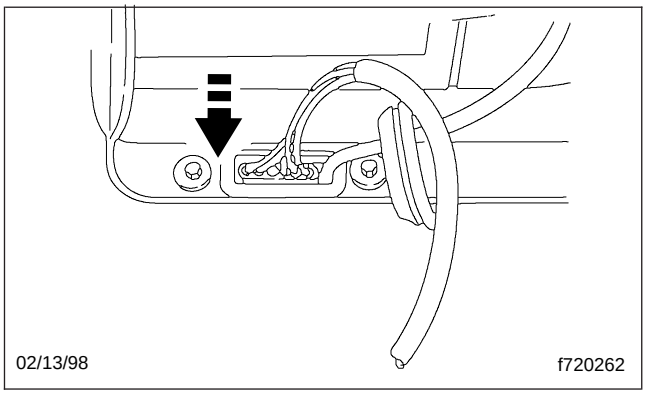


Fig. 3, Door Wire

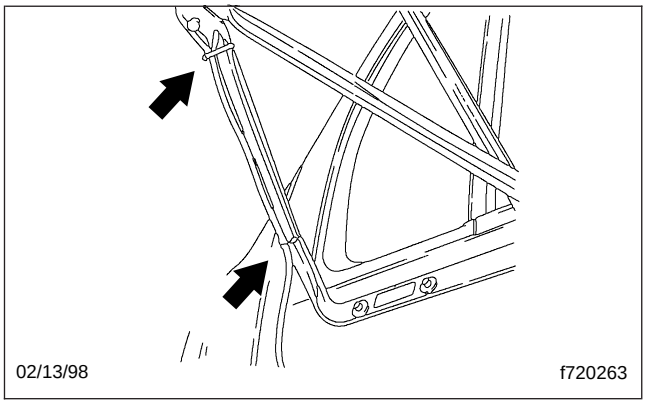


Fig. 4, Mirror Bracket Cable Wraps

10. Remove the upper and lower retaining nuts and remove the mirror. See **Fig. 5**.
11. Replace the mirror and install the upper and lower retaining nuts. Tighten the nuts 9 to 12 lbf·ft (12 to 16 N·m). See **Fig. 5**.
12. Attach the cable wraps on the mirror bracket. See **Fig. 4**.
13. Install the mirror wire on the door. See **Fig. 3**.
14. Install the rubber grommet through the mirror bracket. See **Fig. 2**.
15. Connect the mirror electrical connector. See **Fig. 1**.
16. Install the inner watershield.
17. Install the door trim panel.
18. Install the door grab handle.
19. Connect the batteries.

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West Coast Mirror Replacement

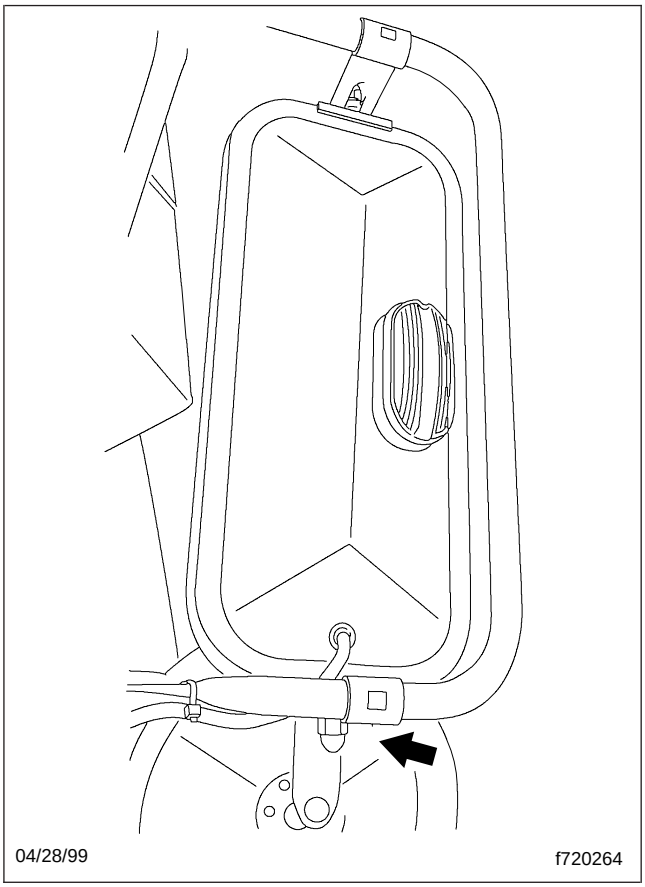


Fig. 5, Mirror Retaining Nuts

20. Remove the chocks from the rear tires.

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Moto Mirror Removal and Installation

Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries.
3. Disconnect the electrical wiring from the mirror.
   - 3.1 Pry the strain relief (grey plastic) from the mirror.
   - 3.2 Pull all four wires from the mirror case until the snap connectors are about 4 inches (100 mm) from the case.
   - 3.3 Disconnect the snap connectors.
4. If a convex mirror is mounted on the Moto Mirror bottom shaft, remove it.

   Remove the hexnuts from the mirror top and bottom shafts. See **Fig. 1**.
5. Loosen the nuts securing the L-brackets to the C-bracket and remove the Moto Mirror.

Installation

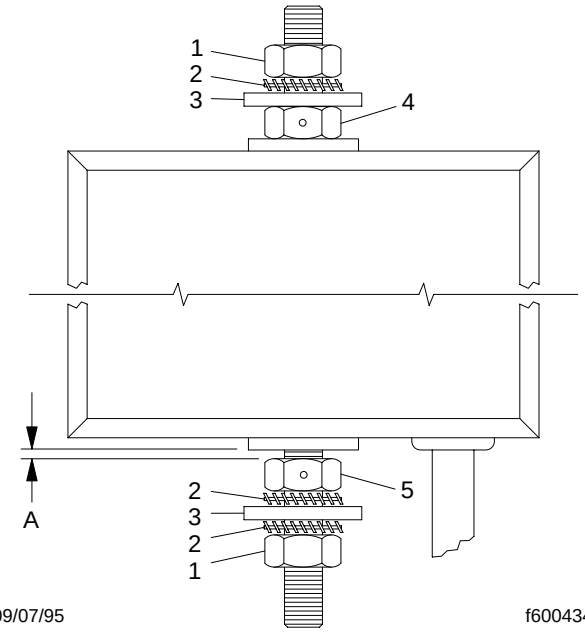
1. Insert the mirror top and bottom shafts through the holes in the L-brackets. See **Fig. 2**.
2. Install the hexnuts and lockwashers, making sure they are positioned correctly. See **Fig. 1**.

IMPORTANT: Do not use an impact wrench; it could cause overtightening of the nuts.

3. Tighten the hexnuts on the top and bottom shafts 15 lbf·ft (20 N·m).
4. Tighten the nuts holding the L-brackets to the C-bracket 10 lbf·ft (14 N·m).

NOTE: If the convex mirror bracket is installed between the two nuts that clamp the Moto Mirror to the L-bracket, the nuts will eventually loosen.

5. If a convex mirror was installed, mount it on the C-bracket to A-bracket bolts, where it does not interfere with the full range of movement of the Moto Mirror. Do not mount the convex mirror to the Moto Mirror shaft.



NOTE: Be sure to maintain the minimum clearance of 1/8 inch (3 mm).

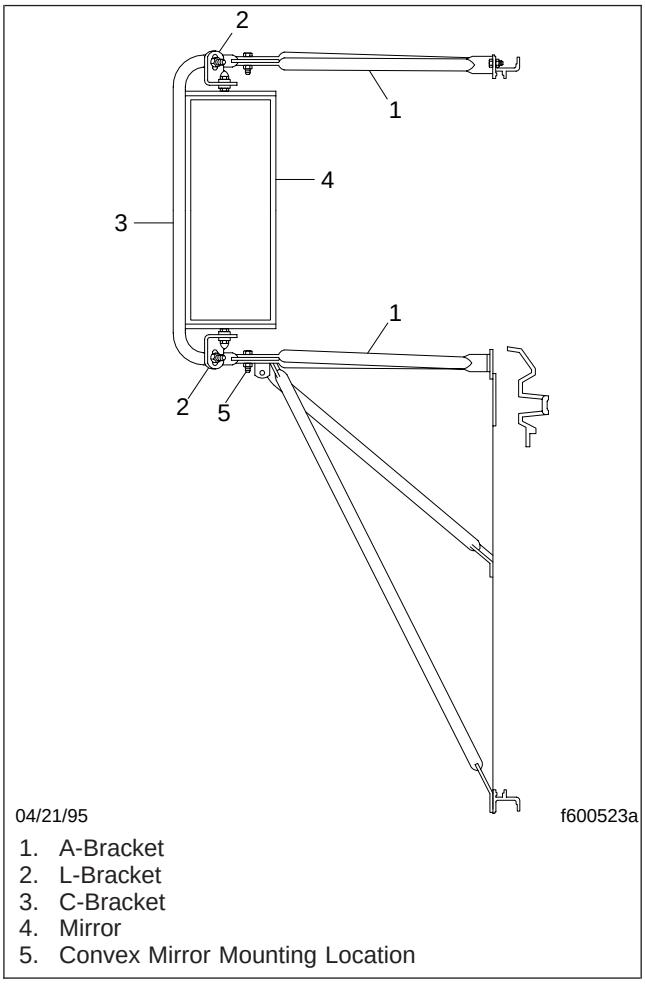
A. Minimum 1/8 in (3 mm)
1. Hexnut
2. Star Washer
3. L-Bracket
4. Upper Pinned Hexnut
5. Lower Pinned Hexnut

Fig. 1, Moto Mirror Installation

6. Position the C-bracket at the correct angle to allow the full range of mirror movement. See **Fig. 3**.
7. Connect the batteries.
   - 7.1 On the right side, the C-bracket should be positioned at 90 degrees to the cab door.
   - 7.2 On the left side, the C-bracket should be positioned at 60 degrees to the cab door (30 degrees aft of perpendicular to the door).
8. Tighten the fasteners at the connections between the C-bracket and the A-bracket 25 to 30 lbf·ft (34 to 40 N·m). This will prevent the C-bracket from moving out of position easily, yet it will allow the mirror to swing away on impact.
9. Connect the electrical wiring to the mirror.
10. Connect the batteries.

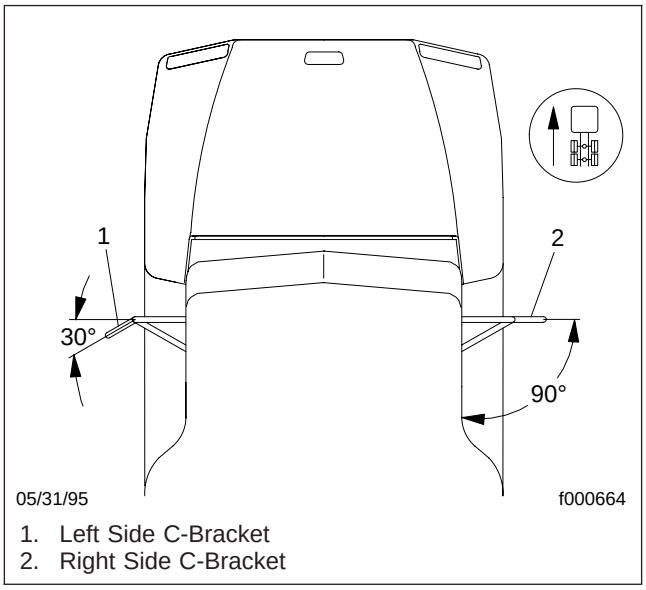
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Moto Mirror Removal and Installation



1. A-Bracket
2. L-Bracket
3. C-Bracket
4. Mirror
5. Convex Mirror Mounting Location

Fig. 2, Mirror Brackets



1. Left Side C-Bracket
2. Right Side C-Bracket

Fig. 3, C-Bracket Positions

11. Check that the mirror is rotating correctly. Turn on the ignition and the mirror heater switch. Feel the mirror glass after five minutes to make sure it is heating. If the mirror is not heating and the heater switch is working, the mirror must be replaced. See "Removal" in this subject.
12. Remove the chocks from the rear tires.

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Mirror Mounting Bracket Replacement

Replacement

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the rearview mirror. If equipped with a power or heated/lighted mirror, see **Subject 100** or **Subject 110**.
3. If equipped with a CB antenna, remove the antenna and cable.
4. Remove the seven screws and remove the bracket. See **Fig. 1**.

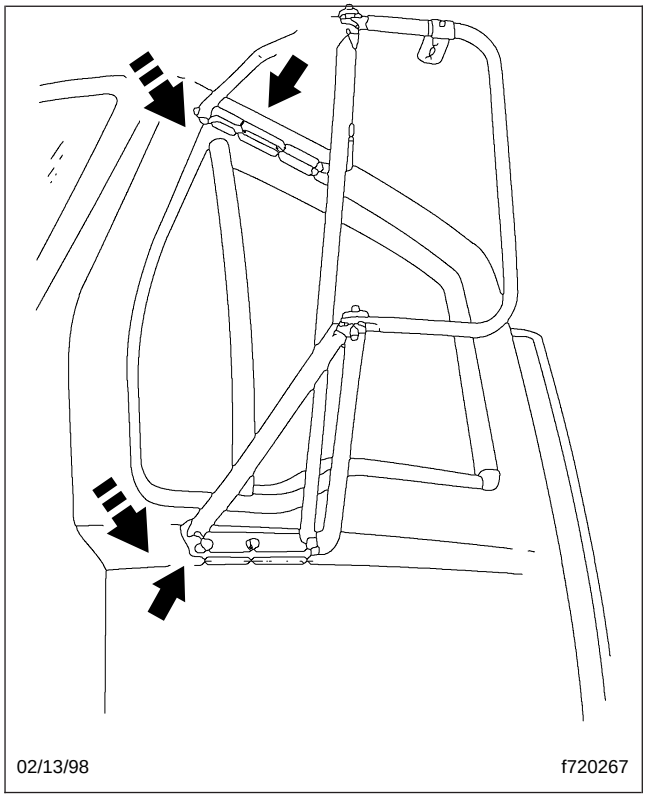


Fig. 1, Bracket Screw Removal

5. Replace the mirror bracket and install the seven screws. Tighten the screws 72 to 108 lbf·in (99 to 120 N·cm). See **Fig. 2**.
6. If equipped with a CB antenna, install the antenna and cable.

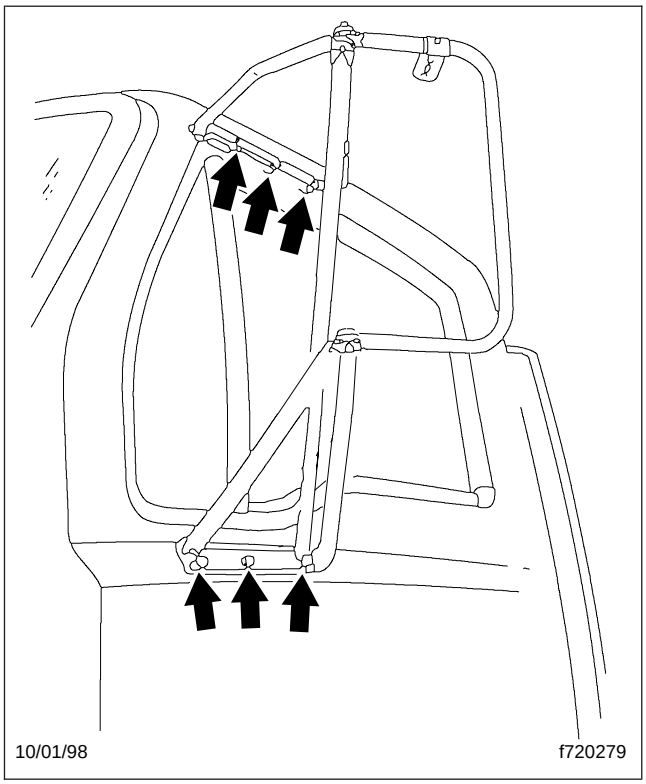


Fig. 2, Bracket Screw Installation

7. Install the rearview mirror. If equipped with a power or heated/lighted mirror, see **Subject 100** or **Subject 110**.
8. Remove the chocks from the rear tires.

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Replacement

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries.
3. Carefully pry the power mirror switch from the door trim panel. See **Fig. 1**.

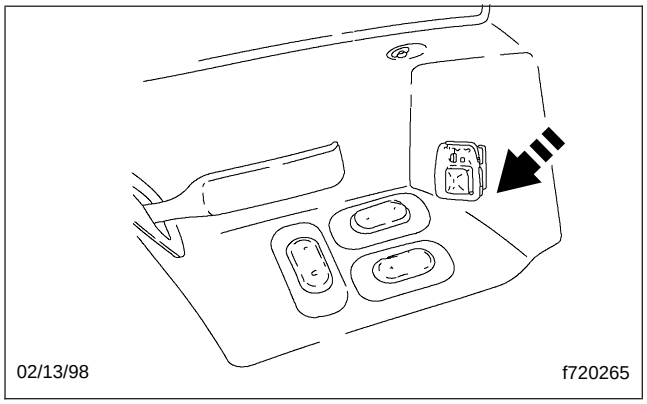


Fig. 1, Power Mirror Switch

4. Depress the electrical connector locking tab and separate the power mirror switch from the electrical harness. See **Fig. 2**.

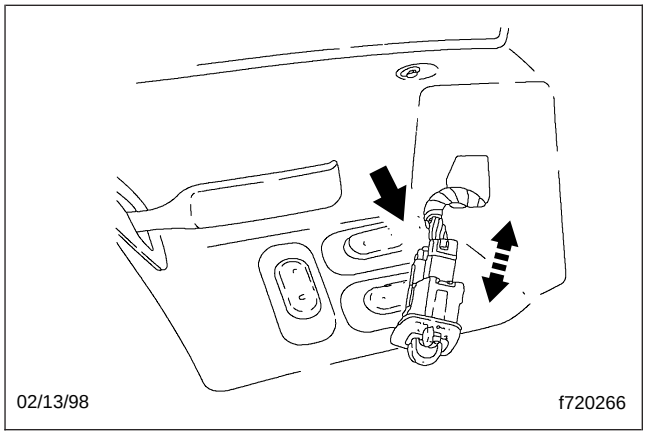


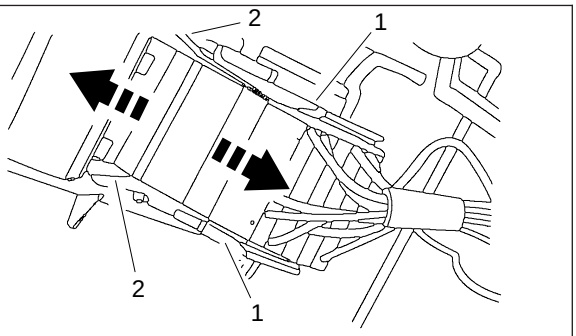
Fig. 2, Power Mirror Switch Electrical Connector

5. Connect the power mirror switch to the electrical harness. See **Fig. 2**.
6. Install power mirror switch into the door trim panel. See **Fig. 1**.
7. Connect the batteries.
8. Remove the chocks from the rear tires.

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Replacement

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries.
3. Remove the right-hand instrument panel trim panel.
4. Remove the heated mirror switch. See **Fig. 1**.



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1. Electrical Connector Locking Tabs
2. Heated Mirror Retaining Tabs

Fig. 1, Heated Mirror Switch Removal

   4.1 Release the locking tabs and disconnect the electrical connector.

   4.2 Depress the heated mirror retaining tabs and push the switch through the front of the trim panel.

5. Install the heated mirror switch. See **Fig. 1**.

   5.1 Depress the heated mirror retaining tabs and push the switch into the front of the trim panel.

   5.2 Insert the locking tabs and connect the electrical connector.

6. Install the right-hand instrument panel trim panel.
7. Connect the batteries.
8. Chock the rear tires.

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See **Fig. 1** for a full view of the power mirror wiring.

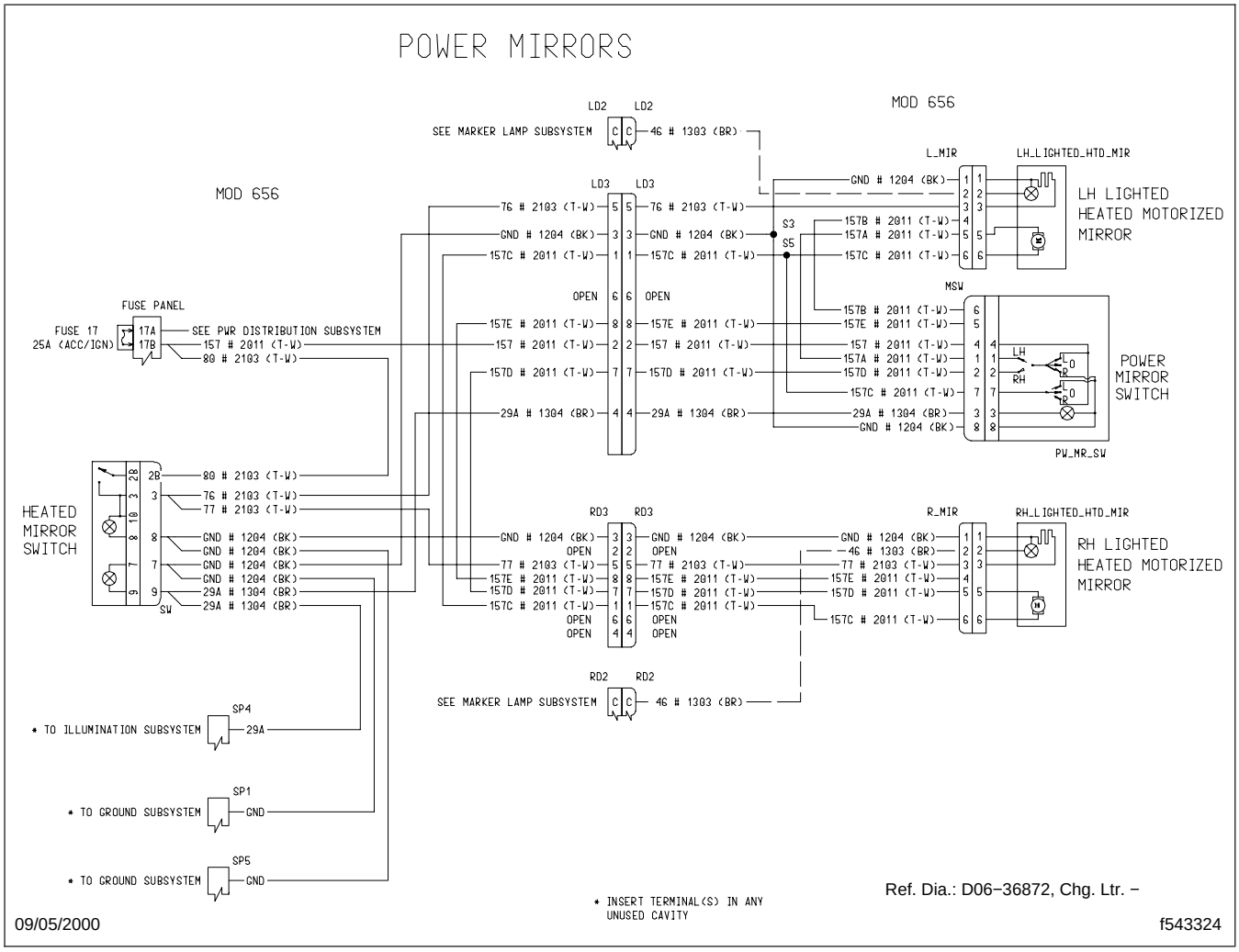


Fig. 1, Power Mirror Wiring

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Replacement

NOTE: The horn is mounted to the inner fender bracket.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Disconnect the battery ground cable(s).
4. Press the locking tabs and remove the horn electrical connector. See **Fig. 1**.

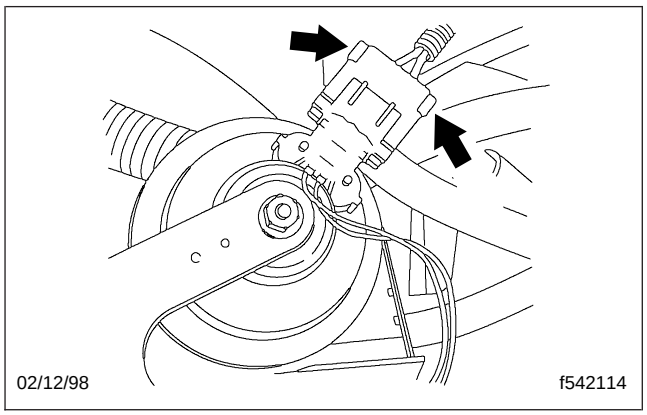


Fig. 1, Horn Electrical Connector

5. Remove the horn retaining bolt and remove the horn.
6. Position the horn and install the horn retaining bolt.
7. Connect the horn electrical connector.
8. Connect the battery ground cable(s).
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

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See **Fig. 1** for a full view of the electric horn wiring.

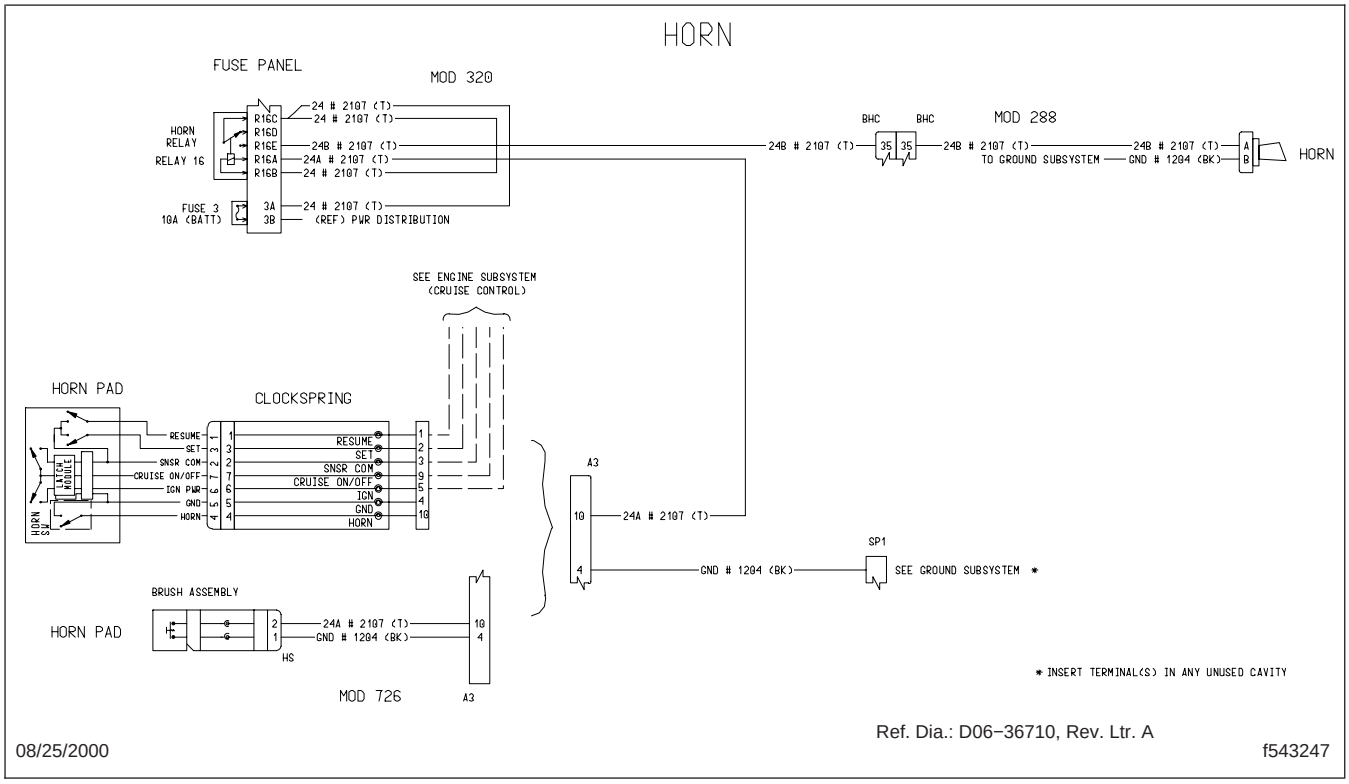


Fig. 1, Electric Horn Wiring

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General Information

Cab rear air-suspension systems absorb road shocks better than solid-mount systems, and thus provide a smoother ride for cab occupants and cab-mounted equipment.

The cab air-suspension system consists of two air springs, a height-control valve, a lateral control rod, two shock absorbers, and a vertical linkage; see **Fig. 1**.

Air Springs

The top of the air spring is mounted to a bracket on the cab underbody, and the bottom is mounted to a frame rail crossmember. Together with the height-control valve, the air spring compensates for changes in cab load by maintaining the correct cab height at the rear of the cab.

Height-Control Valve

NOTE: If a leak occurs in the cab air-suspension system, a pressure protection valve (located at the secondary air tank, which supplies the air to the height-control valve) will maintain a minimum pressure of about 65 psi (450 kPa) in the vehicle secondary air system.

All of the air in the cab air-suspension system is admitted through or exhausted from the height-control valve. It mounts on the lower shock-mount bracket, which is attached to a frame rail crossmember. The height-control valve has a horizontal control lever, the outboard end of which is connected to a vertical linkage. The upper end of the vertical linkage is attached to the cab underbody.

When the load on the cab increases, the dimension between the cab and the crossmember decreases, causing the vertical linkage to push downward on the end of the horizontal control lever. This turns the height-control valve shaft, which activates the height-control valve. Air flows through the valve and into the air springs until the pressure in the springs raises the cab to the correct height. At this height, the control lever and the control shaft are returned to their neutral positions, closing the intake air supply.

When the load on the cab decreases, the rear of the cab rises, causing the vertical linkage to pull up on the end of the horizontal control lever. Turning the height-control valve shaft in this direction activates an exhaust port in the valve. This allows air pressure in the air springs to decrease until the cab is lowered to the correct height. Again, the control lever and control shaft are returned to their neutral positions, and air flow is stopped.

When the vehicle is in motion, small and abrupt movements of the cab will occur, resulting in small or abrupt movements of the control lever. These movements of the control lever do not activate the height-control valve to correct the cab ride height.

Changes in load that occur when occupants or heavy items are added to or removed from the cab will activate the height-control valve to correct the cab ride height. Also, when the vehicle is moving forward at high speed or in a high headwind, a major change in load occurs from the downforce applied to an optional air shield or air fairing. When these changes in load occur, the cab air-suspension system will correct the cab ride height at the rear of the cab.

Lateral Control Rod

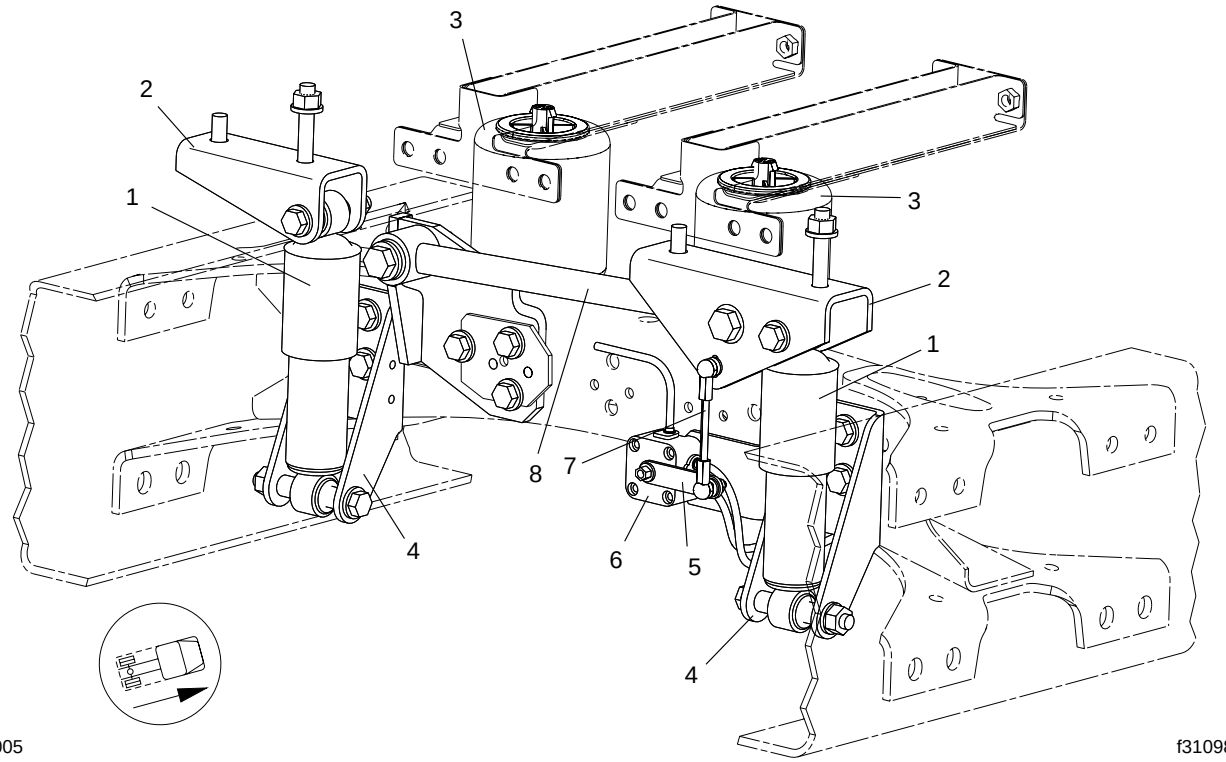
The lateral control rod limits the side-to-side motion of the rear of the cab. The inboard end of the control rod is mounted on the crossmember bracket.

Shock Absorbers

The shock absorber controls the air spring and cab suspension movement, and reduces the amount of oscillation in the cab suspension system.

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General Information



1. Shock Absorber
2. Upper Shock-Mount Bracket
3. Air Spring
4. Lower Shock-Mount Bracket
5. Horizontal Control Lever
6. Cab Height-Control Valve
7. Vertical Linkage
8. Lateral Control Rod

Fig. 1, Cab Air Suspension Installation

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Fitting Leakage Repair

1. Apply the parking brakes and chock the tires.

⚠ WARNING

Do not disconnect any air lines in the cab suspension system without first blocking the cab securely. If the cab isn't securely blocked, disconnecting an air line could cause the cab to fall abruptly, possibly resulting in serious injury.

2. Place blocks between the frame and the bottom of the cab to keep the cab in position when the air springs are deflated.
3. Drain all air from the air tanks.

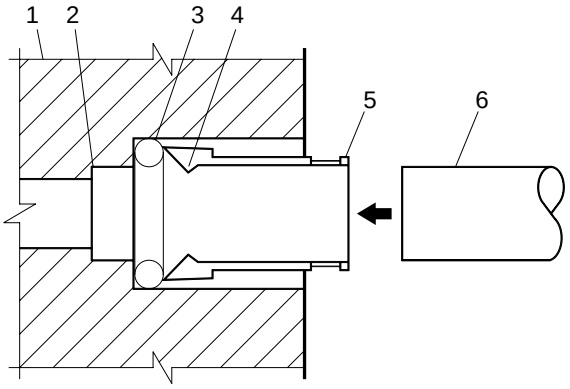
⚠ WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

4. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever.
5. Rotate and hold the control lever up until all air is exhausted from the air spring.
6. Push the collar of the quick-connect fitting into the fitting body with a 1/4-inch (7-mm) open-end wrench; see **Fig. 1**. With the collar pushed into the fitting, pull the tubing from the fitting. The fitting should easily release the tubing.

NOTE: Find the mark on the tubing, about 1/4 inch (7 mm) from the end, where the collar clamped the tubing; see **Fig. 2**. If this mark is less than 1/4 inch (7 mm) from the end of the tubing, the fitting was not assembled correctly and could have caused an air leak.

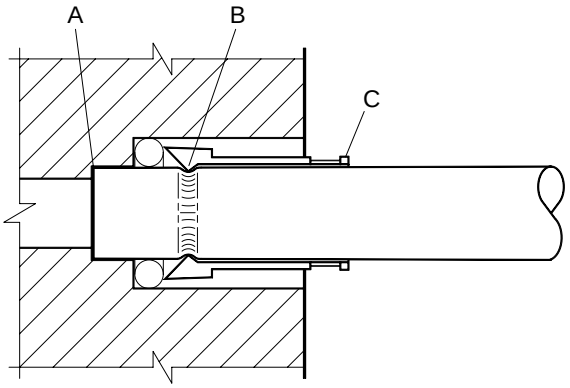
7. Inspect the end of the tubing for paint or debris that could prevent full insertion of the tubing into the fitting. Remove any dirt from the tubing and fitting.
8. Check that the end of the tubing is cut square. If the tubing is cut at an angle other than 90 degrees, the fitting will not seal correctly; cut the end of the tubing at a 90-degree angle.



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1. Fitting Body
2. Shoulder
3. Release Ring
4. Clamping Ring
5. Collar
6. Nylon Tube

Fig. 1, Parts of the Quick-Connect Fitting



03/09/99 f310793

A. Square end of the tube against the shoulder.
B. The collar clamps the tube here.
C. Push the collar to release the tube.

Fig. 2, Correctly Installed Quick-Connect Fitting

9. Insert the squared end of the tubing into the fitting. An initial resistance is felt when the tubing touches the clamping ring section of the collar. Push the tubing past this resistance another 1/4 inch (7 mm) or so until the tubing is fully seated against the shoulder.
10. Tug on the air tubing to ensure the tubing is clamped in the collar.

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Quick-Connect Fittings

11. Align the vertical linkage with the control lever, and install the washer and nut.
12. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa). Check for air leaks.
13. Remove the blocks that were installed to support the cab.
14. Remove the chocks.

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Height-Control Valve Checking

It is normal to hear air leaking from the height-control valve for as much as five minutes after getting out of the vehicle. This air leakage is just the height-control valve exhausting air from the cab suspension air spring to reach the neutral position. The height-control valves used on the Acterra are Barksdale valves.

Two methods are available to check the operation of Barksdale height-control valves. A leak in the valve may be discovered without using a test kit, but a test kit is necessary to determine if the valve has an unacceptable rate of leakage.

Some Barksdale height-control valves have been returned for warranty because the four bolts in the valve housing were overtightened, often, enough to crack the valve housing. These bolts should not be loose, and should not normally require tightening, as there are no serviceable parts in the valve.

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing if you detect leaks in the housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- If it is necessary to remove a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, crushing the valve body and damaging the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

Checking the Height-Control Valve Without Using a Test Kit

⚠ WARNING

Keep your hands and all objects away from the area under and around the cab when removing the pressure from the air system. Parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

1. If not already done, apply the parking brakes and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa).
3. Shut off the engine and wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve.

4. Check all of the fittings and the valve body using a soap-and-water solution. Seal any leaks as necessary.
5. Check the valve exhaust port, and the rubber exhaust flapper, if so equipped, for leaks using a soap-and-water solution. The exhaust port is on the side opposite the supply port of the valve.

NOTE: If a leak is detected on a Barksdale height-control valve, go to "Checking a Barksdale Height-Control Valve Using a Test Kit". Barksdale valves have an acceptable leak rate of 3 cubic inches (50 cc) per minute. You can determine if a leak is acceptable only by using the Barksdale test kit.

⚠ WARNING

Do not disconnect the vertical linkage in the cab suspension system without first blocking the cab securely. If the cab is not securely blocked, mov-

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Height-Control Valve Checking

ing the control lever could cause the cab to drop abruptly, possibly resulting in serious injury.

6. Disconnect the vertical linkage from the control lever.
7. Pull the control lever up about 45 degrees for 6 to 8 seconds. If air passes through the valve, that section of the valve is okay.
8. Return the control lever to the neutral position.
9. Push the control lever down about 45 degrees for 6 to 8 seconds. If the air spring inflates, that section of the valve is okay.
10. Return the control lever to the neutral position. If the air stops again in the neutral position, the valve is working correctly.
11. If the valve works as stated in all of the above steps, no further checking is needed. Connect the vertical linkage to the control lever, then tighten the linkage nut.

    If needed, adjust the cab ride height or replace the height-control valve. For adjustment of the cab ride height, see **Subject 170**. For replacement of the height-control valve, see **Subject 120**.
12. Remove the chocks.

Checking a Barksdale Height-Control Valve Using a Test Kit

WARNING

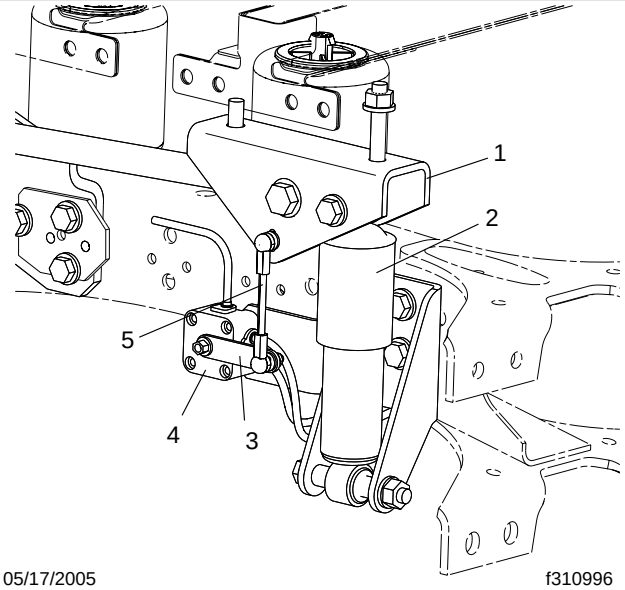
Keep your hands and all objects away from the area under and around the cab when removing the pressure from the air system. Parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

NOTE: The Barksdale field test kit is designed to be used with the height-control valve installed on the vehicle. Refer to **Specifications 400** for information on ordering the Barksdale height-control valve test kit KD2264.

1. If not already done, park the vehicle on a level surface, apply the parking brakes, and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa).
3. Shut off the engine and wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve.

4. Check the rubber exhaust flapper at the back of the valve housing for leaks. Use a soapy solution.
5. Disconnect the vertical linkage from the control lever; see **Fig. 1**.

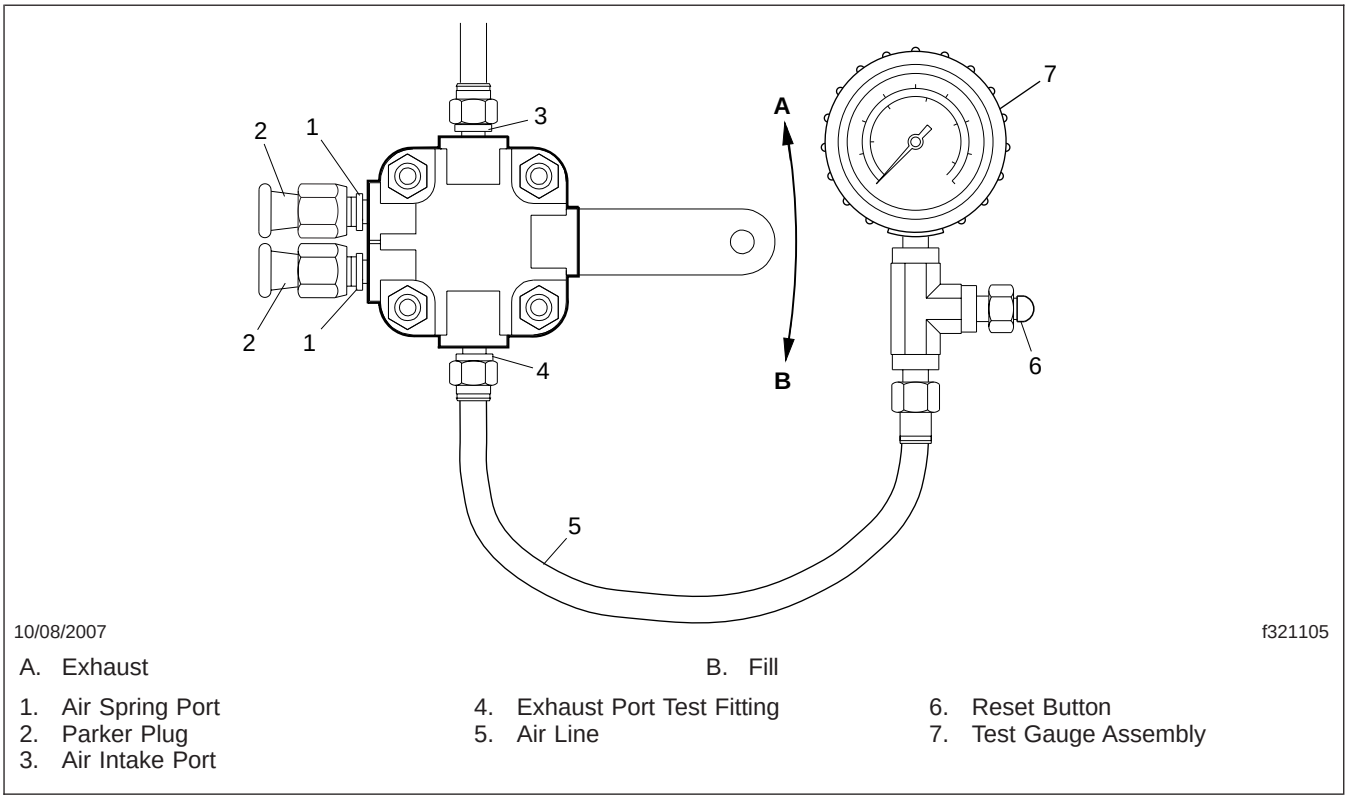


1. Upper Shock-Mount Bracket
2. Shock Absorber
3. Horizontal Control Lever
4. Cab Height-Control Valve
5. Vertical Linkage

Fig. 1, Cab Height-Control Valve Linkage

6. Rotate and hold the control lever up at about 45 degrees to exhaust air from the air springs.
7. Disconnect the air lines from the air spring ports on the height-control valve. Leave the elbow fittings (if equipped) in place. Install a Parker plug into each air spring port (or elbow fitting); see **Fig. 2**.

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A. Exhaust
B. Fill

1. Air Spring Port
2. Parker Plug
3. Air Intake Port
4. Exhaust Port Test Fitting
5. Air Line
6. Reset Button
7. Test Gauge Assembly

Fig. 2, Test Connections

8. If a flapper is present on the exhaust port of the height-control valve, remove it using needlenose pliers.
9. Clean the surface around the exhaust port, then install the test fitting into the exhaust port. The centering pin on the fitting must align with the slot on the exhaust port. Rotate the test fitting 45 degrees clockwise to lock it in place; see **Fig. 2**.
10. Connect one end of the air hose from the kit to the test connector on the exhaust port, and the other end to the test gauge.
11. Check the height-control valve in the fill mode, as follows.
    - 11.1 Rotate the valve control lever down 45 degrees from the horizontal to the fill position.
    - 11.2 Press the reset button on the test gauge.
    - 11.3 Observe the test gauge for 30 seconds. Refer to **Fig. 3** for the maximum allowable exhaust pressure change versus inlet pressure.

      The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.

      If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

12. Check the height-control valve in the exhaust mode, as follows.
    - 12.1 Rotate the valve control lever up 45 degrees from the horizontal to the exhaust position.
    - 12.2 Press the reset button on the test gauge.
    - 12.3 Observe the test gauge for 30 seconds. Refer to **Fig. 3** for the maximum allowable

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Height-Control Valve Checking

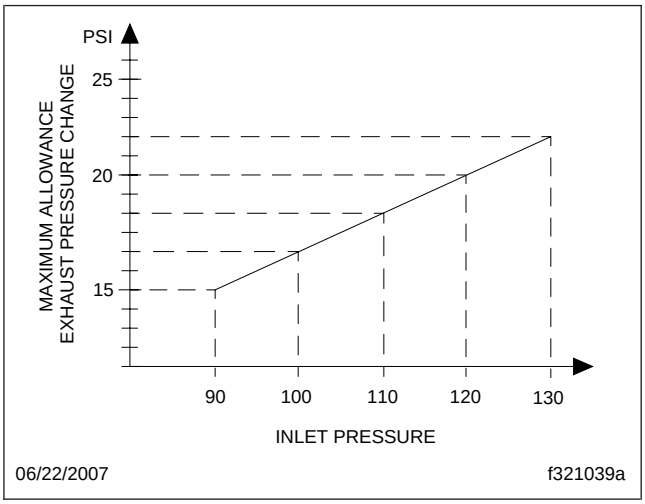


Fig. 3, Inlet Pressure vs. Exhaust Pressure Change in 30 Seconds

exhaust pressure change versus inlet pressure.

The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.

If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

13. Disconnect the test gauge and connector from the valve exhaust port.
14. If the height-control valve is defective, replace it; see **Subject 120**.
15. Install the flapper on the exhaust port by pressing it into place.
16. Remove the two Parker plugs from the air spring ports, and connect the air lines to the air spring ports (or elbow fittings). Connect the vertical linkage to the height-control valve control lever. The ride height will automatically return to the correct position.
17. Remove the chocks.

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Height-Control Valve Replacement

IMPORTANT: Before replacing the height-control valve, perform the steps in **Subject 110** to see if the height-control valve is actually damaged or just out of adjustment.

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.

⚠ WARNING

Do not disconnect any air lines in the cab suspension system without first blocking the cab securely. If the cab isn't securely blocked, disconnecting an air line could cause the cab to fall abruptly, possibly resulting in serious injury.

2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the air springs are deflated.
3. Drain all air from the air tanks.

⚠ WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

4. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever; see **Fig. 1**.
5. Rotate and hold the horizontal control lever up until all air is exhausted from the air spring.
6. Mark the air tubing to the height-control valve for later reference, then disconnect the tubing; see **Subject 100**.

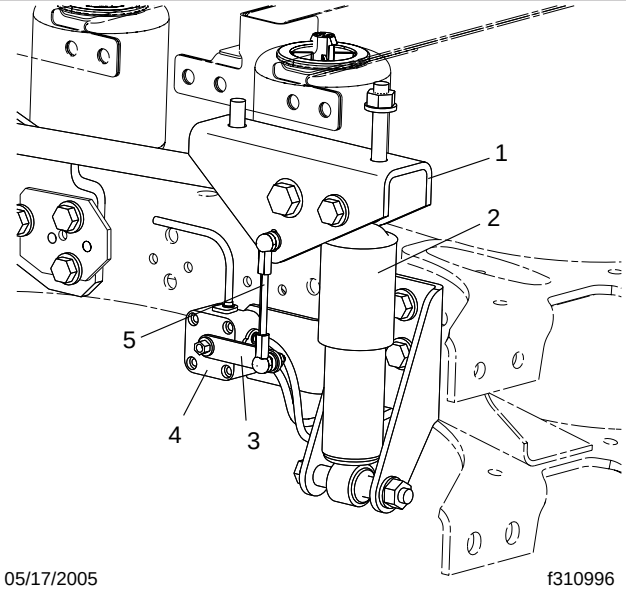
⚠ CAUTION

When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

7. While holding the height-control valve mounting studs in place with an Allen wrench, remove the nuts and washers that attach the valve to the mounting bracket. Remove the height-control valve.
8. Position the new height-control valve on the height-control bracket. While holding the height-control valve mounting studs in place with an Allen wrench, install the nuts and washers, and tighten 45 lbf·in (500 N·cm). Do not overtighten.
9. Connect the air tubing to the height-control valve; see **Subject 100**.
10. Align the vertical linkage with the horizontal control lever and install the washer and nut.
11. Start the engine and run it until air pressure builds to at least 100 psi (690 kPa).
12. Check all air tubing and fittings for leaks.
13. Remove the cab supports.
14. Remove the chocks.

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Height-Control Valve Replacement



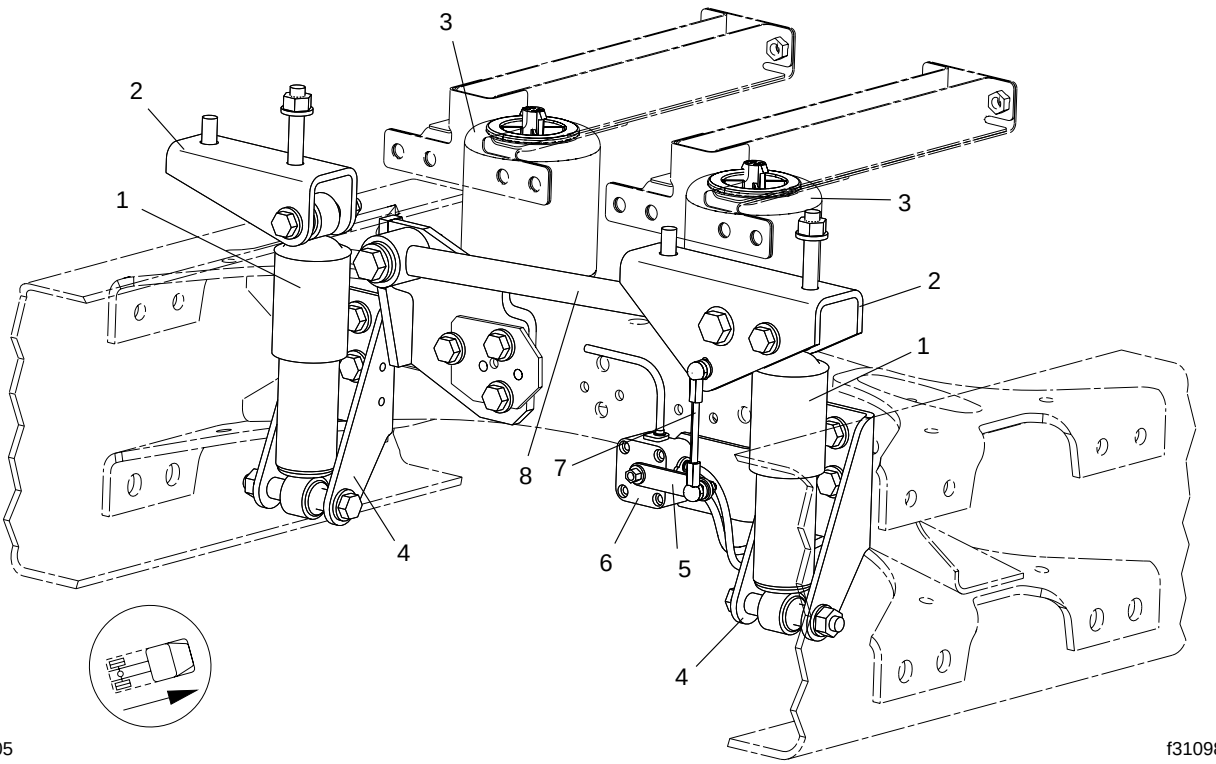
1. Upper Shock-Mount Bracket
2. Shock Absorber
3. Horizontal Control Lever
4. Cab Height-Control Valve
5. Vertical Linkage

Fig. 1, Cab Height-Control Valve Installation

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Shock Absorber Replacement

1. Park the vehicle, apply the parking brakes, shut down the engine, and chock the front and rear tires.
2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the shock is removed.
3. Remove the nut, washers, and bolt that attach the shock absorber to the upper shock-mount bracket. See **Fig. 1**.
4. Remove the nut, washers, and bolt that attach the shock to the lower shock-mount bracket, and remove the shock.
5. Install the shock in the lower shock-mount bracket and install the bolt, washers, and nut.
6. Position the upper end of the shock in the upper shock-mount bracket and install the bolt, washers, and nut.
7. Torque the upper and lower nuts to 45 lbf·ft (61 N·m).
8. Remove the cab supports.
9. Remove the chocks from the tires.



1. Shock Absorber
2. Upper Shock-Mount Bracket
3. Air Spring
4. Lower Shock-Mount Bracket
5. Horizontal Control Lever
6. Cab Height-Control Valve
7. Vertical Linkage
8. Lateral Control Rod

Fig. 1, Cab Air Suspension Installation

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Air Spring Replacement

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.

⚠ WARNING

Do not disconnect any air lines in the cab suspension system without first blocking the cab securely. If the cab isn't securely blocked, disconnecting an air line could cause the cab to fall abruptly, possibly resulting in serious injury.

2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the air spring is deflated.
3. Drain all air from the air tanks.

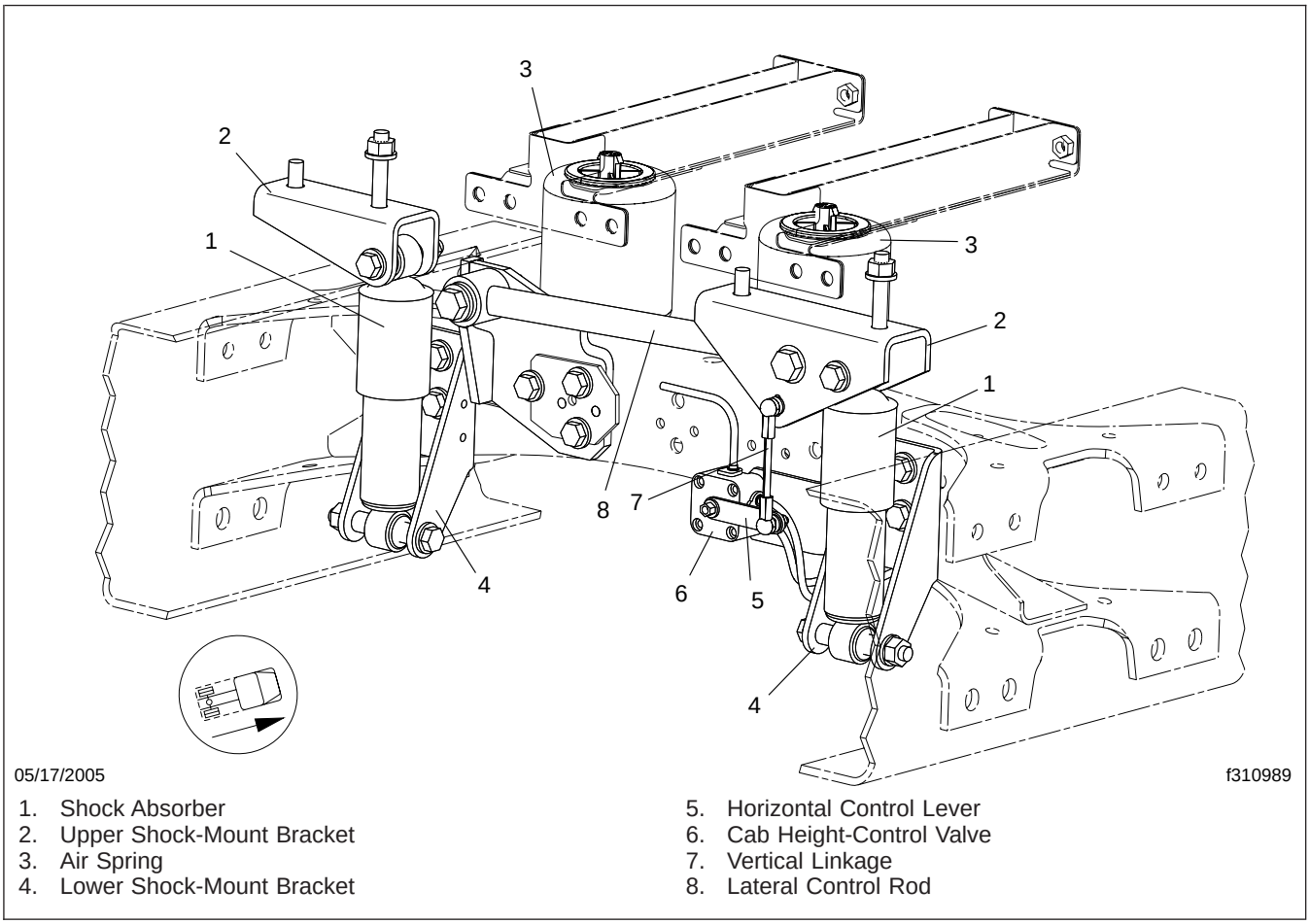
⚠ WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

4. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever; see **Fig. 1**.
5. Rotate and hold the horizontal control lever up until all air is exhausted from the air spring.
6. Disconnect the supply air tubing from the bottom of the air spring. If the new air spring will not be installed immediately, cover the open end of the air tubing to prevent dirt or other foreign material from entering.
7. Remove the nut that holds the bottom of the air spring to the crossmember.
8. Insert a screwdriver between the upper cab mount and air spring, and pry the air spring away from the mount to pop the air spring tangs out of the bracket.
9. Install the new air spring by inserting the bottom of the air spring into the crossmember, then snapping the top of the air spring into the top bracket.
10. Install the nut on the bottom of the air spring. Tighten the nut 35 lbf·in (400 N·cm).
11. Remove the cover from the air tubing, then connect it to the bottom of the new air spring.
12. Align the vertical linkage with the control lever and install the washer and nut.
13. Start the engine, and run it until air pressure builds to at least 100 psi (690 kPa). Check for air leaks at the air spring.
14. Remove the cab supports.
15. Remove the chocks.

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Air Spring Replacement



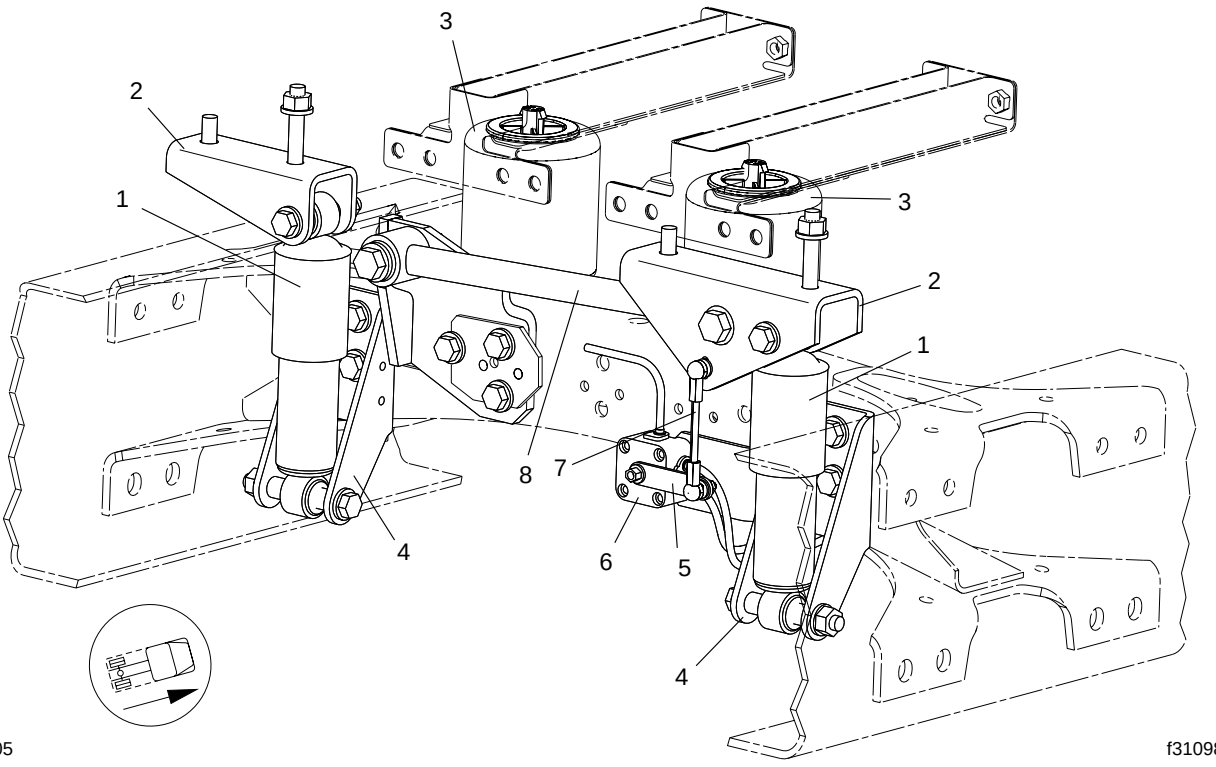
1. Shock Absorber
2. Upper Shock-Mount Bracket
3. Air Spring
4. Lower Shock-Mount Bracket
5. Horizontal Control Lever
6. Cab Height-Control Valve
7. Vertical Linkage
8. Lateral Control Rod

Fig. 1, Cab Air Suspension Installation

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Lateral Control Rod Replacement

1. Park the vehicle, apply the parking brakes, shut down the engine, and chock the front and rear tires.
2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the lateral control rod is removed.
3. Remove the nut, washers, and bolt that attach the lateral control rod to the upper shock-mount bracket. See **Fig. 1**.
4. Remove the nut, washers, and bolt that attach the lateral control rod to the lower chassis mount bracket, and remove the lateral control rod.
5. Install the lateral control rod in the lower chassis mount bracket and install the bolt, washers, and nut.
6. Position the upper end of the lateral control rod in the upper shock-mount bracket and install the bolt, washers, and nut.
7. Torque the upper and lower nuts to 45 lbf·ft (61 N·m).
8. Remove the cab supports.
9. Remove the chocks from the tires.



1. Shock Absorber
2. Upper Shock-Mount Bracket
3. Air Spring
4. Lower Shock-Mount Bracket
5. Horizontal Control Lever
6. Cab Height-Control Valve
7. Vertical Linkage
8. Lateral Control Rod

Fig. 1, Cab Air Suspension Installation

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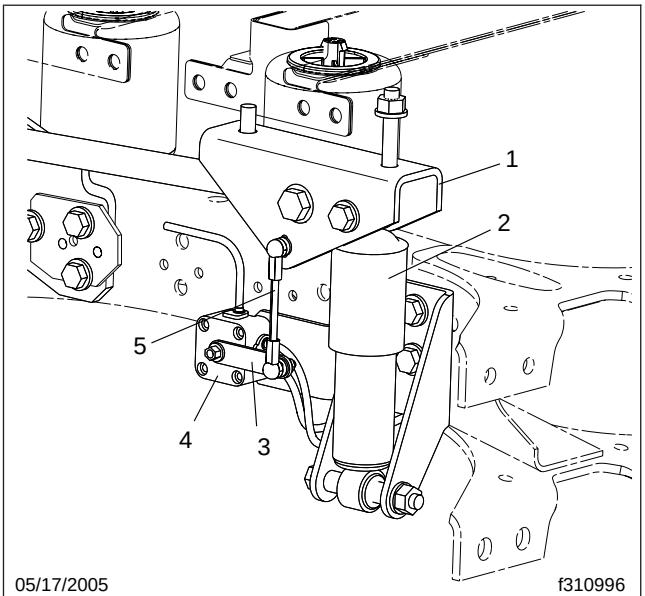
Vertical Linkage Replacement

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa), then shut off the engine.

⚠ WARNING

Do not disconnect the vertical linkage in the cab suspension system without first blocking the cab securely and inserting a pin in the neutral-position hole of the height-control valve and the horizontal control lever. If the cab is not securely blocked, dislodging the pin and moving the control lever could cause the cab to fall or rise abruptly, possibly resulting in serious injury.

3. Place blocks between the frame and the bottom of the cab or use jack stands to keep the cab in position.
4. Insert a 5/32-inch (4-mm) pin or drill bit into the neutral-position hole of the height-control valve and horizontal control lever.
5. Remove the nut and washer that attach the vertical linkage to the upper shock-mount bracket; see **Fig. 1**.
6. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever.
7. Align the new vertical linkage between the upper shock-mount bracket and the control lever. Attach the lower end of the vertical linkage to the control lever, using the washer and nut.
8. Attach the upper end of the vertical linkage to the upper shock-mount bracket with the washer and nut.
9. Remove the drill bit or pin from the height-control valve.
10. Remove the cab supports.
11. Remove the chocks.



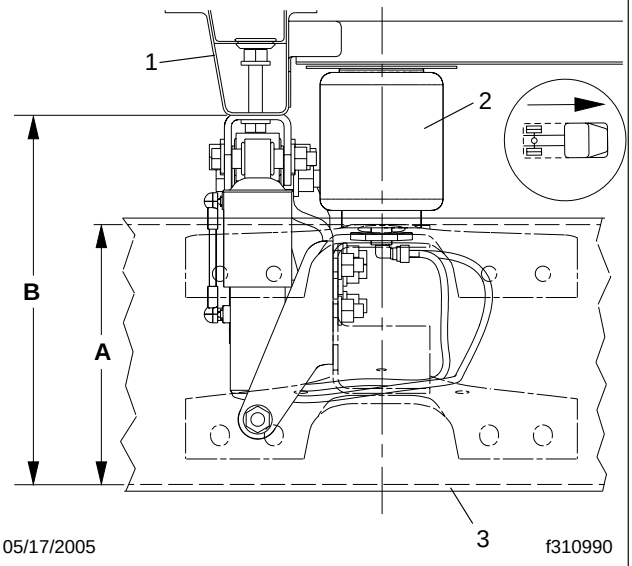
1. Upper Shock-Mount Bracket
2. Shock Absorber
3. Horizontal Control Lever
4. Cab Height-Control Valve
5. Vertical Linkage

Fig. 1, Cab Height-Control Valve Linkage

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Cab Ride-Height Adjustment

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa).
3. Loosen the nut on the upper end of the vertical linkage, allowing the linkage to slide in the upper shock-mount bracket.
4. Lower the horizontal control lever on the height-control valve to exhaust the air from the air springs.
5. Measure the distance between the inside of the upper and lower frame rail flanges (dimension A in **Fig. 1**).



A. Distance between the inside of the upper and lower frame rail flanges.
B. Cab Ride Height

1. Cab Rear Underbody Support
2. Air Spring
3. Frame Rail

Fig. 1, Cab Ride-Height Measurement

6. Lower the horizontal control lever on the height-control valve to fill the air springs. Raise the cab until the distance from the cab rear underbody support to the top of the lower frame rail flange (dimension B in **Fig. 1**) is set to the dimension specified in **Table 1**.

Cab Ride-Height Measurement	
Dimension A (see Fig. 1)	**Dimension B (see Fig. 1)**
9-1/2 in (241 mm)	13-1/2 in (343 mm)
10-1/4 in (260 mm)	13-7/8 in (352 mm)

Table 1, Cab Ride-Height Measurement

7. Hold the height-control valve in the neutral position by inserting a 5/32-inch (4-mm) pin or drill bit in the hole in the height-control valve.
8. Tighten the locknut at the upper end of the vertical linkage.
9. Remove the pin or drill bit previously inserted in the height-control valve.
10. Remove the chocks.

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Checking the Cab Height-Control System for Air Leaks

⚠ WARNING

Keep your hands and all objects away from the area under and around the cab when removing the pressure from the air system. Parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing if you detect leaks in the housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- If it is necessary to remove a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, crushing the valve body and damaging the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

1. Park the vehicle on a level surface, apply the parking brakes, and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa). Turn off the engine and wait 5 to 10 minutes for the system to equalize.

   NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal and does not indicate a damaged valve.
3. Apply a soap-and-water solution to the outside of the air fittings on the height-control valve and on the suspension air springs. Look for bubbles indicating an air leak.
4. If bubbles are seen, check that the air tubing is installed correctly into the fitting; see **Subject 100**.

   If no bubbles are seen, check the height-control valve for air leaks; see **Subject 110**.

Diagnostics and Testing

Air Spring

Inspect the exterior surfaces of the air spring, looking for wear. With the air spring fully inflated, check to see if there is sufficient clearance around the air spring to prevent lines or objects from rubbing against the air spring. Air tubing or cab components that rub against the air spring will cause damage to the air spring. If the air spring is not capable of lifting the cab to its proper ride height, check to see if the shock absorber is damaged. A binding shock absorber will limit the air spring's ability to extend. To clean the air spring, use soap and water.

NOTE: Do not use organic solvents, abrasives, or pressurized steam cleaners to clean the air spring.

Shock Absorber

Inspect the shock body for damage such as bends or dents in the piston. Bends or dents in the shock body will negatively affect the operation of the shock. Inspect the shock body for signs of leaking fluid. Normal operation of the shock will result in some misting of the hydraulic fluid onto the exterior shock body. Large streams of fluid indicate a leak, and the shock should be replaced; see **Fig. 1**.

To test the operation of a shock absorber, hold the shock in an upright position and cycle the piston at least five times by pushing the piston up and down. The piston should move evenly throughout each section of the cycle. If the shock does not move evenly

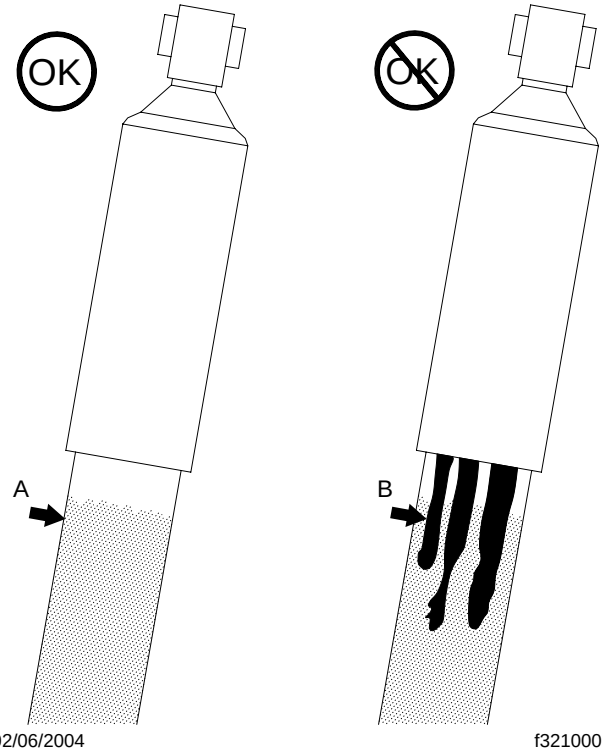
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Troubleshooting

when pushed down or pulled up, the shock should be replaced.

Noises such as squeaks, which may be intermittent, may be caused by the valves used to regulate the internal hydraulic fluid. This problem is not repairable and the shock will need to be replaced. Noises from the shock, such as knocking or rattling, may be due to movement between the bushings and mounting brackets. Inspect the bushings or mounting brackets for wear. Repair worn components as necessary. Check the torque of the shock absorber mounting nuts, and tighten if necessary.

NOTE: The shock absorber bushings do not require any type of lubrication. Do not attempt to stop bushing noise by lubricating them; grease and mineral-oil-base lubricants will deteriorate the bushing rubber.



A. Dust covered mist (normal).
B. Hydraulic fluid streaks indicating an actual leak.

Fig. 1, Differences Between Misting and Leaking

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Torque Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

Torque Specifications				
Fastener Description	**lbf·ft**	**N·m**	**lbf·in**	**N·cm**
Lateral Control Rod Upper and Lower Nut	45	61	—	—
Shock Absorber Upper and Lower Nut	45	61	—	—
Height-Control Valve Mounting Nut	—	—	45	500
Bottom Air Spring Nut	—	—	35	400

Table 1, Torque Specifications

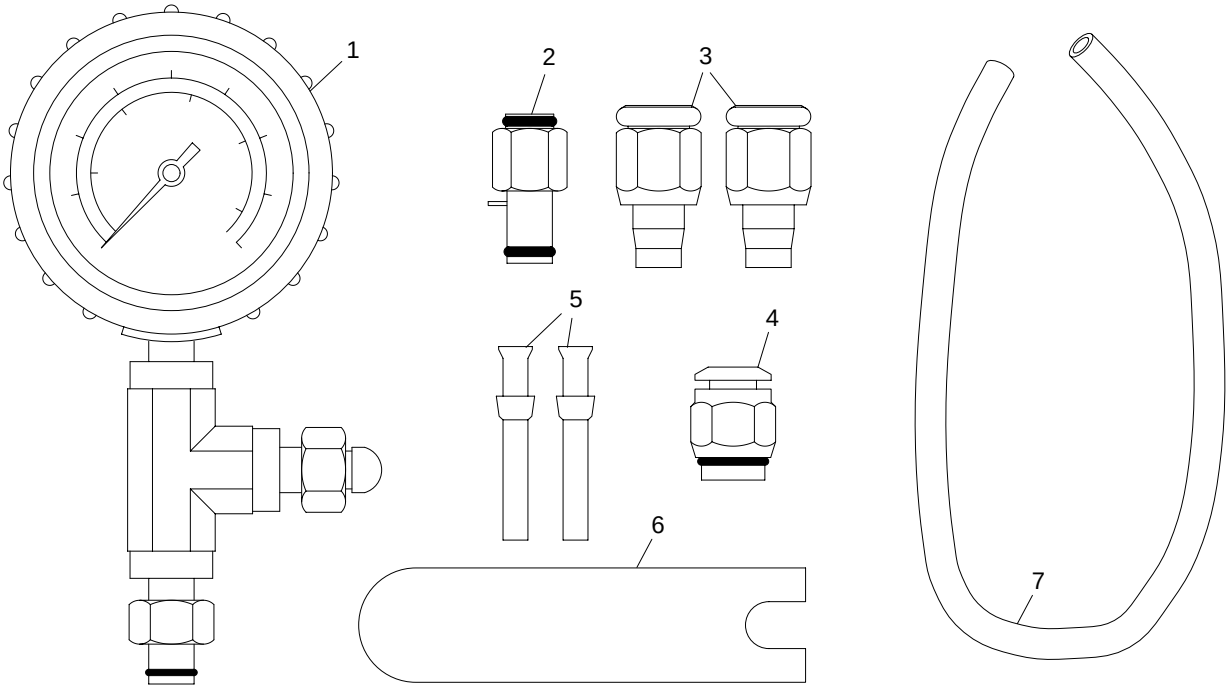
Special Tools

Use the kit shown in **Fig. 1** to test a Barksdale height-control valve. Test kit BKS KD2264 is available via the Direct Ship program in paragon, or directly from Barksdale, at **www.barksdale.com**, or:

Barksdale, Inc.
3211 Fruitland Avenue
Los Angeles, California 90058
Telephone: 866-832-6278

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Specifications



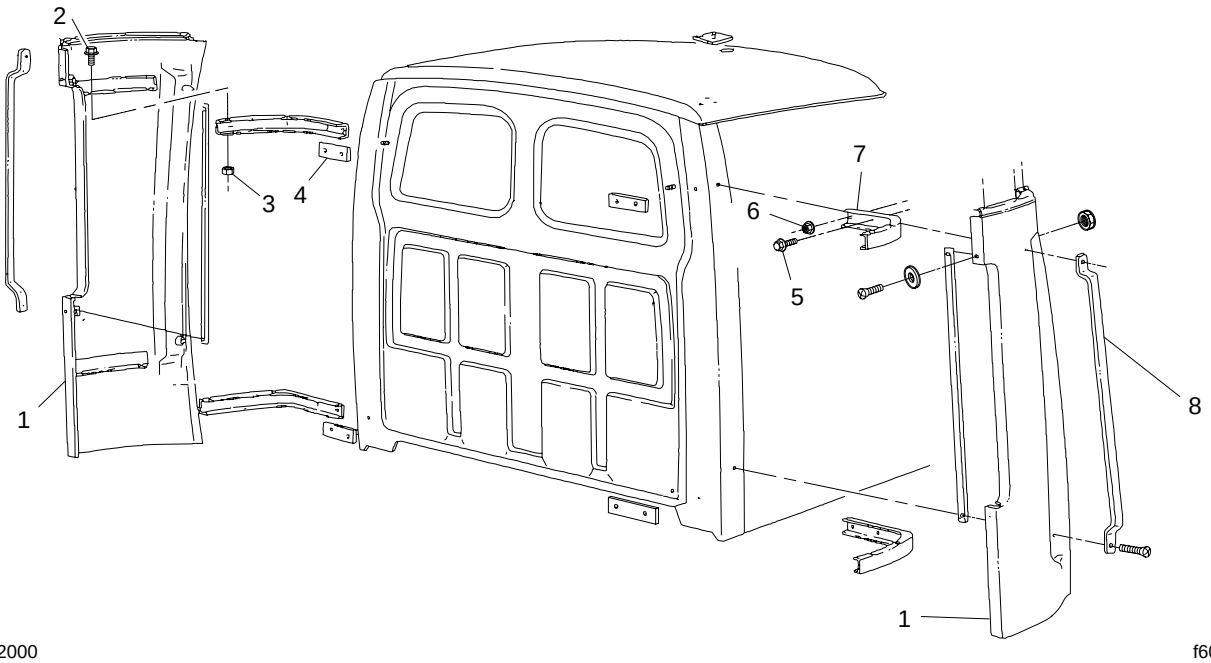
1. Test Gauge Assembly with Reset Button
2. Exhaust Port Test Connector for Cab Suspension Valve
3. Parker Plugs
4. Exhaust Port Test Connector for Chassis Suspension Valve
5. Test Plugs for Cab Suspension Valve
6. Special Tool for Disconnecting Air Line
7. Air Line

Fig. 1, Barksdale Height-Control Valve Test Kit KD2264

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General Information (See Fig. 1)

Acterra vehicles are available with cab side extenders. The side extenders improve aerodynamic efficiency. The side extenders can be ordered with or without a cab roof fairing and trim tabs.

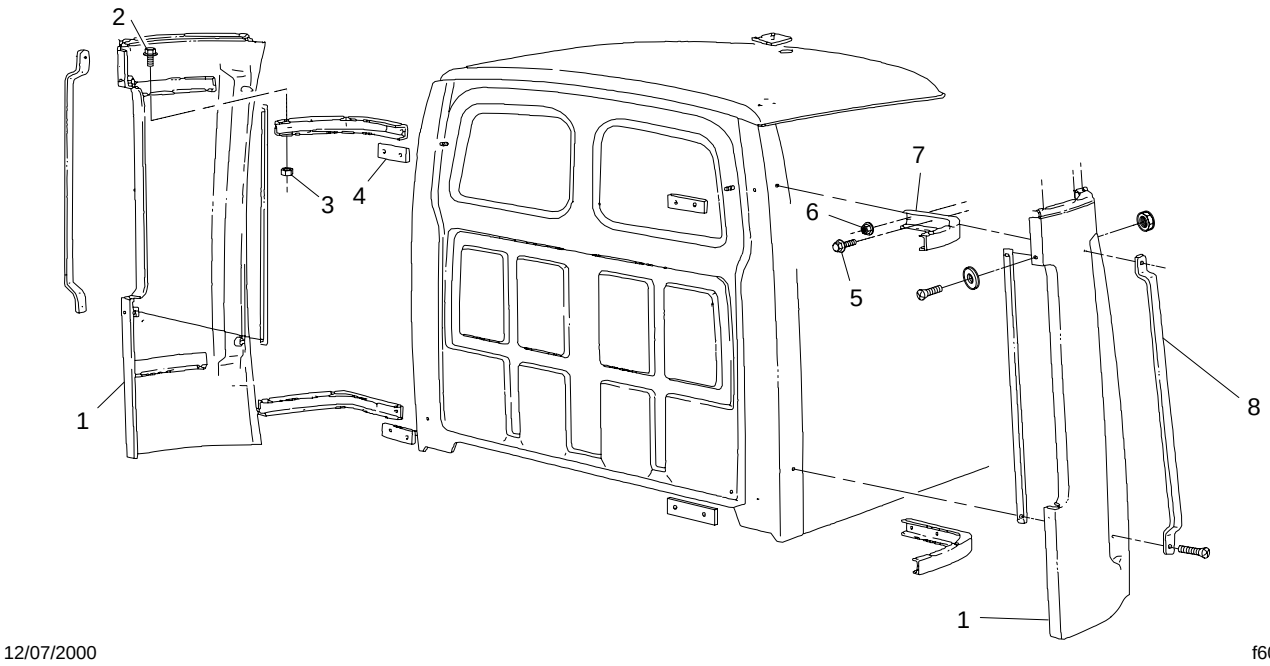


1. Side Extender
2. M8 x 1.25 Hexhead Bolt
3. M8 x 1.25 Nut
4. Isolator Pad
5. M10 x 1.5 Hexhead Bolt
6. M10 x 1.5 Hexnut
7. Upper Bracket
8. Grab Handle

Fig. 1, Side Extenders

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Removal (See Fig. 1)



1. Side Extender
2. M8 x 1.25 Hexhead Bolt
3. M8 x 1.25 Nut
4. Isolator Pad
5. M10 x 1.5 Hexhead Bolt
6. M10 x 1.5 Hexnut
7. Upper Bracket
8. Grab Handle

Fig. 1, Side Extenders

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. If equipped with roof fairing trim tabs, remove the M8 x 1.25 hexhead bolts and nuts attaching the trim tabs to the side extenders.
3. For both sides, remove the M8 x 1.25 hexhead bolts and nuts attaching the side extender to the cab-mounted brackets.
4. Remove the side extender.
5. Remove the M10 x 1.5 hexhead bolts and nuts attaching the mounting brackets to the cab.
6. Remove the mounting brackets and isolator pads.

Installation

1. For both sides, position the mounting brackets and isolator pads on the cab and install the M10 x 1.5 hexhead bolts and nuts. Tighten 27 lbf·ft (37 N·m).
2. Position the side extender and install the M8 x 1.25 hexhead bolts and nuts which attach the side extender to the cab-mounted brackets. Tighten 13 lbf·ft (18 N·m).
3. If equipped with roof fairing trim tabs, install the M8 x 1.25 hexhead bolts and nuts which attach the trim tabs to the side extenders. Tighten 13 lbf·ft (18 N·m).
4. Remove the chocks from the rear tires.

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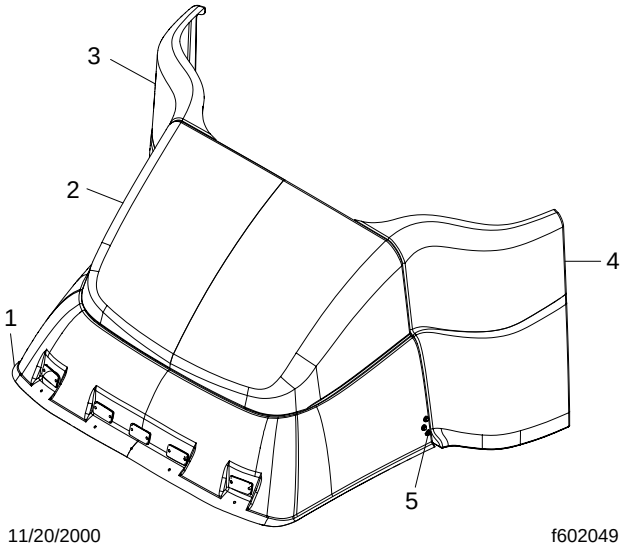
Specifications

Torque Values	
Size	**lbf·ft (N·m)**
M8 x 1.25	13 (18)
M10 x 1.5	27 (37)

Table 1, Torque Values

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General Information (See Fig. 1)



1. Lower Roof Fairing
2. Upper Roof Fairing
3. Right-Side Trim Tab
4. Left-Side Trim Tab
5. Fasteners

Fig. 1, Roof Fairing

Acterra vehicles are available with a cab roof fairing. The roof fairing improves aerodynamic efficiency. The roof fairing can be ordered with or without trim tabs and cab side extenders.

For ease in shipment, the upper roof fairing is initially installed upside down in the lower roof fairing. See **Fig. 2**. Once delivered, the upper roof fairing must be properly installed for use.

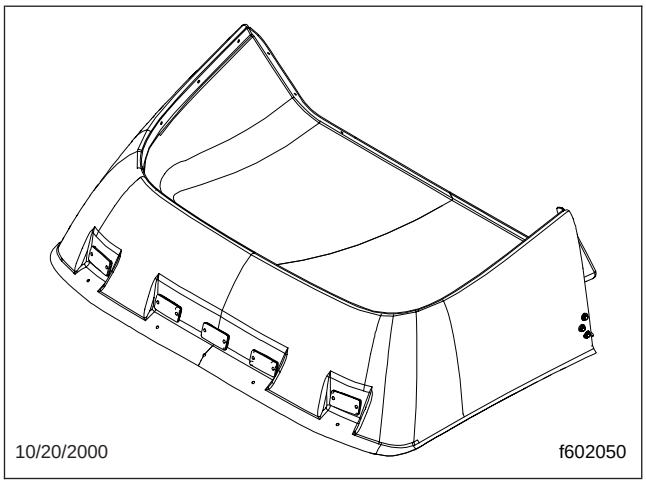
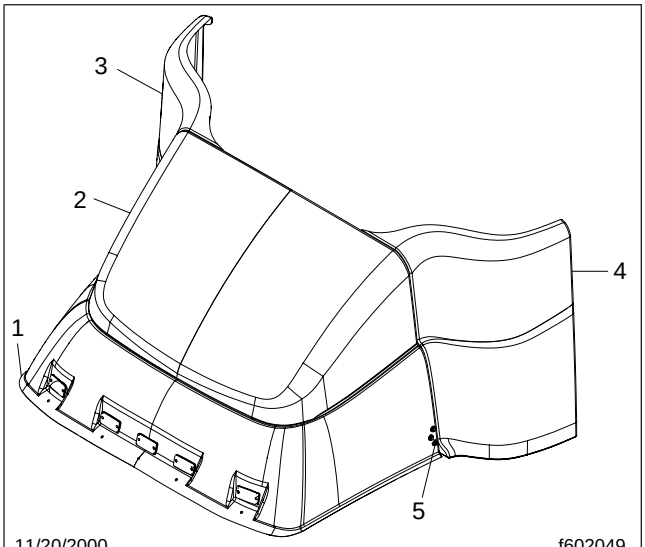


Fig. 2, Upper Roof Fairing as Shipped

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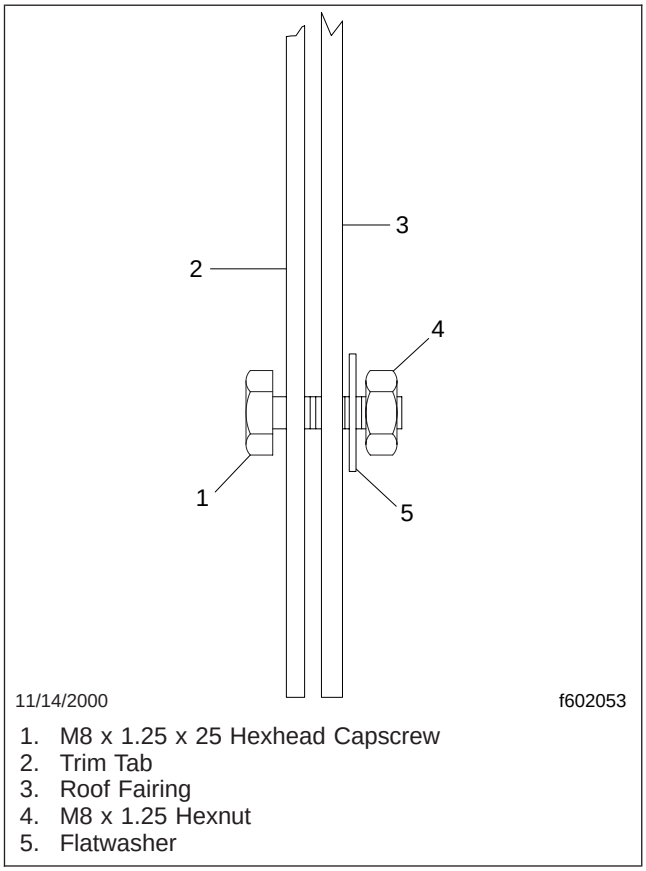
Removal (See Fig. 1)



1. Lower Roof Fairing
2. Upper Roof Fairing
3. Right-Side Trim Tab
4. Left-Side Trim Tab
5. Fasteners

Fig. 1, Roof Fairing

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the side extenders, if equipped. For instructions, see **Section 60.05**.
3. If equipped with trim tabs, remove the M8 x 1.25 x 25 hexhead capscrews, flatwashers and M8 x 1.25 hexnuts attaching the trim tabs to the roof fairing. Remove the trim tabs. See **Fig. 2**.
4. Remove the M8 x 1.25 x 30 hexhead capscrews, flatwashers and rubber washers attaching the roof fairing to the front of the cab. See **Fig. 3**.
5. Remove the M8 x 1.25 x 25 hexhead capscrews, flatwashers, rubber washers and M8 x 1.25 hexnuts attaching the roof fairing to the cab-mounted brackets. See **Fig. 4**.
6. Remove the upper and lower roof fairings from the cab as a unit.
7. Remove the fasteners attaching the cab-mounted brackets to the cab and remove the brackets.



1. M8 x 1.25 x 25 Hexhead Capscrew
2. Trim Tab
3. Roof Fairing
4. M8 x 1.25 Hexnut
5. Flatwasher

Fig. 2, Trim Tab Mounting Fasteners

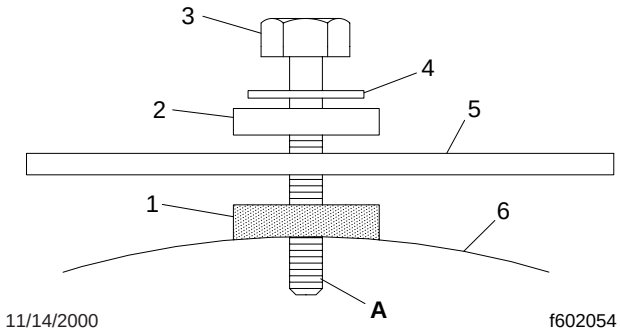
8. Remove the adhesive-backed rubber washers from the cab and discard the washers.
9. Remove the M8 x 1.25 x 25 hexhead capscrews, flatwashers and M8 x 1.25 hexnuts attaching the upper roof fairing to the lower roof fairing. See **Fig. 5**.
10. Separate the upper and lower roof fairings.

Installation

1. Position the upper roof fairing on the lower roof fairing and install the M8 x 1.25 x 25 hexhead capscrews, flatwashers and M8 x 1.25 hexnuts. Tighten 13 lbf·ft (18 N·m). Do not overtighten. See **Fig. 5**.
2. Position the cab-mounted brackets on the cab and install the fasteners. Finger-tighten the bracket fasteners.

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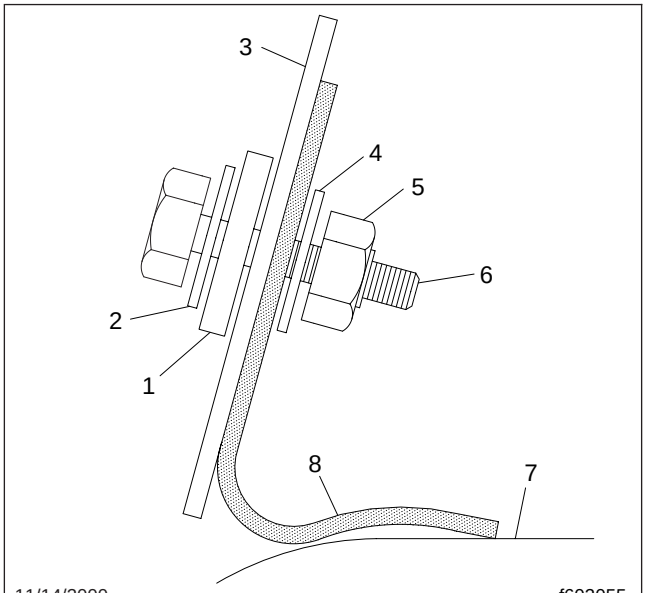
Removal and Installation



A. Apply Loctite® 24241 here before installing the capscrew.
1. Adhesive-Backed Rubber Washer
2. Rubber Washer
3. M8 x 1.25 x 30 Hexhead Capscrew
4. Flatwasher
5. Roof Fairing
6. Cab

Fig. 3, Roof Fairing-to-Cab Fasteners

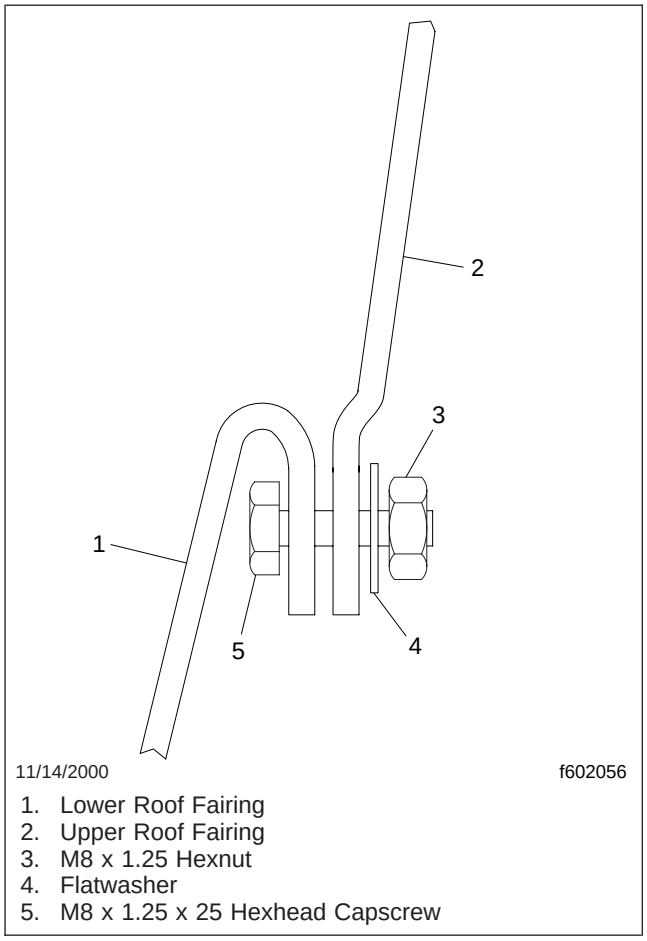
3. Remove the adhesive protection and install the five rubber washers on the cab. Align the washers with the holes in the cab.
4. Position the roof fairing on the cab.
5. Install the M8 x 1.25 x 25 hexhead capscrews, flatwashers, rubber washers and M8 x 1.25 hexnuts which attach the roof fairing to the cab-mounted brackets. Finger-tighten the fasteners. See **Fig. 4**.
6. Install the M8 x 1.25 x 30 hexhead capscrews, flatwashers and rubber washers which attach the roof fairing to the front of the cab. Finger-tighten the fasteners. See **Fig. 3**.
7. Finish tightening all M8 x 1.25 hexhead capscrews and hexnuts 13 lbf·ft (18 N·m). Do not overtighten.
8. If equipped with trim tabs, position the trim tabs on the roof fairing and install the M8 x 1.25 x 25 hexhead capscrews, flatwashers and M8 x 1.25 hexnuts. Tighten 13 lbf·ft (18 N·m). Do not overtighten. See **Fig. 2**.
9. Install the side extenders, if equipped. For instructions, see **Section 60.05**.
10. Remove the chocks from the rear tires.



1. Rubber Washer
2. Flatwasher
3. Roof Fairing
4. Flatwasher
5. M8 x 1.25 Hexnut
6. M8 x 1.25 x 25 Hexhead Capscrew
7. Cab
8. Cab-Mounted Bracket

Fig. 4, Roof Fairing Attachment to Cab-Mounted Bracket

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1. Lower Roof Fairing
2. Upper Roof Fairing
3. M8 x 1.25 Hexnut
4. Flatwasher
5. M8 x 1.25 x 25 Hexhead Capscrew

Fig. 5, Upper Roof Fairing Fasteners

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Specifications

Torque Values	
Size	**lbf·ft (N·m)**
M8 x 1.25	13 (18)

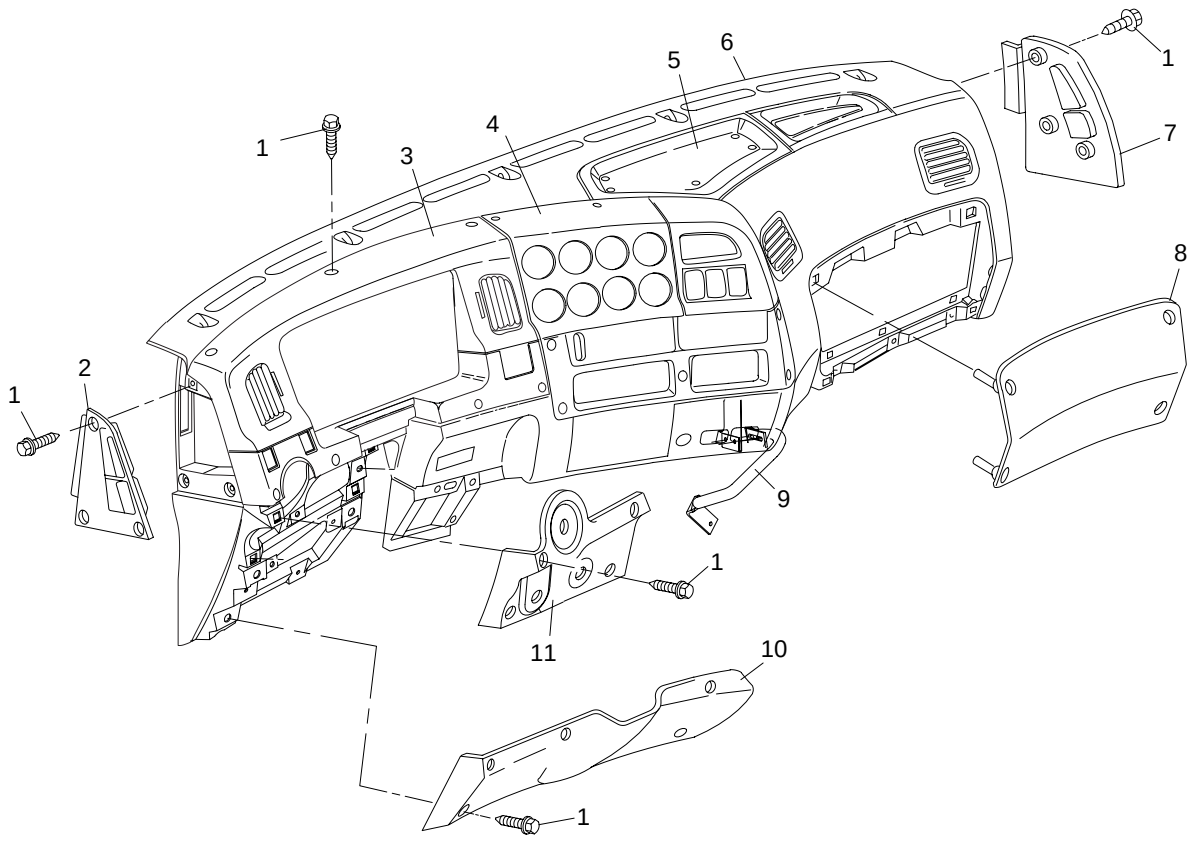
Table 1, Torque Values

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Instrument Panel Removal and Installation

Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Disconnect the batteries.
3. Drain the air system.
4. Remove the under steering panel. See **Fig. 1**. For instructions, see **Subject 130**.
5. Disconnect the steering column. For instructions, see **Group 46**.
6. Remove the driver side finish panel. See **Fig. 2**. For instructions, see **Subject 110**.
7. Remove the instrument cluster. For instructions, see **Group 54**.
8. Remove the ignition switch bezel. See **Fig. 1**. Support the ignition switch, headlight switch and starter button, if equipped, while removing the bezel.
9. Remove the screws and remove the driver side end panel. See **Fig. 1**.



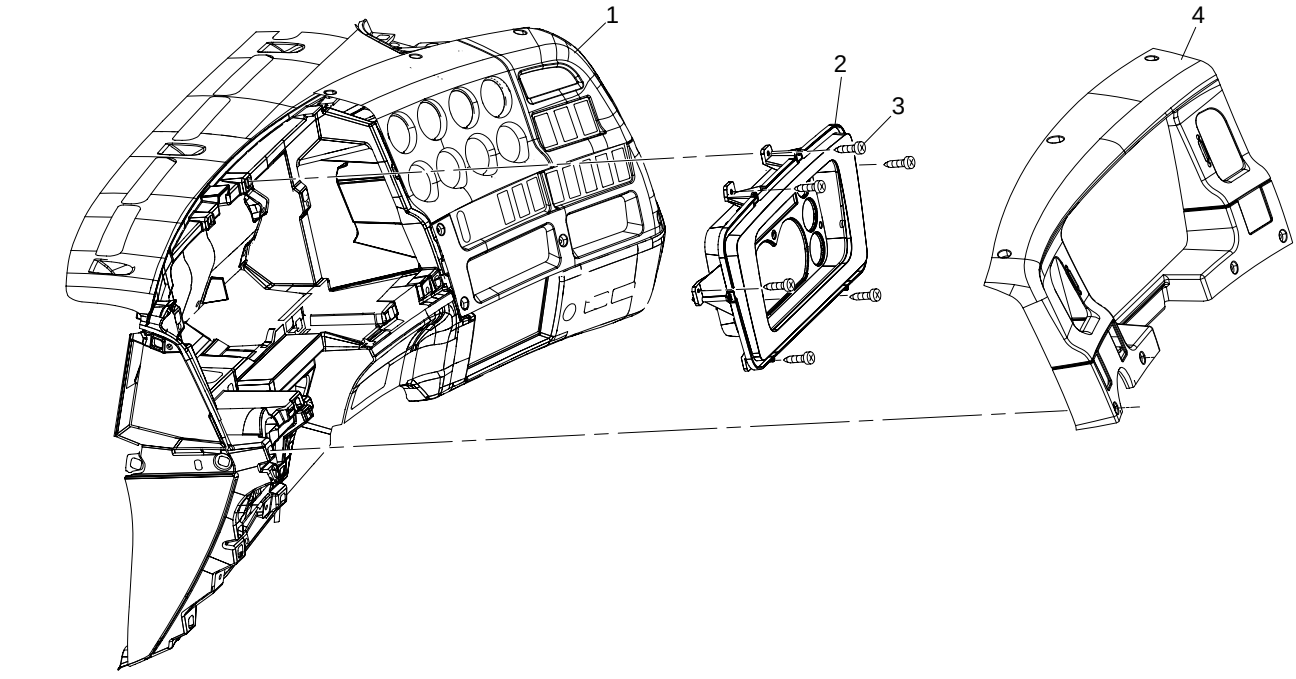
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1. Hexhead Screw
2. Driver Side End Panel
3. Driver Side Finish Panel
4. Auxiliary Finish Panel
5. Top-Of-Dash Cover
6. Instrument Panel
7. Passenger Side End Panel
8. Power Distribution Module Cover
9. Support Bracket
10. Under Steering Panel
11. Ignition Switch Bezel

Fig. 1, Dash Finish Panels

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Instrument Panel Removal and Installation



1. Instrument Panel
2. Instrument Cluster
3. Fastener
4. Driver Side Finish Panel

Fig. 2, Instrument Cluster Mounting

10. Remove the auxiliary finish panel. See **Fig. 1**. For instructions, see **Subject 120**. Support the engine brake switch and differential lock switch, if equipped, while removing the finish panel.
11. Remove the top-of-dash cover. See **Fig. 1**.
12. Remove the center bracket. Remove the manifold screws and remove the manifold. See **Fig. 3**.
13. Disconnect the air lines to the tractor and trailer air valves, if equipped. See **Fig. 4**.
14. Remove the screws located behind the radio bracket retaining the connectors to the instrument panel. Lower the harness between the instrument panel and the engine cover opening. See **Fig. 5**.
15. Release the four quarter-turn fasteners and remove the power distribution module cover. See **Fig. 6**.
16. Remove the screws and remove the power distribution module mask. See **Fig. 7**.

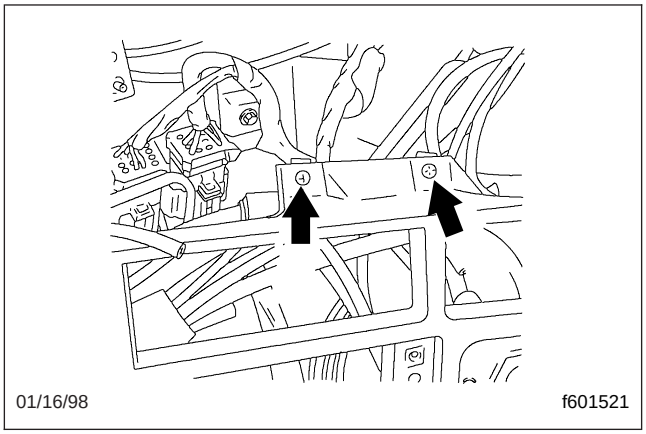


Fig. 3, Manifold Screws

17. Remove the screws and lower the power distribution module to the cab floor. See **Fig. 8**.
18. Remove the screws and remove the passenger side end panel. See **Fig. 1**.

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Instrument Panel Removal and Installation

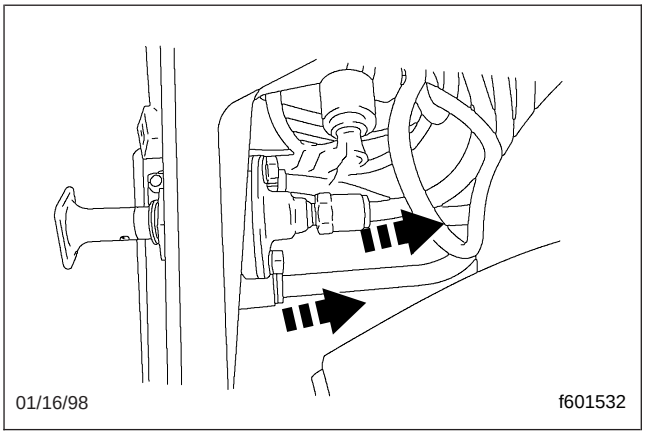


Fig. 4, Air Lines

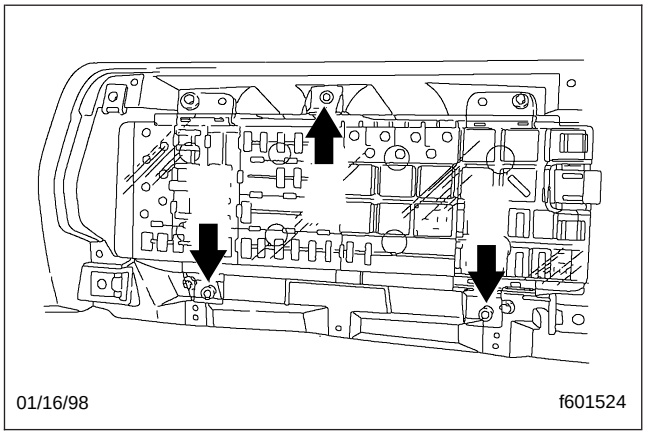


Fig. 7, Power Distribution Module Mask Screws

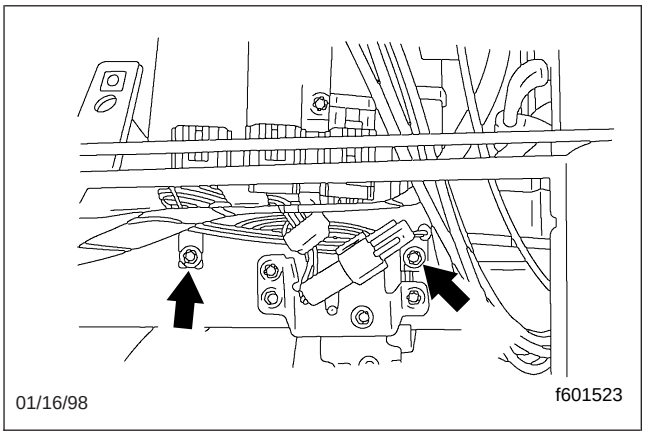


Fig. 5, Instrument Panel Connector Retaining Screws

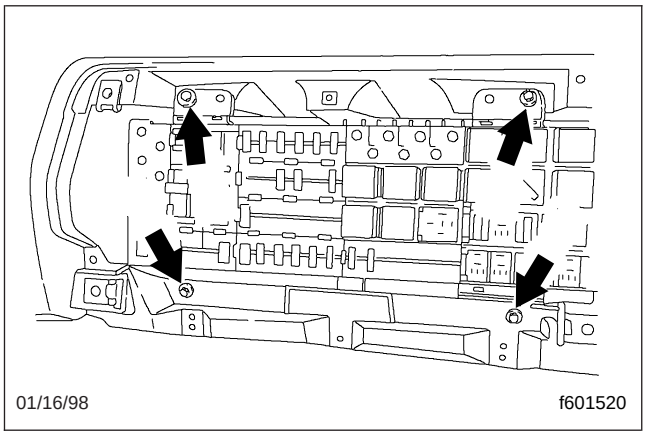


Fig. 8, Power Distribution Module Screws

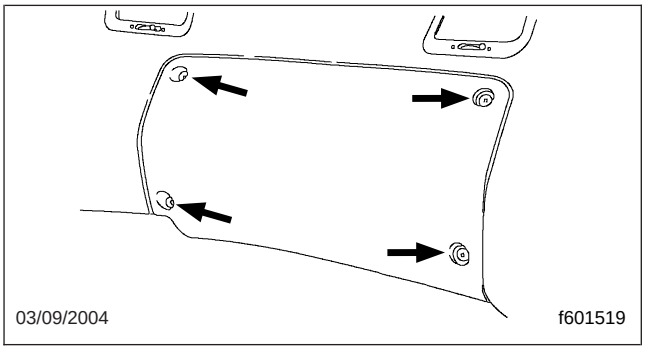


Fig. 6, Power Distribution Module Cover Fasteners

19. Remove the passenger side instrument panel mounting bolts. See **Fig. 9**.
20. Remove the five top instrument panel retaining screws. See **Fig. 10**.
21. Remove the driver side instrument panel mounting bolts. See **Fig. 11**.
22. Remove the bolt located behind the lap duct. See **Fig. 12**.
23. Remove all remaining mounting screws. This includes four behind the instrument cluster, two lower right of the steering column, three lower left of the steering column, four on the lower edge under the radio/cigar lighter, four behind the center instrument panel and three behind the fuse block.

NOTE: Carefully pull the instrument panel away from the vehicle noting not to damage any of the air pressure lines or the wiring harnesses.

24. Remove the instrument panel. See **Fig. 13**.

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Instrument Panel Removal and Installation

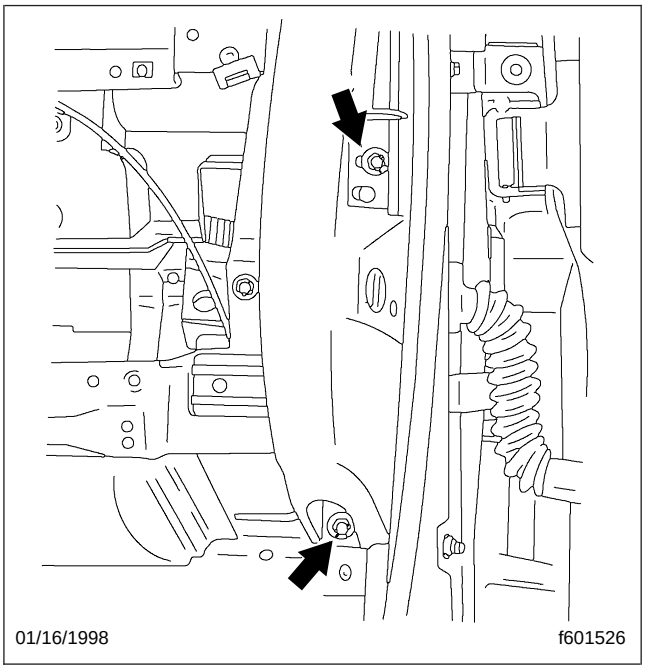


Fig. 9, Passenger Side Instrument Panel Mounting Bolts

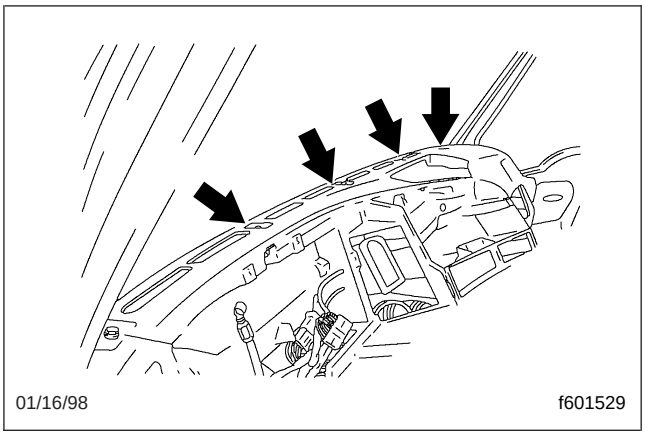


Fig. 10, Instrument Panel Retaining Screws

Installation

NOTE: Make sure all the air pressure lines and wiring harnesses are clear of the instrument panel mounting surfaces.

1. With the help of an assistant, position the instrument panel in the vehicle. It may be necessary to remove the two passenger side air ducts to provide clearance when positioning the instrument panel.

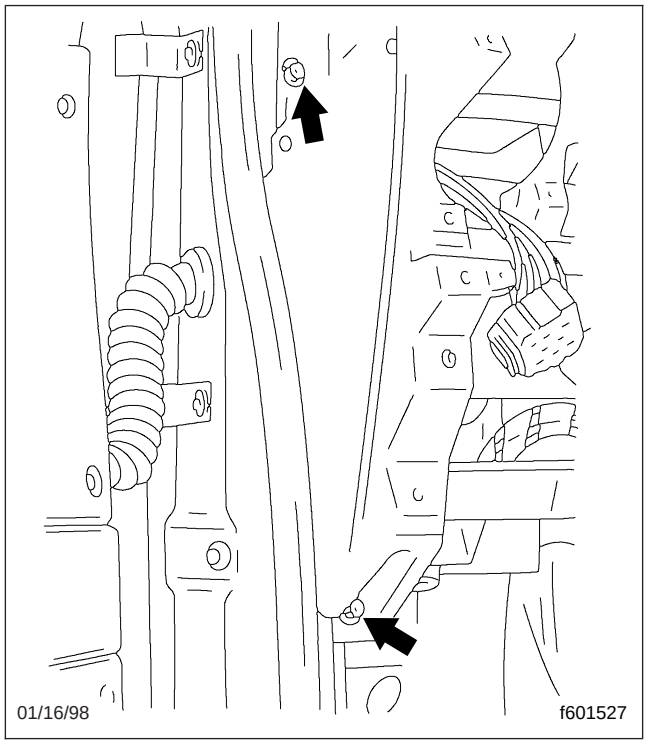


Fig. 11, Driver Side Instrument Panel Mounting Bolts

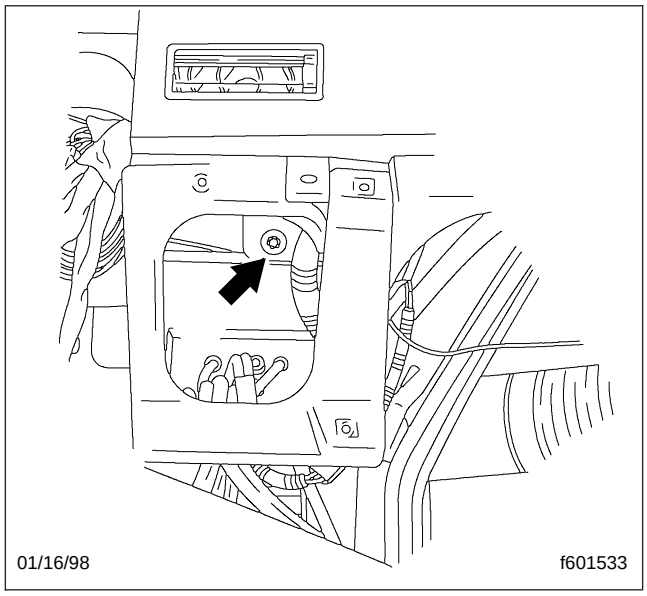
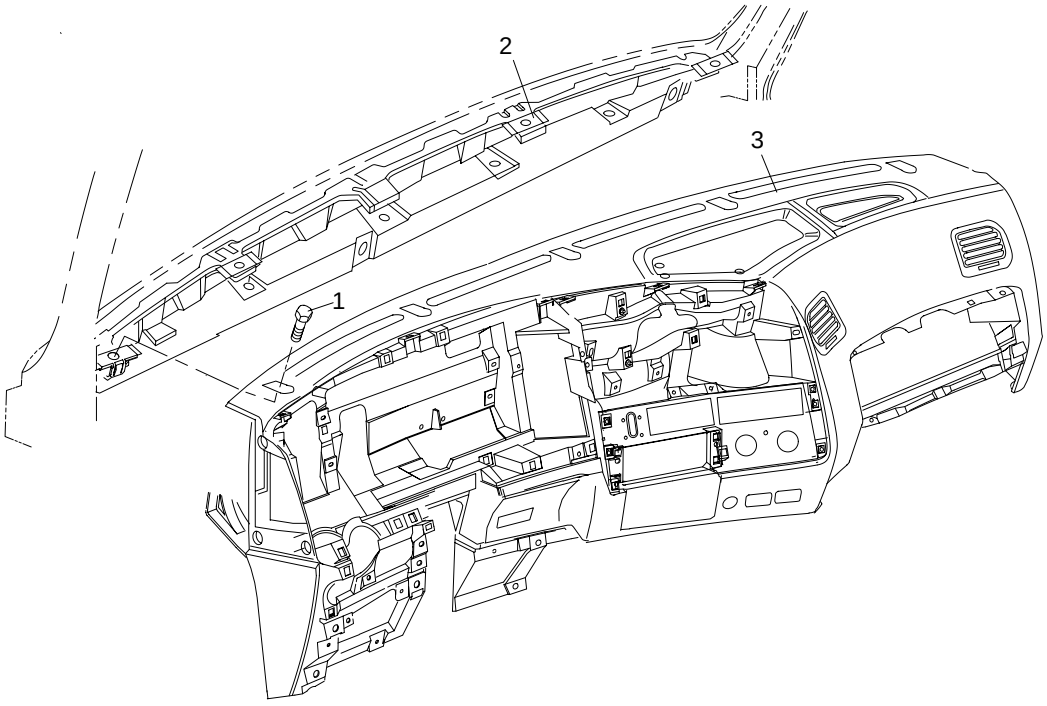


Fig. 12, Bolt Behind Lap Duct

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Instrument Panel Removal and Installation



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1. Hexhead Screw
2. Mounting Bracket
3. Instrument Panel

Fig. 13, Instrument Panel Mounting

2. Install the five top instrument panel retaining bolts. Tighten the bolts 44 to 53 lbf·in (500 to 600 N·cm). See **Fig. 10**.
3. Install the driver side instrument panel mounting bolts. Tighten the bolts to 27 to 35 lbf·in (300 to 400 N·cm). See **Fig. 11**.
4. Install the passenger side instrument panel mounting bolts. Tighten the bolts to 27 to 35 lbf·in (300 to 400 N·cm). See **Fig. 9**.
5. Install the four mounting screws behind the instrument cluster. Install the mounting screws in the lower left and right sides of the steering column, on the lower edge under the radio/cigar lighter, behind the center instrument panel and behind the fuse block.
6. Install the bolt located behind the lap duct. Tighten the bolt to 44 to 53 lbf·in (500 to 600 N·cm). See **Fig. 12**.
7. Route the wiring harness between the instrument panel and the engine cover opening. Install the screws located behind the radio bracket. See **Fig. 5**.
8. Attach the air manifold to the center bracket.
9. Connect the air lines to the brake valves and install the center mount bracket, if equipped.
10. Install the passenger side air ducts removed earlier to provide clearance for positioning the instrument panel.
11. Install the power distribution module and the screws. See **Fig. 8**.
12. Install the power distribution module mask and the screws. See **Fig. 7**.
13. Install the power distribution module cover and the quarter-turn screws. See **Fig. 6**.

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Instrument Panel Removal and Installation

14. Install the passenger side end panel and the screws. See **Fig. 1**.
15. Install the top-of-dash cover. See **Fig. 1**.
16. Install the auxiliary finish panel. See **Fig. 1**. For instructions, see **Subject 120**. Install the engine brake switch and differential lock switch, if equipped.
17. Install the driver side end panel and the screws. See **Fig. 1**.
18. Install the ignition switch bezel. See **Fig. 1**. Install the ignition switch, headlight switch and starter button, if equipped.
19. Install the instrument cluster. For instructions, see **Group 54**.
20. Install the driver side finish panel. See **Fig. 2**. For instructions, see **Subject 110**.
21. Connect the steering column. For instructions, see **Group 46**.
22. Install the under steering panel. See **Fig. 1**. For instructions, see **Subject 130**.
23. Connect the batteries.
24. Charge the brake air systems and check for leaks, if equipped.
25. Remove the chocks from the tires.

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Driver Side Finish Panel Removal and Installation

Removal

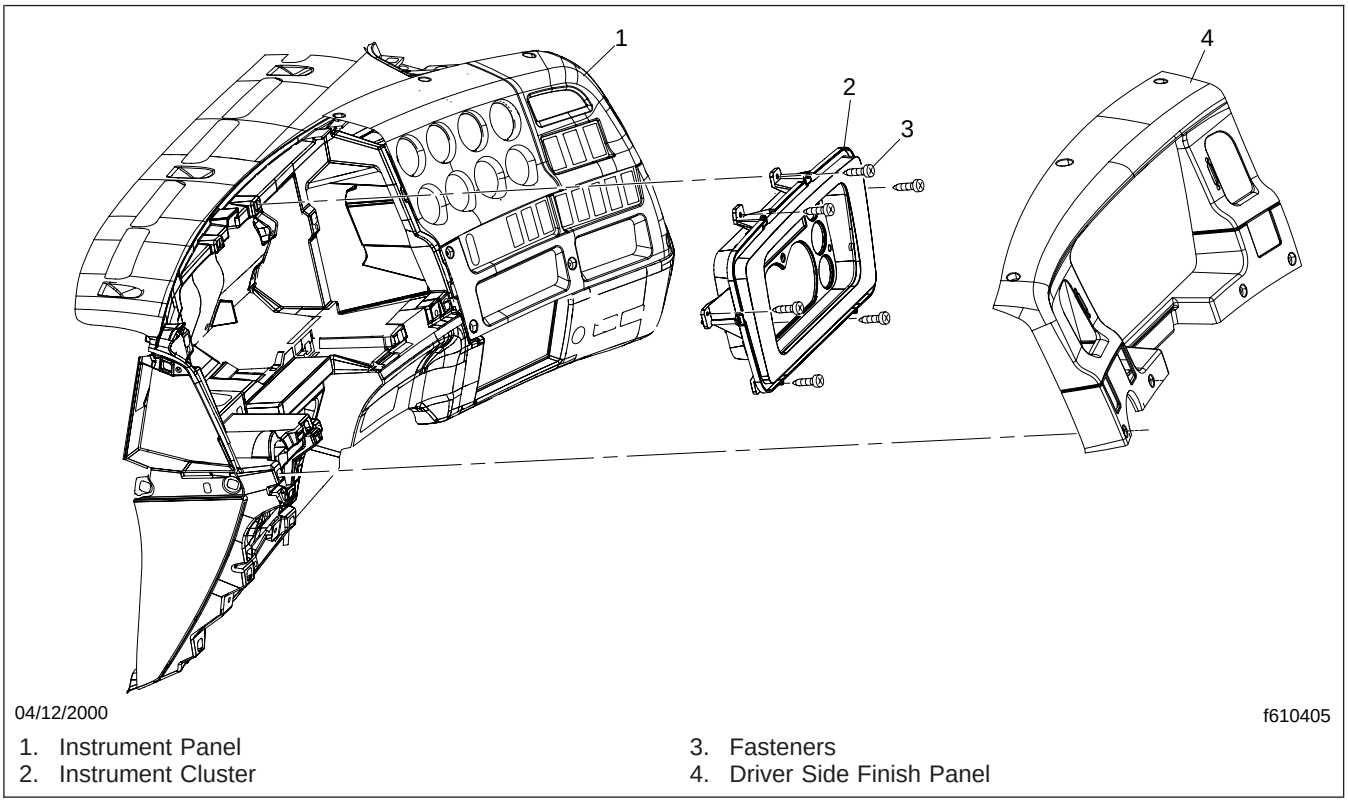
1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the screws from the driver side finish panel. See **Fig. 1**.
3. Remove only the auxiliary finish panel screws from the side closest to the driver side finish panel. See **Fig. 2**.
4. Remove the driver side finish panel.

Installation

1. Install the driver side finish panel.
2. Install and tighten the auxiliary finish panel screws.
3. Install and tighten the driver side finish panel screws.
4. Remove the chocks from the tires.

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Driver Side Finish Panel Removal and Installation



1. Instrument Panel
2. Instrument Cluster
3. Fasteners
4. Driver Side Finish Panel

Fig. 1, Driver Side Finish Panel Mounting

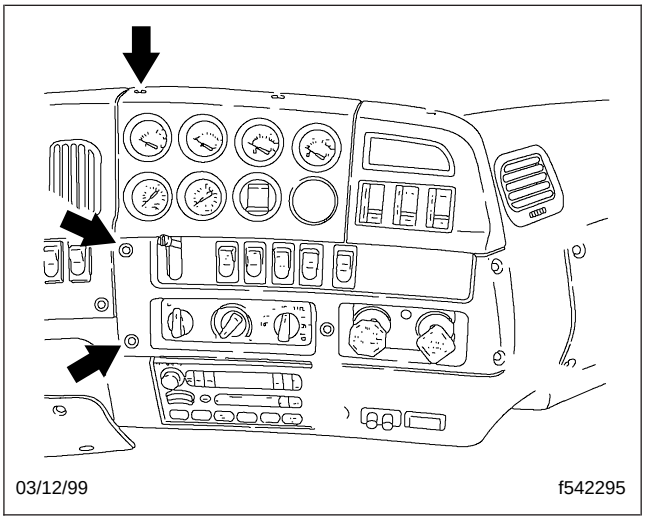


Fig. 2, Auxiliary Finish Panel Screws

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Auxiliary Finish Panel Removal and Installation

Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Disconnect the batteries.
3. Remove the trailer brake hand control valve knob, if equipped. See **Fig. 1**.

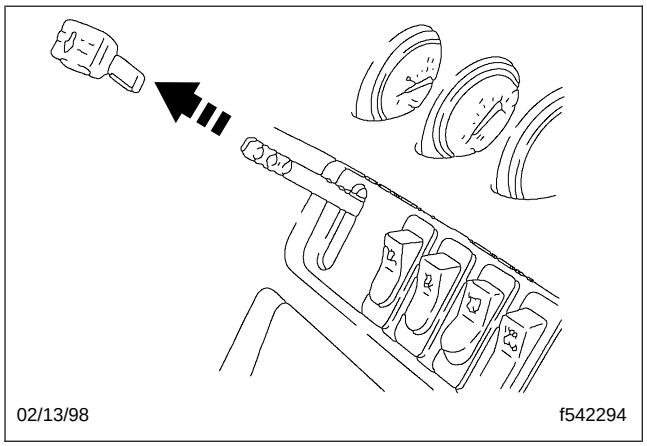


Fig. 1, Trailer Brake Hand Control Valve Knob

4. Remove the auxiliary finish panel screws. See **Fig. 2**.

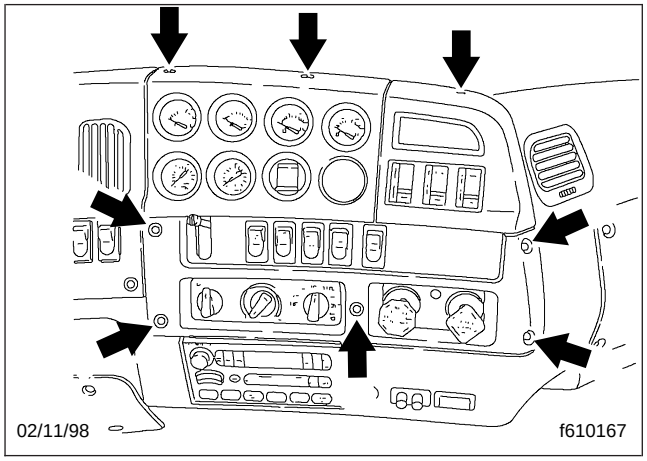


Fig. 2, Auxiliary Finish Panel Screws

5. Bleed the air from both the primary and secondary brake air systems, if equipped.
6. Disconnect the electrical connectors and remove the auxiliary finish panel.
7. Disconnect the air lines, if equipped.

Installation

1. Connect the electrical connectors and the air lines, if equipped.
2. Install the auxiliary finish panel.
3. Install the trailer brake hand control valve knob, if equipped. See **Fig. 1**.
4. Install and tighten the auxiliary finish panel screws. See **Fig. 2**.
5. Connect the batteries.
6. Remove the chocks from the tires.

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Under Steering Panel Removal and Installation

Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the five screws from the under steering panel. See **Fig. 1**.

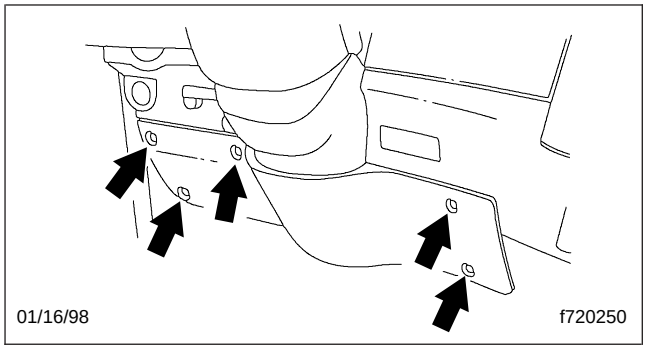


Fig. 1, Under Steering Panel Screw Location

3. Remove the spacer.
4. Remove the panel.

Installation

1. Position the under steering panel.
2. Install the spacer.
3. Tighten the five screws. See **Fig. 1**.
4. Remove the chocks from the tires.

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Specifications

Torque Specifications	
Description	**lbf·in (N·cm)**
Instrument Panel Top and Side Cowl Screws	44–53 (500–600)
Instrument Panel Finish End Panel Screws	27–35 (300–400)
Instrument Panel Extension Bracket Screws	44–53 (500–600)

Table 1, Torque Specifications

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B-Pillar Exterior Panel Replacement, TwinCab

1. Remove the grab handle by removing the two Torx® screws that attach it to the B-pillar panel, along with the two nylon washers between the grab handle and the panel.
2. Open the front door. Remove the six screws that hold the B-pillar exterior panel to the front door frame. See **Fig. 1**.

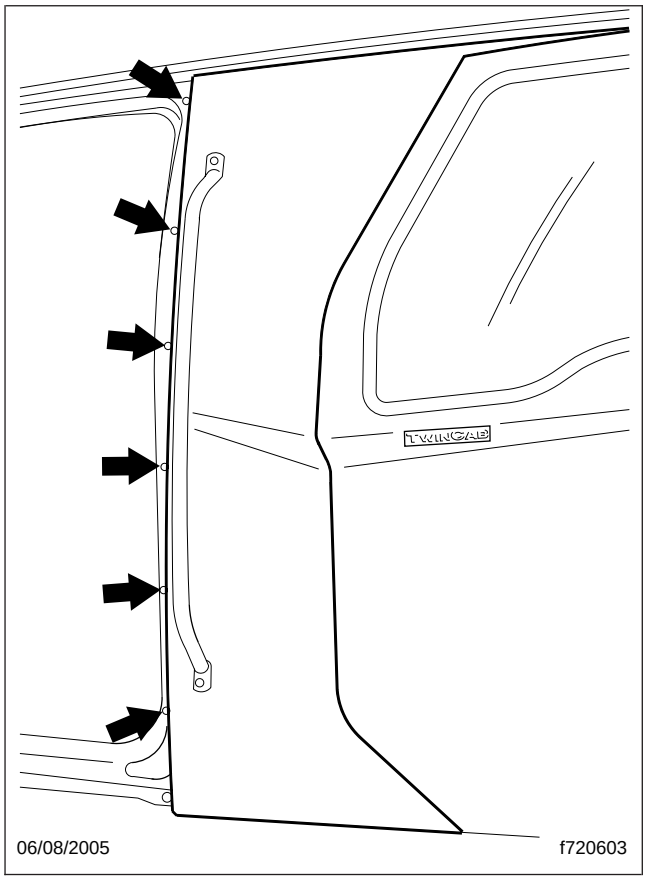


Fig. 1, B-Pillar Exterior Panel Fastener Locations, Front Door Frame

3. Open the rear door. Remove the seven screws that hold the B-pillar exterior panel to the rear door frame. See **Fig. 2**.
4. Remove the screw that holds the bottom of the B-pillar exterior panel to the cab structure. See **Fig. 2**.

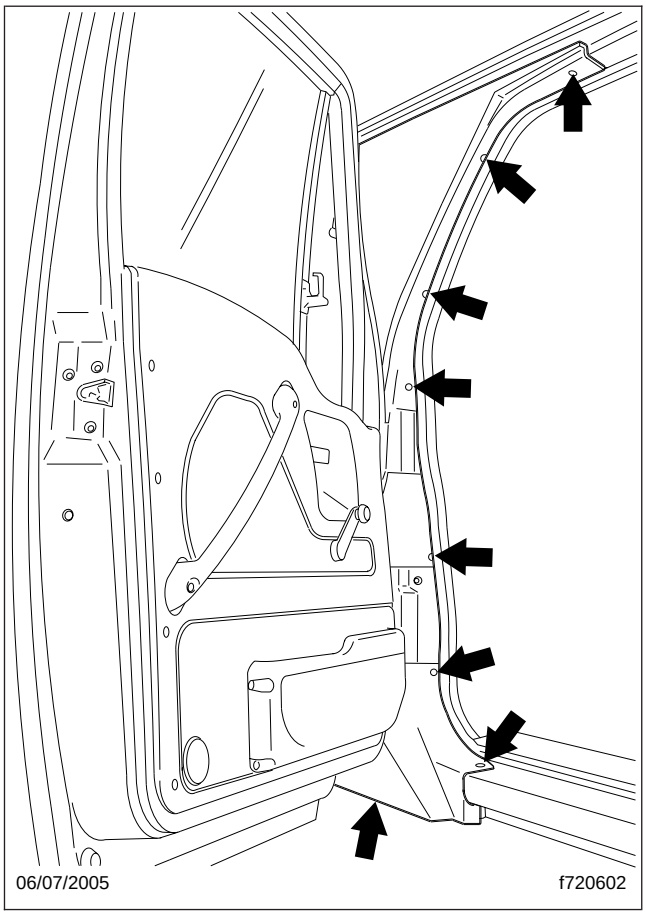


Fig. 2, B-Pillar Exterior Panel Fastener Locations, Rear Door Frame

5. Remove the panel, taking care not to damage the finish of the front edge of the rear door.
6. Position the new B-pillar exterior panel between the door frames, taking care not to damage the finish of the front edge of the rear door.
7. Install the screw that holds the bottom of the B-pillar exterior panel to the cab structure. See **Fig. 2**.
8. Install the seven screws that hold the panel to the rear door frame. See **Fig. 2**.
9. Install the six screws that hold the panel to the front door frame. See **Fig. 1**.
10. Install the grab handle with the two Torx screws, placing the two nylon washers between the grab handle and the B-pillar exterior panel.

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Cab Water-Leak Detection

Use the following procedure to locate areas where water may intrude into the cab.

1. Park the vehicle, apply the parking brakes, and chock the front and rear tires.
2. Prepare a wash solution of at least one-quarter cup of soap to one gallon of water in a spray bottle.
3. Place tape over the cab exhausters.
4. Close all doors, windows, and vents.
5. With the HVAC system in "Fresh Air" mode, turn the fan blower motor on high.

NOTE: Perform the leak detection test with the HVAC system in the "Fresh Air" mode only. Do not set the system in the "Recirculation" mode.

6. Spray the cab with the wash solution, and look for bubbles. See **Fig. 1**. Inspect all applicable areas listed below:
    - windshield perimeter
    - visor brackets (if so equipped)
    - air horns and marker lights (if so equipped)
    - roof deflector mounts (if so equipped)
    - roof coach joints (TwinCab)

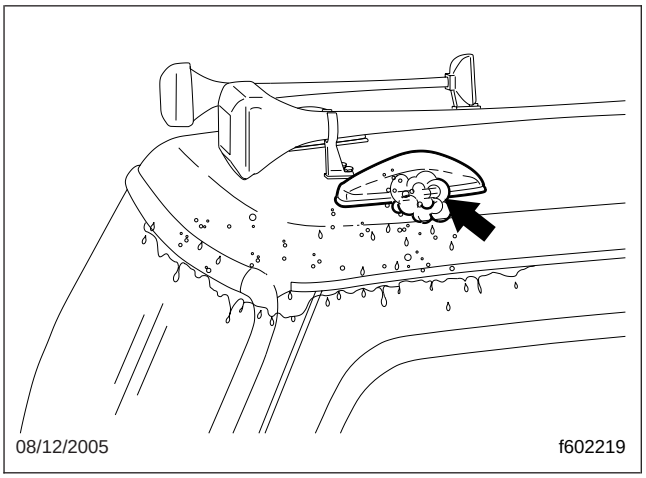


Fig. 1, Cab Water-Leak Detection with Wash Solution

7. Mark areas of suspected leaks.

NOTE: This method of leak detection may also identify areas that will not leak water, even though those areas produce bubbles. Bubbles around door seals and along the vehicle side walls will likely not cause water intrusion issues.

If small bubbles are found in an area that is not suspected to leak, a repair may not be necessary.

8. Rinse the wash solution off the vehicle with water.
9. Turn off the fan blower motor.
10. Remove the tape from the cab exhausters.
11. Remove the chocks from the tires.

Cab Water-Leak Repair

If a leak is found, the repair method will depend on the area and type of leak. It may be necessary to remove some components, though most leaks should be repairable by sealing the area of the leak with silicone sealant.

Repair leaks in the windshield using the approved method. See **Section 60.00, Subject 100**.

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Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Disconnect the batteries.
3. Roll down the window.
4. Pull the door wiring grommet from the seated position. See **Fig. 1**.

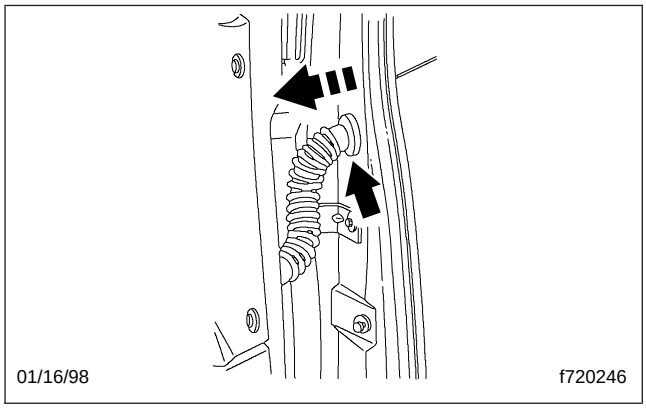


Fig. 1, Door Wiring Grommet

5. Remove the scuff panel. See **Fig. 2**.

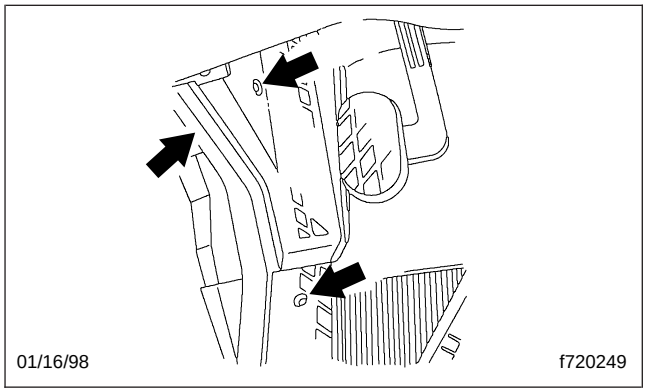


Fig. 2, Scuff Panel

6. Remove the under steering panel screws and remove the panel. See **Fig. 3**.
7. Disconnect the electrical connectors. See **Fig. 4**.
8. Disconnect the CB antenna cable.
9. Remove the ground bolt and the ground strap. See **Fig. 5**.

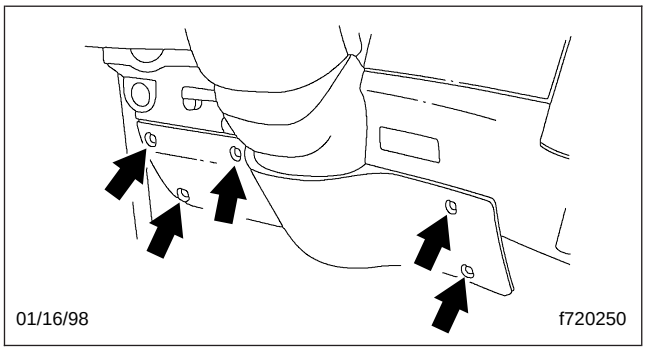


Fig. 3, Under Steering Panel Screw Locations

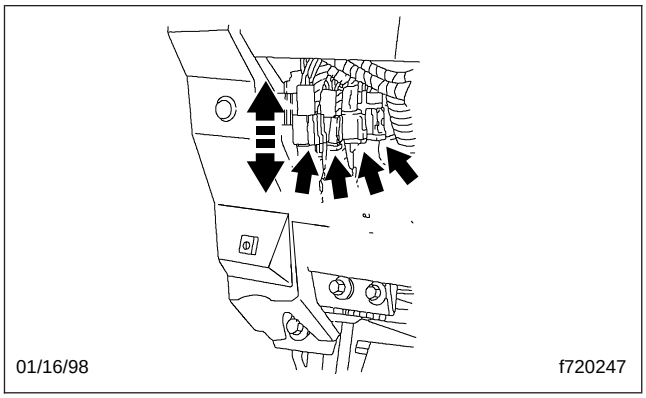


Fig. 4, Electrical Connectors

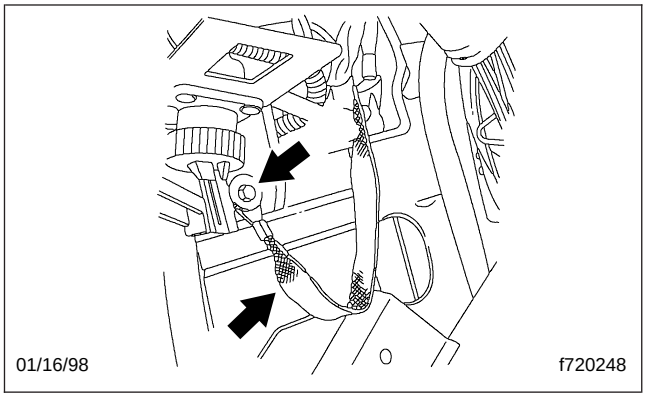


Fig. 5, Ground Bolt and Ground Strap

10. Pull the wiring out of the A-pillar, one connector at a time.
11. Remove the cowl panel.
12. Place indicator marks around the door hinges on the door surface.

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Door Removal and Installation

13. Close the door and remove the hinge-to-door bolts. Remove the door. See **Fig. 6**.

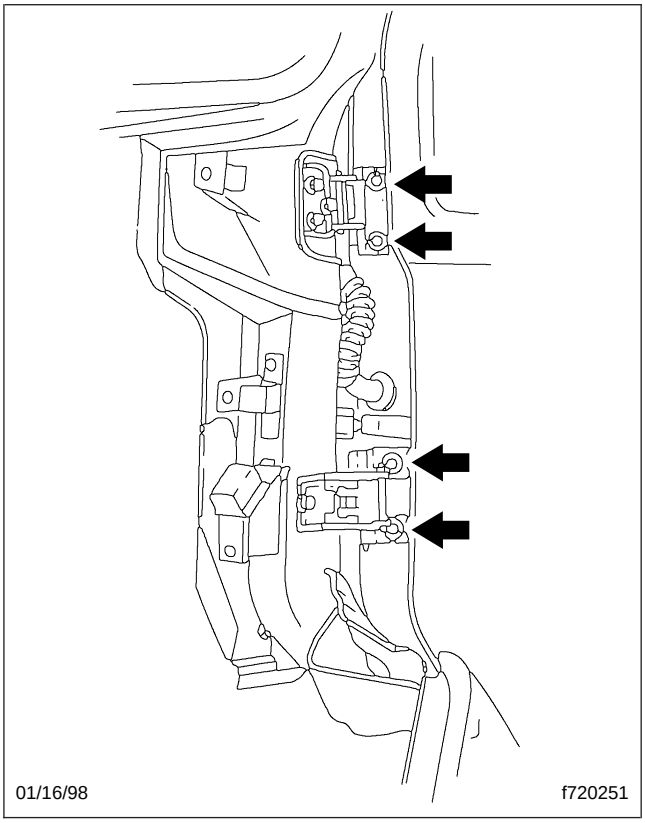


Fig. 6, Hinge-to-Door Bolts

Installation

1. Position the door and install the hinge-to-door bolts. Align the door hinges with the marks made during removal. Tighten the nuts 15 to 24 lbf·ft (21 to 32 N·m). See **Fig. 6**.
2. Install the cowl panel.
3. Feed the wiring into the A-pillar, one connector at a time.
4. Install the ground bolt and the ground strap. See **Fig. 5**.
5. Connect the CB antenna cable.
6. Connect the electrical connectors. See **Fig. 4**.
7. Install the under steering panel. See **Fig. 3**.
8. Install the scuff panel. See **Fig. 2**.
9. Position and seat the door wiring grommet. See **Fig. 1**.
10. Roll up the window.
11. Connect the batteries.
12. Remove the chocks from the tires.

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Adjustment

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Remove the cowl panel.
3. Loosen the bolts if necessary, and adjust the door at the A-pillar for up-down and fore-aft movement. See **Fig. 1**.
4. Loosen the bolts if necessary, and adjust at the door for in-out movement. See **Fig. 2**.

CAUTION

To ensure proper fit of the door, this adjustment procedure must be performed on both upper and lower hinges. Failure to adjust both hinges could result in premature wear of the hinges.

NOTE: The door opening clearance is 55 degrees with the door hinge bushings installed and 65 degrees with the door hinge bushings uninstalled.

5. Adjust the door opening clearance to 65 degrees, if necessary. See **Fig. 3**.
   - 5.1 Remove the hinge bushing nut.
   - 5.2 Pull out the hinge bushing bolt.
   - 5.3 Remove the hinge bushing, and install the hinge bushing bolt and nut.

IMPORTANT: To be certain the doors are properly positioned within the door opening, it is necessary to measure the door alignment.

6. Measure the door alignment.
   - 6.1 Locally fabricate a door alignment gauge. See **Fig. 4**.
   - 6.2 Use the gauge to check the alignment of the door to the cab A-pillar. The measurement should be made on the front edge of the door, approximately 8 inches (203 mm) below the front upper corner. See **Fig. 5**. The gauge should rest on the door window frame and contact the A-pillar as shown in **Fig. 6**. If the gauge does not make contact with the A-pillar, adjust the door as necessary to obtain the proper door alignment.
7. Tighten the fasteners to specification. See **Fig. 7**.
8. Install the cowl panel.
9. Remove the chocks from the rear tires.

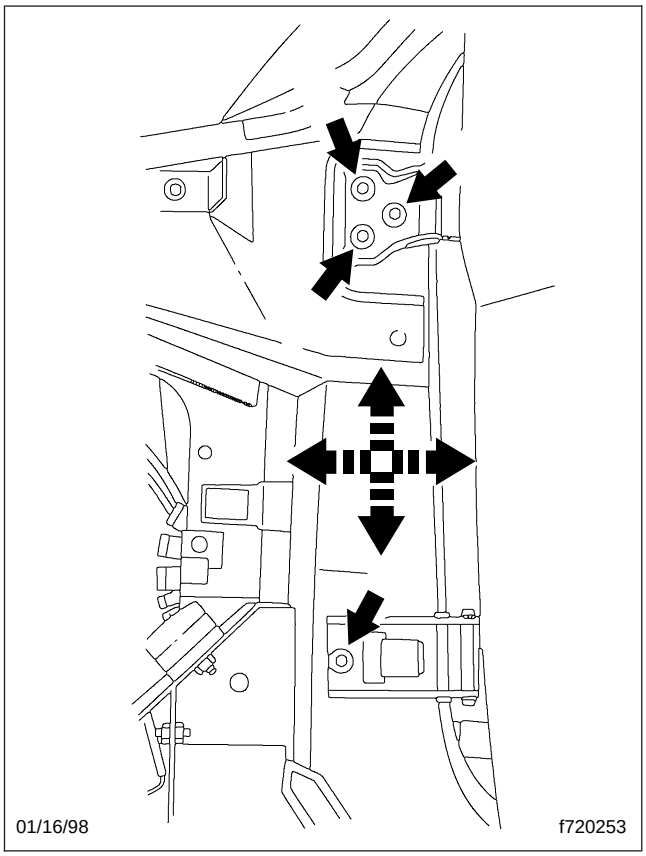


Fig. 1, Adjusting Up-Down and Fore-Aft Movement

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Door Adjustment

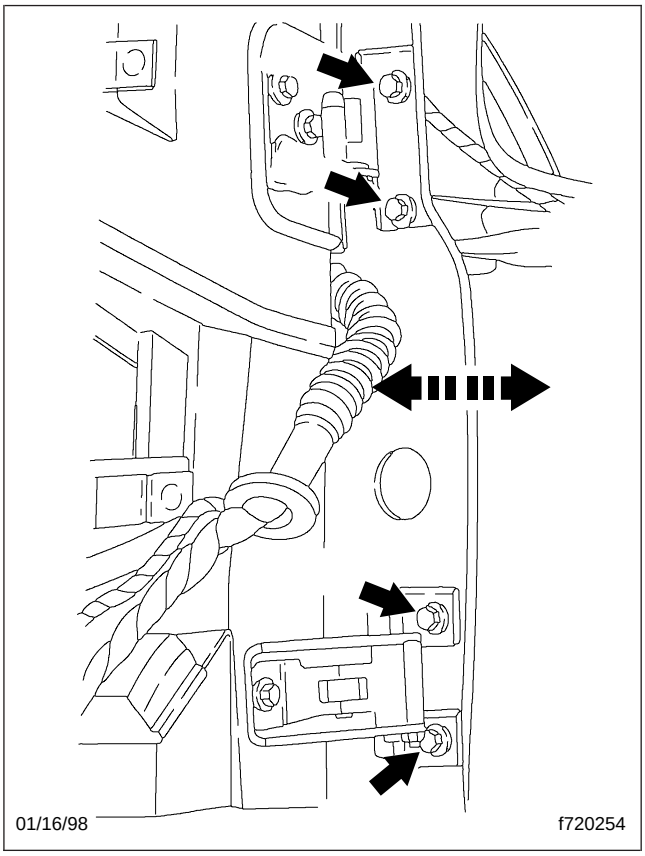
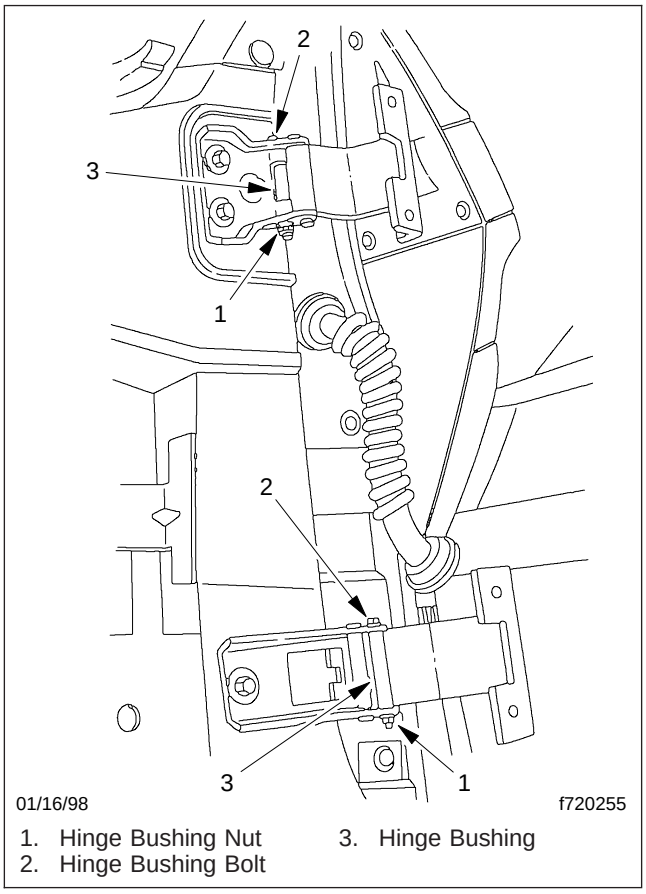


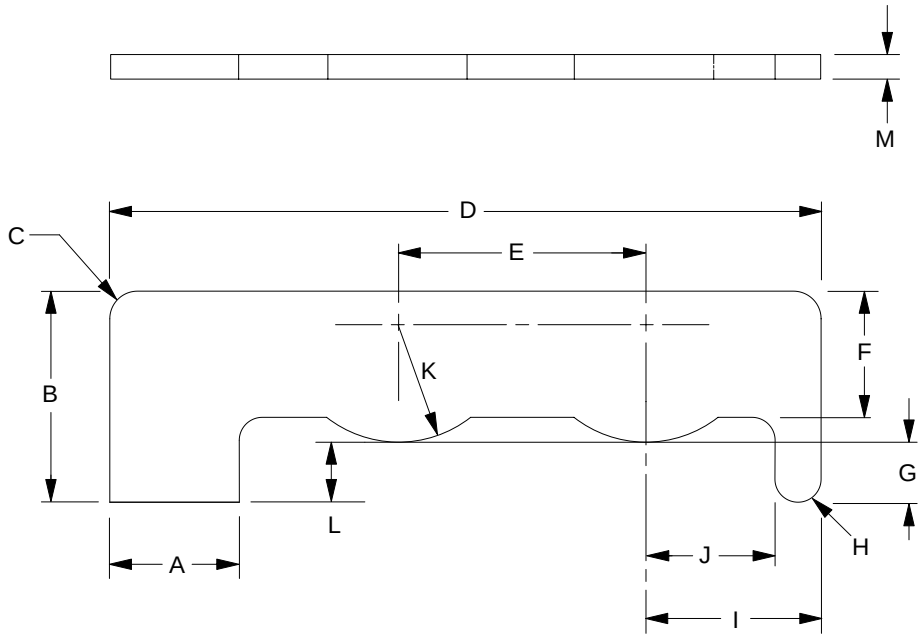
Fig. 2, Adjusting In-Out Movement



1. Hinge Bushing Nut
2. Hinge Bushing Bolt
3. Hinge Bushing

Fig. 3, Adjusting Door Opening Clearance

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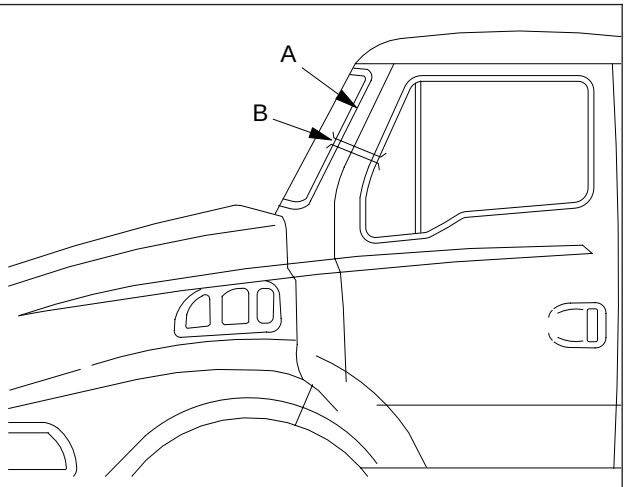
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A. 0.55 inches (14 mm)
B. 0.9 inches (22.9 mm)
C. 0.12 inches (3 mm), 8x
D. 3.04 inches (77.18 mm)
E. 1.06 inches (26.84 mm)
F. 0.54 inches (13.7 mm)
G. 0.26 inches (6.5 mm)
H. 0.1 inches (2.5 mm), 2x
I. 0.75 inches (19 mm)
J. 0.55 inches (13.98 mm)
K. 0.39 inches (10 mm), 2x
L. 0.55 inches (14 mm)
M. 0.12 inches (3 mm)

Fig. 4, Door Alignment Gauge

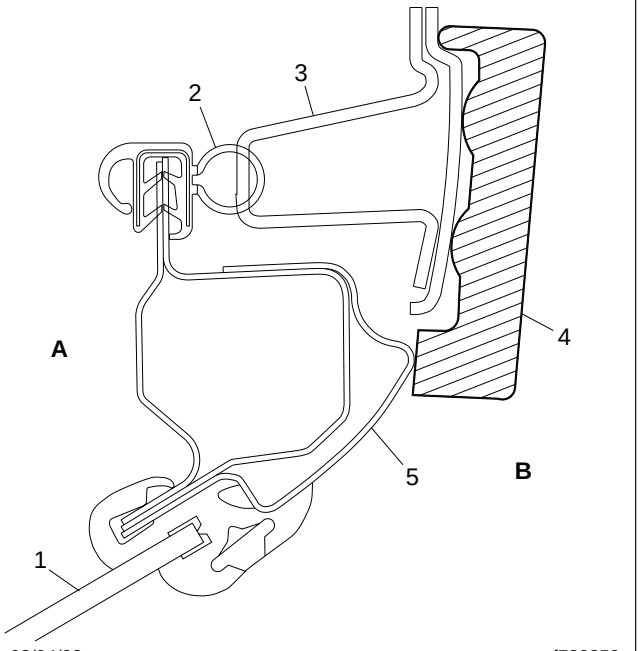
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Door Adjustment



A. Measure the alignment at this point.
B. See Figure 6 for a cross-section view.

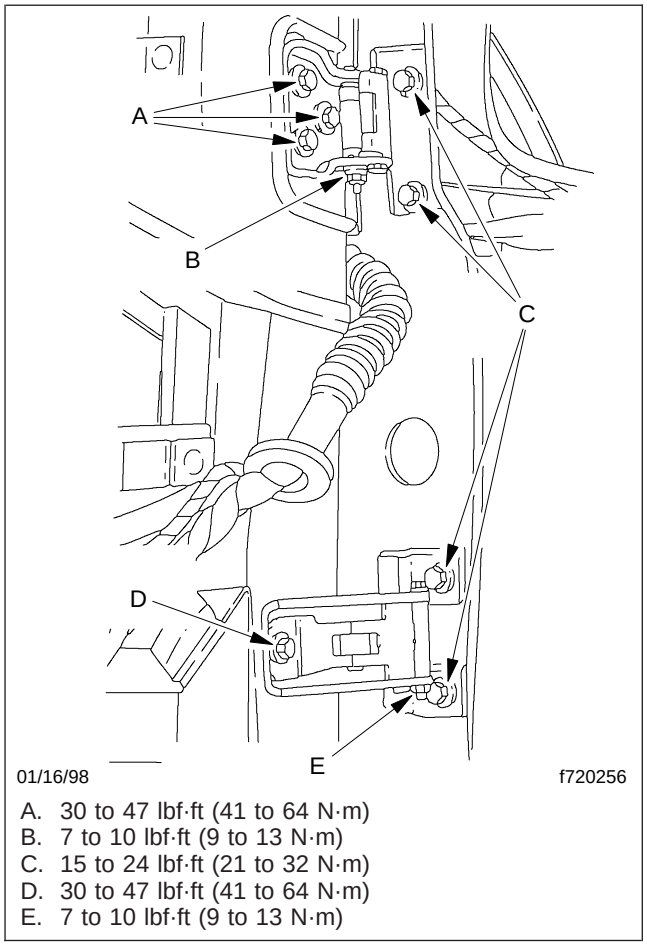
Fig. 5, Gauge Placement



A. Inside Cab
B. Outside Cab
1. Windshield
2. Door Opening Weatherstrip
3. Door
4. Door Alignment Gauge
5. Cab A-Pillar

Fig. 6, Cross-Section View

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A. 30 to 47 lbf·ft (41 to 64 N·m)
B. 7 to 10 lbf·ft (9 to 13 N·m)
C. 15 to 24 lbf·ft (21 to 32 N·m)
D. 30 to 47 lbf·ft (41 to 64 N·m)
E. 7 to 10 lbf·ft (9 to 13 N·m)

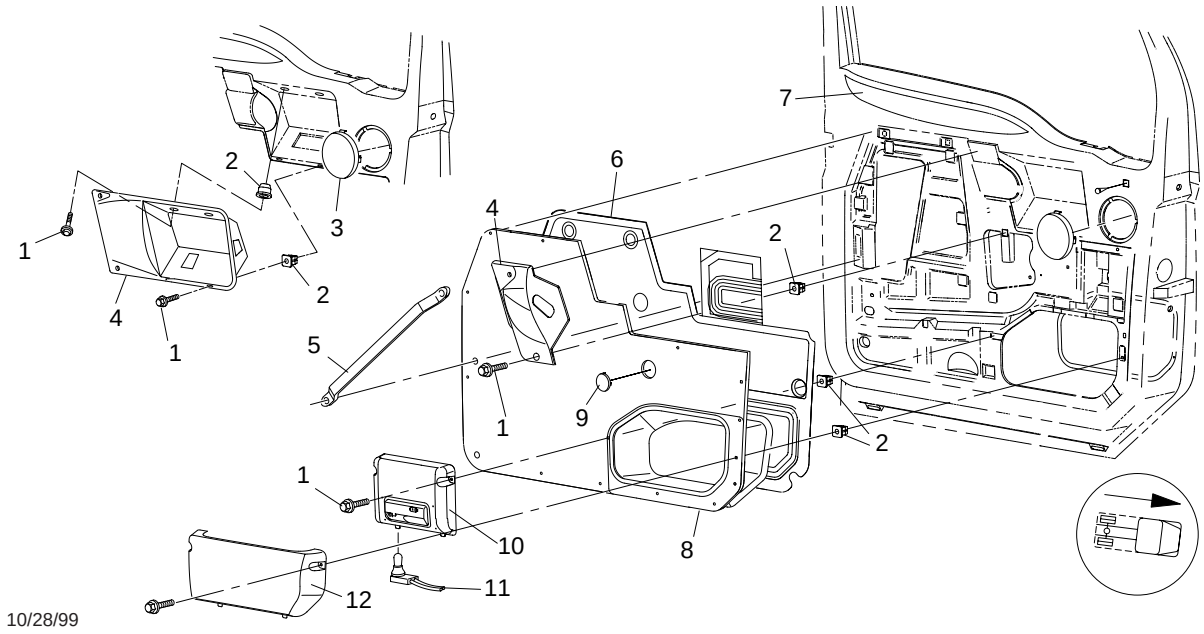
Fig. 7, Tightening Specifications

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Door Window Glass Replacement

Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Disconnect the batteries.
3. Remove the grab handle. See **Fig. 1**.
4. Remove the power window switch cover, the power door locks switch cover and the mirror control trim cover, if equipped.
5. Remove the door window regulator crankhandle, if equipped.
6. Remove the door trim panels. See **Fig. 1**.
   - 6.1 Remove the door trim finish panel.
   - 6.2 Remove the map pocket, if equipped.
   - 6.3 Remove the courtesy lamp.
   - 6.4 Remove the door trim panel.
   - 6.5 Remove the armrest assembly.
7. Remove the door trim watershield. See **Fig. 1**.
8. Lower the window.
9. Remove the door glass run assembly and the interior door window glass weatherstrip. See **Fig. 2**.
   - 9.1 Pull the door glass run assembly from the flange.
   - 9.2 Pull the interior door window glass weatherstrip from the flange.
10. Disconnect the electrical connector from the window motor, if equipped.
11. Remove the four screws from the window regulator assembly, if equipped. Remove the window regulator assembly and the window motor. See **Fig. 2**.
12. Remove the door glass run retainer bolts.
13. Remove the four retaining screws from the vent window/door glass divider. Pull the vent window/door glass divider out. See **Fig. 3**.

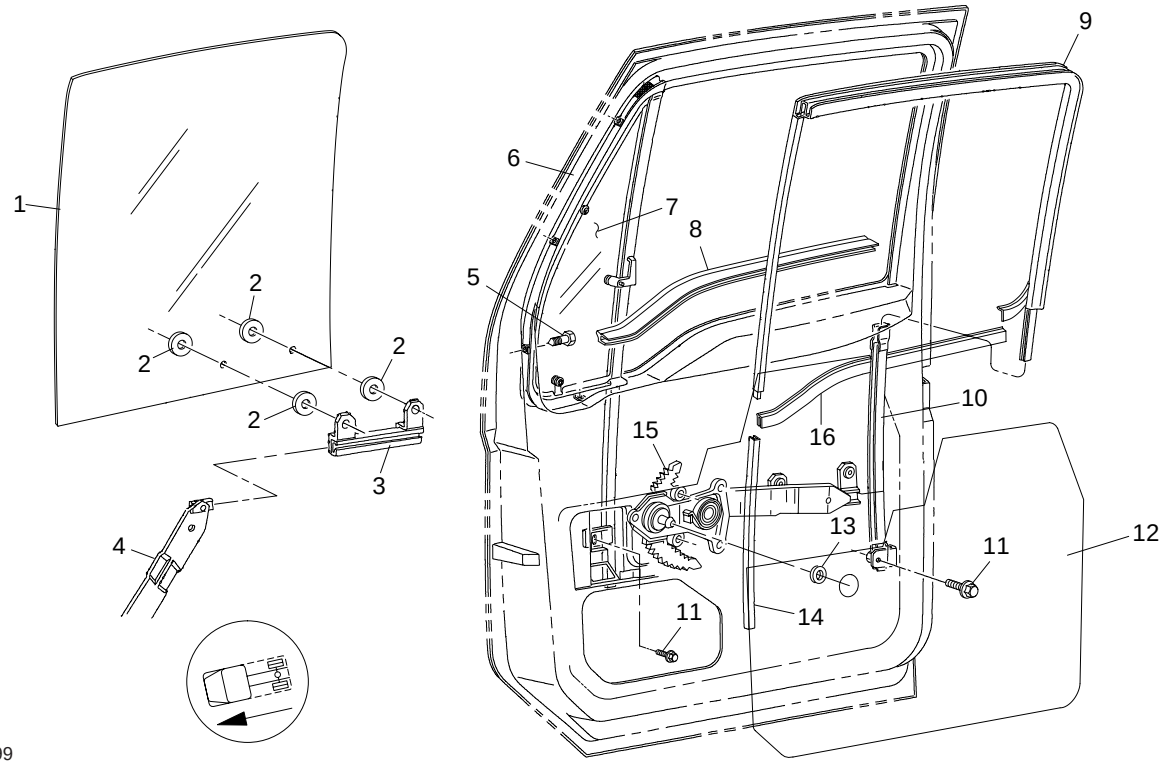


1. Self Tapping Screw
2. Screw Insert
3. Door Trim Panel Opening Cover
4. Door Trim Finish Panel
5. Grab Handle
6. Door Trim Watershield
7. Armrest Assembly
8. Door Trim Panel
9. Window Regulator Opening
10. Courtesy Lamp
11. Wiring Harness
12. Map Pocket

Fig. 1, Door Trim and Components

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Door Window Glass Replacement



1. Door Window Glass
2. Spacers
3. Window Glass Channel
4. Window Regulator (track follower end)
5. Screw
6. Vent Window Assembly
7. Vent Window Glass
8. Exterior Door Window Glass Weatherstrip
9. Door Glass Run Assembly
10. Rear Door Glass Run
11. Hexhead Screw
12. Door Trim Watershield
13. Window Regulator Seal
14. Vent Window/Door Glass Divider
15. Window Regulator
16. Interior Door Window Glass Weatherstrip

Fig. 2, Door Interior Components

14. Lower the window until the track follower end of the window regulator can be seen through the rear access hole in the door panel.
15. Push the window glass forward to remove the window regulator track follower from the window glass channel. See **Fig. 2**.
16. Lift the window out of the door and through the window opening.
17. Drill out the window glass channel rivets and replace them if new window glass is being installed. See **Fig. 4**.
18. Position the window into the door.
19. Insert the window regulator track follower into the window glass channel. See **Fig. 2**.
20. Install the vent window/door glass divider and the door glass run retainer in the door. See **Fig. 2**.
21. Using the four retaining screws, install the vent window/door glass divider. See **Fig. 3**.
22. Install the door glass run retainer bolts.
23. Position the window regulator assembly and the window motor, if equipped, in the door. Install the four retaining screws. See **Fig. 2**.
24. Connect the window motor electrical connector, if equipped.

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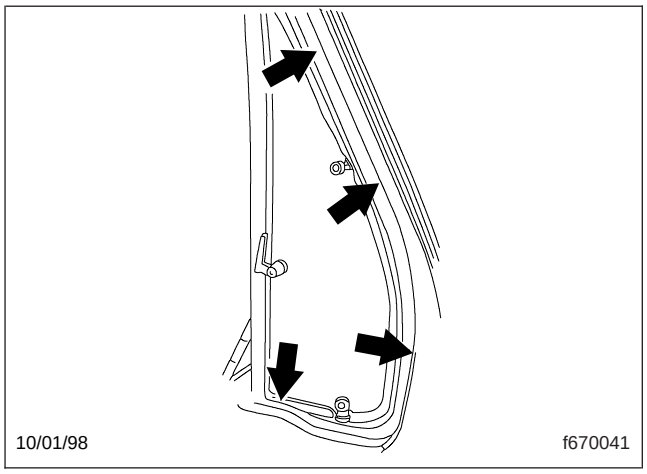


Fig. 3, Vent Window Division Bar Screw Locations

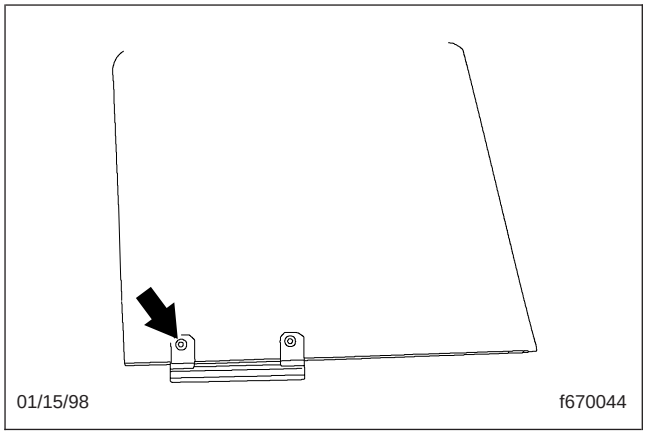


Fig. 4, Window Glass Channel Rivet

25. Install the door window glass weatherstrip. See **Fig. 2**.
26. Push the door glass run assembly and the door window glass weatherstrip into the pinch weld. See **Fig. 2**.
27. Raise and lower the window to make sure it operates properly.
28. Install the door trim watershield. See **Fig. 1**.
29. Install the door trim panels. See **Fig. 1**.
    - 29.1 Install the armrest assembly.
    - 29.2 Install the door trim panel.
    - 29.3 Install the courtesy lamp.
    - 29.4 Install the map pocket, if equipped.
    - 29.5 Install the door trim finish panel.
30. Install the power window switch cover, the power door locks switch cover and the mirror control trim cover, if equipped.
31. Install the door window regulator crankhandle, if equipped.
32. Install the grab handle. See **Fig. 1**.
33. Connect the batteries.
34. Remove the chocks from the tires.

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Observation Window Glass Replacement

Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Protect the paint finish by taping paper around the opening.
3. From outside the vehicle, unzip the integral locking tab on the rubber seal. See **Fig. 1**.

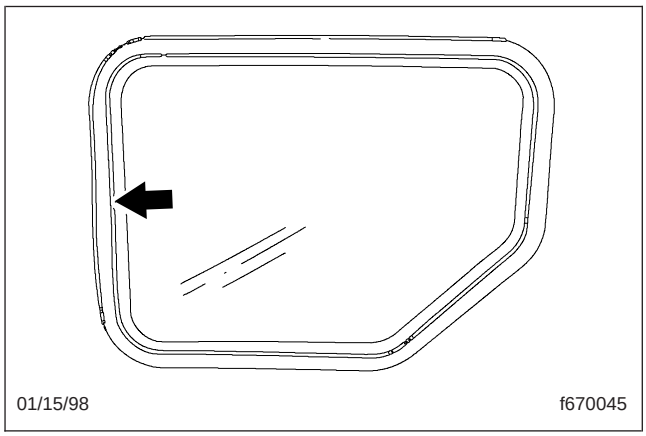


Fig. 1, Integral Locking Tab

NOTE: One assistant is necessary to push on the glass from the inside.

4. Insert an appropriate tool and pry the glass from the rubber seal. See **Fig. 2**.

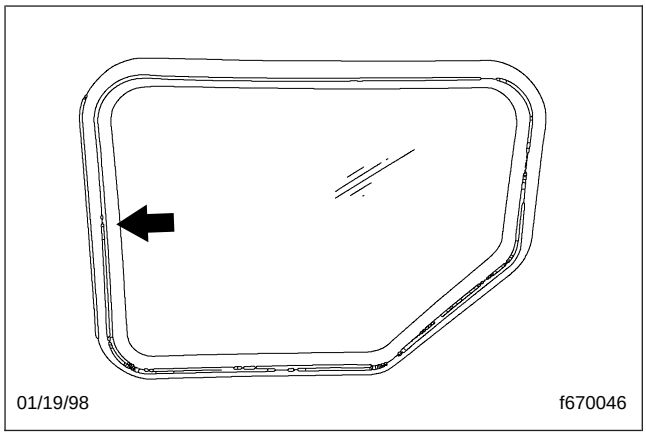


Fig. 2, Rubber Glass Seal

5. Remove the rubber seal from the door. See **Fig. 3**.

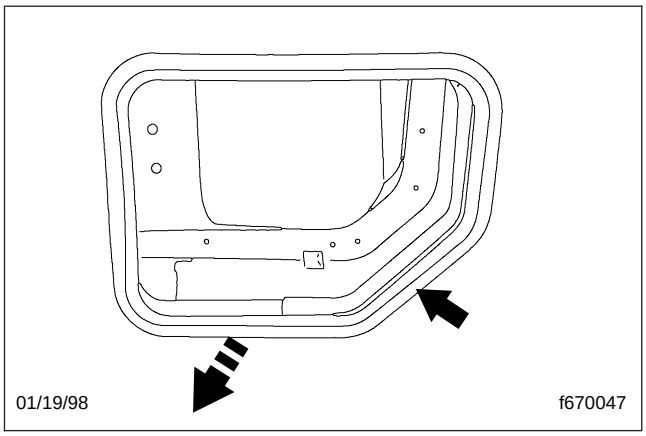


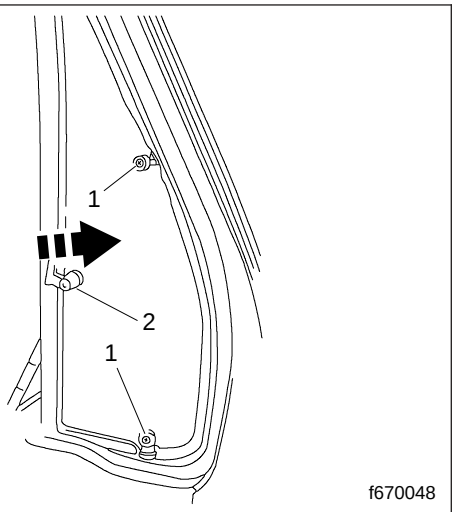
Fig. 3, Rubber Door Seal

6. Install the rubber seal around the door.
7. Lubricate the rubber seal with a soap and water solution.
8. Using an appropriate tool, install the new glass into the rubber seal.
9. From outside the vehicle, install the integral locking tab on the rubber seal.
10. Remove the protective tape from around the opening.
11. Remove the chocks from the tires.

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Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Roll down the window.
3. Remove the vent window glass. See **Fig. 1**.



1. Bolts
2. Locking Lever

Fig. 1, Vent Window

   3.1 Remove the bolts.

   3.2 Turn the locking lever clockwise and remove the vent window glass.

4. Install the vent window glass.

   4.1 Insert the vent window glass and turn the locking lever counterclockwise.

   4.2 Install the bolts.

5. Roll up the window.
6. Remove the chocks from the tires.

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Vent Window Glass Latch Replacement

Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Punch out the locking lever pin and remove the handle. See **Fig. 1**.

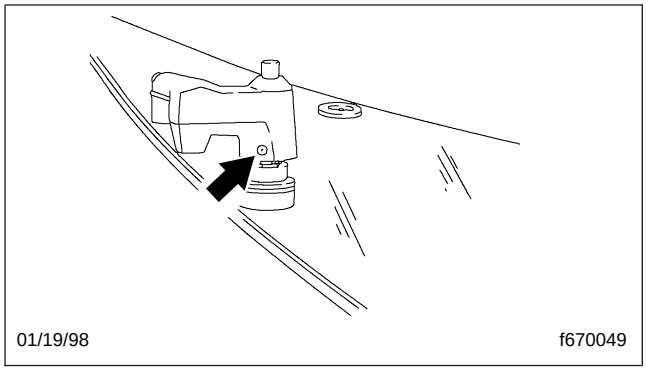


Fig. 1, Locking Lever Pin

3. Lift off the top locking lever piece. See **Fig. 2**.

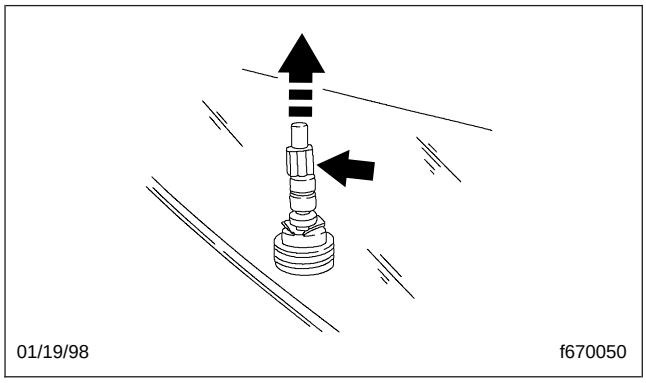
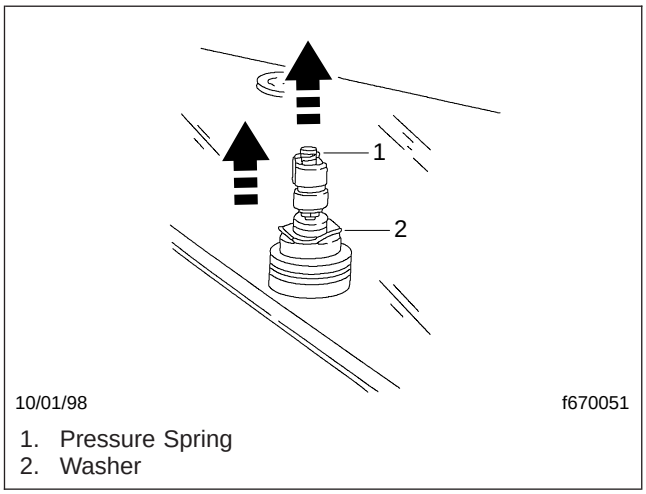


Fig. 2, Locking Lever Piece

4. Remove the locking lever pressure spring and the washer. See **Fig. 3**.

NOTE: Reference the locking lever post position.

5. Remove the locking lever locking nut and slide the locking lever post and washers from the glass. See **Fig. 4**.
6. Replace the washers, locking lever post, and locking nut.



1. Pressure Spring
2. Washer

Fig. 3, Locking Lever Pressure Spring and Washer

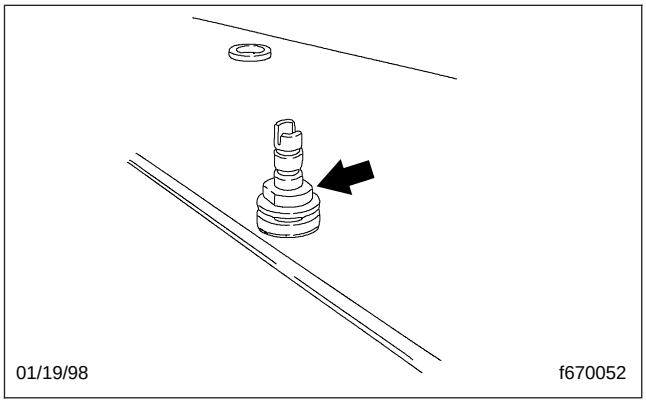


Fig. 4, Locking Lever Locking Nut

7. Replace the pressure spring and the washer. See **Fig. 3**.
8. Install the top locking lever piece.
9. Install the handle and locking lever pin.
10. Remove the chocks from the tires.

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Window Motor Removal and Installation

WARNING

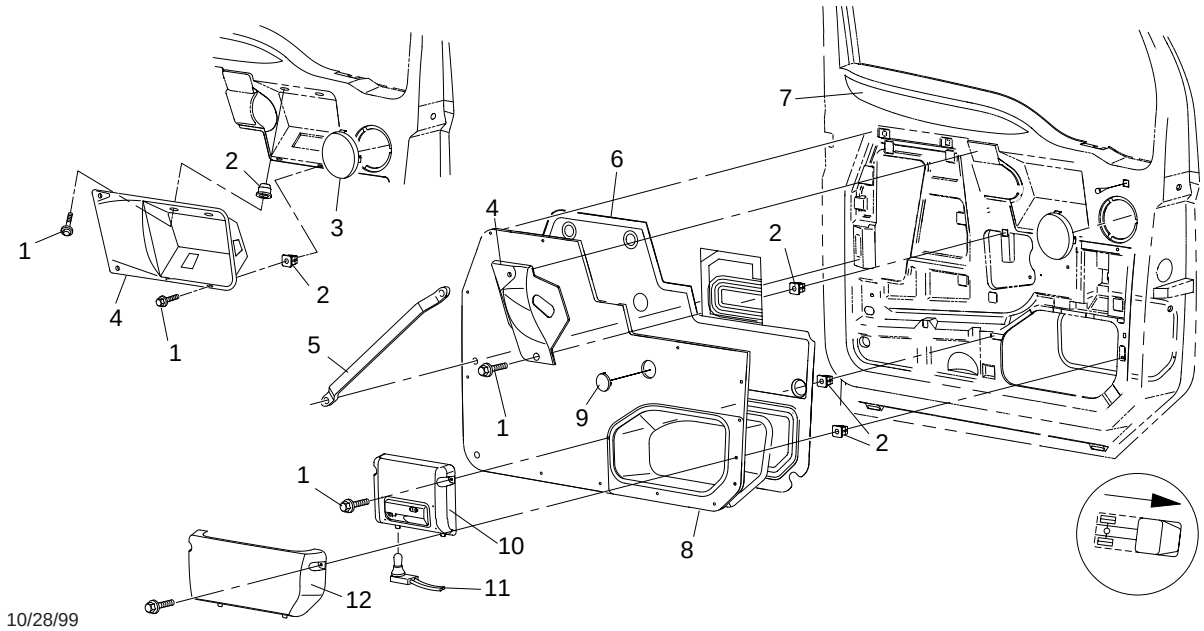
The window motor must be removed and installed as described below. The motor should be removed only while the regulator is firmly mounted to the door. Do not loosen or remove any fasteners that attach the regulator assembly to the door. The regulator mechanism contains a large spring under tension, which can be released if the regulator is disassembled or loosened, possibly resulting in personal injury.

Removal

If it is necessary to remove or service the regulator assembly, follow the procedure in **Subject 170**.

1. Apply the parking brakes and chock the tires.
2. Roll up the window, if possible, leaving a gap of no more than 1/4 inch (6 mm) at the top.
3. Disconnect the batteries.
4. Remove the grab handle; see **Fig. 1**.
5. Remove the power window switch cover, the power door locks switch cover, and the mirror control trim cover, if equipped. Use care when removing the covers to prevent damage to the switches.
6. Remove the door trim panels, as follows; see **Fig. 1**.
   - 6.1 Remove the door trim finish panel.
   - 6.2 Remove the map pocket, if equipped.
   - 6.3 Remove the courtesy lamp.
   - 6.4 Remove the door trim panel.
   - 6.5 Remove the armrest assembly.
7. Remove the door trim watershield; see **Fig. 1**.

NOTE: The window motor removal procedure requires drilling of the inner door. See **Fig. 2** and **Fig. 3** for the templates (to scale) to use when this procedure is required.



1. Self-Tapping Screw
2. Screw Insert
3. Door Trim Panel Opening Cover
4. Door Trim Finish Panel
5. Grab Handle
6. Door Trim Watershield
7. Armrest Assembly
8. Door Trim Panel
9. Window Regulator Opening
10. Courtesy Lamp
11. Wiring Harness
12. Map Pocket

Fig. 1, Door Trim and Components

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Window Motor Removal and Installation

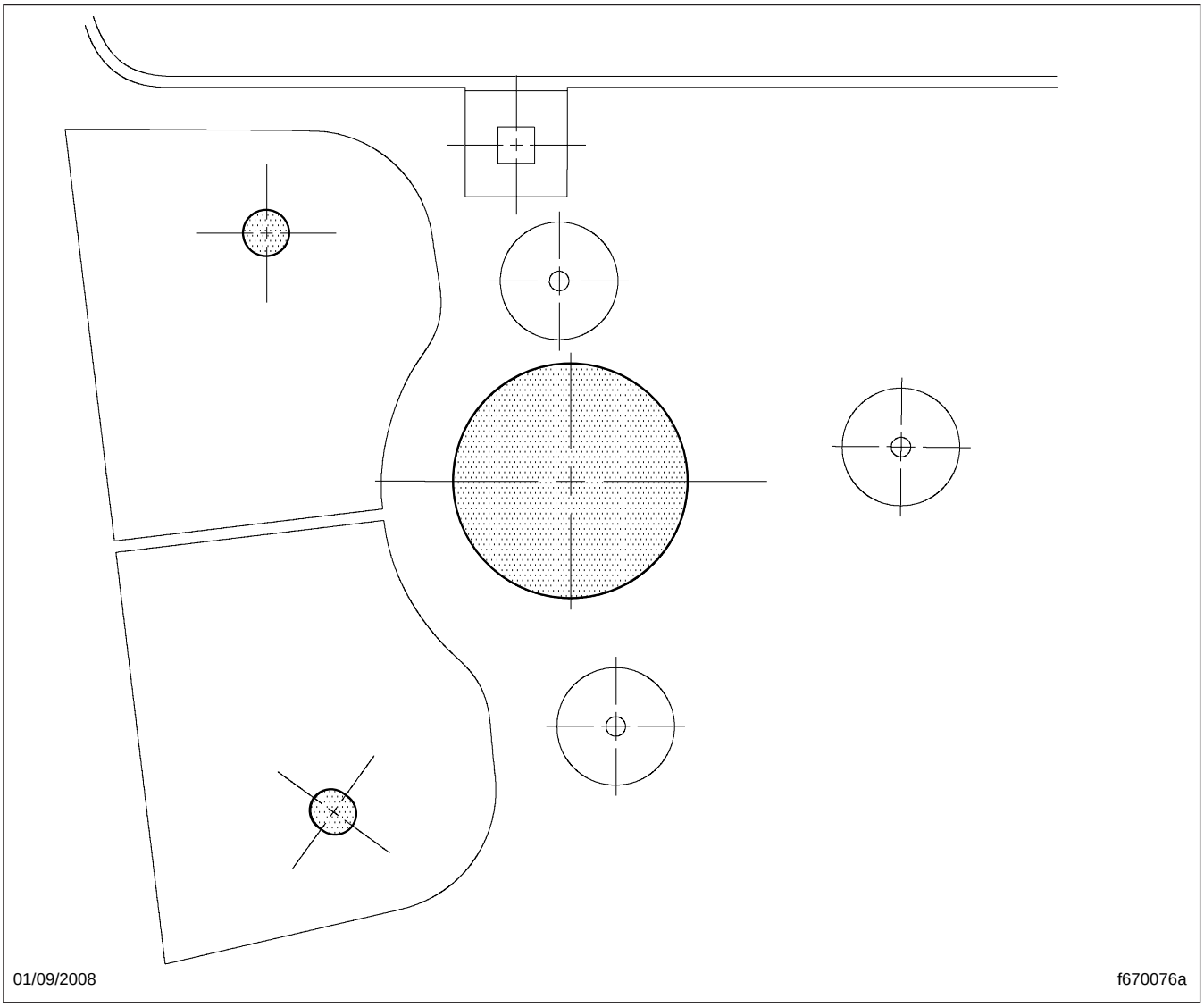


Fig. 2, Left Inner Door Window Motor Template

8. Photocopy the template without reduction or enlargement.
9. Prepare the template, and using a razor knife, cut out the inside of the shaded circles as accurately as possible.
10. Align the template and center punch the holes, as follows; see **Fig. 4**.
    - 10.1 Align the template to the door using the large hole and the upper inner door line.
    - 10.2 Tape the template securely in place.
    - 10.3 Center punch the three retaining bolt hole centers.
11. Remove the template.
12. Using an 18-mm diameter hole saw drill bit, drill out the three retaining bolt access holes; see **Fig. 5**.
13. Disconnect the motor electrical connector.
14. Tape the window glass to the door; see **Fig. 6**.
15. Support the motor and remove the retaining bolts; see **Fig. 7**. Remove the motor.

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Window Motor Removal and Installation

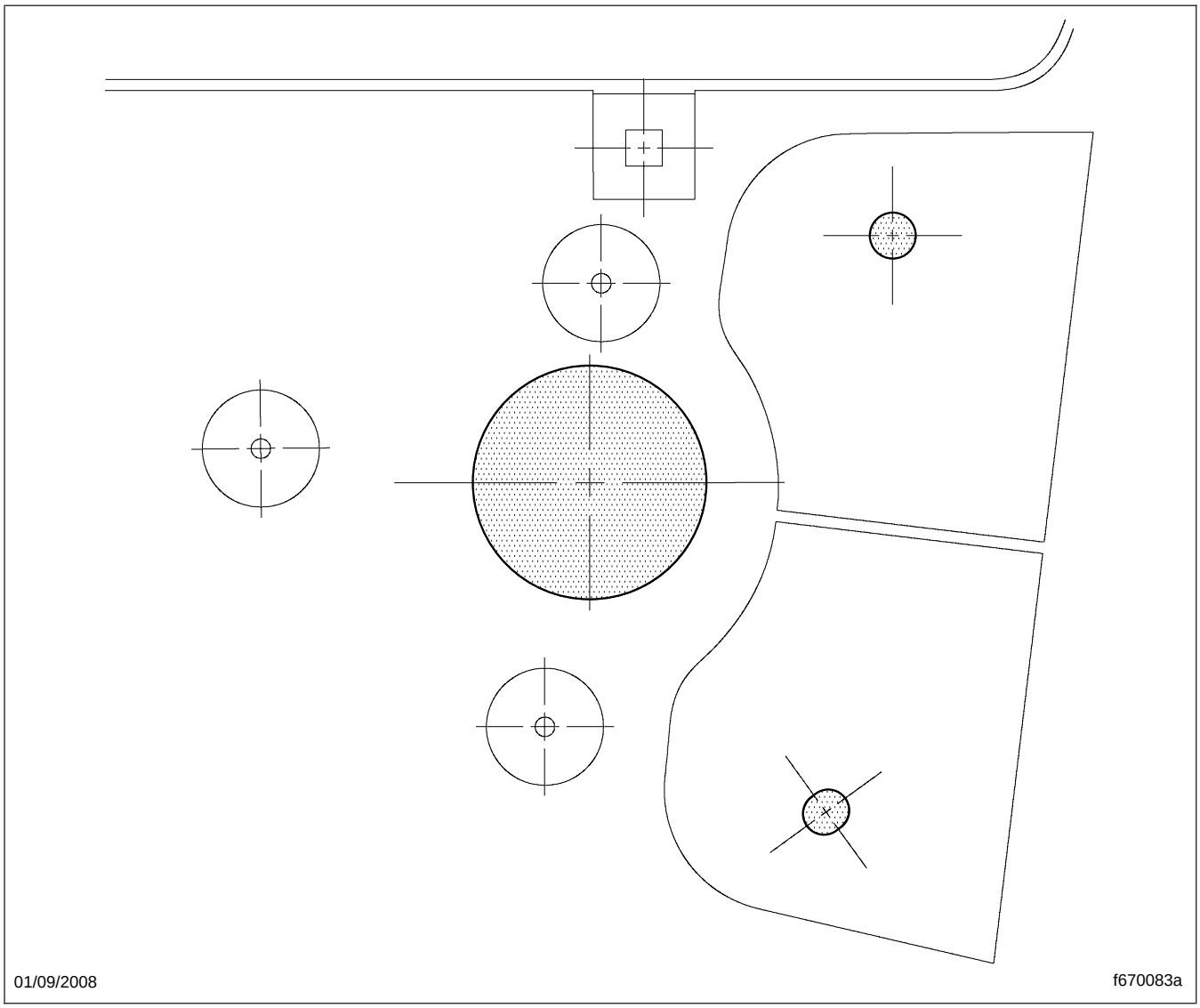


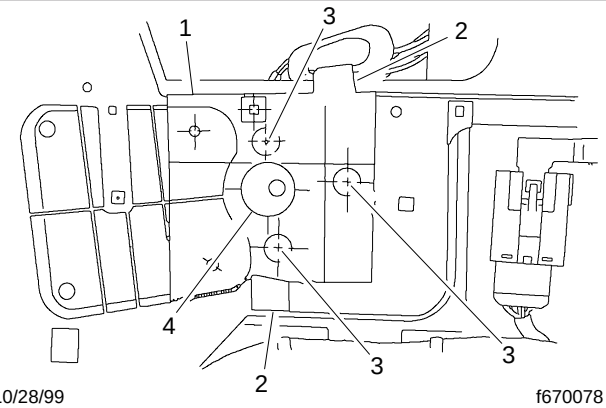
Fig. 3, Right Inner Door Window Motor Template

Installation

1. With the vehicle tires chocked, install the motor and the retaining bolts. Tighten the bolts 7 to 10 lbf·ft (9 to 13 N·m); see **Fig. 7**.
2. Remove the tape from the window; see **Fig. 6**.
3. Connect the motor electrical connector.
4. Install the door trim watershield; see **Fig. 1**.
5. Install the door trim panels, as follows; see **Fig. 1**.
   - 5.1 Install the armrest assembly.
   - 5.2 Install the door trim panel.
   - 5.3 Install the courtesy lamp.
   - 5.4 Install the map pocket, if equipped.
   - 5.5 Install the door trim finish panel.

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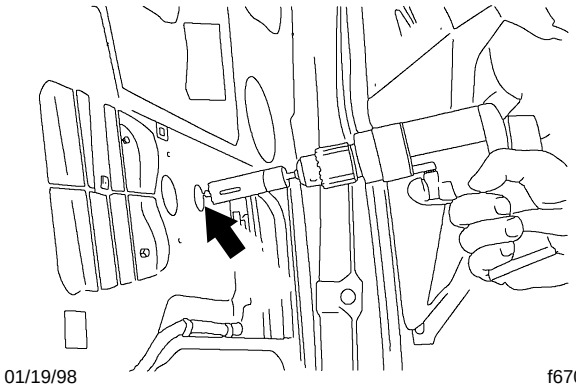
Window Motor Removal and Installation



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1. Upper Inner Door Line
2. Tape
3. Retaining Bolt Access Hole (centerpunched)
4. Large Hole

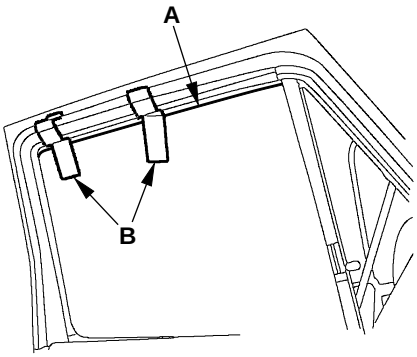
Fig. 4, Aligning the Template



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Fig. 5, 18-mm Diameter Hole Saw Drill Bit

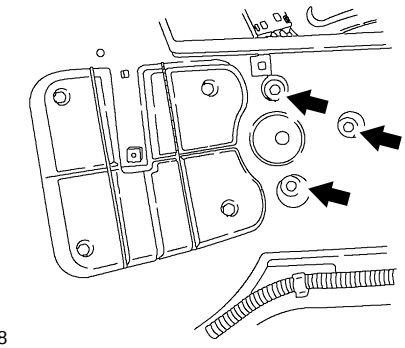
6. Install the power window switch cover, the power door locks switch cover, and the mirror control trim cover, if equipped.
7. Install the grab handle; see **Fig. 1**.
8. Connect the batteries.
9. Remove the chocks.



11/07/2007 f670138

A. 1/4-inch (6-mm) gap at the top of the window
B. Tape the window glass to the door.

Fig. 6, Securing the Window Glass



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Fig. 7, Retaining Bolts

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Manual and Power Window Regulator Replacement

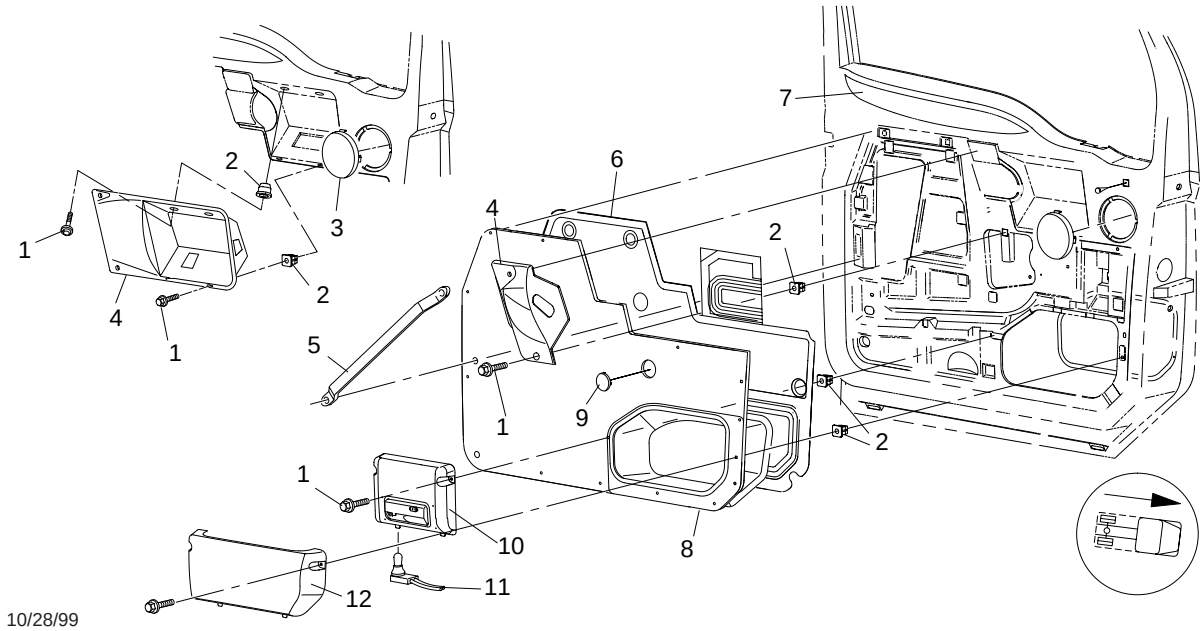
Replacement

WARNING

The window regulator must be removed as described below. The regulator mechanism contains a large spring under tension, which can be released, possibly resulting in personal injury. Follow the precautions listed below when replacing the regulator.

- **Keep the window motor, if so equipped, secured to the regulator while removing the regulator.**
- **Do not attempt to disassemble the regulator or motor until they have been removed from the door as an assembly. Once removed from the door, use caution if removing the motor from the regulator, as the spring is held under tension by the motor.**
- **Do not loosen or remove the regulator fasteners if the motor has been loosened or removed.**

1. Apply the parking brakes and chock the tires.
2. Disconnect the batteries.
3. Remove the grab handle; see **Fig. 1**.
4. Remove the power window switch cover, the power door locks switch cover, and the mirror control trim cover, if equipped. Use care when removing the covers to prevent damage to the switches.
5. Remove the door window regulator crankhandle, if equipped.
6. Remove the door trim panels, as follows; see **Fig. 1**.
   - 6.1 Remove the door trim finish panel.
   - 6.2 Remove the map pocket, if equipped.
   - 6.3 Remove the courtesy lamp.
   - 6.4 Remove the door trim panel.
   - 6.5 Remove the armrest assembly.
7. Remove the door trim watershield; see **Fig. 1**.



1. Self-Tapping Screw
2. Screw Insert
3. Door Trim Panel Opening Cover
4. Door Trim Finish Panel
5. Grab Handle
6. Door Trim Watershield
7. Armrest Assembly
8. Door Trim Panel
9. Window Regulator Opening
10. Courtesy Lamp
11. Wiring Harness
12. Map Pocket

Fig. 1, Door Trim and Components (door with power window regulator shown)

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Manual and Power Window Regulator Replacement

8. Lower the window until the track follower end of the window regulator is visible; see **Fig. 2**.

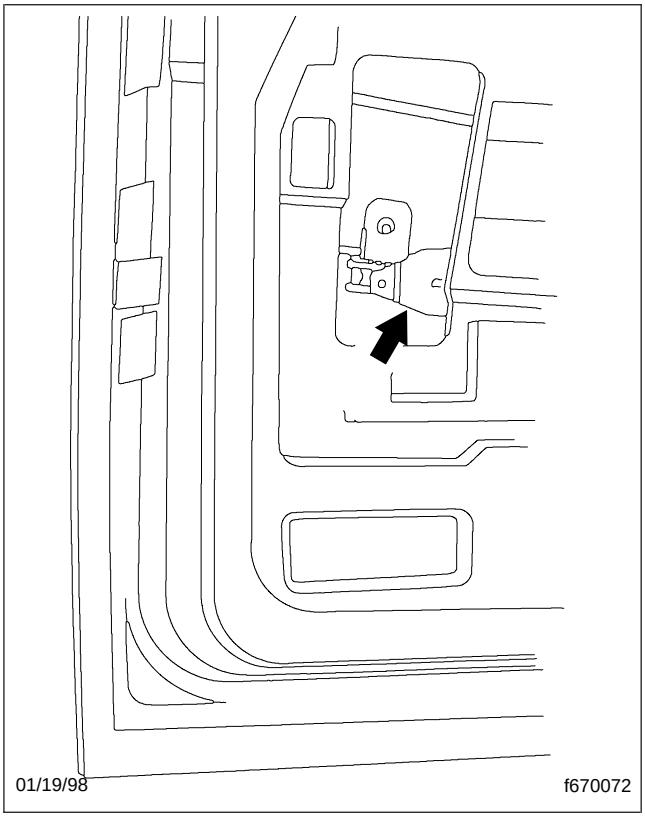


Fig. 2, Track Follower End of the Window Regulator

9. Using a suitable tool, wedge the window in place.
10. If equipped with power windows, disconnect the window motor connector.
11. Remove the window regulator bolts; see **Fig. 3**.
12. Lower the forward end of the window regulator to the forward access hole in the door.
13. Push the window regulator rearward to remove the track follower from the window glass channel.

NOTE: It may be necessary to reposition the window to align the new window regulator with the mounting holes.

14. Pull the window regulator out of the access hole in the door.
15. Place the new window regulator in the access hole in the door.

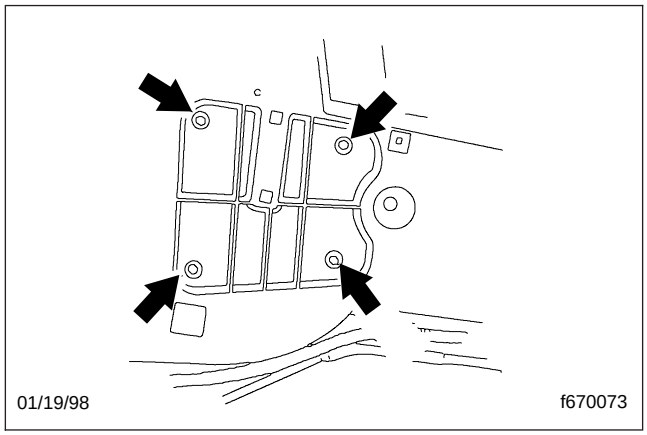


Fig. 3, Window Regulator Bolts

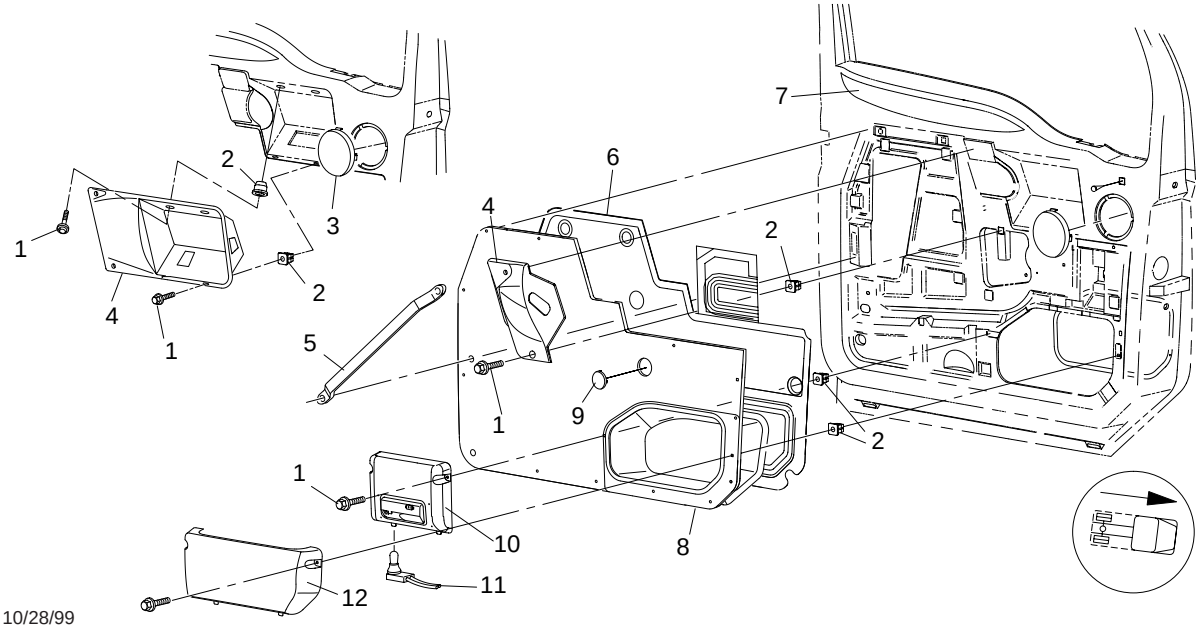
16. Push the window regulator forward to insert the track follower into the window glass channel.
17. Raise the forward end of the window regulator to the forward access hole in the door.
18. Install and tighten the window motor bolts 7 to 10 lbf·ft (9 to 13 N·m); see **Fig. 3**.
19. If equipped with power windows, connect the window motor connector.
20. Remove the wedge that's supporting the window.
21. Lower the window into the track follower end until the window regulator is visible; see **Fig. 2**.
22. Install the door trim watershield; see **Fig. 1**.
23. Install the door trim panels, as follows; see **Fig. 1**.
    - 23.1 Install the armrest assembly.
    - 23.2 Install the door trim panel.
    - 23.3 Install the courtesy lamp.
    - 23.4 Install the map pocket, if equipped.
    - 23.5 Install the door trim finish panel.
24. Install the power window switch cover, the power door locks switch cover, and the mirror control trim cover, if equipped.
25. Install the door window regulator crankhandle, if equipped.
26. Install the grab handle; see **Fig. 1**.
27. Connect the batteries.
28. Remove the chocks.

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Replacement

NOTE: For this procedure, the window must be fully closed.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Disconnect the batteries.
3. Remove the grab handle. See **Fig. 1**.
   - 6.4 Remove the door trim panel.
   - 6.5 Remove the armrest assembly.
7. Remove the door trim watershield. See **Fig. 1**.
8. Remove the lower rear window run. See **Fig. 2**.
   - 8.1 Remove the bolt.
   - 8.2 Pull the run straight down to disconnect it and remove the lower rear window run.



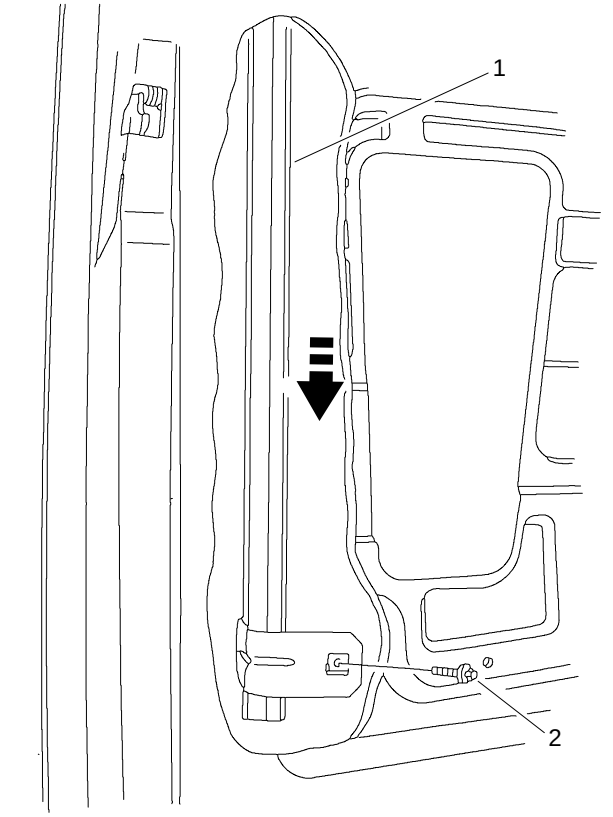
1. Self Tapping Screw
2. Screw Insert
3. Door Trim Panel Opening Cover
4. Door Trim Finish Panel
5. Grab Handle
6. Door Trim Watershield
7. Armrest Assembly
8. Door Trim Panel
9. Window Regulator Opening
10. Courtesy Lamp
11. Wiring Harness
12. Map Pocket

Fig. 1, Door Trim and Components

4. Remove the power window switch cover, the power door locks switch cover and the mirror control trim cover, if equipped.
5. Remove the door window regulator crankhandle, if equipped.
6. Remove the door trim panels. See **Fig. 1**.
   - 6.1 Remove the door trim finish panel.
   - 6.2 Remove the map pocket, if equipped.
   - 6.3 Remove the courtesy lamp.
9. Disconnect the outside door handle rod. See **Fig. 3**.
10. Disconnect the inside door handle remote control rod. See **Fig. 4**.
11. Disconnect the lock cylinder rod. See **Fig. 5**.
12. Drill out the power door lock actuator rivet and disconnect the electrical connector, if so equipped. See **Fig. 6**.
13. Remove the door latch attachment screws and remove the door latch. See **Fig. 7**.

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Door Latch Replacement



1. Lower Rear Window Run
2. Bolt

Fig. 2, Lower Rear Window Run Removal

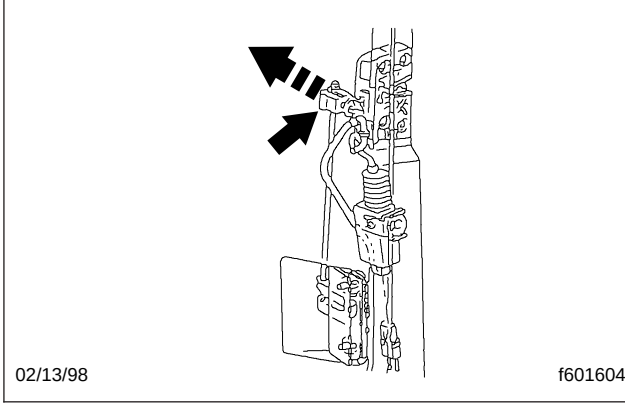


Fig. 3, Outside Door Handle Rod

IMPORTANT: Connect the inside door handle remote control rod, lock cylinder control rod, push button rod and the power door lock actuator and rod (if so equipped) to the door latch before installation of the new latch.

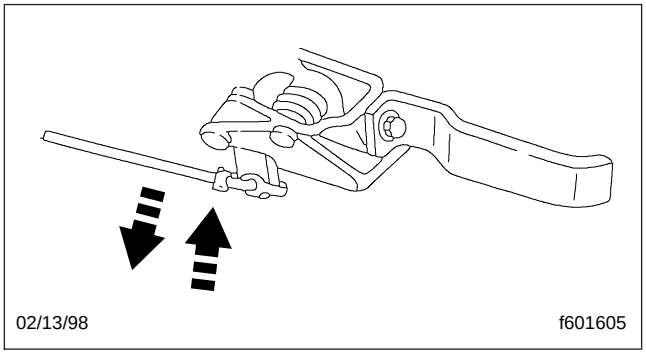


Fig. 4, Inside Door Handle Remote Control Rod

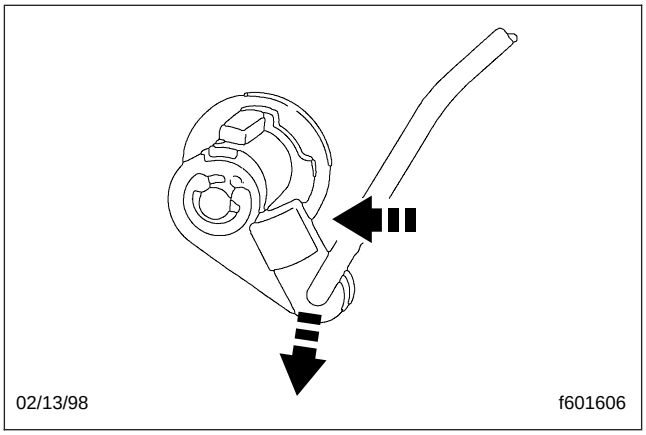
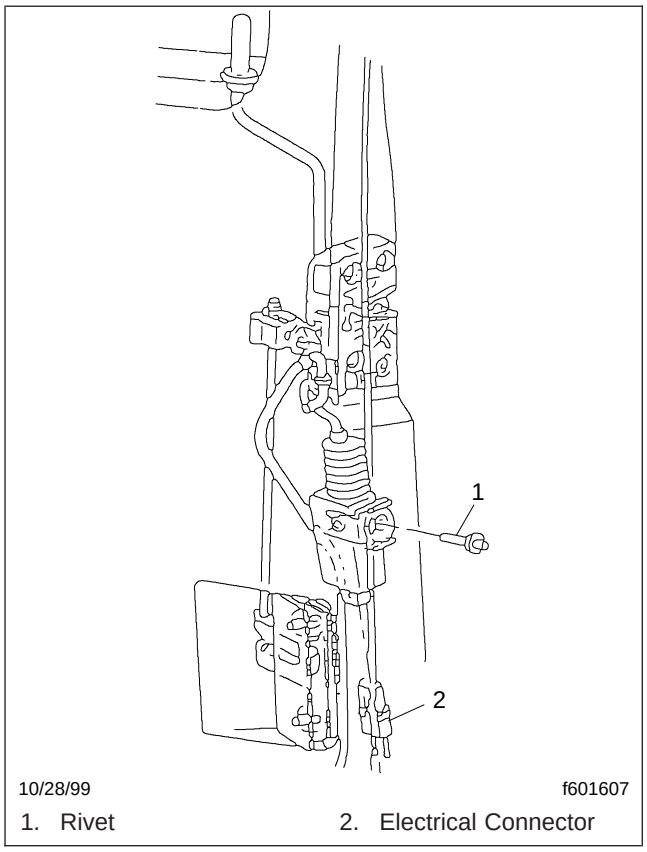


Fig. 5, Lock Cylinder Rod

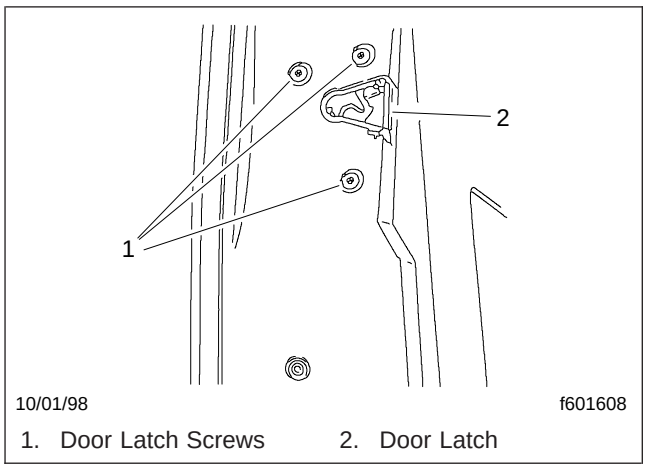
14. Install the door latch. See **Fig. 7**.
    - 14.1 Position the door latch.
    - 14.2 Install the screws. Tighten the screws 7 to 10 lbf·ft (9 to 13 N·m).
15. Connect the electrical connector and install the power door lock actuator rivet, if so equipped. See **Fig. 6**.
16. Connect the lock cylinder rod. See **Fig. 5**.
17. Connect the inside door handle remote control rod. See **Fig. 4**.
18. Connect the outside door handle rod. See **Fig. 3**.
19. Install the lower rear window run. See **Fig. 2**.
    - 19.1 Pull the lower rear window run straight up and connect it.

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1. Rivet 2. Electrical Connector

Fig. 6, Power Door Lock Actuator



1. Door Latch Screws 2. Door Latch

Fig. 7, Door Latch Removal

19.2 Install the bolt.

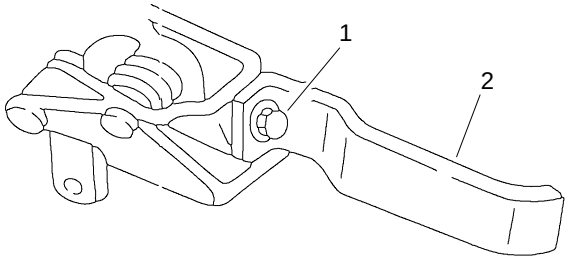
20. Install the door trim watershield. See **Fig. 1**.

21. Install the door trim panels. See **Fig. 1**.
    - 21.1 Install the armrest assembly.
    - 21.2 Install the door trim panel.
    - 21.3 Install the courtesy lamp.
    - 21.4 Install the map pocket, if equipped.
    - 21.5 Install the door trim finish panel.
22. Install the power window switch cover, the power door locks switch cover and the mirror control trim cover, if equipped.
23. Install the door window regulator crankhandle, if equipped.
24. Install the grab handle. See **Fig. 1**.
25. Connect the batteries.
26. Remove the chocks from the tires.

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Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the inside door handle boot.
3. Remove the handle bolt and the handle. See **Fig. 1**.



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1. Handle Bolt
2. Handle

Fig. 1, Handle Removal

4. Position the handle and install the bolt. Tighten the bolt 7 to 10 lbf·ft (9 to 13 N·m). See **Fig. 1**.
5. Install the inside door handle boot.
6. Remove the chocks from the tires.

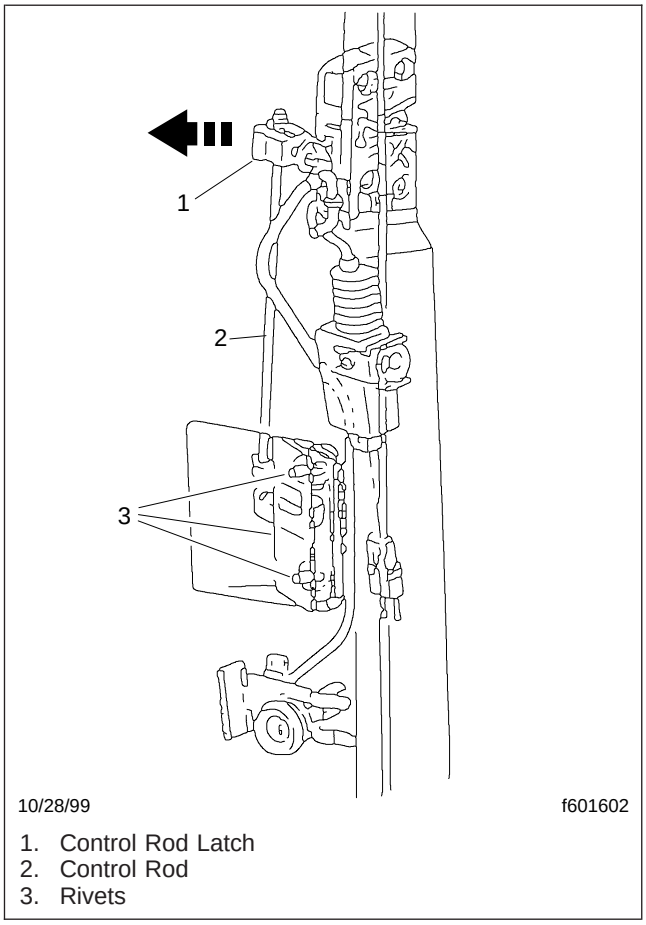
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Outside Door Handle Replacement

Replacement

NOTE: For this procedure, the window must be fully closed.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Disconnect the batteries.
3. Remove the door trim panels.
   - 3.1 Remove the inside door handle.
   - 3.2 Remove the door window regulator crank handle, if equipped.
   - 3.3 Remove the door trim finish panel.
   - 3.4 Remove the map pocket, if equipped.
   - 3.5 Remove the courtesy lamp.
   - 3.6 Remove the door trim panel.
4. Remove the watershield.
5. Remove the outside door handle. See **Fig. 1**.
   - 5.1 Disconnect the control rod at the latch.
   - 5.2 Drill out the two rivets and remove the outside door handle.
6. Install the outside door handle. See **Fig. 1**.
   - 6.1 Connect the control rod at the latch.
   - 6.2 Install the two outside door handle rivets.
7. Install the watershield.
8. Install the door trim panels.
   - 8.1 Install the door trim panel.
   - 8.2 Install the courtesy lamp.
   - 8.3 Install the map pocket, if equipped.
   - 8.4 Install the door trim finish panel.
   - 8.5 Install the door window regulator crank handle, if equipped.
   - 8.6 Install the inside door handle.
9. Connect the batteries.
10. Remove the chocks from the tires.



1. Control Rod Latch
2. Control Rod
3. Rivets

Fig. 1, Door Handle Mechanism (Inside Door)

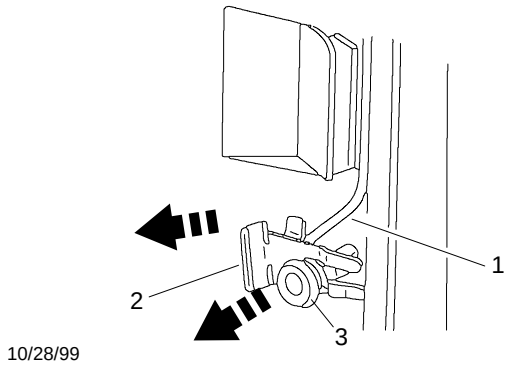
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Replacement

NOTE: When a lock cylinder is replaced, both door lock cylinders and the ignition lock cylinder should be replaced in a set; this will eliminate carrying an extra key which will fit only one lock. If a lock cylinder is to be replaced, the new key code is stamped on a metal tag attached to the key.

NOTE: For this procedure, the window must be fully closed.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the door trim panel.
   - 2.1 Remove the courtesy lamp.
   - 2.2 Remove the map pocket, if equipped.
   - 2.3 Remove the door trim panel.
3. Partially remove the watershield.
4. Remove the lock cylinder. See **Fig. 1**.



1. Door Latch Control Rod
2. Retainer Clip
3. Lock Cylinder

Fig. 1, Lock Cylinder Removal

   - 4.1 Disconnect the door latch control rod at the lock cylinder.
   - 4.2 Remove the lock cylinder retainer clip and remove the lock cylinder.

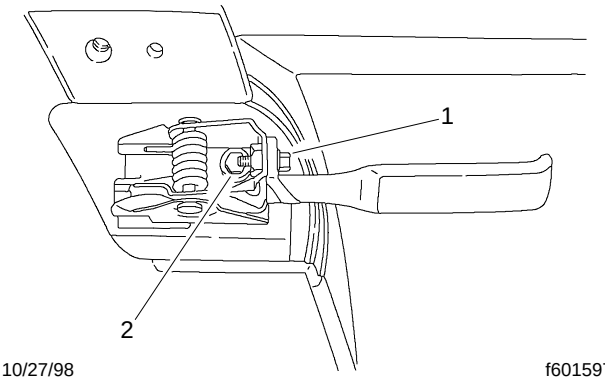
NOTE: The window must be fully closed.

5. Replace the lock cylinder. See **Fig. 1**.
   - 5.1 Connect the door latch control rod at the lock cylinder.
   - 5.2 Attach the lock cylinder retainer clip.
6. Install the watershield.
7. Install the door trim panel.
   - 7.1 Install the door trim panel.
   - 7.2 Install the map pocket, if equipped.
   - 7.3 Install the courtesy lamp.
8. Remove the chocks from the tires.

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Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Disconnect the batteries.
3. Remove the door window regulator crank handle, if equipped.
4. Remove the door trim panels.
   - 4.1 Remove the inside door panel.
   - 4.2 Remove the door trim finish panel.
   - 4.3 Remove the map pocket, if equipped.
   - 4.4 Remove the courtesy lamp.
   - 4.5 Remove the door trim panel.
5. Remove the latch control. See **Fig. 1**.



1. Door Handle Bolt
2. Latch Control Bolt

Fig. 1, Latch Control

   - 5.1 Remove the inside door handle bolt and handle.
   - 5.2 Remove the latch control bolt.
   - 5.3 Rotate the latch control 90 degrees counterclockwise and remove the latch control.
6. Install the latch control. Tighten the bolts 7 to 10 lbf·ft (9 to 13 N·m). See **Fig. 1**.
   - 6.1 Position the latch control and install the bolt.
   - 6.2 Position the inside door handle and install the bolt.
7. Install the door trim panels.
   - 7.1 Install the door trim panel.
   - 7.2 Install the map pocket, if equipped.
   - 7.3 Install the courtesy lamp.
   - 7.4 Install the door trim finish panel.
8. Install the door window regulator crank handle, if equipped.
9. Connect the batteries.
10. Remove the chocks from the tires.

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Replacement

NOTE: For this procedure, the window must be fully closed.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Remove the door trim panel.
   - 2.1 Remove the courtesy lamp.
   - 2.2 Remove the map pocket, if equipped.
   - 2.3 Remove the door trim panel.
3. Set aside the watershield.
4. Remove the three screws from the door latch. See **Fig. 1**.

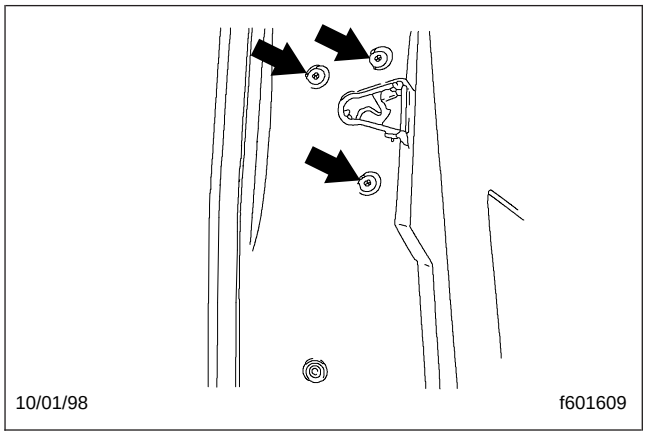
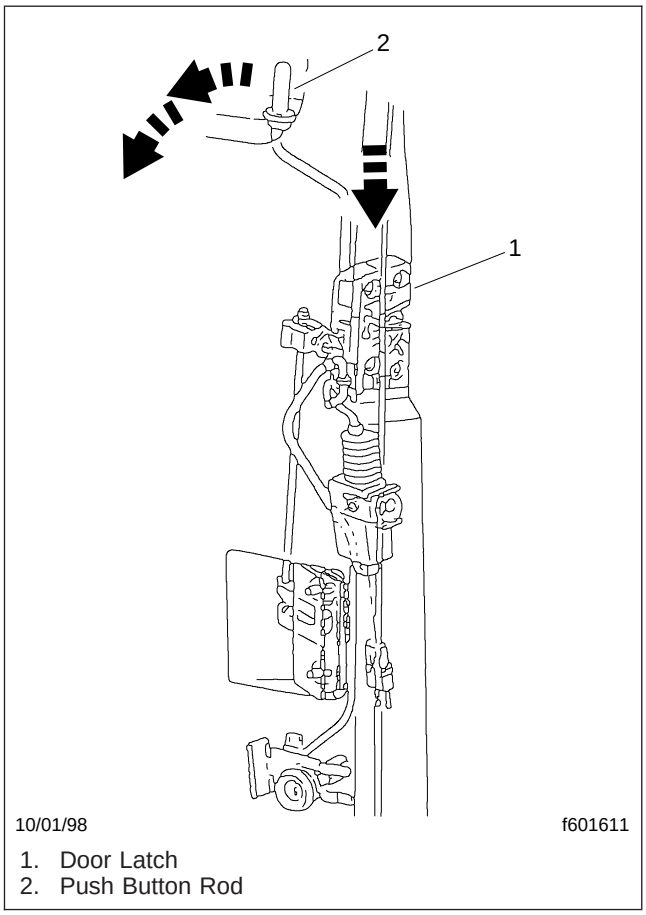


Fig. 1, Door Latch Screws

5. Remove the push button. See **Fig. 2**.
   - 5.1 Lower the door latch enough to let the push button rod clear the door.
   - 5.2 Swing the top of the push button rod away from the door latch and remove it from the door latch.
6. Replace the push button.
   - 6.1 Replace the door latch and position it with the push button rod.
   - 6.2 Swing the top of the push button rod to the door latch and connect it to the door latch.



1. Door Latch
2. Push Button Rod

Fig. 2, Push Button Assembly

7. Install the three screws to the door latch. Tighten the screws 7 to 10 lbf·ft (9 to 13 N·m). See **Fig. 1**.
8. Install the watershield.
9. Install the door trim panel.
   - 9.1 Install the door trim panel.
   - 9.2 Install the map pocket, if equipped.
   - 9.3 Install the courtesy lamp.
10. Remove the chocks from the tires.

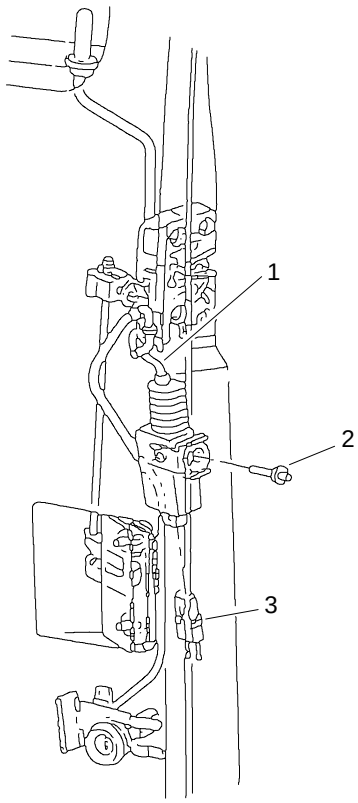
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Power Door Lock Actuator Replacement

Replacement

NOTE: For this procedure, the window must be fully closed.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Disconnect the batteries.
3. Remove the door trim panel.
   - 3.1 Remove the courtesy lamp.
   - 3.2 Remove the map pocket, if equipped.
   - 3.3 Remove the door trim panel.
4. Set aside the watershield.
5. Remove the power door lock actuator. See **Fig. 1**.
   - 5.1 Remove the door glass run.
   - 5.2 Disconnect the electrical connector.
   - 5.3 Remove the actuator from the retainer bracket.
   - 5.4 Rotate the actuator upward 90 degrees and disconnect the actuator rod and remove the actuator.
6. Install the power door lock actuator. See **Fig. 1**.
   - 6.1 With the actuator at 90 degrees, connect the actuator rod.
   - 6.2 Install the actuator into the retainer bracket.
   - 6.3 Connect the electrical connector.
   - 6.4 Connect the actuator rod.
   - 6.5 Install the rear glass door run.
7. Install the watershield.
8. Install the door trim panel.
   - 8.1 Install the door trim panel.
   - 8.2 Install the map pocket, if equipped.
   - 8.3 Install the courtesy lamp.
9. Connect the batteries.
10. Remove the chocks from the tires.



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1. Actuator Rod
2. Rivet
3. Electrical Connector

Fig. 1, Power Door Lock Actuator

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Troubleshooting

POWER WINDOWS

Inspection and Verification

1. Verify the original problem by operating the power window system to duplicate the original condition.
2. Check for one of the following electrical problems:
   - short circuits
   - power distribution box fuses E and V
   - power distribution module fuses 17, 34 CB, and 35 CB
3. If the problem(s) remains after the inspection, determine the symptom(s) and proceed to the following problem chart.

Problem—Power Windows are Inoperative (See Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6 and Fig. 7)

Problem—Power Windows are Inoperative	
Possible Cause	**Remedy**
Power feeds	Turn the ignition switch to the "On" position. Pull the power distribution module fuses 34 CB and 35 CB out just enough to probe the top terminals. Measure the voltage between the top terminals of the power distribution module fuses 34 CB and 35 CB, circuits 400 (BL/BK) and 296 (R) and ground. If the voltage is less than 10 volts, check the driver and passenger power window relays. If the voltage is greater than 10 volts, check the window switches.
Power window relays	Turn the ignition switch to the "Off" position. Remove the driver and passenger power window relays from the power distribution module and substitute known good relays. Turn the ignition switch to the "On" position. If the system operates correctly, replace the power window relay(s). Test the system for normal operation. If the system does not operate correctly, check the relay feed wiring.
Relay feed wiring	Turn the ignition switch to the "Off" position. Disconnect the power window relay connectors C2025 and C2026. Turn the ignition switch to the "On" position. Measure the voltage between the passenger or driver power window relay connector C2025 Pins 30 and 85, circuits 37 (BK/Y) and 960 (R) and ground. If the voltage is less than 10 volts, repair the open in circuit 960 (R) at the power distribution module or circuit 37 (BK/Y) between the power distribution box, fuses V and E and the power distribution module power window relays. If the voltage is greater than 10 volts, repair the affected relay ground(s) Pin 86, circuit 57 (BK). Test the system for normal operation.
Window switch(es)	Remove, but do not disconnect, the driver window switch and the passenger window switch located on the driver door. Remove the plastic covers to gain access to the pins. Measure the voltage between the driver window switch connector C503 Pin 4, and the passenger window switch connector C502 Pin 4, circuits 400 (BL/BK) and 296 (R) and ground. Remove, but do not disconnect, the passenger window switch. Remove the plastic cover to gain access to the pins. Measure the voltage between the passenger window switch connector C604 Pin 4, circuit 296 (R) and ground. If the voltage is less than 10 volts, repair circuit 400 (BL/BK) or 296 (R) between the power distribution module and the window switch. Test the system for normal operation. If the voltage is greater than 10 volts, check the system grounds.

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Troubleshooting

Problem—Power Windows are Inoperative	
Possible Cause	**Remedy**
System grounds	Turn the ignition switch to the "Off" position. Disconnect the battery ground cable(s). Disconnect the driver window switch connector C503, window regulator assembly Connector C511, driver door passenger window switch connector C502, and passenger window switch connector C604. Measure the resistance between the driver window switch connector C503 Pins 2 and 7, the window regulator assembly connector C511 Pin 5 and the driver door passenger window switch connector C502 Pins 2 and 7, circuit 57 (BK) and ground. If the resistance is more than 5 ohms, repair the open in circuit 57 (BK) between the affected window switch and ground. Test the system for normal operation. If the resistance is less than 5 ohms, check the driver or the passenger system. If the symptom is present in the passenger window, check the passenger power window. Connect the battery ground cable(s). Connect the driver window switch connector C503, window regulator assembly connector C511, driver door passenger window switch connector C503, and passenger window switch connector C604. Turn the ignition switch to the "On" position. Actuate the driver door passenger window switch to the up position. Measure the voltage between the driver door passenger window switch connector C502 Pin 6, circuit 314 (W/O) and the driver door passenger window switch connector C502 Pin 3, circuit 313 (O/W). Actuate the driver door passenger window switch to the down position. Measure the voltage between the driver door passenger window switch connector C502 Pin 3, circuit 313 (O/W) and the driver door passenger window switch connector C502 Pin 6, circuit 314 (W/O). If the voltage is less than 10 volts, replace the driver door passenger window switch. Test the system for normal operation. If the voltage is greater than 10 volts, check the vehicle options. If the vehicle equipped with a passenger power window only, check the passenger window motor connector C607. Actuate the driver door passenger window switch to the up position. Measure the voltage between the passenger window motor connector C607, circuit 314 (W/O) and the passenger window motor connector C607, circuit 313 (O/W). Actuate the driver door passenger window switch to the down position. Measure the voltage between the passenger window motor connector C607, circuit 313 (O/W) and the passenger window motor connector C607, circuit 314 (W/O). If the voltage is greater than 10 volts, replace the passenger window motor. Test the system for normal operation. If the voltage is less than 10 volts, repair the open circuit between the driver door passenger window switch and the passenger window motor. Test the system for normal operation.

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Problem—Power Windows are Inoperative	
Possible Cause	**Remedy**
Passenger window switch	If the vehicle is equipped with power windows on both the passenger- and driver-sides, check the voltage at the passenger window switch. Actuate the driver door passenger window switch to the up position. Measure the voltage between the passenger window switch connector C604 Pin 7, circuit 314 (W/O) and the passenger window switch connector C604 Pin 2, circuit 313 (O/W). Actuate the driver door passenger window switch to the down position. Measure the voltage between the passenger window switch connector C604 Pin 2, circuit 313 (O/W) and the passenger window switch connector C604 Pin 7, circuit 314 (W/O). If the voltage is less than 10 volts, repair the open in the affected circuit(s). Test the system for normal operation. If the voltage is greater than 10 volts, check the passenger window switch. Actuate the passenger window switch to the up position. Measure the voltage between the passenger window switch connector C604 Pin 6, circuit 314 (W/O) and the passenger window switch connector C604 Pin 3, circuit 313 (O/W). Actuate the passenger window switch to the down position. Measure the voltage between the passenger window switch connector C604 Pin 3, circuit 313 (O/W) and the passenger window switch connector C604 Pin 6, circuit 314 (W/O). If the voltage is less than 10 volts, replace the passenger window switch. Test the system for normal operation. If the voltage is greater than 10 volts, check the passenger window motor and wiring.
Passenger window motor and wiring	Disconnect the passenger window motor connector C607. Actuate the passenger window switch to the up position. Measure the voltage between the passenger window motor connector C607, circuit 314 (W/O) and the passenger window motor connector C607, circuit 313 (O/W). Actuate the passenger window switch to the down position. Measure the voltage between the passenger window motor connector C607, circuit 313 (O/W) and the passenger window motor connector C607, circuit 314 (W/O). If the voltage is greater than 10 volts, replace the passenger window motor. Test the system for normal operation. If the voltage is less than 10 volts, repair the open in the affected circuit(s). Test the system for normal operation.

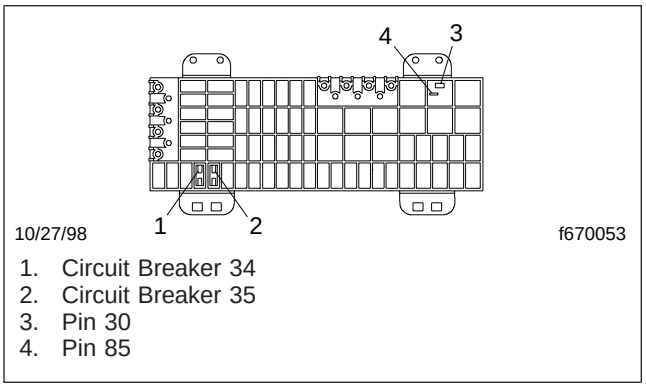
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Troubleshooting

Problem—Power Windows are Inoperative	
Possible Cause	**Remedy**
Driver window switch	Connect the driver window switch connector C502, window regulator assembly connector C511, driver door passenger window switch connector C502, and the passenger window switch connector C604. Connect the battery ground cable. Turn the ignition switch to the "On" position. Actuate the driver window switch to the up position. Measure the voltage between the driver window switch connector C503 Pin 6, circuit 314 (O/W) and the driver window switch connector C503 Pin 3, circuit 313 (W/O). Actuate the driver window switch to the down position. Measure the voltage between the driver window switch connector C503 Pin 3, circuit 313 (O/W) and the driver window switch connector C503 Pin 6, circuit 314 (W/O). If the voltage is less than 10 volts, replace the driver window switch. Test the system for normal operation. If the voltage is greater than 10 volts, check the window regulator assembly switch. Disconnect the window regulator assembly connector C511. Measure the voltage between the window regulator assembly connector C511 Pin 3, circuit 400 (BL/BK) and ground. If the voltage is less than 10 volts, repair the open in circuit 400 (BL/BK) between the power distribution module fuse 34 CB and the window regulator assembly. Test the system for normal operation. If the voltage is greater than 10 volts, check the inputs to the window regulator assembly switch.
Inputs to window regulator assembly switch	Connect the window regulator assembly connector C511. Actuate the driver window switch to the up position. Using sharp probes, measure the voltage between the window regulator assembly connector C511 Pin 4 wire, circuit 314 (W/O) and the window regulator assembly connector C511 Pin 2 wire, circuit 313 (O/W). Actuate the driver window switch to the down position. Using sharp probes, measure the voltage between the window regulator assembly connector C511 Pin 2 wire, circuit 313 (O/W) and the window regulator assembly connector C511 Pin 4 wire, circuit 314 (W/O). If the voltage is less than 10 volts, repair the open in the affected circuit(s). Test the system for normal operation. If the voltage is greater than 10 volts, check the window regulator assembly.
Window regulator assembly	Actuate the driver window completely up. Actuate the driver window switch to the down position momentarily. Using sharp probes, measure the voltage between the window regulator assembly connector C511 Pin 1 wire, circuit 333 (Y/R) and the window regulator assembly connector C511 Pin 4 wire, circuit 314 (W/O). If the voltage is not greater than 10 volts for about 2.5 seconds, replace the window regulator assembly. Test the system for normal operation. If the voltage is greater than 10 volts, check the motor and wiring.
Motor and wiring	Close the driver window completely. Disconnect the driver window module connector C510. Actuate the driver window switch to the down position momentarily. Measure the voltage between the driver window motor connector C510, circuit 333 (Y/R) and the driver window motor connector C510, circuit 314 (W/O). If the voltage is greater than 10 volts for about 2.5 seconds, replace the driver window motor. Test the system for normal operation. If the voltage is not greater than 10 volts for about 2.5 seconds, repair the open in the affected circuit(s). Test the system for normal operation.

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HANDLES, LOCKS, LATCHES,



1. Circuit Breaker 34
2. Circuit Breaker 35
3. Pin 30
4. Pin 85

Fig. 1, Power Distribution Module Terminal Identification

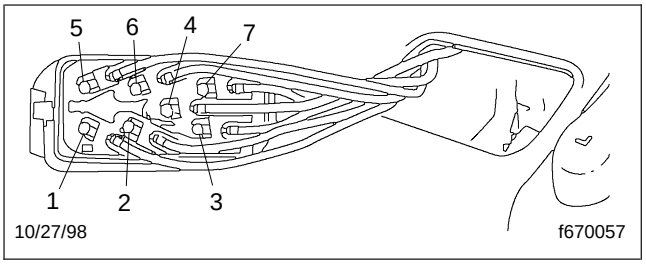


Fig. 2, Passenger-Side Window Switch Pin Identification

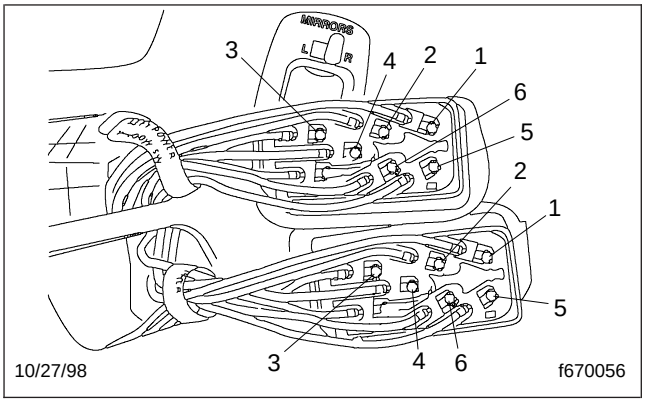


Fig. 3, Driver-Side Window Switches Pin Identification

AND MECHANISMS

Inspection and Verification

1. Verify the owner's original problem by operating the handles, locks, latches, and mechanisms to duplicate the problem.

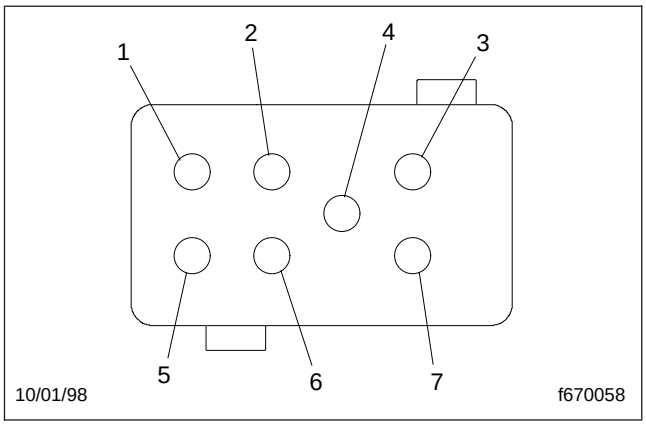


Fig. 4, Passenger Window Switch Connector Pin Identification

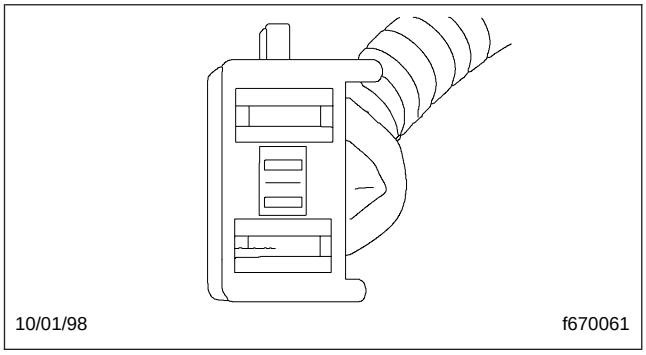


Fig. 5, Driver and Passenger Window Motor Connector

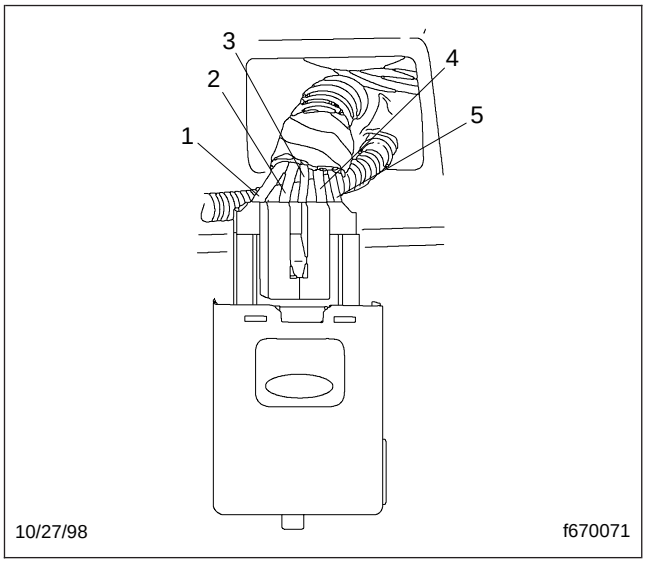


Fig. 6, Window Regulator Assembly Pin Identification

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Troubleshooting

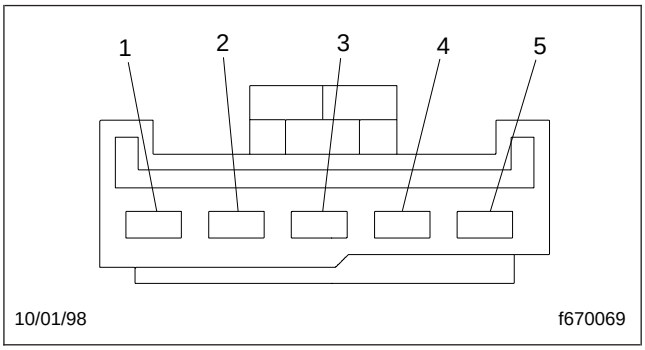


Fig. 7, Window Regulator Assembly Connector Pin Identification

NOTE: Before starting any electrical diagnosis, make sure the battery is charged and check for mechanical binds by manually operating the door lock. Then operate the door lock system several times from each switch, while observing the operation of all door locks.

2. Verify that other components and systems related to the door lock fuse operate properly. If the other components and systems are not operating properly, the fuse, fuse feed circuit or load side circuit may be at fault.
3. Visually inspect for obvious signs of mechanical and electrical damage. See **Table 1**.

Visual Inspection Chart	
Mechanical	**Electrical**
Binding latch mechanisms	Open fuse: instrument panel fuse junction panel fuse 32 (15 A)
Binding linkage	Damaged door lock switch
Misaligned door	Damaged power door lock actuator
	Damaged circuitry
	Corroded connectors

Table 1, Visual Inspection Chart

4. If the problem is not visually evident, determine the possible cause and proceed to the problem charts.

Problem—The Door Lock is Inoperative (See Fig. 8)

Problem—The Door Lock is Inoperative	
Possible Cause	**Remedy**
Stuck or binding components	Check the operation of the inoperative door lock. Manually operate the inoperative door lock. Check for a binding or stuck condition. If the door lock is stuck or binding, repair or replace the stuck or binding component. Test the system for normal operation. If the door lock is not stuck or binding, check the inoperative door lock actuator lock operation.
Lock operation	Disconnect the inoperative door lock actuator harness connector. Measure the voltage between door lock actuator connector C504, Pin 1, circuit 117 (PK/BK) for the driver door or C605, Pin 1, circuit 117 (PK/BK) for the passenger door and chassis ground while operating the door lock switch to the LOCK position. If the voltage is not greater than 10 volts, repair circuit 117 (PK/BK). Test the system for normal operation. If the voltage is greater than 10 volts, check the inoperative door lock actuator for unlock operation.
Unlock operation	Measure the voltage between door lock actuator connector C504, Pin 2, circuit 122 (PK/O) for the driver door or C605, Pin 2, circuit 122 (PK/O) for the passenger door and chassis ground while operating the door lock switch to the UNLOCK position. If the voltage is greater than 10 volts, replace the power door lock actuator. Test the system for normal operation. If the voltage is not greater than 10 volts, repair circuit 122 (PK/O). Test the system for normal operation.

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Problem—The Door Locks are Inoperative (See Fig. 8 and Fig. 9)

Problem—The Door Locks are Inoperative	
Possible Cause	**Remedy**
Door lock switch	Check for power to the passenger door lock switch. Disconnect the passenger door lock switch harness connector. Measure the voltage between passenger door lock switch connector C603, Pin 4, circuit 33 (Y) and chassis ground. If the voltage is less than 10 volts, repair circuit 33 (Y). Test the system for normal operation. If the voltage is greater than 10 volts, check the ground circuit.
Ground circuit	Measure the voltage between passenger door lock switch connector C603, Pin 4, circuit 33 (Y) and Pin 2, circuit 57 (BK). If the voltage is less than 10 volts, repair circuit 57 (BK). Test the system for normal operation. If the voltage is greater than 10 volts, check the passenger door switch to driver door switch circuits.
Passenger door to driver door switch circuits	Disconnect the driver door lock switch harness connector. Measure the resistance between driver door lock switch connector C501, Pin 7, circuit 119 (PK/Y) and passenger door lock switch connector C603, Pin 6, circuit 119 (PK/Y). Measure the resistance between driver door lock switch connector C501, Pin 2, circuit 121 (PK/GN) and passenger door lock switch connector C603, Pin 3, circuit 121 (PK/GN). If the resistance is not less than 5 ohms on both circuits, repair the damaged circuit. Test the system for normal operation. If the resistance is less than 5 ohms on both circuits, check the passenger door lock switch for power.
Passenger door lock switch power	Reconnect the passenger door lock switch harness connector. Measure the voltage between driver door lock switch connector C501, Pin 2, circuit 121 (PK/GN) and chassis ground while operating the passenger door lock switch to the UNLOCK position. Measure the voltage between driver door lock switch connector C501, Pin 7, circuit 119 (PK/Y) and chassis ground while operating the passenger door lock switch to the LOCK position. If the voltage is not greater than 10 volts on both circuits, replace the passenger door lock switch. Test the system for normal operation. If the voltage is greater than 10 volts on both circuits, check the passenger door switch for continuity to ground.
Passenger door switch continuity to ground	Measure the resistance between driver door lock switch connector C501, Pin 2, circuit 121 (PK/GN) and chassis ground while the door lock switch is in the neutral position. Measure the resistance between driver door lock switch connector C501, Pin 7, circuit 119 (PK/Y) and chassis ground while the door lock switch is in the neutral position. If the resistance is not less than 5 ohms on both circuits, replace the passenger door lock switch. Test the system for normal operation. If the resistance is less than 5 ohms on both circuits, check the driver door lock switch output circuits.
Driver door lock switch output circuit	Disconnect the driver door lock actuator harness connector. Measure the resistance between driver door lock switch connector C501, Pin 3, circuit 122 (PK/O) and driver door lock actuator connector C504, Pin 2, circuit 122 (PK/O). Measure the resistance between driver door lock switch connector C501, Pin 6, circuit 117 (PK/BK) and driver door lock actuator connector C504, Pin 1, circuit 122 (PK/BK). If the resistance is less than 5 ohms for both circuits, replace the driver door lock switch. Test the system for normal operation. If the resistance is not less than 5 ohms for both circuits, repair the damaged circuit. Test the system for normal operation.

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Troubleshooting

Problem—All Locks Operate from One Switch Only (See Fig. 9)

Problem—All Locks Operate from One Switch Only	
Possible Cause	**Remedy**
Supply voltage	Disconnect the inoperative door lock switch harness connector. Measure the voltage between the inoperative door lock switch connector, C603 for the passenger door lock switch or C501 for the driver door lock switch, Pin 4, circuit 33 (Y) and chassis ground. If the voltage is greater than 10 volts, replace the inoperative door lock switch. Test the system for normal operation. If the voltage is less than 10 volts, repair circuit 33 (Y). Test the system for normal operation.

Problem—The Door Locks Operate Only One Way (See Fig. 9)

Problem—The Door Locks Operate Only One Way	
Possible Cause	**Remedy**
Ground circuits	Disconnect the driver door lock switch harness connector. Measure the resistance between driver door lock switch connector C501, Pin 2, circuit 121 (PK/GN) and chassis ground with the passenger door lock switch operated to the LOCK position. Measure the resistance between driver door lock switch connector C501, Pin 7, circuit 119 (PK/Y) and chassis ground with the passenger door lock switch operated to the UNLOCK position. If the resistance is less than 5 ohms for both circuits, replace the driver door lock switch. Test the system for normal operation. If the resistance is not less than 5 ohms for both circuits, check the passenger door lock switch.
Passenger door lock switch	Disconnect the passenger door lock switch harness connector. Measure the resistance between passenger door lock switch connector C603, Pin 2, circuit 57 (BK) and chassis ground. Measure the resistance between passenger door lock switch connector C603, Pin 7, circuit 57 (BK) and chassis ground. If the resistance is less than 5 ohms for both circuits, replace the passenger door lock switch. Test the system for normal operation. If the resistance is not less than 5 ohms for both circuits, repair the damaged circuit. Test the system for normal operation.

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COMPONENT TESTS

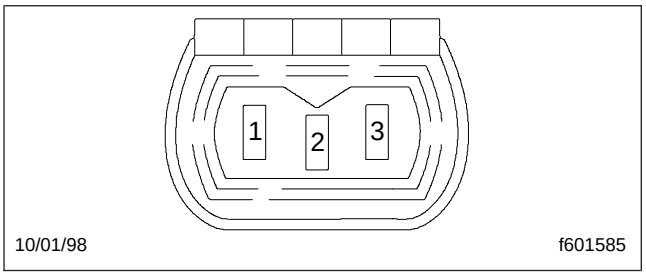


Fig. 8, Door Lock Actuator Connector Pin Identification

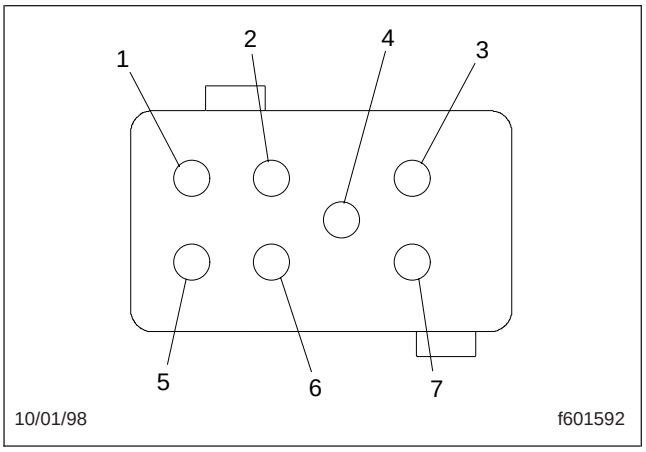


Fig. 9, Door Lock Switch Connector Pin Identification

Switches

Pins	Switch Position	Result
1,2	Neutral	Open
1,2	Lock	Open
1,2	Unlock	Open
1,3	Neutral	Open
1,3	Lock	Open
1,3	Unlock	Open
1,4	Neutral	Open
1,4	Lock	Open
1,4	Unlock	Open
1,5	Neutral	Open
1,5	Lock	Open
1,5	Unlock	Open
1,6	Neutral	Open
1,6	Lock	Open
1,6	Unlock	Open
1,7	Neutral	Open
1,7	Lock	Open
1,7	Unlock	Open
2,3	Neutral	Closed
2,3	Lock	Open
2,3	Unlock	Closed
2,4	Neutral	Open
2,4	Lock	Closed
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2,5	Neutral	Open
2,5	Lock	Open
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3,5	Unlock	Open
3,6	Neutral	Open
3,6	Lock	Open
3,6	Unlock	Open
3,7	Neutral	Open
3,7	Lock	Open
3,7	Unlock	Open
4,5	Neutral	Open
4,5	Lock	Open
4,5	Unlock	Open
4,6	Neutral	Open
4,6	Lock	Open

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Troubleshooting

Pins	Switch Position	Result
4,6	Unlock	Open
4,7	Neutral	Open
4,7	Lock	Open
4,7	Unlock	Closed
5,6	Neutral	Open
5,6	Lock	Open
5,6	Unlock	Open
5,7	Neutral	Open
5,7	Lock	Open
5,7	Unlock	Open
6,7	Neutral	Closed
6,7	Lock	Closed
6,7	Unlock	Open

Table 2, Switches

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Specifications

Torque Specifications	
Description	**lbf·ft (N·m)**
Door Hinge-to-A-Pillar Bolts	30–47 (41–64)
Door Hinge-to-Door Bolts	15–24 (21–32)
Door Hinge Bushing Nuts	7–10 (9–13)
Window Motor Bolts	7–10 (9–13)
Inside Door Handle Remote Control Bolt	7–10 (9–13)
Inside Door Handle Bolt	7–10 (9–13)
Door Latch Screws	7–10 (9–13)

Table 1, Torque Specifications

Specifications For Manual Windows	
Item	**Specification**
Window Handle Effort	22–31 lbf·in (240–360 N·cm)

Table 2, Specifications For Manual Windows

Specifications For Power Windows	
Item	**Specification**
Window Motor Current Draw—Up and Down	15 amps (maximum)
Window Motor Current Draw—Stall	38 amps (maximum)
Window Motor Resistance	0.16–0.20 ohms
Full Drop Time—Up or Down	2.7–4 seconds
Full Drop Time—Restricted Up or Down	2.3–3.5 seconds

Table 3, Specifications For Power Windows

Approved Sealants	
Item	**Specification**
Liquid Butyl Sealer C9AZ-19554-B	ESB-M4G162-A

Table 4, Approved Sealants

See **Fig. 1** for a full view of the power door locks wiring.

See **Fig. 2** and **Fig. 3** for partial views of the power door locks wiring.

See **Fig. 4** for a full view of the power windows wiring.

See **Fig. 5** and **Fig. 6** for partial views of the power windows wiring.

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Specifications

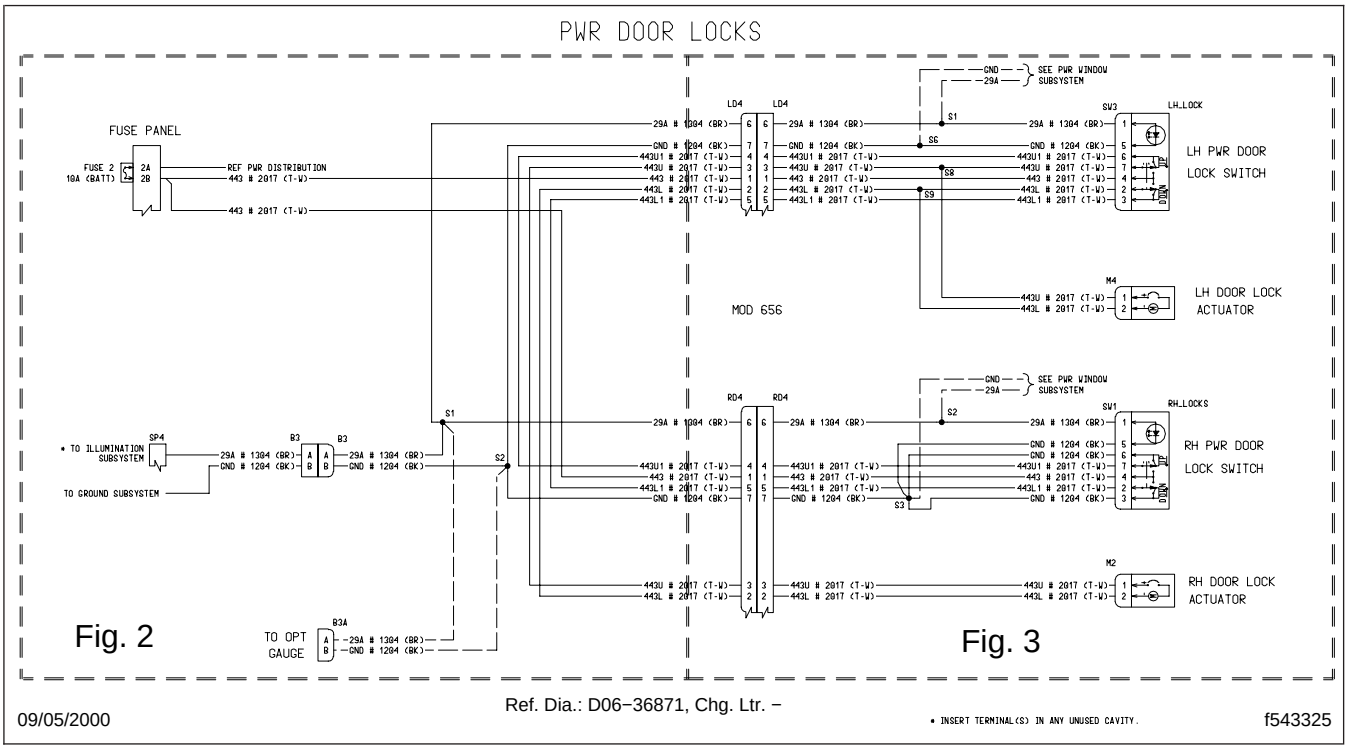


Fig. 1, Power Door Locks Wiring (full view)

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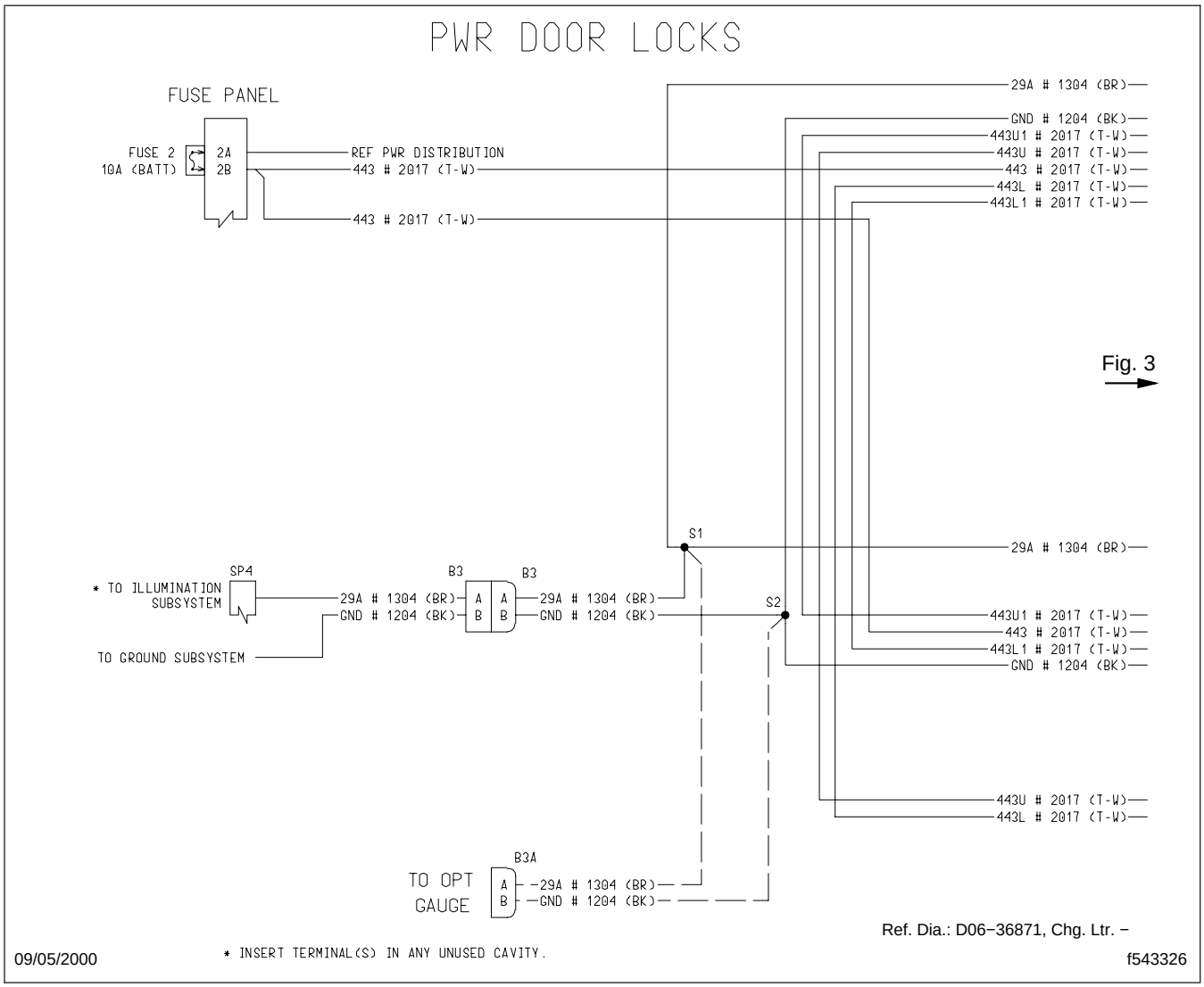


Fig. 2, Power Door Locks Wiring (partial view)

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Specifications

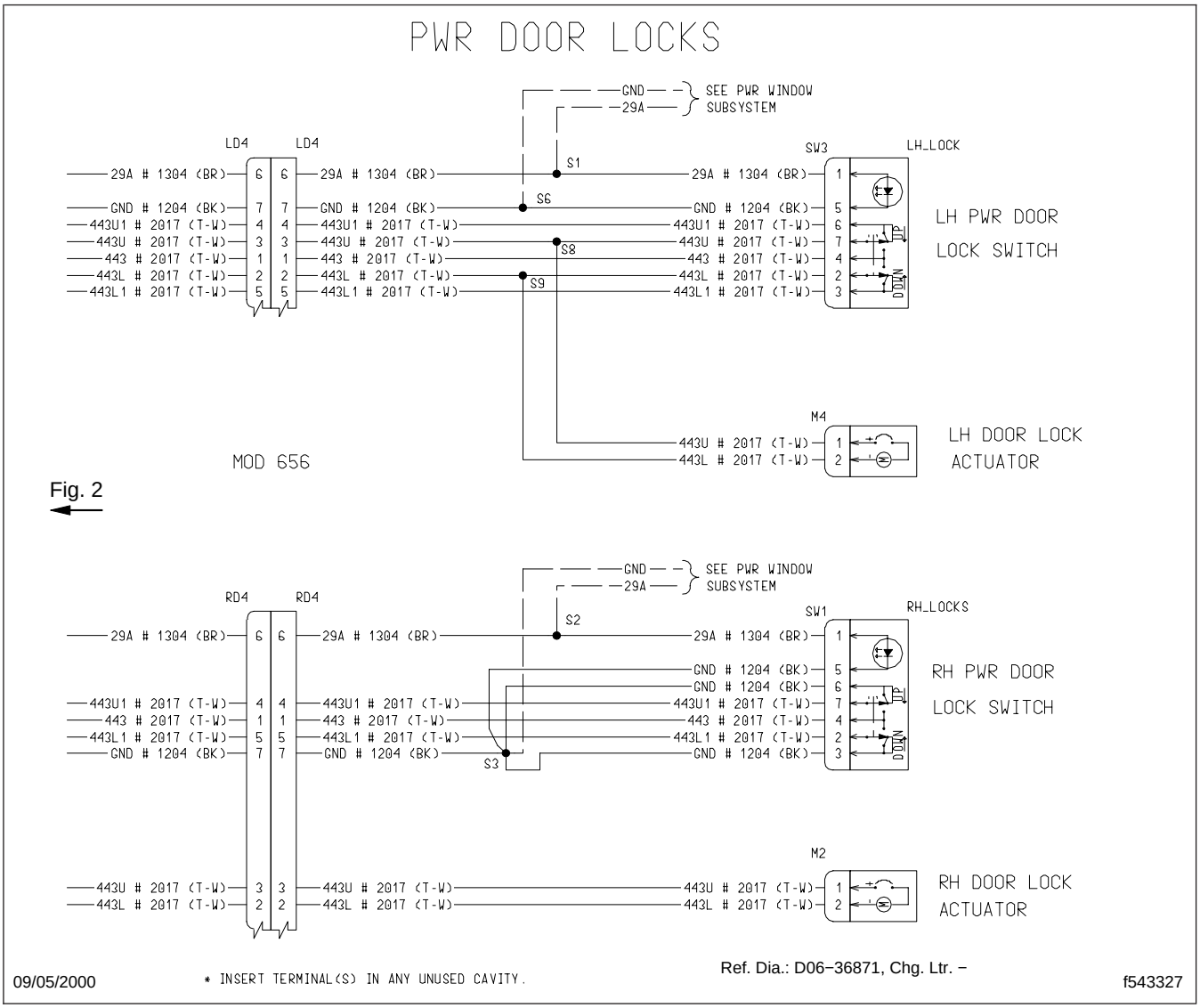
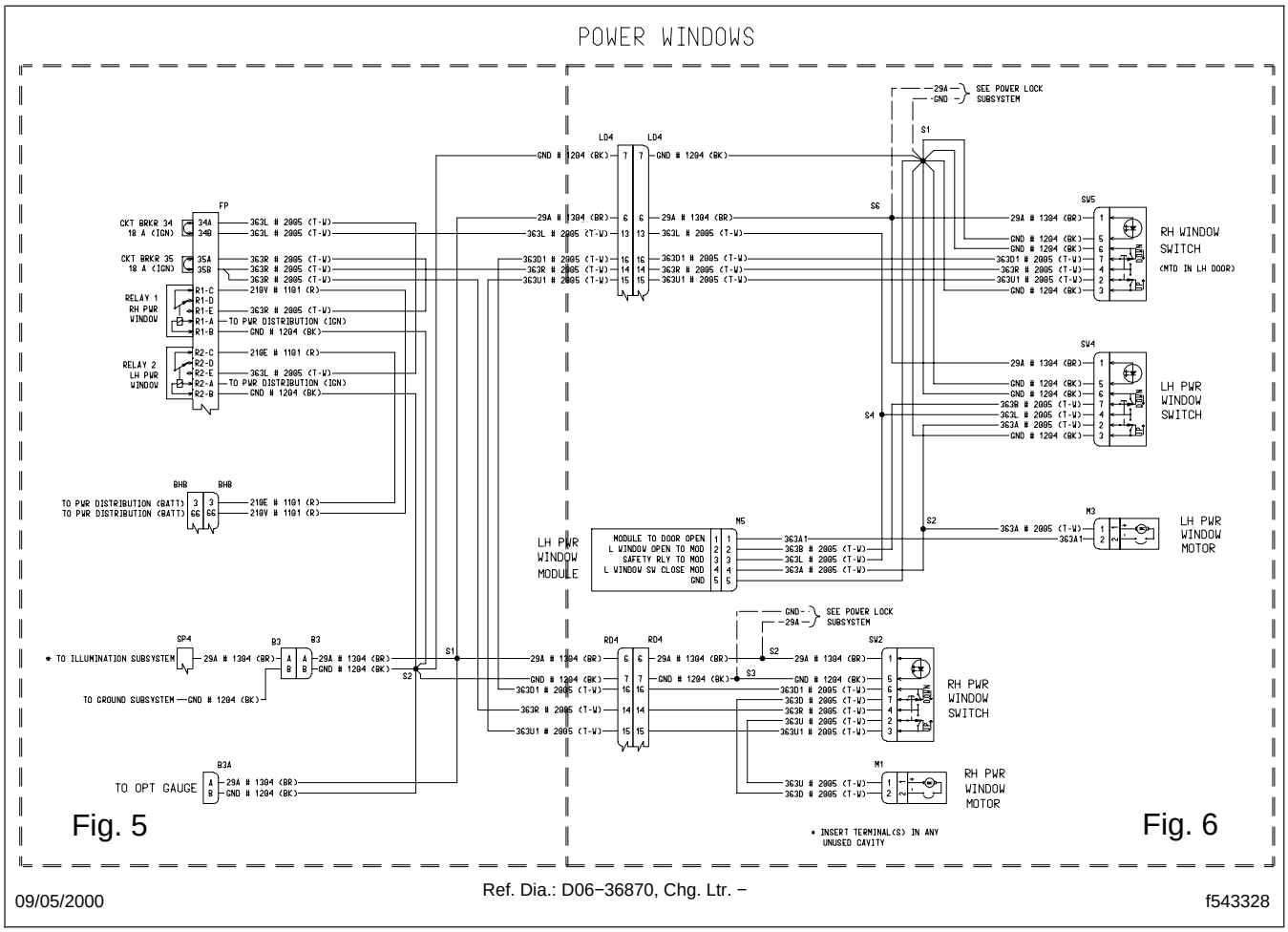


Fig. 3, Power Door Locks Wiring (partial view)

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Fig. 4, Power Windows Wiring (full view)

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Specifications

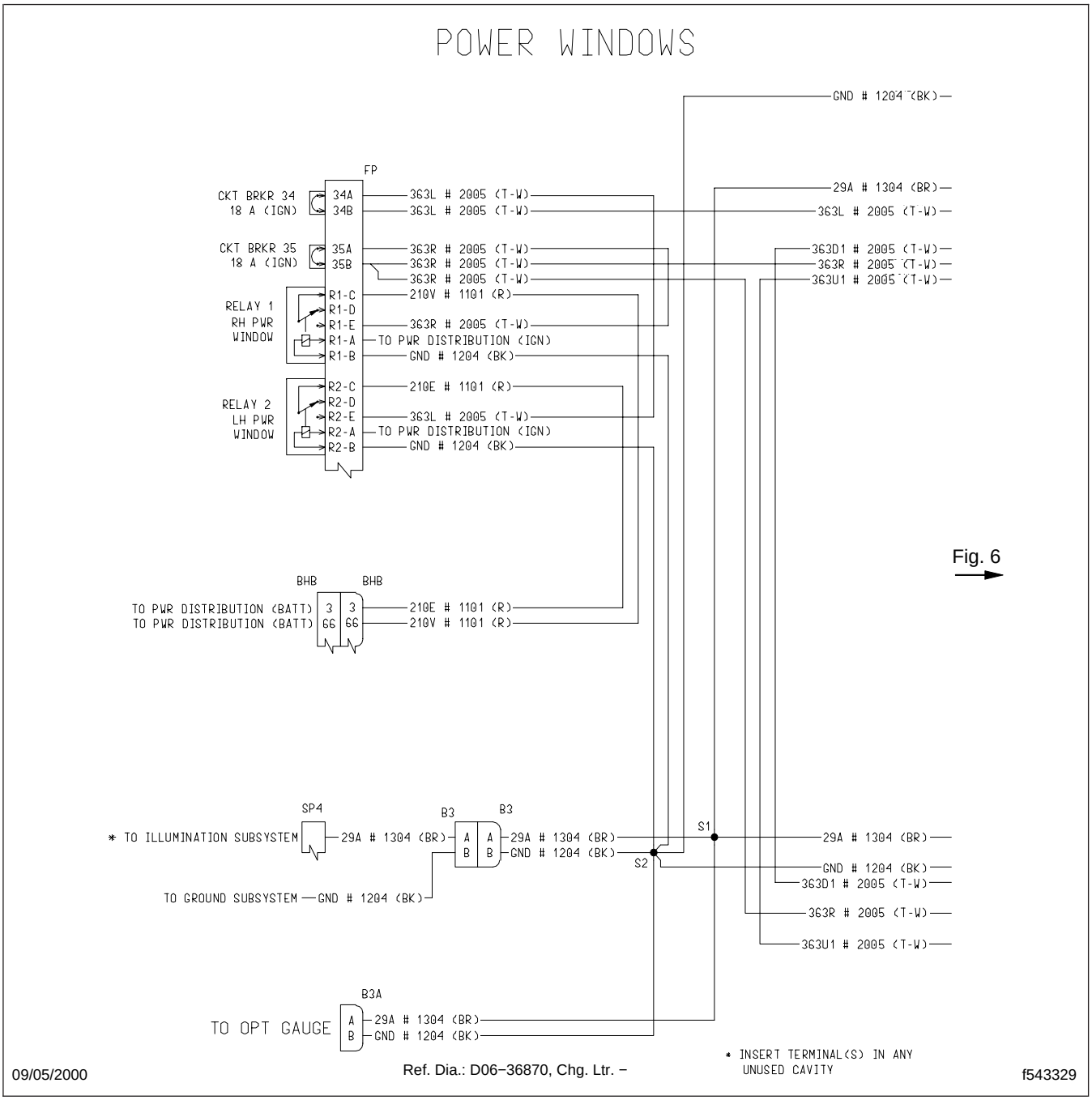


Fig. 6

Fig. 5, Power Windows Wiring (partial view)

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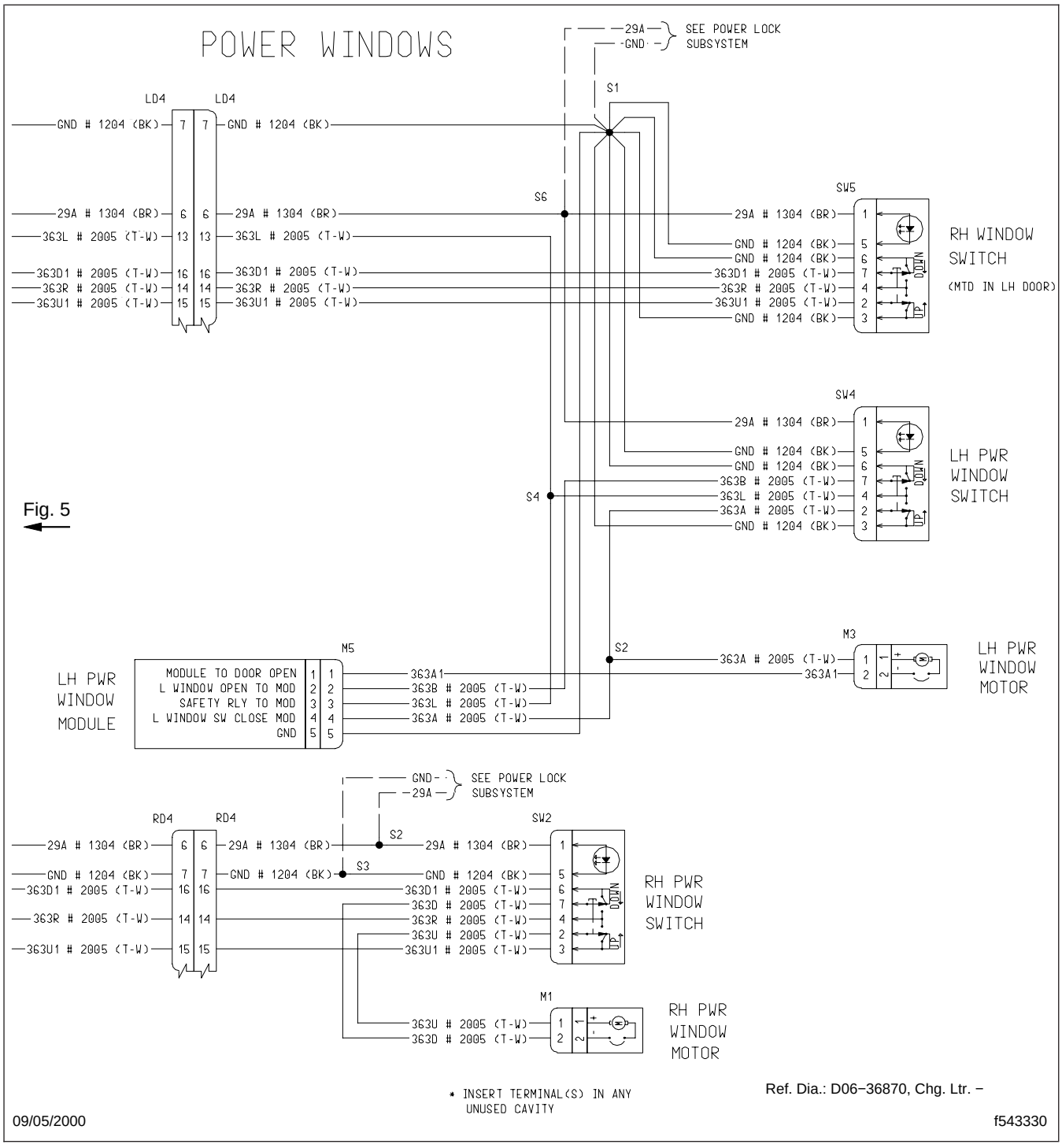


Fig. 5

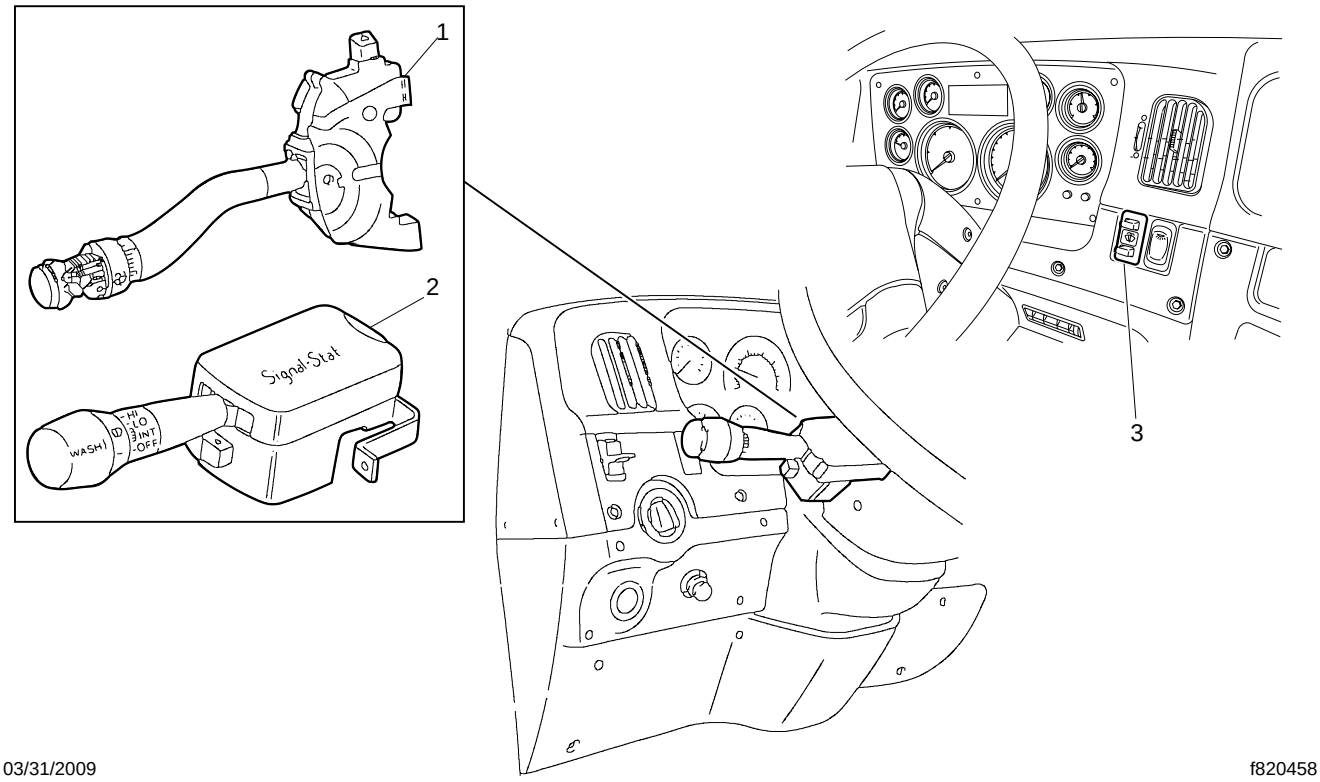
Fig. 6, Power Windows Wiring (partial view)

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General Information

For the wiper system switch and control module locations, see **Fig. 1** and **Fig. 2**.

ground and open signals from the multi-function switch. Each different combination directs the windshield wiper control module to place the windshield wiper motor in a different mode.



1. Multi-Function Switch, United Technologies
2. Multi-Function Switch, Signal-Stat
3. Wiper/Washer Switch, Dash-Mounted

Fig. 1, Wiper/Washer System, Switch Location

Wiper/Washer Switch, Multi-Function

The United Technologies multi-function switch uses a series of internal resistances to determine which mode the windshield wiper control module will place the windshield wiper motor. It is important that each resistance or combination of resistances be within the specified range.

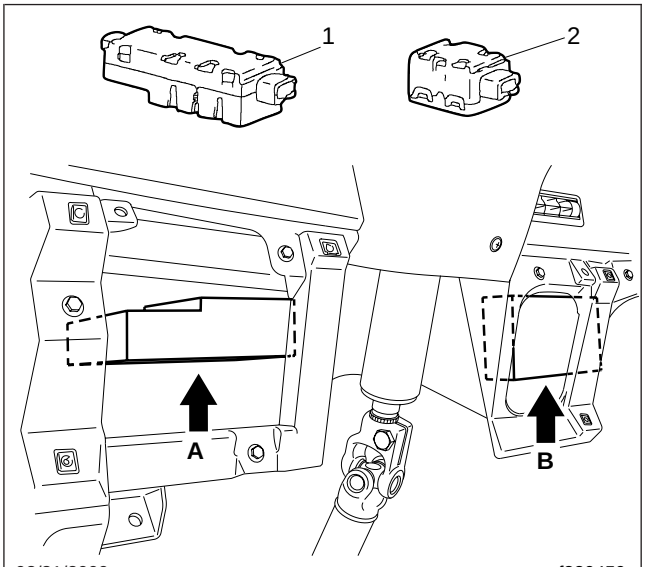
The Signal-Stat multi-function switch uses a binary code strategy to determine which mode the windshield wiper control module will place the windshield wiper motor. This strategy is based on the windshield wiper control module receiving a combination of

There are four modes of wiper operation:

- **Off:** In this mode, there is no windshield wiper motor activity and the windshield wiper motor will be in the "Park" position.
- **Low Speed:** In this mode, the windshield wiper control module will activate the windshield wiper motor through the low speed motor winding.
- **High Speed:** In this mode, the windshield wiper control module will activate the windshield wiper motor through the high speed motor winding.

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General Information



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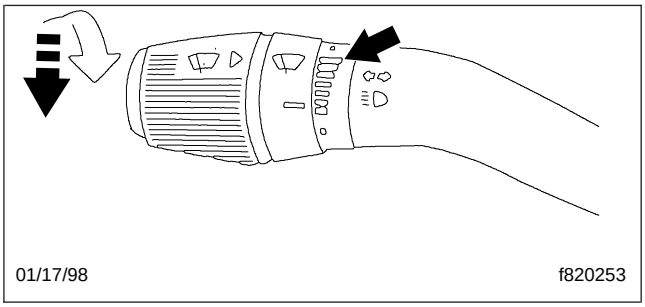
NOTE: The wiper/washer control module is found at either location A or location B.

1. Windshield Wiper Control Module, Signal-Stat
2. Windshield Wiper Control Module, United Technologies

Fig. 2, Wiper/Washer System, Control Module Location

- **Interval:** In this mode, the windshield wiper control module will activate the windshield wiper motor through the low speed motor winding.

When the switch is in the interval position (**Fig. 3**), the windshield wipers will make a single sweep followed by a pause. The pause duration is controlled by the setting the operator has selected for the control knob on the end of the multi-function switch.

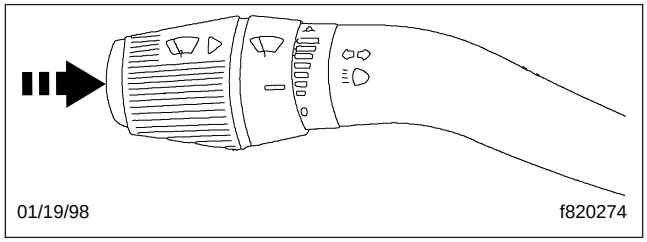


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Fig. 3, Windshield Wiper Switch, Interval Position

To engage the windshield washer, push the knob at the end of the multi-function switch; see **Fig. 4**.

When the multi-function switch is in the "Off" or "Intermittent" position, the windshield wipers will run in "Low" while the knob is pushed in. When the washer knob is released, the washer will stop immediately, but the windshield wipers will continue to run for two or three sweeps, then return to their previously set mode. Washer engagement does not affect windshield wiper operation when the multi-function switch is in the "Low" or "High" position.



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Fig. 4, Windshield Washer

Wiper/Washer Switch, Dash-Mounted

The dash-mounted wiper switch controls the wipers through relays that are located in the dash-mounted power distribution module (PDM). Wiper speed and delay timing are controlled by electronics in the switch.

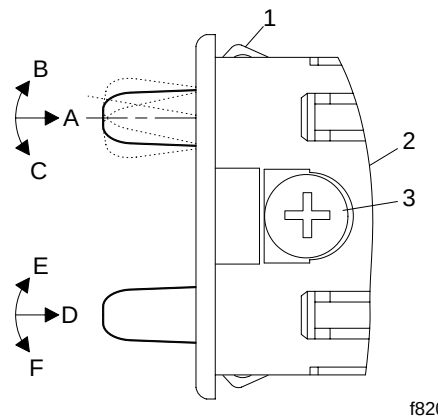
The windshield wipers and washers are operated by a double-paddle switch mounted on the auxiliary instrument panel. Each paddle can be pushed in, up, or down, for three different functions. For wiper switch functions and operation, see **Fig. 5**.

The wipers have five cycles: fast, slow, mist, wash, and delay. There are six delay intervals, 3 seconds, 5 seconds (default fast), 8 seconds, 12 seconds, 17 seconds (default slow), and 23 seconds.

The top paddle, when pushed in, turns the wipers on (if they are off) or off (if they are on). When pushed up, the top paddle switches the wipers to high speed; when pushed down, it switches them to low speed.

The bottom paddle, when pushed in momentarily (for less than 1/2 second), turns the wipers on mist (one dry cycle at low speed). When pushed in and held in (for at least 1/2 second), the bottom paddle turns on the washers for a minimum of three cycles after release. For more wash cycles, hold the bottom paddle in longer (but it will always cycle three more times after release).

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A. Push in to turn wipers on (low speed) or off.
B. Push up for high speed.
C. Push down for low speed.
D. Push in momentarily for mist cycle. Push in and hold in for wash cycle.
E. Push up for fast delay. If already in delay, push up for the next faster delay.
F. Push down for slow delay. If already in delay, push down for the next slower delay.

1. Locking Clip
2. Wiper/Washer Switch
3. Light Bulb Screw

Fig. 5, Dash-Mounted Wiper/Washer Switch Operation

Pushing **the bottom paddle** up or down controls the delay cycle of the intermittent wipers. If the wipers are not in delay, push up for default fast delay (5 seconds) or down for default slow delay (17 seconds). If the wipers are already in delay, push up for the next faster delay or push down for the next slower delay.

Windshield Washer System

The windshield washer nozzles are an integral part of the windshield wiper arm. They are not serviceable separate from the windshield wiper arm.

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Replacement

1. Apply the parking brakes and chock the tires.
2. Disconnect the batteries.

CAUTION

Disconnect the batteries before working on the wipers. This will prevent the windshield wiper motor from cycling. The motor could cycle if the wiper linkage driveshaft is forced out of the parked position, which could result in personal injury.

3. Disconnect the washer hose; see **Fig. 1**.

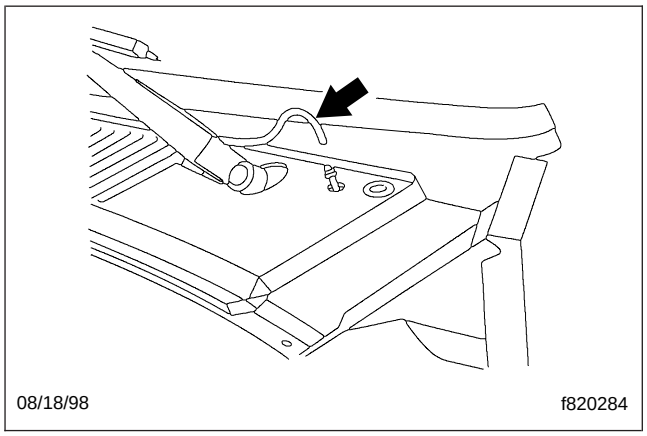


Fig. 1, Windshield Washer Hose

NOTE: The windshield wiper arm can be removed at any point in the wiper sweep without the use of any special tools.

4. Carefully raise the windshield wiper blade away from the windshield glass until it stops.
5. Pull the locking lever away from the windshield wiper arm; see **Fig. 2**.
6. Lift the windshield wiper arm from the pivot shaft; see **Fig. 3**.
7. Install the new windshield wiper arm on the pivot shaft; see **Fig. 3**.
8. Close the locking lever on the windshield wiper arm; see **Fig. 2**.
9. Connect the washer hose; see **Fig. 1**.
10. Connect the batteries.

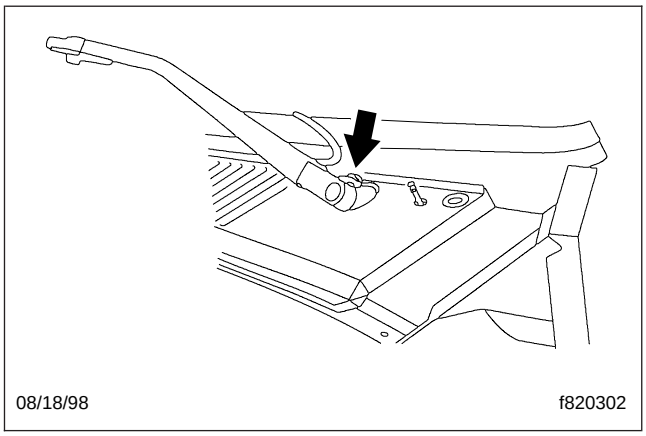


Fig. 2, Windshield Wiper Arm Locking Lever

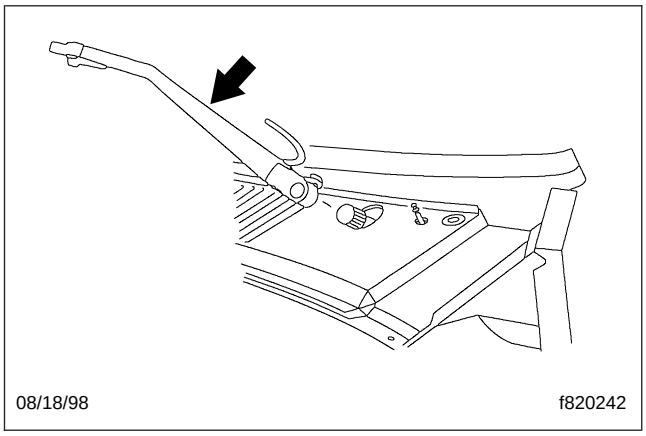


Fig. 3, Windshield Wiper Arm

11. Check and if necessary, adjust the windshield wiper arm; see **Subject 160**.

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Replacement

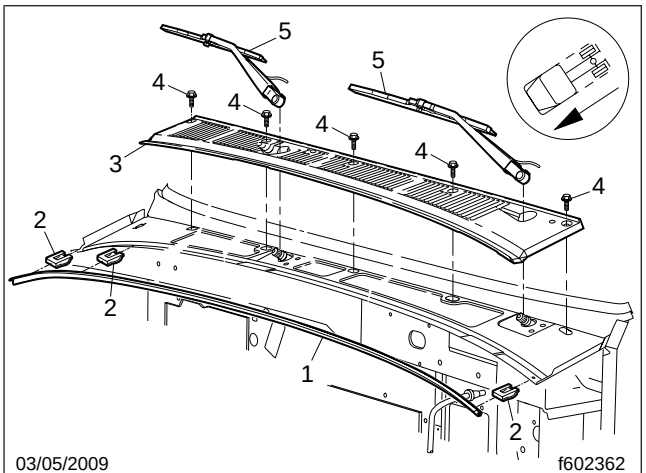
NOTE: The windshield wiper linkage and pivot shafts are serviced as an assembly.

1. Apply the parking brakes and chock the tires.
2. Disconnect the batteries.

CAUTION

Disconnect the batteries before working on the wipers. This will prevent the windshield wiper motor from cycling. The motor could cycle if the wiper linkage driveshaft is forced out of the parked position, which could result in personal injury.

3. Remove the windshield wiper arms; see **Subject 100**.
4. Remove the cowl top vent panel (rain tray grille) as follows.
   - 4.1 Remove the rubber seal from the forward edge of the rain tray.
   - 4.2 Remove the five screws that attach the vent panel to the top of the rain tray; see **Fig. 1**. Remove the vent panel.



1. Rubber Seal
2. Retainer
3. Vent Panel
4. Screw
5. Wiper Arm and Blade

Fig. 1, Cowl Top Vent Panel Installation

5. Remove the retaining clip and disconnect the windshield wiper linkage from the wiper motor arm; see **Fig. 2**. Note that some linkages are secured with an E-clip, two seals, and a washer.

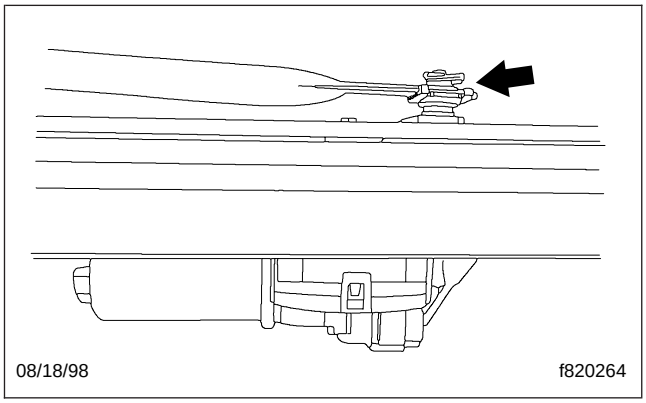
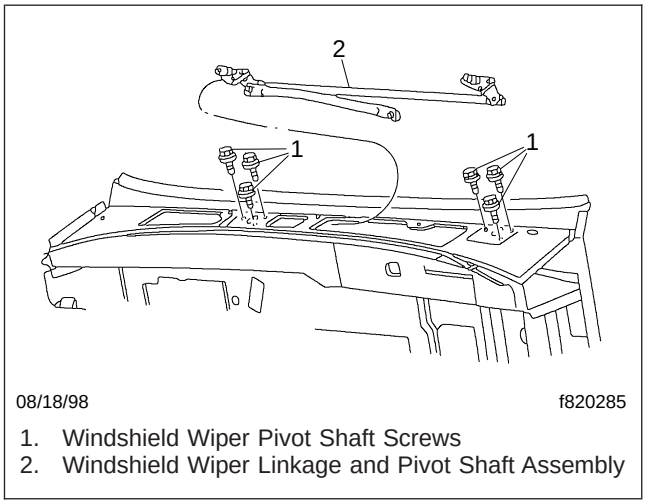


Fig. 2, Windshield Wiper Linkage Retaining Clip

6. Remove the windshield wiper linkage and pivot shaft assembly as follows; see **Fig. 3**.



1. Windshield Wiper Pivot Shaft Screws
2. Windshield Wiper Linkage and Pivot Shaft Assembly

Fig. 3, Windshield Wiper Linkage and Pivot Shafts

   - 6.1 Remove the six pivot shaft screws.
   - 6.2 Slide the windshield wiper linkage and pivot shaft assembly to the passenger side of the vehicle until the driver-side pivot clears the opening in the cowl. Bring the assembly up and out through the large cowl opening.
7. Install the new windshield wiper linkage and pivot shaft assembly as follows; see **Fig. 3**.
   - 7.1 Slide the windshield wiper linkage assembly in through the large cowl opening to-

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Wiper Linkage Replacement

ward the passenger side until it drops into the cowl rain tray. Align the assmbly and lift the pivots through the openings in the cowl top panel.

7.2 Install the six pivot shaft screws (**Fig. 3**, Items 1), then tighten them 80 to 115 lbf·in (900 to 1300 N·cm).

8. Connect the windshield wiper motor arm to the linkage and install the retaining clip (or if so equipped, the E-clip, two seals, and washer); see **Fig. 2**. Apply grease to the joint.
9. Install the cowl top vent panel (rain tray grille) as follows.

   9.1 Attach the vent panel to the top the rain tray, using the five screws.

   9.2 Install the rubber seal on the forward edge of the rain tray.
10. Install the windshield wiper arms; see **Subject 100**.
11. Connect the batteries.
12. Check and, if necessary, adjust the windshield wiper arms; see **Subject 160**.

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Windshield Wiper Motor Replacement

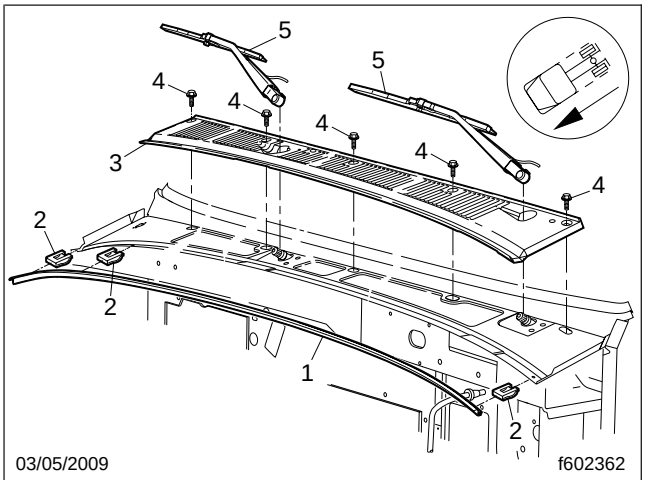
Replacement

1. Apply the parking brakes and chock the tires.
2. Open the hood.
3. Disconnect the batteries.

⚠ CAUTION

Disconnect the batteries before working on the wipers. This will prevent the windshield wiper motor from cycling. The motor could cycle if the wiper linkage driveshaft is forced out of the parked position, which could result in personal injury.

4. Remove the windshield wiper arms; see **Subject 100**.
5. Remove the cowl top vent panel (rain tray grille) as follows.
   - 5.1 Remove the rubber seal from the forward edge of the rain tray.
   - 5.2 Remove the five screws that attach the vent panel to the top of the rain tray; see **Fig. 1**. Remove the vent panel.

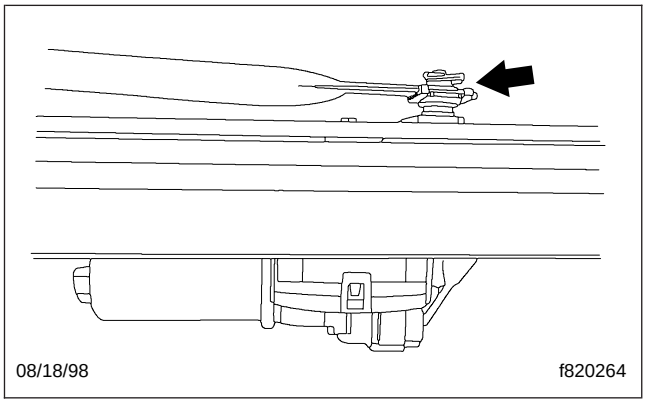


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1. Rubber Seal
2. Retainer
3. Vent Panel
4. Screw
5. Wiper Arm and Blade

Fig. 1, Cowl Top Vent Panel Installation

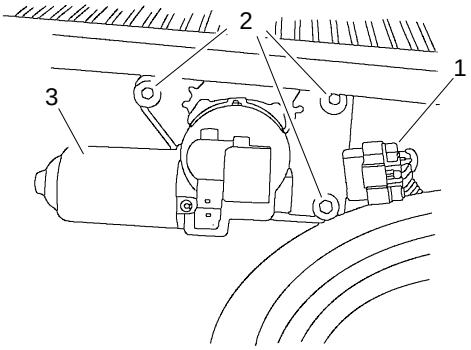
6. Remove the retaining clip and disconnect the windshield wiper linkage from the wiper motor arm; see **Fig. 2**. Note that some linkages are secured with an E-clip, two seals, and a washer.



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Fig. 2, Windshield Wiper Linkage Retaining Clip

7. Disconnect the wiper motor electrical connector; see **Fig. 3**.



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1. Windshield Wiper Motor Electrical Connector
2. Windshield Wiper Motor Retaining Bolts
3. Windshield Wiper Motor

Fig. 3, Windshield Wiper Motor

8. Remove the three wiper motor mounting bolts, then remove the wiper motor.
9. Install the new windshield wiper motor, using the three mounting bolts; see **Fig. 3**. Tighten the bolts 80 to 115 lbf·in (900 to 1300 N·cm).
10. Connect the wiper motor electrical connector.
11. Connect the windshield wiper motor arm to the linkage, then install the retaining clip (or if so equipped, the E-clip, two seals, and washer); see **Fig. 2**. Apply grease to the joint.

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Windshield Wiper Motor Replacement

12. Install the cowl top vent panel (rain tray grille) as follows.
    - 12.1 Attach the vent panel to the top the rain tray, using the five screws.
    - 12.2 Install the rubber seal on the forward edge of the rain tray.
13. Install the windshield wiper arms; see **Subject 100**.
14. Connect the batteries and close the hood.
15. Check and, if necessary, adjust the windshield wiper arms; see **Subject 160**.

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Windshield Washer Reservoir Replacement

Replacement

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Open the hood.

NOTE: Windshield washer fluid must be collected in a container after the windshield washer hose is disconnected.

3. Disconnect the electrical connector and the washer hose.
4. Remove the windshield washer reservoir. See **Fig. 1**.
   - 4.1 If equipped with an hydraulic clutch, remove the bolt, washers and nut connecting the hydraulic clutch reservoir to the windshield washer reservoir.
   - 4.2 Remove the two retaining nuts and washers on the top of the reservoir and the three bolts and washers at the bottom of the reservoir.
   - 4.3 Remove the windshield washer reservoir.
5. Install the windshield washer reservoir. See **Fig. 1**.
   - 5.1 Position the windshield washer reservoir.
   - 5.2 Install the two retaining nuts and washers and three bolts and washers.
   - 5.3 If equipped with an hydraulic clutch, install the bolt, washers and nut connecting the hydraulic clutch reservoir to the windshield washer reservoir.
6. Connect the washer hose.

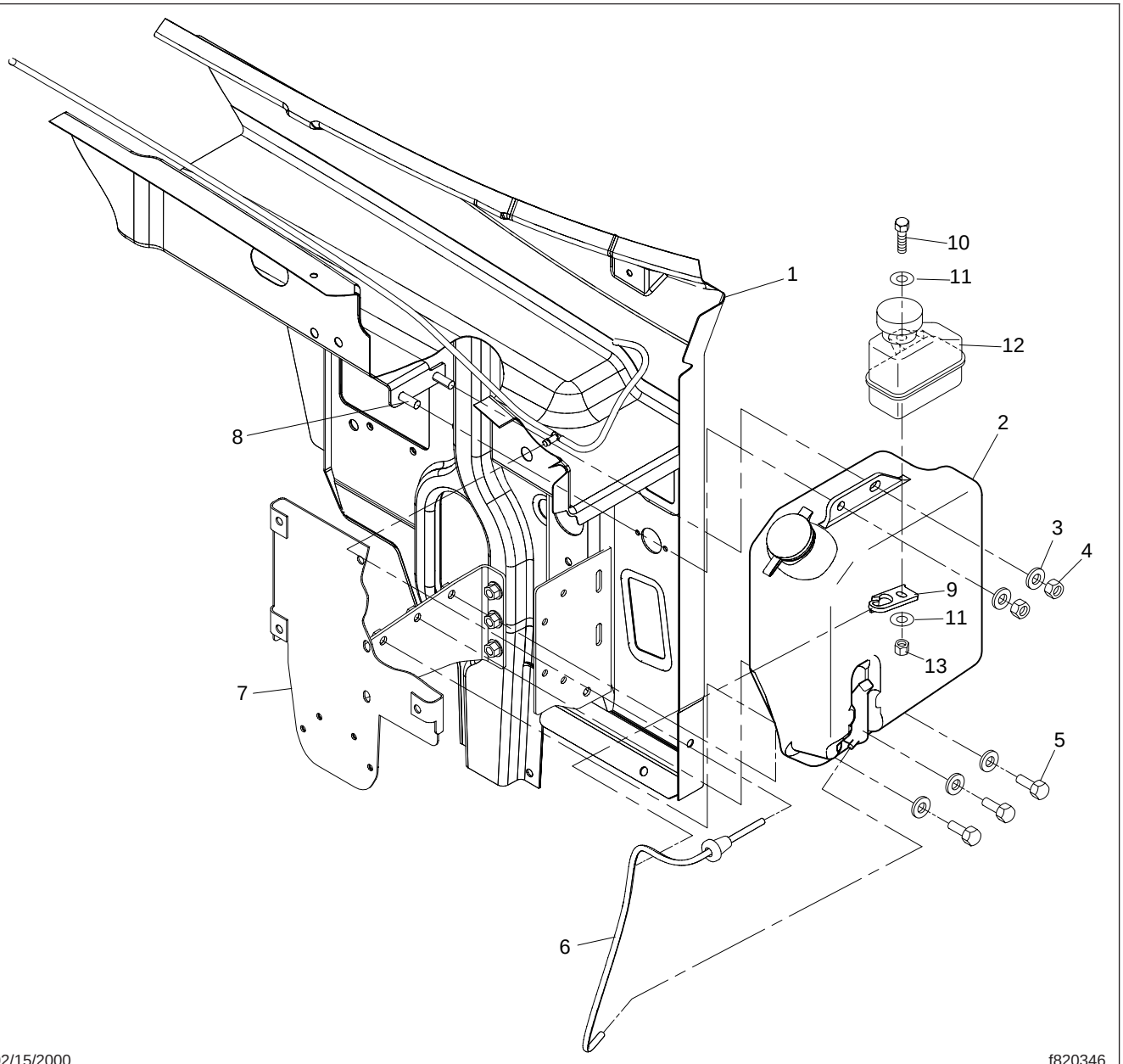
CAUTION

Do not connect the electrical connector prior to filling the windshield washer reservoir or operate the windshield washer pump prior to filling the windshield washer reservoir or damage to the pump could result.

7. Fill the windshield washer reservoir with windshield washer fluid.
8. Connect the electrical connector.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

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Windshield Washer Reservoir Replacement



1. Cowl
2. Windshield Washer Reservoir
3. Washer
4. Nut
5. Bolt
6. Hose
7. Bracket
8. Mounting Stud
9. Mounting Bracket
10. Bolt
11. Washer
12. Hydraulic Clutch Reservoir
13. Nut

Fig. 1, Windshield Washer Reservoir

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Replacement

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Open the hood.

NOTE: Windshield washer fluid must be collected in a container after the windshield washer hose is disconnected.

3. Disconnect the windshield washer pump electrical connector and washer hose.
4. Remove the windshield washer pump.
5. Install the windshield washer pump.
6. Connect the washer hose.

⚠ CAUTION

Do not connect the electrical connector prior to filling the windshield washer reservoir or operate the windshield washer pump prior to filling the windshield washer reservoir or damage to the pump could result.

7. Fill the windshield washer reservoir with windshield washer fluid.
8. Connect the electrical connector.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

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Wiper Control Module Replacement

NOTE: The following procedure applies to United Technologies and Signal Stat wiper systems. On the dash-mounted wiper switch systems, there is no separate wiper control module.

Replacement

1. Apply the parking brakes and chock the tires.
2. Remove the five under-steering-panel screws, then remove the panel; see **Fig. 1**.

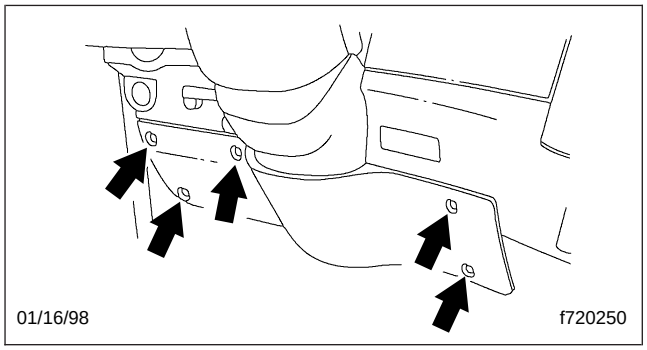
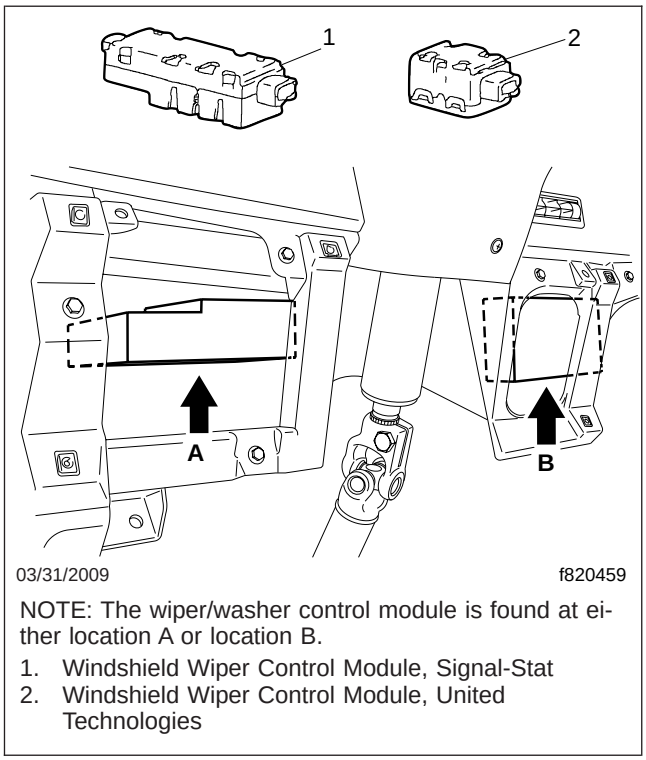


Fig. 1, Under-Steering-Panel Screws

3. Locate the wiper control module, either to the left or right of the steering column; see **Fig. 2**. Disconnect the electrical connector(s).

NOTE: United Technologies wiper control modules have one electrical connector, and Signal Stat wiper control modules have two electrical connectors.

4. Pull the wiper control module off the wiper control module mounting bracket; see **Fig. 3**.
5. Install the new wiper control module.
6. Connect the electrical connector(s).
7. Attach the under-steering panel to the dash, using the five screws; see **Fig. 1**.



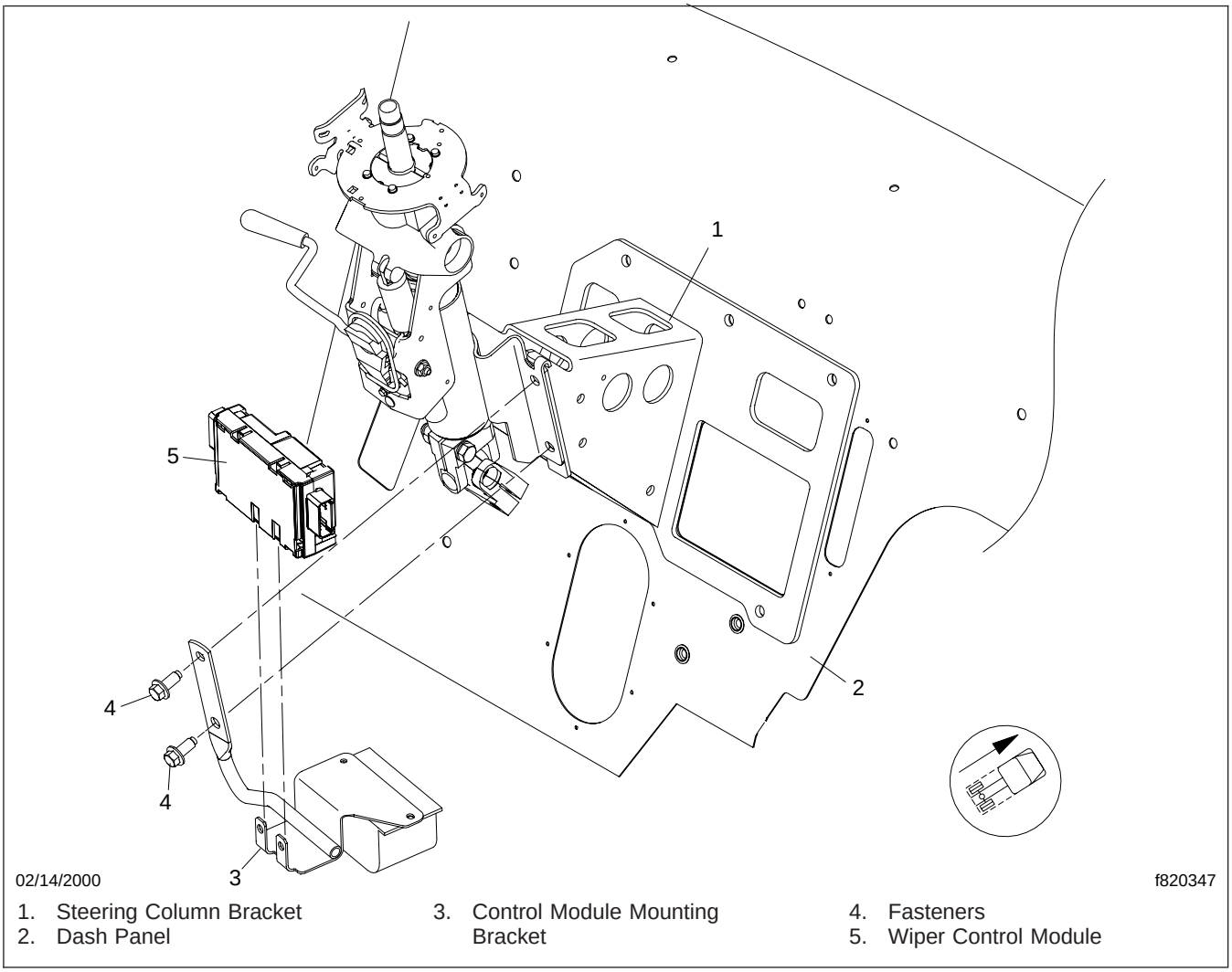
NOTE: The wiper/washer control module is found at either location A or location B.

1. Windshield Wiper Control Module, Signal-Stat
2. Windshield Wiper Control Module, United Technologies

Fig. 2, Wiper/Washer System, Control Module Location

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Wiper Control Module Replacement



1. Steering Column Bracket
2. Dash Panel
3. Control Module Mounting Bracket
4. Fasteners
5. Wiper Control Module

Fig. 3, Wiper Control Module Mounting (typical)

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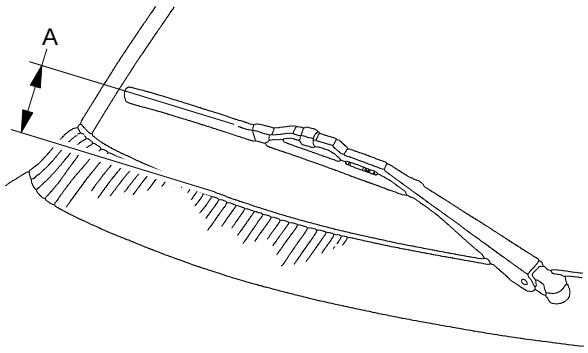
Adjustment

1. Apply the parking brakes and chock the tires.
2. Disconnect the batteries.

CAUTION

Disconnect the batteries before working on the wipers. This will prevent the windshield wiper motor from cycling. The motor could cycle if the wiper linkage driveshaft is forced out of the parked position, which could result in personal injury.

3. Cycle and park the windshield wipers.
4. Verify that the distance between the center of the right-hand windshield wiper blade and the cowl top vent panel is within 3 inches (76 mm); see **Fig. 1**.

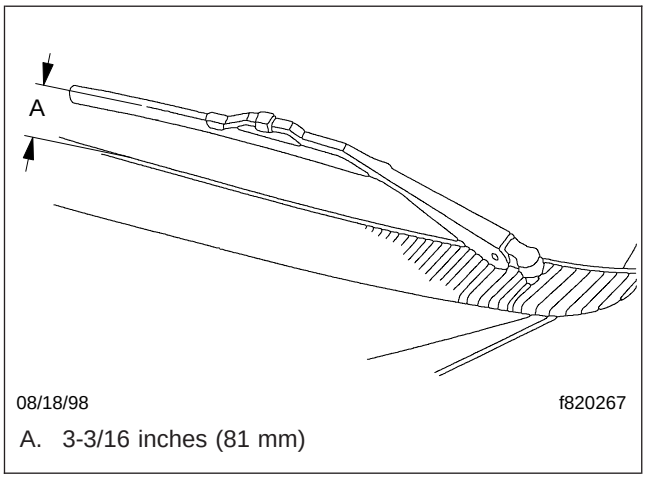


08/18/98 f820245

A. 3 inches (76 mm)

Fig. 1, Right-Hand Windshield Blade Park Dimension

5. Verify that the distance between the center of the left-hand windshield wiper blade and the cowl top vent panel is within 3-3/16 inches (81 mm); see **Fig. 2**.
6. If a windshield wiper arm is not positioned within the above specifications, remove and reposition the wiper arm; see **Subject 100**.
7. Connect the batteries.



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A. 3-3/16 inches (81 mm)

Fig. 2, Left-Hand Windshield Blade Park Dimension

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Troubleshooting, United Technologies Wiper and Washer

Troubleshooting

CAUTION

Use caution when working on or near the wiper linkage, arms, and motor. An intermittent wiper system may swipe without warning, posing a risk of personal injury.

NOTICE

Make sure the ignition switch is off before disconnecting any wiper/washer harness connectors. Removing connectors with the ignition switch on may cause electrical arcing, which will damage the pins.

Preliminary Checks

Before beginning the troubleshooting procedures, verify the driver's complaint by checking the system components, and operating the wiper and washer to duplicate the problem.

1. Check the wiper arms, blades, and linkage for wear and damage.
2. Check the washer fluid level in the reservoir.
3. Turn the ignition switch to the ON position without starting the engine.
4. Test the wipers on low speed, high speed, and several intermittent speeds.
5. Test the windshield washers.
6. Turn the ignition switch to the OFF position.
7. Check the washer hoses for leaks and damage.

Diagnostic Procedures

Symptoms

The diagnostic procedures listed in **Table 1** are described in detail in the succeeding tables. When performing the diagnostic procedures, refer to the wiring diagram (**Fig. 1**) and the tables in this subject.

NOTICE

Use caution when backprobing sealed connectors. If the seal is damaged, water could intrude into the connection, resulting in corrosion and electrical failure.

IMPORTANT: The following wiper and washer diagnostic procedures are performed with the ignition switch in the ON position, and the engine NOT running.

Troubleshooting Procedures	
Symptom	**Table Number**
Wipers are inoperative in all modes.	**Table 2**
High-speed mode only is inoperative.	**Table 3**
Low-speed and all intermittent speed modes are inoperative, high-speed mode is OK.	**Table 4**
Some intermittent setting modes are inoperative.	**Table 5**
Wipers do not park in the proper position.	**Table 6**
Wipers stay on or swipe intermittently until ignition is turned off.	**Table 7**
Washers are inoperative, wipers are OK.	**Table 8**
Washer spray does not correctly cover wipe area.	**Table 9**

Table 1, Troubleshooting Procedures

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Troubleshooting, United Technologies Wiper and Washer

Wipers Are Inoperative In All Modes			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed.	—	—
2	With the connector remaining connected, backprobe the wiper motor connector on pins 2 and 3 to measure for battery voltage; see **Table 10**. Is battery voltage present?	Yes	Make sure that the wiper linkage is not slipping or binding. Otherwise, replace the wiper motor; see **Subject 120**.
		Low or at zero	Go to **step 3**.
3	Access the wiper control module (**Fig. 2**), and backprobe pin 8 to measure the voltage, with the connector remaining connected to the module; see **Fig. 3**. Is battery voltage present?	Yes	There is a wiring fault on circuit 315L or the wiper motor ground circuit. Disconnect the power, and perform continuity testing to locate the circuit fault, then repair as appropriate.
		No	Go to **step 4**.
4	Measure the voltage on pins 2 and 11 of the wiper control module; see **Fig. 3**. Is battery voltage present on both pins, one pin (either 2 or 11), or neither pin?	Both pins	Test the wiper switch; see **Table 11**. Test the wiring from the wiper switch to the wiper control module for open or short circuits. If any of the wiper switch tests fail, replace the switch.
		One pin (either 2 or 11)	Locate the open circuit between splice S48 and the wiper control module in the circuit 315 wire that does not have voltage.
		Neither pin	Verify that fuse S in the underhood PDM is not open. Fuse S supplies the wipers in addition to F1, F2, and F3 in the dashboard PDM. Test relay R11 and circuit breaker CB4 in the dashboard PDM; see **Fig. 4**. Circuit breaker CB4 or fuse S will open if the wiper control module is internally shorted. If unplugging the wiper module allows circuit breaker CB4 to reset, then replace the wiper control module; see **Subject 150**. Otherwise, troubleshoot for wiring problems with circuit 315.
5	Turn the ignition switch to the OFF position, then test for continuity to ground at pins 3 and 5 of the wiper control module connector; see **Fig. 3**. Are both pins low resistance to ground?	Yes	Go to **step 6**.
		No	Locate and repair the open ground circuit.
6	Did all the preceding tests pass?	Yes	Replace the wiper control module; see **Subject 150**.

Table 2, Wipers Are Inoperative In All Modes

High-Speed Mode Only Is Inoperative			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to high speed.	—	—

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Troubleshooting, United Technologies Wiper and Washer

High-Speed Mode Only Is Inoperative			
Step	**Test Procedure**	**Test Result**	**Action**
2	With the connector remaining connected, backprobe the wiper motor connector on pins 1 and 3 to measure for battery voltage; see **Table 10**. Is battery voltage present?	Yes	Make sure that the wiper linkage is not slipping or binding. Otherwise, replace the wiper motor; see **Subject 120**.
		Low or at zero	Go to **step 3**.
3	Access the wiper control module (**Fig. 2**), and backprobe pin 14 to measure the voltage, with the connector remaining connected to the module; see **Fig. 3**. Is battery voltage present?	Yes	There is a wiring fault on circuit 315H. Disconnect the power, and perform continuity testing to locate the circuit fault, then repair as appropriate.
		No	Go to **step 4**.
4	Test the wiper switch. Perform the wiper switch resistance test; see **Table 11**. Check the wiring from the wiper switch to the wiper control module for open or short circuits. Did any of the wiper switch tests fail?	Yes	Replace the wiper switch.
		No	Replace the wiper control module; see **Subject 150**.

Table 3, High-Speed Mode Only Is Inoperative

Low Speed and All Intermittent Setting Modes Are Inoperative, High Speed Mode Is OK			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed.	—	—
2	With the connector remaining connected, backprobe the wiper motor connector on pins 2 and 3 to measure for battery voltage; see **Fig. 3**. Is battery voltage present?	Yes	Make sure that the wiper linkage is not slipping or binding. Otherwise, replace the wiper motor; see **Subject 120**.
		Low or at zero	Go to **step 3**.
3	Access the wiper control module (**Fig. 2**), and backprobe pin 8 to measure the voltage, with the connector remaining connected to the module; see **Fig. 3**. Is battery voltage present?	Yes	There is a wiring fault on circuit 315L. Disconnect the power, and perform continuity testing to locate the circuit fault, then repair as appropriate.
		No	Go to **step 4**.
4	Test the wiper switch. Perform the wiper switch resistance test; see **Table 11**. Check the wiring from the wiper switch to the wiper control module for open or short circuits. Did any of the wiper switch tests fail?	Yes	Replace the wiper switch.
		No	Replace the wiper control module; see **Subject 150**.

Table 4, Low Speed and All Intermittent Setting Modes Are Inoperative, High Speed Mode Is OK

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Troubleshooting, United Technologies Wiper and Washer

Some Intermittent Setting Modes Are Inoperative			
Step	**Test Procedure**	**Test Result**	**Action**
1	Test the wiper switch. Perform the wiper switch resistance test; see **Table 11**. Check the wiring from the wiper switch to the wiper control module (**Fig. 2**) for open or short circuits. Did all the tests pass?	Yes	Replace the wiper control module; see **Subject 150**.
		No	Replace the wiper switch.

Table 5, Some Intermittent Setting Modes Are Inoperative

Wipers Do Not Park in Proper Position			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed.	—	—
2	Turn the wiper switch off when the wipers are in mid-swipe. Do the wipers stop immediately, or continue traveling, then stop?	Immediately	Go to **step 3**.
		Continue traveling, then stop	Note the stopped position. Repeat the test to make sure that the wipers always stop in the same position. If the wipers always stop in the same position, regardless of where the switch was turned off, the wiper arm position is improperly adjusted. Turn the ignition switch to OFF, disconnect the batteries, then adjust the wiper arms to the correct position; see **Subject 160**.
3	With the ignition switch in the ON position, the wipers switched off, and the connector remaining connected, backprobe to measure the voltage on pin 4 of the wiper motor connector; see **Table 10**. Is battery voltage present?	Yes	Go to **step 4**.
		No	Locate and repair the open circuit on circuit 315 between the wiper motor and splice S48.
4	With the ignition in the ON position and the wipers switched to low speed, backprobe to measure the voltage on pin 5 of the wiper motor connector; see **Table 10**. Battery voltage should be present except when the wipers travel through the park position and the circuit is momentarily at ground. Is battery voltage present?	Yes	Go to **step 5**.
		No	Replace the wiper motor; see **Subject 120**.
5	With the ignition switch in the ON position and the wipers on low speed, backprobe to measure the voltage on pin 13 of the wiper control module; see **Fig. 2** and **Fig. 3**. Is battery voltage present?	Yes	Replace the wiper control module; see **Subject 150**.
		No	Locate and repair the open circuit between pin 13 and the wiper motor in circuit 315P.

Table 6, Wipers Do Not Park in Proper Position

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Troubleshooting, United Technologies Wiper and Washer

Wipers Stay On or Wipe Intermittently Until Ignition Is Turned Off			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and leave the wiper switch in the OFF position. Do the wipers remain on, swiping continuously or intermittently?	Yes	Go to **step 2**.
		No	Go to **step 3**.
2	Disconnect power, then perform the wiper switch test measuring for the resistance values shown in **Table 11**. Did any of the resistance tests fail?	Yes	Replace the wiper switch.
		No	Go to **step 3**.
3	With the ignition switch in the ON position, the wipers on low speed, and the connector remaining connected, backprobe pin 5 of the wiper motor connector to check the voltage through the wiper motor's internal park switch; see **Table 10**. When the wipers travel through the park position, pin 5 should be momentarily at ground. Most voltmeters respond quickly enough to show this momentary voltage transition. Is the momentary voltage transition to ground present?	Yes	Go to **step 4**.
		No	The wiper motor internal park switch is not working. Replace the wiper motor; see **Subject 120**.
4	With the ignition switch in the ON position, the wipers on low speed, and the connector remaining connected, backprobe pin 13 of the wiper control module; see **Fig. 2** and **Fig. 3**. Verify that the momentary voltage transition to ground is present.	Yes	Replace the wiper control module; see **Subject 150**.
		No	Locate and repair the wiring fault on circuit 315P between the wiper motor and the wiper control module.

Table 7, Wipers Stay On or Wipe Intermittently Until Ignition Is Turned Off

Washers Are Inoperative, Wipers Are OK			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed. Do the wipers work?	Yes	Turn the wipers off. Go to **step 2**.
		No	Follow the troubleshooting procedure under "Wipers Are Inoperative In All Modes"; see **Table 2**.
2	Check the washer reservoir fluid level. Add fluid if needed, then test the washer operation. Hold the washer switch on for at least 5 seconds in case the hoses are leaking, or the system has lost its prime. Is the pump running?	Yes	Check the system for leaks. Also follow the troubleshooting procedure under "Washer Spray Does Not Correctly Cover Wipe Area"; see **Table 9**.
		No	Go to **step 3**.
3	If the system is not leaking, backprobe the connections at the washer pump, and test for battery voltage when the washer switch is activated; see **Table 12**. Is battery voltage present?	Yes	Replace the washer pump; see **Subject 140**.
		No	Go to **step 4**.

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Troubleshooting, United Technologies Wiper and Washer

Washers Are Inoperative, Wipers Are OK			
Step	**Test Procedure**	**Test Result**	**Action**
4	Disconnect the wiper control module connector (**Fig. 2**), and perform a continuity test between pins 9 and 7 of the harness. When the washer switch is activated, there should be continuity. Is there continuity?	Yes	Go to **step 5**.
		No	Troubleshoot for open wiring in circuits 315D and 315C, and also for an open in the wiper switch. Replace the switch if it tests open.
5	Connect the wiper module connector, then turn the ignition switch to ON. Turn on the washers while backprobing pin 4 of the wiper control module connector; see **Fig. 3**. Is the battery voltage present?	Yes	Troubleshoot and repair a wiring fault in circuit 320 between the washer pump and the wiper control module.
		No	Replace the wiper control module; see **Subject 150**.

Table 8, Washers Are Inoperative, Wipers Are OK

Washer Spray Does Not Correctly Cover Wipe Area			
Step	**Test Procedure**	**Test Result**	**Action**
1	Make sure that the fluid level in the washer fluid reservoir is adequate. If needed, add fluid.	—	—
2	Test the washer operation. Hold the washer switch in the ON position for at least 5 seconds, in case the washer system has lost its prime. Is the fluid flow adequate?	Yes	Troubleshooting is completed.
		No	Check the nozzles for damage, plugging, or improper installation. Check the hoses for kinks, or tie-wraps that may be too tight. Make sure that there are no breaks or disconnected fittings. Go to **step 3**.
3	Test the washer operation. Does the washer work properly?	Yes	Troubleshooting is completed.
		No	Replace the washer pump; see **Subject 140**.

Table 9, Washer Spray Does Not Correctly Cover Wipe Area

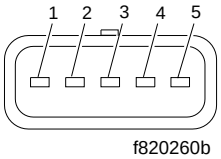
Terminal Identification of the Wiper Motor Harness Connector			
Wiper Motor Harness Connector (wire insertion view)	**Pin**	**Circuit Number**	**Circuit Description**
 f820260b	1	315H	Wiper Motor High Speed
	2	315L	Wiper Motor Low Speed
	3	GND	Ground
	4	315	Ignition Power
	5	315P	Park Switch Signal

Table 10, Terminal Identification of the Wiper Motor Harness Connector

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Troubleshooting, United Technologies Wiper and Washer

Wiper/Washer Switch Resistance Values				
Switch Position	Pins 1 to 2 (kohms)		Pins 2 to 3 (kohms)	
	Lowest	Highest	Lowest	Highest
Off	95.0	105.0	46.8	48.3
Int 1	95.0	105.0	10.86	11.54
Int 2	77.9	86.1	10.86	11.54
Int 3	64.6	71.4	10.86	11.54
Int 4	48.45	53.55	10.86	11.54
Int 5	34.2	37.8	10.86	11.54
Int 6	19.0	21.0	10.86	11.54
Int 7	3.14	3.47	10.86	11.54
Low	3.14	3.47	3.96	4.20
Hi	3.14	3.47	0.0	0.4
Wash	0.0	0.4	—	—

Table 11, Wiper/Washer Switch Resistance Values

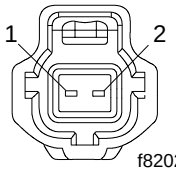
Terminal Identification of the Washer Pump Connector				
Washer Pump Connector	Terminal	Circuit Number	Color	Circuit Description
	1	320	Dark Blue	Washer Power
	2	GND	Black	Washer Ground

Table 12, Terminal Identification of the Washer Pump Connector

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Troubleshooting, United Technologies Wiper and Washer

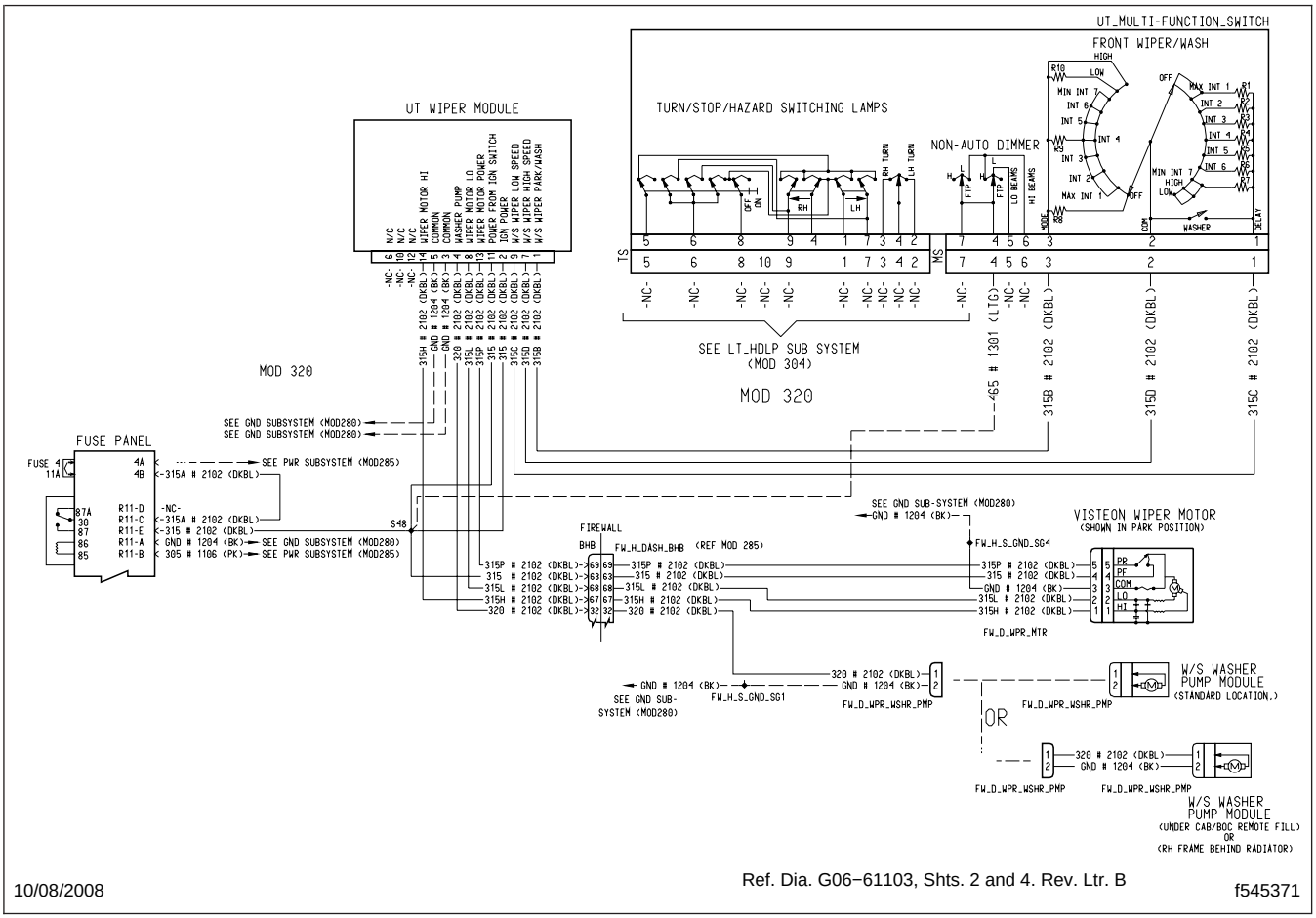
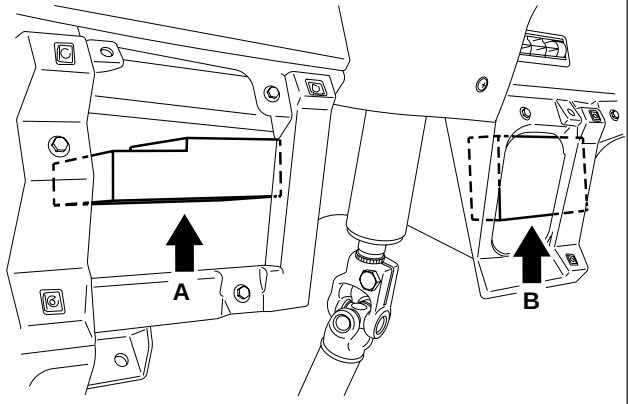


Fig. 1, Wiper/Washer With United Technologies Switch Wiring



NOTE: The wiper control module is found at either location A or location B.

Fig. 2, Wiper Control Module Location

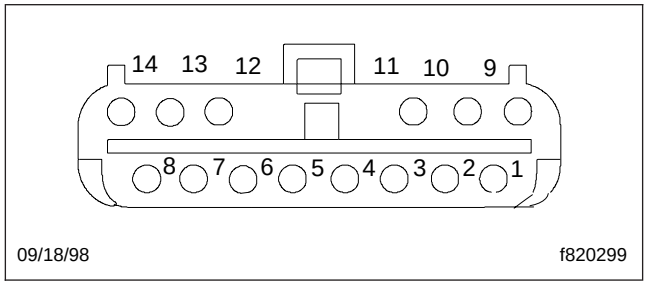
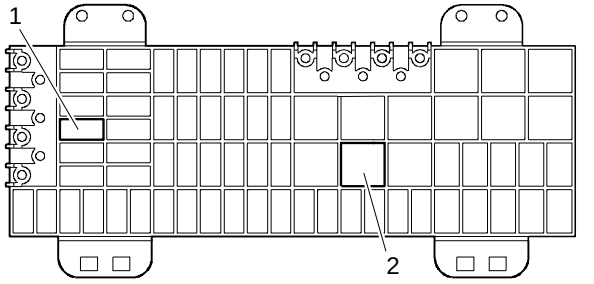


Fig. 3, Wiper Control Module Connector

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Troubleshooting, United Technologies Wiper and Washer



1. CB4, Wiper/Washer Power
2. R11, Wiper/Washer Power

Fig. 4, Power Distribution Module (PDM), Instrument Panel

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Troubleshooting

CAUTION

Use caution when working on or near the wiper linkage, arms, and motor. An intermittent wiper system may swipe without warning, posing a risk of personal injury.

NOTICE

Make sure the ignition switch is off before disconnecting any wiper/washer harness connectors. Removing connectors with the ignition switch on may cause electrical arcing, which will damage the pins.

Preliminary Checks

Before beginning the troubleshooting procedures, verify the driver's complaint by checking the system components, and operating the wiper and washer to duplicate the problem.

1. Check the wiper arms, blades, and linkage for wear and damage.
2. Check the washer fluid level in the reservoir.
3. Turn the ignition switch to the ON position without starting the engine.
4. Test the wipers on low speed, high speed, and several intermittent speeds.
5. Test the windshield washers.
6. Turn the ignition switch to the OFF position.
7. Check the washer hoses for leaks and damage.

Diagnostic Procedures

Symptoms

The diagnostic procedures listed in **Table 1** are described in detail in the succeeding tables. When performing the diagnostic procedures, refer to the applicable wiring diagram (**Fig. 1** for vehicles built from November 2001, or **Fig. 2** for vehicles built before November 2001) and the tables in this subject.

NOTICE

Use caution when backprobing sealed connectors. If the seal is damaged, water could intrude into the connection, resulting in corrosion and electrical failure.

IMPORTANT: The following wiper and washer diagnostic procedures are performed with the ignition switch in the ON position, and the engine NOT running.

Troubleshooting Procedures	
Symptom	**Table Number**
Wipers are inoperative in all modes.	**Table 2**
High-speed mode only is inoperative.	**Table 3**
Low-speed and all intermittent speed modes are inoperative, high-speed mode is OK.	**Table 4**
Some intermittent setting modes are inoperative.	**Table 5**
Wipers do not park in the proper position.	**Table 6**
Wipers stay on or swipe intermittently until ignition is turned off.	**Table 7**
Washers are inoperative, wipers are OK.	**Table 8**
Washer spray does not correctly cover wipe area.	**Table 9**

Table 1, Troubleshooting Procedures

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Troubleshooting, Signal Stat Wiper and Washer

NOTE: When working on vehicles built before November 2001, use the circuit numbers referenced in parenthesis in the troubleshooting tables.

Wipers Are Inoperative In All Modes			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed.	—	—
2	With the connector remaining connected, backprobe the wiper motor connector on pins 2 and 3 to measure for battery voltage; see **Table 10**. Is battery voltage present?	Yes	Make sure that the wiper linkage is not slipping or binding. Otherwise, replace the wiper motor; see **Subject 120**.
		Low or at zero	Go to **step 3**.
3	Access the wiper control module (**Fig. 3**), and backprobe pin 9 of the vehicle harness connector to measure the voltage, with the connector remaining connected to the module; see **Fig. 4**. Is battery voltage present?	Yes	There is a wiring fault on circuit 315L (58) or the wiper motor ground circuit. Disconnect the power, and perform continuity testing to locate the circuit fault, then repair as appropriate.
		No	Go to **step 4**.
4	Measure the voltage on pins 4 and 11 of the vehicle harness connector; see **Fig. 4**. Is battery voltage present on both pins, one pin (either 4 or 11), or neither pin?	Both pins	Test the wiper switch. Perform the wiper switch continuity test; see **Table 11**. Test the wiring from the wiper switch to the wiper control module for open or short circuits. If any of the wiper switch tests fail, replace the switch.
		One pin (either 4 or 11)	**Vehicles built from November 2001:** Locate and repair the open circuit between splice S4 and the wiper control module in the circuit 315/465 wire that does not have voltage. **Vehicles built before November 2001:** If battery voltage is present on pin 11, and not pin 4, test fuse F36 and circuit 575 for wiring faults. If battery voltage is present on pin 4, and not pin 11, test relay R11 and circuit breaker CB4 in the dashboard PDM (**Fig. 5**), in addition to testing for wiring faults in the relay ground circuit and circuit 65.
		Neither pin	Verify that fuse S in the underhood PDM is not open. Fuse S supplies the wipers in addition to F1, F2, and F3 in the dashboard PDM. Test for shorts in the circuits powered through these fuses, in addition to shorts to the wipers, if fuse S is open. Test relay 11 and circuit breaker CB4 in the dashboard PDM; see **Fig. 5**. Circuit breaker CB4 or fuse S will open if the wiper control module is internally shorted. If unplugging the wiper module allows circuit breaker CB4 to reset, then replace the wiper control module; see **Subject 150**.

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Troubleshooting, Signal Stat Wiper and Washer

Wipers Are Inoperative In All Modes			
Step	**Test Procedure**	**Test Result**	**Action**
5	Turn the ignition switch to the OFF position, then test for continuity to ground at pin 6 of the wiper module vehicle harness connector; see **Fig. 4**. Is the pin low resistance to ground?	Yes	Go to **step 6**.
		No	Locate and repair the open ground circuit.
6	Did all the preceding tests pass?	Yes	Replace the wiper control module; see **Subject 150**.

Table 2, Wipers Are Inoperative In All Modes

High-Speed Mode Only Is Inoperative			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to high speed.	—	—
2	With the connector remaining connected, backprobe the wiper motor connector on pins 1 and 3 to measure for battery voltage; see **Table 10**. Is battery voltage present?	Yes	Make sure that the wiper linkage is not slipping or binding. Otherwise, replace the wiper motor; see **Subject 120**.
		Low or at zero	Go to **step 3**.
3	Access the wiper control module (**Fig. 3**), and backprobe pin 5 on the vehicle harness connector to measure the voltage, with the connector remaining connected to the module; see **Fig. 4**. Is battery voltage present?	Yes	There is a wiring fault on circuit 315H (56). Disconnect the power, and perform continuity testing to locate the circuit fault, then repair as appropriate.
		No	Go to **step 4**.
4	Test the wiper switch. Perform the wiper switch continuity test; see **Table 11**. Check the wiring from the wiper switch to the wiper control module for open or short circuits. Did any of the wiper switch tests fail?	Yes	Replace the wiper switch.
		No	Replace the wiper control module; see **Subject 150**.

Table 3, High-Speed Mode Only Is Inoperative

Low Speed and All Intermittent Setting Modes Are Inoperative, High Speed Mode Is OK			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed.	—	—
2	With the connector remaining connected, backprobe the wiper motor connector on pins 2 and 3 to measure for battery voltage; see **Table 10**. Is battery voltage present?	Yes	Make sure that the wiper linkage is not slipping or binding. Otherwise, replace the wiper motor; see **Subject 120**.
		Low or at zero	Go to **step 3**.

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Troubleshooting, Signal Stat Wiper and Washer

Low Speed and All Intermittent Setting Modes Are Inoperative, High Speed Mode Is OK			
Step	**Test Procedure**	**Test Result**	**Action**
3	Access the wiper control module (**Fig. 3**), and backprobe pin 9 on the vehicle harness connector to measure the voltage, with the connector remaining connected to the module; see **Fig. 4**. Is battery voltage present?	Yes	There is a wiring fault on circuit 315L (58). Disconnect the power, and perform continuity testing to locate the circuit fault, then repair as appropriate.
		No	Go to **step 4**.
4	Test the wiper switch. Perform the wiper switch continuity test; see **Table 11**. Check the wiring from the wiper switch to the wiper control module for open or short circuits. Did any of the wiper switch tests fail?	Yes	Replace the wiper switch.
		No	Replace the wiper control module; see **Subject 150**.

Table 4, Low Speed and All Intermittent Setting Modes Are Inoperative, High Speed Mode Is OK

Some Intermittent Setting Modes Are Inoperative			
Step	**Test Procedure**	**Test Result**	**Action**
1	Test the wiper switch. Perform the wiper switch continuity test; see **Table 11**. Check the wiring from the wiper switch to the wiper control module (**Fig. 3**) for open or short circuits. Did all the tests pass?	Yes	Replace the wiper control module; see **Subject 150**.
		No	Replace the wiper switch.

Table 5, Some Intermittent Setting Modes Are Inoperative

Wipers Do Not Park in Proper Position			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed.	—	—
2	Turn the wiper switch off when the wipers are in mid-swipe. Do the wipers stop immediately, or continue traveling, then stop?	Immediately	Go to **step 3**.
		Continue traveling, then stop	Note the stopped position. Repeat the test to make sure that the wipers always stop in the same position. If the wipers always stop in the same position, regardless of where the switch was turned off, the wiper arm position is improperly adjusted. Turn the ignition switch to OFF, disconnect the batteries, then adjust the wiper arms to the correct position; see **Subject 160**.
3	With the ignition switch in the ON position, the wipers switched off, and the connector remaining connected, backprobe to measure the voltage on pin 4 of the wiper motor connector; see **Table 10**. Is battery voltage present?	Yes	Go to **step 4**.
		No	Locate and repair the open circuit on circuit 315 (65) between the wiper motor and the splice.

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Wipers Do Not Park in Proper Position			
Step	**Test Procedure**	**Test Result**	**Action**
4	With the ignition in the ON position and the wipers switched to low speed, backprobe to measure the voltage on pin 5 of the wiper motor connector; see **Table 10**. Battery voltage should be present except when the wipers travel through the park position and the circuit is momentarily at ground. Is battery voltage present?	Yes	Go to **step 5**.
		No	Replace the wiper motor; see **Subject 120**.
5	With the ignition switch in the ON position and the wipers on low speed, backprobe to measure the voltage on pin 10 of the vehicle harness connector at the wiper control module; see **Fig. 3** and **Fig. 4**. Is battery voltage present?	Yes	Replace the wiper control module; see **Subject 150**.
		No	Locate and repair the open circuit between pin 10 and the wiper motor in circuit 315P (28).

Table 6, Wipers Do Not Park in Proper Position

Wipers Stay On or Wipe Intermittently Until Ignition Is Turned Off			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and leave the wiper switch in the OFF position. Do the wipers remain on, swiping continuously or intermittently?	Yes	Go to **step 2**.
		No	Go to **step 3**.
2	Disconnect power, then perform the wiper switch test measuring for continuity as shown in **Table 11**. Did any of the tests fail?	Yes	Replace the wiper switch.
		No	Go to **step 3**.
3	With the ignition switch in the ON position, the wipers on low speed, and the connector remaining connected, backprobe pin 5 of the wiper motor connector to check the voltage through the wiper motor's internal park switch; see **Table 10**. When the wipers travel through the park position, pin 5 should be momentarily at ground. Most voltmeters respond quickly enough to show this momentary voltage transition. Is the momentary voltage transition to ground present?	Yes	Go to **step 4**.
		No	The wiper motor internal park switch is not working. Replace the wiper motor; see **Subject 120**.
4	With the ignition switch in the ON position, and the wipers on low speed, backprobe pin 10 of the vehicle harness connector at the wiper control module; see **Fig. 3** and **Fig. 4**. Verify that the momentary voltage transition to ground is present.	Yes	Replace the wiper control module; see **Subject 150**.
		No	Locate and repair the wiring fault on circuit 315P (28) between the wiper motor and the wiper control module.

Table 7, Wipers Stay On or Wipe Intermittently Until Ignition Is Turned Off

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Troubleshooting, Signal Stat Wiper and Washer

Washers Are Inoperative, Wipers Are OK			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed. Do the wipers work?	Yes	Turn the wipers off. Go to **step 2**.
		No	Follow the troubleshooting procedure under "Wipers Are Inoperative In All Modes"; see **Table 2**.
2	Check the washer reservoir fluid level. Add fluid if needed, then test the washer operation. Hold the washer switch on for at least 5 seconds in case the hoses are leaking, or the system has lost its prime. Is the pump running?	Yes	Check the system for leaks. Also follow the troubleshooting procedure under "Washer Spray Does Not Correctly Cover Wipe Area"; see **Table 9**.
		No	Go to **step 3**.
3	If the system is not leaking, backprobe the connections at the washer pump, and test for battery voltage when the washer switch is activated; see **Table 12**. Is battery voltage present?	Yes	Replace the washer pump; see **Subject 140**.
		No	Go to **step 4**.
4	Disconnect the wiper switch, and perform a continuity test between pins 1 and 6 of the switch harness connector. When the washer switch is activated, there should be continuity. Is there continuity?	Yes	Go to **step 5**.
		No	Troubleshoot for open wiring between the wiper control module (**Fig. 3**) and the wiper switch, and also for an open in the switch. Replace the switch if it tests open.
5	Connect the wiper switch, then turn the ignition switch to ON. Turn on the washers while backprobing pin 8 of the vehicle harness connector at the wiper control module connector; see **Fig. 3** and **Fig. 4**. Is the battery voltage present?	Yes	Troubleshoot and repair a wiring fault in circuit 320 (941) between the washer pump and the wiper control module.
		No	Replace the wiper control module; see **Subject 150**.

Table 8, Washers Are Inoperative, Wipers Are OK

Washer Spray Does Not Correctly Cover Wipe Area			
Step	**Test Procedure**	**Test Result**	**Action**
1	Make sure that the fluid level in the washer fluid reservoir is adequate. If needed, add fluid.	—	—
2	Test the washer operation. Hold the washer switch in the ON position for at least 5 seconds, in case the washer system has lost its prime. Is the fluid flow adequate?	Yes	Troubleshooting is completed.
		No	Check the nozzles for damage, plugging, or improper installation. Check the hoses for kinks, or tie-wraps that may be too tight. Make sure that there are no breaks or disconnected fittings. Go to **step 3**.
3	Test the washer operation. Does the washer work properly?	Yes	Troubleshooting is completed.
		No	Replace the washer pump; see **Subject 140**.

Table 9, Washer Spray Does Not Correctly Cover Wipe Area

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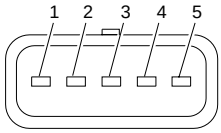
Terminal Identification of the Wiper Motor Harness Connector			
Wiper Motor Harness Connector (wire insertion view)	**Pin**	**Circuit Number**	**Circuit Description**
 f820260b	*Vehicles Built Before February 2001*		
	1	56	Wiper Motor High Speed
	2	58	Wiper Motor Low Speed
	3	57	Ground
	4	65	Ignition Power
	5	26	Park Switch Signal
	Vehicles Built From February 2001		
	1	315H	Wiper Motor High Speed
	2	315L	Wiper Motor Low Speed
	3	GND	Ground
	4	315	Ignition Power
	5	315P	Park Switch Signal

Table 10, Terminal Identification of the Wiper Motor Harness Connector

Values for Wiper Switch Positions Test*			
Switch Position	**Pin 6 to 7**	**Pin 6 to 8**	**Pin 6 to 14**
Off	1	1	1
Delay 1	1	1	0
Delay 2	1	0	1
Delay 3	1	0	0
Delay 4	0	1	1
Delay 5	0	1	0
Low Speed	0	0	1
High Speed	0	0	0

* Test for continuity betweens pin 6 and pins 7, 8, and 14. In the table, 1 indicates continuity, and 0 indicates an open circuit. When the measured resistance is less than 0.4 kohms, the continuity test passes. Replace the switch assembly if the test fails for any of the switch positions.

Table 11, Values for Wiper Switch Positions Test

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Troubleshooting, Signal Stat Wiper and Washer

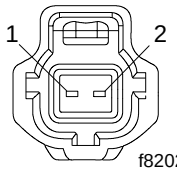
Terminal Identification of the Washer Pump Connector				
Washer Pump Connector	Terminal	Circuit Number	Color	Circuit Description
	*Vehicles Built Before November 2001*			
	1	941	Black/White	Washer Power
	2	57	Black	Washer Ground
	Vehicles Built From November 2001			
	1	320	Dark Blue	Washer Power
	2	GND	Black	Washer Ground

Table 12, Terminal Identification of the Washer Pump Connector

Terminal Identification of the Vehicle Harness Connector (see Fig. 4, Ref. D)		
Pin*	Circuit Number	Circuit Function
Vehicles Built From February 2001		
4	465	Battery Power 12V+ Module Supply
5	315H	High Speed to Wiper Motor 12V+
6	GND	Module Ground
8	320	Washer Pump 12V+
9	315L	Low Speed to Wiper Motor 12V+
10	315P	Park Switch Signal from Wiper Motor
11	315	Park Switch and Module 12V+ Supply
Vehicles Built Before February 2001		
4	575	Battery Power 12V+ Module Supply
5	56	High Speed to Wiper Motor 12V+
6	25	Module Ground
8	941	Washer Pump 12V+
9	58	Low Speed to Wiper Motor 12V+
10	28	Park Switch Signal from Wiper Motor
11	65	Park Switch and Module 12V+ Supply

* Pin numbers not listed are not used.

Table 13, Terminal Identification of the Vehicle Harness Connector

Terminal Identification of the Wiper Switch Connector (see Fig. 4, Ref. E)		
Pin*	Color	Circuit Function
1	Blue	Washer
6	White	Ground
7	Brown	Code C
8	Red	Code B

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Terminal Identification of the Wiper Switch Connector (see Fig. 4, Ref. E)		
Pin*	**Color**	**Circuit Function**
14	Green	Code A

* Pin numbers not listed are not used.

Table 14, Terminal Identification of the Wiper Switch Connector

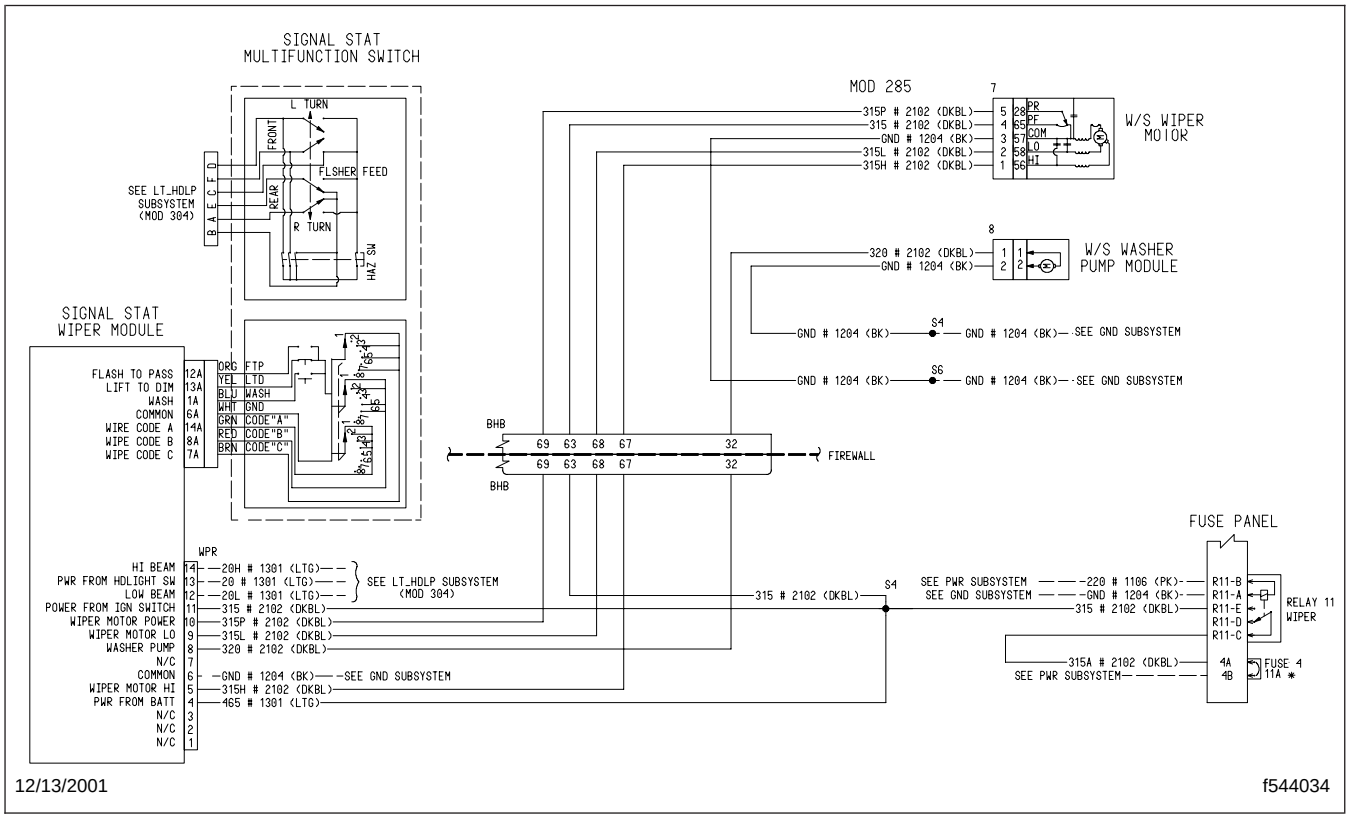


Fig. 1, Signal Stat Wiper/Washer Wiring Diagram, Vehicles Built From November 2001

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Troubleshooting, Signal Stat Wiper and Washer

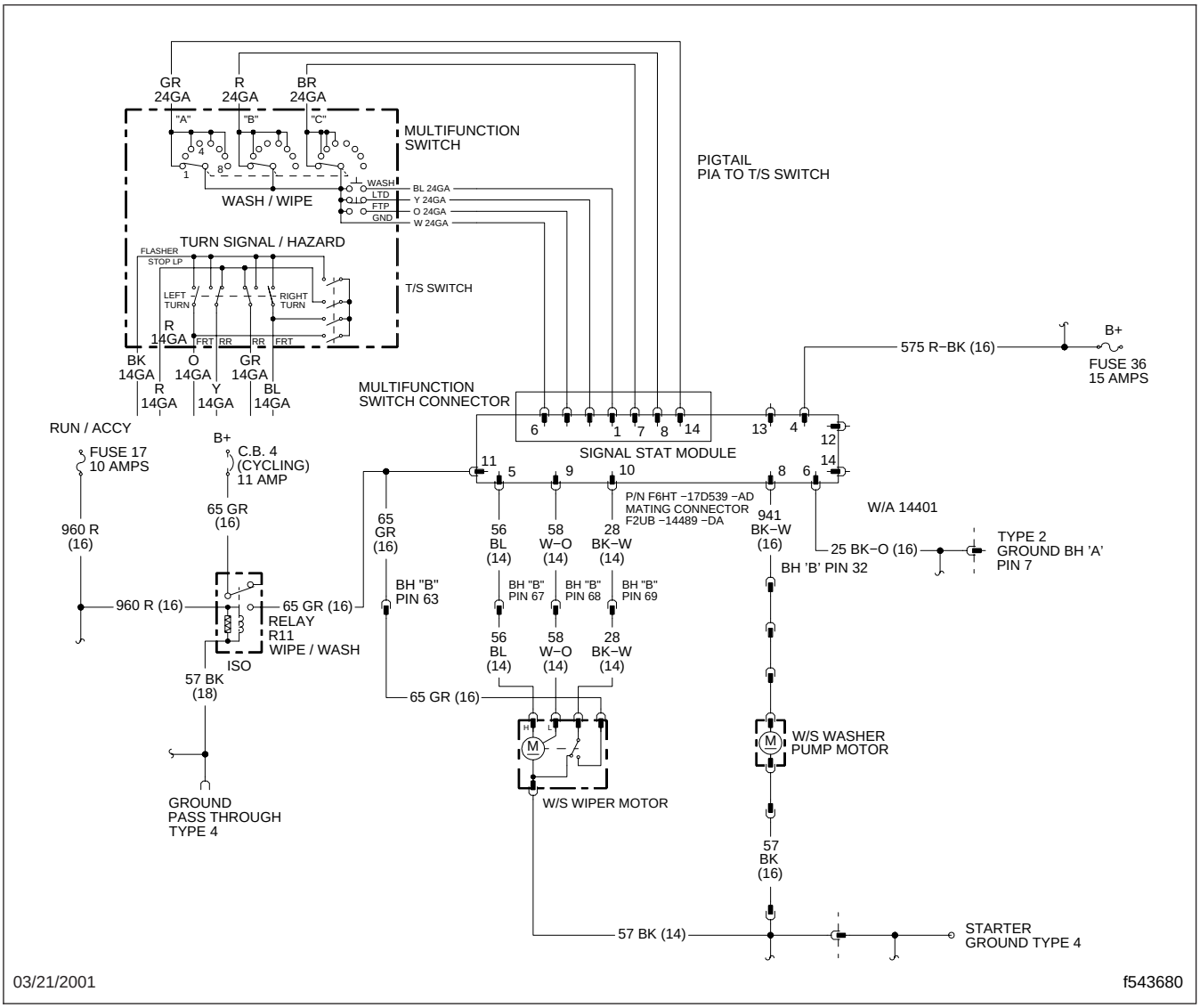
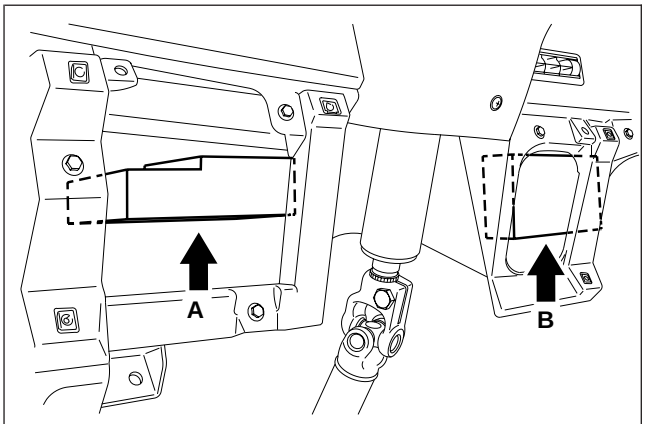


Fig. 2, Signal Stat Wiper/Washer Wiring Diagram, Vehicles Built Before November 2001

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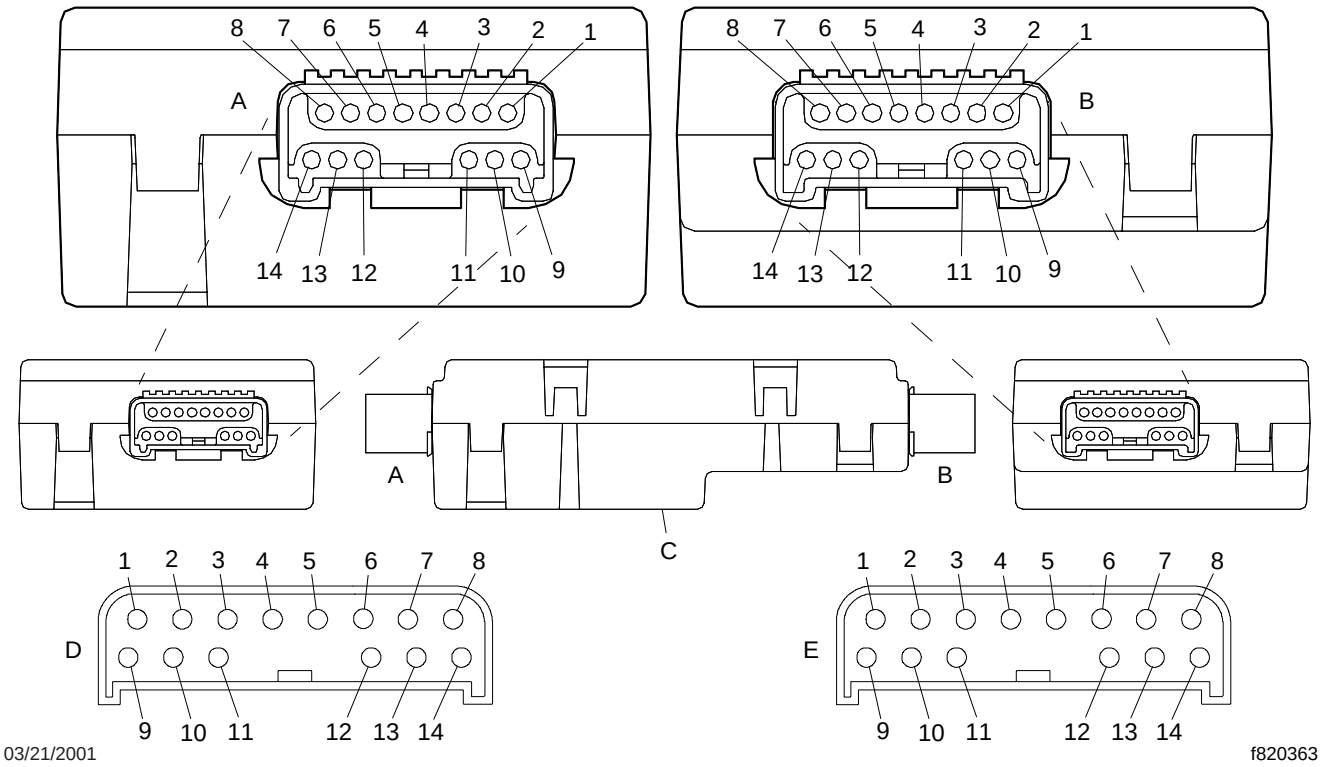


NOTE: The wiper control module is found at either location A or location B.

Fig. 3, Wiper Control Module Location

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Troubleshooting, Signal Stat Wiper and Washer

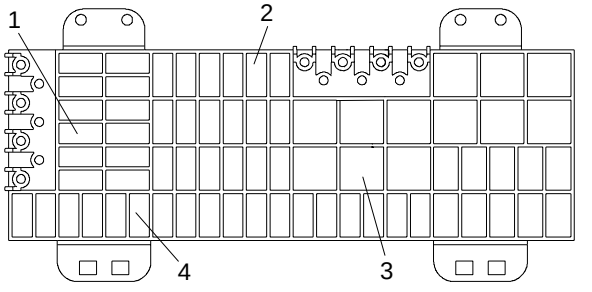


NOTE: For terminal identification of the vehicle harness connector to and from the vehicle, items A and D, see **Table 13**. For terminal identification of the connector to and from the multifunction wiper control switch, items B and E, see **Table 14**.

A. Port A of Control Module, To and From the Vehicle
B. Port B of Control Module, To and From the Wiper Control Switch
C. Signal Stat Control Module
D. Vehicle Harness Connector To and From the Vehicle
E. Connector To and From the Multifunction Wiper Control Switch

Fig. 4, Signal Stat Control Module and Mating Connectors

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1. CB4, Wiper/Washer Power
2. Fuse 17, Wiper/Washer Relay Ignition Switched Power
3. R11, Wiper/Washer Power
4. Fuse 36, Wiper/Washer Power

Fig. 5, Power Distribution Module (PDM), Instrument Panel

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Troubleshooting, Wiper System with Dash-Mounted Switch

Troubleshooting

CAUTION

Use caution when working on or near the wiper linkage, arms, and motor. An intermittent wiper system may swipe without warning, posing a risk of personal injury.

NOTICE

Make sure the ignition switch is off before disconnecting any wiper/washer harness connectors. Removing connectors with the ignition switch on may cause electrical arcing, which will damage the pins.

Preliminary Checks

Before beginning the troubleshooting procedures, verify the driver's complaint by checking the system components, and operating the wiper and washer to duplicate the problem.

1. Check the wiper arms, blades, and linkage for wear and damage.
2. Check the washer fluid level in the reservoir.
3. Turn the ignition switch to the ON position without starting the engine.
4. Test the wipers on low speed, high speed, and several intermittent speeds.
5. Test the windshield washers.
6. Turn the ignition switch to the OFF position.
7. Check the washer hoses for leaks and damage.

Diagnostic Procedures

Symptoms

The diagnostic procedures listed in **Table 1** are described in detail in the succeeding tables. When performing the diagnostic procedures, refer to the wiring diagram (**Fig. 1**) and the tables in this subject.

NOTICE

Use caution when backprobing sealed connectors. If the seal is damaged, water could intrude into the connection, resulting in corrosion and electrical failure.

IMPORTANT: The following wiper and washer diagnostic procedures are performed with the ignition switch in the ON position, and the engine NOT running.

Troubleshooting Procedures	
Symptom	**Table Number**
Wipers are inoperative in all modes.	**Table 2**
High-speed mode only is inoperative.	**Table 3**
Low-speed and all intermittent speed modes are inoperative, high-speed mode is OK.	**Table 4**
Wipers do not park in the proper position.	**Table 5**
Wipers stay on until ignition is turned off.	**Table 6**
Washers are inoperative.	**Table 7**
Washer spray does not correctly cover wipe area.	**Table 8**

Table 1, Troubleshooting Procedures

Wipers Are Inoperative In All Modes			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed.	—	—

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Troubleshooting, Wiper System with Dash-Mounted Switch

Wipers Are Inoperative In All Modes			
Step	**Test Procedure**	**Test Result**	**Action**
2	With the connector remaining connected, backprobe the wiper motor connector on pins 2 and 3 to measure for battery voltage; see **Table 9**. Is battery voltage present?	Yes	Make sure that the wiper linkage is not slipping or binding. Otherwise, replace the wiper motor; see **Subject 120**.
		Low or at zero	Go to **step 3**.
3	Verify that pin 3 of the wiper motor connector is at ground potential; see **Table 9**. Is pin 3 at ground potential?	Yes	Go to **step 4**.
		No	Troubleshoot and repair the wiring fault in the ground circuit.
4	Access the wiper switch (**Fig. 2**) connector, and backprobe pin 1 to measure the voltage, with the connector remaining connected to the module; see **Table 10**. Is battery voltage present on pin 1?	Yes	Go to **step 5**.
		Low or at zero	Verify that fuse S in the underhood PDM is not open. Fuse S supplies the wipers in addition to F1, F2, and F3 in the dashboard PDM. Test for shorts in the circuits powered through these fuses, in addition to shorts to the wipers in circuits 315 and 315A, if fuse S is open. Test relay R11 and circuit breaker CB4 in the dashboard PDM; see **Fig. 3**. Circuit breaker CB4 or fuse S will open if the wiper switch is internally shorted. If unplugging the wiper switch allows circuit breaker CB4 to reset, then replace the wiper switch.
5	Test for ground at pin 6 of the wiper switch connector; see **Table 10**. Is ground present?	Yes	Go to **step 6**.
		No	Locate and repair the wiring fault in the ground circuit.
6	With the ignition set to the ON position and the wipers switched to low speed, measure the voltage on pin 3 of the wiper switch connector. Is the measured voltage at or within a few tenths of a volt to ground?	Yes	Test for an open circuit through the speed switching relays R24 and R25. Troubleshoot circuits 315, 315H, and 315L from the PDM to the wiper motor for wiring faults.
		No	Replace the wiper switch.

Table 2, Wipers Are Inoperative In All Modes

High-Speed Mode Only Is Inoperative			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to high speed.	—	—
2	With the connector remaining connected, backprobe the wiper motor connector on pins 1 and 3 to measure for battery voltage; see **Table 9**. Is battery voltage present?	Yes	Make sure that the wiper linkage is not slipping or binding. Otherwise, replace the wiper motor; see **Subject 120**.
		Low or at zero	Go to **step 3**.

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Troubleshooting, Wiper System with Dash-Mounted Switch

High-Speed Mode Only Is Inoperative			
Step	**Test Procedure**	**Test Result**	**Action**
3	Access the wiper switch (**Fig. 2**) connector, and backprobe pin 4 to measure the voltage, with the connector remaining connected to the module, the ignition switch in the ON position, and the wipers set to high speed; see **Table 10**. Is the measured voltage at or within a few tenths of a volt to ground?	Yes	Test for an open circuit through relay R25 and its interconnecting wiring, including circuit 315H from the PDM to the wiper motor.
		No	Replace the wiper switch.

Table 3, High-Speed Mode Only Is Inoperative

Low Speed and All Intermittent Setting Modes Are Inoperative, High Speed Mode Is OK			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed.	—	—
2	With the connector remaining connected, backprobe the wiper motor connector on pins 2 and 3 to measure for battery voltage; see **Table 9**. Is battery voltage present?	Yes	Make sure that the wiper linkage is not slipping or binding. Otherwise, replace the wiper motor; see **Subject 120**.
		Low or at zero	Go to **step 3**.
3	Verify the ground at pin 3 of the wiper motor connector. Is it at ground potential?	Yes	Go to **step 4**.
		No	Repair the ground circuit 320.
4	With the wiper switch (**Fig. 2**) remaining connected to the connector, the ignition switch in the ON position, and the wipers set to low speed, backprobe the wiper switch connector on pin 3 to measure for battery voltage; see **Table 10**. Is the measured voltage at or within a few tenths of a volt to ground?	Yes	Test for an open circuit through the speed switching relays R24 and R25, and the interconnected wiring. Troubleshoot circuit 315L from the PDM to the wiper motor. Make sure that circuit 316 is at ground potential at both the wiper switch and at relay R24.
		No	Replace the wiper switch.

Table 4, Low Speed and All Intermittent Setting Modes Are Inoperative, High Speed Mode Is OK

Wipers Do Not Park in Proper Position			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed.	—	—

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Troubleshooting, Wiper System with Dash-Mounted Switch

Wipers Do Not Park in Proper Position			
Step	**Test Procedure**	**Test Result**	**Action**
2	Turn the wiper switch off when the wipers are in mid-swipe. Do the wipers stop immediately, or continue traveling, then stop?	Immediately	Go to **step 3**.
		Continue traveling, then stop	Note the stopped position. Repeat the test to make sure that the wipers always stop in the same position. If the wipers always stop in the same position, regardless of where the switch was turned off, the wiper arm position is improperly adjusted. Turn the ignition switch to OFF, disconnect the batteries, then adjust the wiper arms to the correct position; see **Subject 160**.
3	With the ignition switch in the ON position and the wipers switched off, measure the voltage on pin 4 of the wiper motor connector; see **Table 9**. Is battery voltage present?	Yes	Go to **step 4**.
		No	Locate and repair the open circuit on circuit 315 between the wiper motor and splice S48.
4	With the ignition in the ON position and the wipers switched to low speed, measure the voltage on pin 5 of the wiper motor connector; see **Table 9**. Battery voltage should be present except when the wipers travel through the park position and the circuit is momentarily at ground. Is battery voltage present?	Yes	Go to **step 5**.
		No	Replace the wiper motor; see **Subject 120**.
5	With the wipers switched on, measure the voltage at terminal 87A of relay R24; see **Fig. 3**. Is battery voltage present?	Yes	Test for an open R24 relay.
		No	Locate and repair the open circuit between relay R24 and the wiper motor in circuit 315P.

Table 5, Wipers Do Not Park in Proper Position

Wipers Stay On Until Ignition Is Turned Off			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position. Leave the wiper switch in the OFF position. Do the wipers stay on at high speed or low speed?	High speed	Troubleshoot for circuit 318 shorted to ground, and for relay R25 shorted between terminals 87 and 30.
		Low speed	Go to **step 2**.
2	Backprobe pin 5 of the wiper motor connector to check the voltage through the wiper motor's internal park switch; see **Table 9**. When the wipers travel through the park position, pin 5 should be momentarily at ground. Most voltmeters respond quickly enough to show this momentary voltage transition. Is the momentary voltage transition to ground present?	Yes	Troubleshoot and repair for circuit 316 shorted to ground, and for relay R24 shorted between terminals 87 and 30.
		No	The wiper motor internal park switch is not working. Replace the wiper motor; see **Subject 120**.

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Troubleshooting, Wiper System with Dash-Mounted Switch

Wipers Stay On Until Ignition Is Turned Off			
Step	**Test Procedure**	**Test Result**	**Action**
3	Did all the preceding tests pass?	Yes	Replace the wiper switch.

Table 6, Wipers Stay On Until Ignition Is Turned Off

Washers Are Inoperative			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition switch to the ON position, and the wiper switch to low speed. Do the wipers work?	Yes	Turn the wipers off. Go to **step 2**.
		No	Follow the troubleshooting procedure under "Wipers Are Inoperative In All Modes"; see **Table 2**.
2	Check the washer reservoir fluid level. Add fluid if needed, then test the washer operation. Hold the washer switch on for at least 5 seconds in case the hoses are leaking, or the system has lost its prime. Is the pump running?	Yes	Check the system for leaks. Also follow the troubleshooting procedure under "Washer Spray Does Not Correctly Cover Wipe Area"; see **Table 8**.
		No	Go to **step 3**.
3	If the system is not leaking, backprobe the connections at the washer pump, and test for battery voltage when the washer switch is activated. Is battery voltage present?	Yes	Replace the washer pump; see **Subject 140**.
		No	Go to **step 4**.
4	With the wiper switch (**Fig. 2**) remaining connected to the connector, and the ignition switch in the ON position, backprobe pin 5 of the wiper switch to measure for battery voltage; see **Table 10**. When the washers are activated, is the measured voltage at or within a few tenths of a volt to ground?	Yes	Troubleshoot for a fault in circuit 320 or with relay R20 and its wiring. Also troubleshoot for a fault in the ground circuit between the washer pump and the ground stud.
		No	Replace the wiper switch.

Table 7, Washers Are Inoperative

Washer Spray Does Not Correctly Cover Wipe Area			
Step	**Test Procedure**	**Test Result**	**Action**
1	Make sure that the fluid level in the washer fluid reservoir is adequate. If needed, add fluid.	—	—
2	Test the washer operation. Hold the washer switch in the ON position for at least 5 seconds, in case the washer system has lost its prime. Is the fluid flow adequate?	Yes	Troubleshooting is completed.
		No	Check the nozzles for damage, plugging, or improper installation. Check the hoses for kinks, or tie-wraps that may be too tight. Make sure that there are no breaks or disconnected fittings. Go to **step 3**.

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Troubleshooting, Wiper System with Dash-Mounted Switch

Washer Spray Does Not Correctly Cover Wipe Area			
Step	**Test Procedure**	**Test Result**	**Action**
3	Test the washer operation.	Yes	Troubleshooting is completed.
	Does the washer work properly?	No	Replace the washer pump; see **Subject 140**.

Table 8, Washer Spray Does Not Correctly Cover Wipe Area

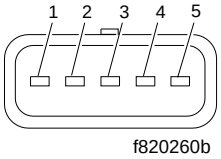
Terminal Identification of the Wiper Motor Harness Connector			
Wiper Motor Harness Connector (wire insertion view)	**Pin**	**Circuit Number**	**Circuit Description**
 f820260b	1	315H	Wiper Motor High Speed
	2	315L	Wiper Motor Low Speed
	3	GND	Ground
	4	315	Ignition Power
	5	315P	Park Switch Signal

Table 9, Terminal Identification of the Wiper Motor Harness Connector

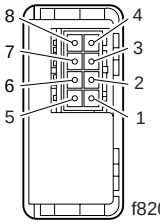
Terminal Identification of the Wiper/Washer Switch Connector			
Washer/Wiper Switch Connector	**Pin**	**Circuit Number**	**Circuit Description**
 f820455	1	315	Ignition Power
	2	29A	Backlighting
	3	316	Wiper Motor Low Speed
	4	318	Wiper Motor High Speed
	5	320A	Washer Pump
	6	GND	Ground
	7	—	Not used
	8	—	Not used

Table 10, Terminal Identification of the Wiper/Washer Switch Connector

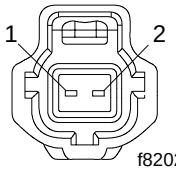
Terminal Identification of the Washer Pump Connector				
Washer Pump Connector	**Terminal**	**Circuit Number**	**Color**	**Circuit Description**
 f820296a	1	320	Dark Blue	Washer Power
	2	GND	Black	Washer Ground

Table 11, Terminal Identification of the Washer Pump Connector

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Troubleshooting, Wiper System with Dash-Mounted Switch

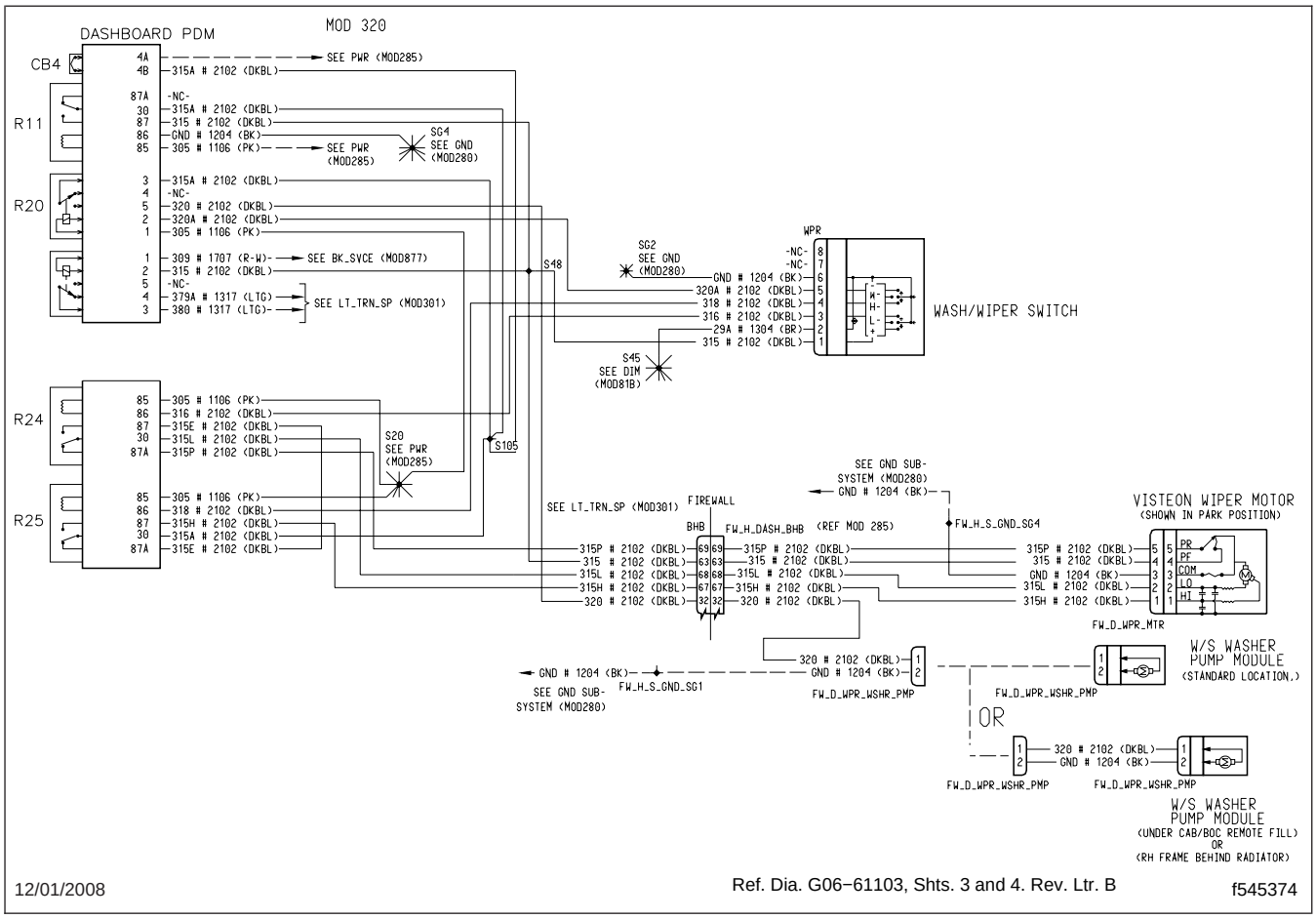


Fig. 1, Wiring Diagram, Wiper/Washer With a Dash-Mounted Switch

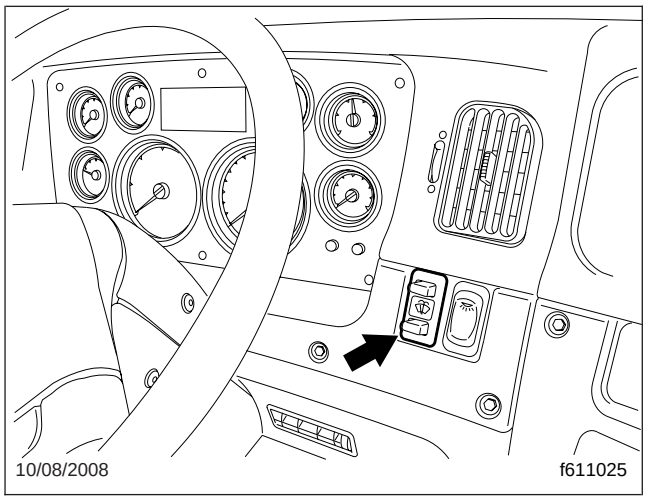
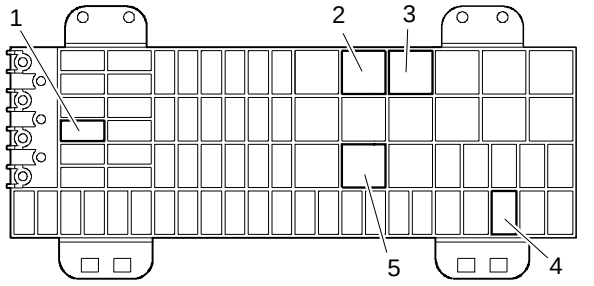


Fig. 2, Location of Dash-Mounted Wiper/Washer Switch

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Troubleshooting, Wiper System with Dash-Mounted Switch



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1. CB4, Wiper/Washer Power
2. R24, Wiper—Low Speed
3. R25, Wiper—High Speed
4. R20, Washer Pump
5. R11, Wiper/Washer Power

Fig. 3, Power Distribution Module (PDM), Instrument Panel

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Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

Torque Specifications	
Description	**lbf·in (N·cm)**
Wiper Motor Retaining Screws	80–115 (900–1300)
Mounting Arm and Pivot Shaft Retaining Screws	80–115 (900–1300)

Table 1, Torque Specifications

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General Information

The heater and air conditioner assembly is mounted behind the passenger dash panels and on the engine side of the frontwall. The heater and air conditioner system includes the following major components:

- accumulator
- blower motor
- climate control panel
- condenser
- electric actuators
- evaporator
- heater core
- orifice tube
- refrigerant compressor
- refrigerant compressor cycling switch

The heating, air conditioning, and ventilating functions of the cab heater and air conditioner system are controlled by the cab climate control panel mounted on the dashboard. Refer to the *Acterra Driver's Manual* for operating instructions.

Thermodynamic Principles

Air conditioning is the cooling or refrigeration and circulation of the air in the passenger compartment. Refrigeration is accomplished by making practical use of three thermodynamic principles. These principles and how they work in a vehicle are described below.

Heat Transfer

If two objects of different temperatures are placed near each other, the heat in the warmer object will always travel to the cooler object until both are of equal temperature.

For example, a block of ice in a refrigerator does not transfer its coldness to a nearby carton of milk. Rather, the heat in the warm milk automatically flows to the ice.

The British Thermal Unit (BTU) is used to determine the amount of heat transferred from one object to another. One BTU is the amount of heat required to raise the temperature of 1 pound (0.45 kg) of water 1°F (0.55°C).

For example, to raise the temperature of 1 pound (0.45 kg) of water from 32°F to 212°F (0°C to 100°C), one BTU of heat must be added for 1°F (0.55°C) rise in temperature or a total of 180 BTUs of heat. Conversely, in order to lower the temperature of 1 pound (0.45 kg) of water from 212°F to 32°F (100°C to 0°C), 180 BTUs of heat must be removed from the water.

Latent Heat of Vaporization

When a liquid boils, it absorbs heat and passes the heat off in the vapor it gives off. The vapor leaves the liquid at the boiling point, but can go no higher. When the gas condenses, changing back to a liquid, it gives off heat without reducing the temperature of the resulting liquid.

For example, when 1 pound (0.45 kg) of water at 32°F (0°C) is heated over a flame, the temperature of the water rises 1°F (0.55°C) with each BTU of heat that the water absorbs from the flame. Thus, after it has absorbed 180 BTUs of heat, the water reaches a temperature of 212°F (100°C) and boils.

Though the flame continues to heat the water, the temperature of the water will not exceed 212°F (100°C). The water, however, starts to change from a liquid to a gaseous state. It continues to boil until the water has passed off into the atmosphere as vapor. If this vapor were checked with a thermometer, it also would show a temperature of 212°F (100°C).

In other words, there was a rise of only 180°F (from 32°F to 212°F or 0°C to 100°C) in the water and vapor temperature, even though the flame applied many more than 180 BTUs of heat. In this case, the heat is absorbed by the liquid in the process of boiling, and dissipates in the vapor. As the vapor contacts the relatively cool air, the hidden heat flows into the cooler air and the vapor condenses back to water. Scientists refer to this principle as the latent (hidden) heat of vaporization.

Water has a latent heat of vaporization of 970 BTUs and a boiling point of 212°F (100°C). This means that 1 pound (0.45 kg) of water at 212°F (100°C), will absorb 970 BTUs of heat when changing to vapor at 212°F (100°C). Conversely, the vapor will give off 970 BTUs of heat when condensing back to water at 212°F (100°C).

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General Information

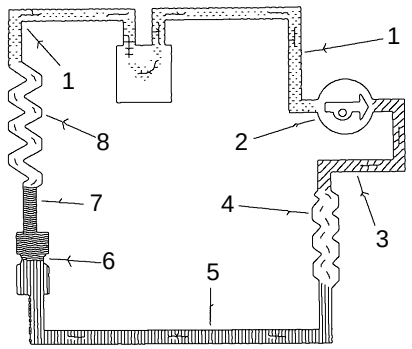
This heat transfer, occurring when a liquid boils or a vapor condenses, forms the basic principle of all conventional refrigerant systems.

For a liquid to be a refrigerant, it must also have a low boiling point. That is, the temperature at which it boils must be lower than the substance to be cooled.

R–134a is a non-CFC refrigerant. Its temperature/pressure relationship makes it suitable for mobile air conditioning systems.

Effect of Pressure on Boiling or Condensation

As refrigerant passes through an air conditioning system, it flows under high-pressure conditions, first as a high-pressure vapor between the refrigerant compressor and the condenser, then as a high-pressure liquid between the condenser and the evaporator orifice. It expands to a low-pressure vapor between the evaporator orifice and the refrigerant return port in the refrigerant compressor. As pressures in the closed refrigerant circuit vary, temperatures will also vary. As pressure increases, temperatures also increase; as the pressure decreases, temperatures also decrease. The refrigerant flow diagram highlights the changes that take place. See **Fig. 1**.



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1. Low-Pressure Vapor
2. Refrigerant Compressor
3. High-Pressure Vapor
4. Condenser
5. High-Pressure Liquid
6. Restriction
7. Low-Pressure Liquid
8. Evaporator

Fig. 1, Refrigerant Flow

Description of Components

Accumulator

When entering the inlet of the accumulator, the refrigerant contacts the liquid diverter dome and flows to the bottom of the housing. The refrigerant completes vaporization and passes into the suction inlet. A small, screened bleed hole in the bottom allows oil to be sucked into the suction tube to return to the compressor.

A desiccant bag inside the accumulator absorbs any moisture that may be in the system. A fitting on the accumulator is used to mount the refrigerant compressor cycling switch. The fitting prevents refrigerant loss when the cycling switch is removed.

Blower Motor

The blower motor forces air through the HVAC assembly and through the duct work.

Climate Control Panel

The fan switch, temperature control switch, and air selection switch are mounted on the climate control panel, which is also called the control head. The fan switch is used to control the rate of airflow through the outlets. The temperature control switch is used to select the desired temperature. The air selection switch is used to select the direction of warm or cool air through the air outlets.

Condenser

A condenser turns hot refrigerant gas coming from the refrigerant compressor into liquid. The condenser is mounted in front of the radiator. Because of its location, the condenser transfers heat to air that is drawn in by the engine fan, and to ram air that is forced through the condenser as the vehicle moves forward.

Electric Actuator

The electric actuator is a combined motor and gearbox that is used to control the position of the doors within the HVAC assembly. The position of the doors is controlled by the settings on the climate control panel. There are five electric actuators on the HVAC assembly:

- the temperature/blend air actuator

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- the defrost/panel actuator
- the right-side panel/demist actuator
- fresh air/recirculation actuator
- panel/floor actuator

Evaporator

The evaporator is located in the evaporator housing on the engine side of the frontwall. Because the evaporator is an area of low pressure in the HVAC system, the boiling point of refrigerant lowers, which causes it to absorb heat from the tubing walls and fins. As it absorbs heat, liquid refrigerant quickly boils and turns into a gas.

As heat is absorbed from the outside surfaces of the evaporator, air passing over the unit loses its heat to these cooler surfaces. Moisture in the air condenses on the outside of the evaporator and drains off as water; the air becomes dehumidified.

Heater Core

When the engine is on, coolant flows through the heater core tube, heating the tubes and fins. The heat is absorbed by air that is forced through the heater core by the blower motor.

Orifice Tube

The orifice tube is located in the inlet tube to the evaporator. The orifice tube separates the high- and low-pressure sides of the HVAC system and meters the flow of refrigerant into the evaporator. The orifice tube has screens on the inlet and outlet ends of the tube. The inlet screen is a strainer for the liquid refrigerant flowing through the opening. The outlet screen reduces the noise of the refrigerant flowing through the orifice tube. O-rings on the orifice tube prevent the high-pressure liquid refrigerant from bypassing the orifice tube. The orifice tube cannot be adjusted or repaired; it must be replaced.

Refrigerant Compressor

Heat in the low-pressure gas of the evaporator does not feel hot to the touch, because liquid refrigerant boils at a temperature much lower than the temperature at which water turns to ice. By touch, the heated gas in the evaporator is very cold. As a result, there is the problem of how to remove heat from cool gas using outside air that may be higher than 100°F (38°C).

With a refrigerant compressor, low-pressure gas from the evaporator can be squeezed into a much smaller space. When the gas is compressed, the heat it contains becomes concentrated. In this way, the gas is made hotter than the outside air without adding heat. Another function of the compressor is to move refrigerant through the system.

Refrigerant Compressor Cycling Switch

The refrigerant compressor cycling switch is mounted on the accumulator. The electrical contacts within the cycling switch are normally open below an operating pressure of 23 psi (159 kPa). The electrical contacts close to allow compressor operation when internal pressure rises above 40 to 47 psi (275 to 324 kPa). Lower ambient air temperatures (below 50°F or 10°C) during cold seasons will also open the contacts due to the pressure/temperature relationship of the refrigerant in the system.

The electrical contacts control the circuit to the compressor clutch field coil. When the contacts are closed, the compressor clutch field is energized and the clutch engages to drive the compressor. When the contacts are open, the compressor clutch field coil is de-energized and the compressor does not operate. The cycling switch, when operating properly, will control the refrigerant pressure within the evaporator at a point where the plate/fin surface of the evaporator will be maintained slightly above freezing to prevent icing and blockage of airflow.

Definition of Terms

Refer to the following terms for a better understanding of the HVAC system.

Accumulator A combination desiccant, filter, and storage container for liquid refrigerant.

Air Conditioner A system used to control the temperature, humidity, and movement of air in the cab.

Ambient Air Temperature The temperature of air around an object, or the outside temperature.

Blower Motor A blower motor forces air through the HVAC assembly and through the duct work.

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General Information

Blower Resistor Block Assembly Inline resistors that control the amount of voltage going to the blower motor. By controlling the voltage, you can control the fan speed.

Boiling Point The temperature at which a liquid changes to a gas. The boiling point varies with pressure.

Bulk Charging Use of large containers of refrigerant for charging a refrigerant system. Normally used for charging empty systems.

Charge A specific amount of refrigerant or oil by volume or weight. Also the act of placing an amount of refrigerant or oil in the air conditioning system.

Clutch Cycling Switch Engages or disengages the refrigerant compressor depending on changes in system pressure. Protects the system in extreme cold conditions and in situations where there is no refrigerant.

Condensate Water taken from the air, which forms on the outer surface of the evaporator.

Condenser A heat exchanger that is used to remove heat from the refrigerant, changing it from a high-pressure hot gas to a high-pressure warm liquid. Typically the condenser is mounted in front of the radiator.

Condensing Pressure Pressure as read from the gauge at the discharge service valve. Pressure from the discharge side of the compressor into the condenser.

Contaminants Anything other than refrigerant or refrigerant oil in the system. Usually means water, dirt, or air in the system.

Cycling Clutch System A system which controls compressor clutch operation in order to raise or lower the temperature in the cab.

Dehumidify To remove water from the air at the evaporator.

Dehydrate To remove all traces of moisture from the refrigerant system. This process occurs during evacuation.

Desiccant A drying agent used in the accumulator to remove water and create an extremely dry condition.

Discharge Line Connects the refrigerant compressor outlet to the condenser inlet.

Discharge Pressure High-side pressure or condensing pressure being discharged from the compressor.

Drive Pulley A pulley attached to the front of the engine crankshaft. It drives the compressor clutch pulley with a belt.

Duct A passageway for the transfer of air from one point to another.

Electric Actuator The actuator is a combined motor and gearbox used to drive the doors within the HVAC assembly.

Evacuate To place a high vacuum in the refrigerant system to remove air and dehydrate or remove traces of moisture.

Evaporate To change state from a liquid to a gas.

Evaporator A component in which liquid refrigerant changes to a gas after it absorbs heat from the air. It also removes some moisture from the air.

Flushing A process of passing liquid refrigerant through an air-conditioner component to remove dirt and water from the part. Liquid refrigerant removes heavy contamination, such as gritty dirt and large dirt buildup.

Freeze-Up Failure of a unit to operate properly because of ice forming at the expansion valve orifice or on the evaporator.

Heater Core A part of the heating system in which hot engine coolant flows to provide heat to the cab or to adjust the temperature produced by the air conditioner.

High-Side Service Valve A device located on the liquid line near the orifice tube. It allows high-side pressure to be checked and other service operations to be performed.

High-Pressure Switch Located on the discharge side of the refrigerant compressor, the high-pressure switch signals the climate control panel to turn the fan on and to prevent operation of the refrigerant compressor in the event of a high-pressure condition.

Humidity The amount of water vapor in the air.

Hydraulic Lock The return of liquid refrigerant to the compressor, which could destroy the unit.

Leak Detector Any electronic or UV light device used to detect refrigerant leaks in a refrigerant system.

Liquid Pressure Pressure of refrigerant in the liquid line from the condenser to the expansion device.

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Low Head Pressure High-side pressure that is lower than normal due to a system problem.

Low-Pressure Switch Located on the suction side of the refrigerant compressor, the low pressure switch signals the clutch to cycle or shut down in extremely cold temperatures, or if there is a loss of charge.

Low-Suction Pressure Low-side pressure that is lower than normal due to a system problem.

Magnetic Clutch An electrical coupling device used to engage or disengage the compressor.

Manifold A device to control refrigerant flow for system test purposes. It is used with manifold gauges.

Manifold Gauge A calibrated instrument used for measuring system pressures.

Manifold Gauge Set A manifold that is complete with gauges and charging hoses and is used to measure or test pressure.

Micron A metric unit of length equal to one-millionth of a meter. The unit of measure is used to measure vacuum drawn from a refrigerant system by a vacuum pump.

Nitrogen A colorless, odorless, dry, inert gas.

Opacity A measure of contamination of refrigerant oil in the compressor. Fresh refrigerant oil is clear, but when contaminated, it appears cloudy or may have fine particles held in suspension.

Overcharge Too much refrigerant or oil in the system.

Polyalkylene Glycol (PAG) Highly refined synthetic refrigerant oil that is used in R–134a air conditioning systems.

psia Pounds per square inch, absolute pressure. Pressure exerted by the air at sea level. Atmospheric pressure is usually measured with a mercury barometer.

psig PSIG, or gauge pressure, measures pressure relative to the local atmosphere. At sea level, 0 PSIG is about 14.7 PSIA, but in Denver, which is at about 5000 feet altitude, 0 PSIG is about 12.5 PSIA. A PSIG reading below 0 indicates a vacuum.

Recovery Removal of the refrigerant from air conditioning systems.

Recycling Removal of contaminants and moisture from R–134a using a recovery and recycling station.

Refrigerant–134a (R–134a) The cooling agent used in automotive air conditioning systems. The chemical name for R–134a is tetrafluoroethane.

Refrigerant Compressor A device used to draw low-pressure refrigerant gas from the evaporator and squeeze it into a high-temperature, high-pressure gas. A second purpose of the compressor is to move refrigerant through the system.

Refrigeration Cycle The complete circulation of refrigerant through an air conditioning system, accompanied by changes in temperature and pressure.

Relative Humidity The actual water content of the air in relation to the total water vapor the air can hold at a given temperature.

Resistor A voltage-dropping device, usually wire wound, for controlling fan speed.

Suction Line The line connecting the accumulator outlet to the compressor inlet.

Suction Pressure Compressor inlet pressure or the system's low-side pressure.

Suction Service Valve A device located on the suction hose near the accumulator that allows low-side pressure to be checked and other service operations to be performed.

Suction Side The low-pressure area of the system extending from the expansion device to the compressor inlet.

Thermistor A vacuum pressure sensor that is used to measure, in microns of mercury, internal system vacuum levels after evacuation.

Thermostatic Vacuum Gauge A high-vacuum gauge sensitive to pressures ranging from atmospheric pressure to less than 1 micron of mercury with scales reading from 25,000 microns to 1 micron of mercury.

Undercharge A system low on refrigerant resulting in lack of cooling and possible compressor damage.

Vacuum Refers to pressure that is less than atmospheric pressure.

Vacuum Pump A mechanical device used to evacuate and place a high vacuum in the refrigerant system.

Vacuum Pump Oil Water-soluble oil used in some vacuum pumps to absorb moisture from the refrigerant system.

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General Information

Vapor The gaseous state of a material.

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Safety Precautions

Whenever repairs are made to any air conditioner parts that hold R–134a refrigerant, you must recover, flush (if contaminated), evacuate, charge, and leak test the system. In a good system, refrigerant lines are always under pressure and you should disconnect them only after the refrigerant charge has been recovered (discharged) at the service valves.

R–134a refrigerant is safe when used under the right conditions. Always wear safety goggles and non-leather gloves while recovering, evacuating, charging, and leak testing the system. Do not wear leather gloves. When refrigerant gas or liquid contacts leather, the leather will stick to your skin.

⚠ WARNING

Use care to prevent refrigerant from touching your skin or eyes because liquid refrigerant, when exposed to the air, quickly evaporates and will freeze skin or eye tissue. Serious injury or blindness could result if you come in contact with liquid refrigerant.

Refrigerant splashed in the eyes should be rinsed with lukewarm water, not hot or cold. Do not rub the eyes. Apply a light bandage and contact a physician right away.

Refrigerant splashed on the skin should be rinsed with lukewarm water, not hot or cold. Do not rub the skin. Apply a light coat of a nonmedicated ointment, such as petroleum jelly. Contact a physician right away.

R–134a refrigerant does not burn at ambient temperatures and atmospheric pressure. However, it can be combustible at pressures as low as 5.5 psig (38 kPa absolute) at 350°F (177°C) when mixed with air concentrations that are greater than 60 percent.

⚠ WARNING

R–134a air conditioning systems should not be pressure tested or leak tested with compressed air. Combustible mixtures of air and R–134a may form, resulting in a fire or explosion that could cause personal injury or property damage.

You must work in an area where there is a constant flow of fresh air when the system is recovered, evacuated, charged, and leak tested. R–134a vapors have a slightly sweet odor that is difficult to detect. Frequent leak checks and air monitoring equipment are recommended to ensure a safe working environment.

IMPORTANT: When servicing an R–134a air conditioning system, use only service equipment certified to meet the requirements of SAE J2210 (R–134a recycling equipment). The equipment should be operated only by qualified personnel who are familiar with the recycling station manufacturer's instructions.

Because of its very low boiling point, refrigerant must be stored under pressure. To prevent the refrigerant containers from exploding, never expose them to temperatures higher than 125°F (52°C).

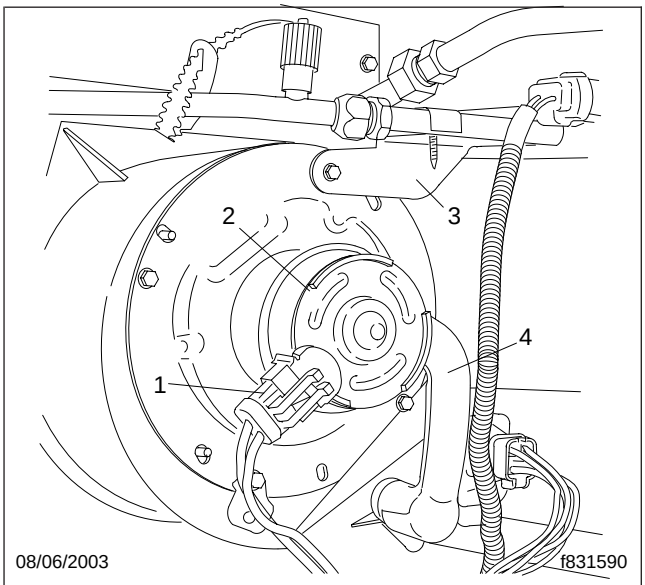
Polyalkylene glycol (PAG) refrigerant oil is the **only** refrigerant oil recommended for use in the refrigerant compressors. When handling refrigerant oil, observe the following:

- Keep the oil free of contaminants.
- Do not expose the air conditioning system or the oil container to air for long periods of time; refrigerant oil absorbs moisture quickly.
- Use care when handling: painted surfaces, plastic parts, and other components (drive belts) could be damaged if the oil is spilled on them.
- Never mix PAG oil with other types of refrigerant oil.

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Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Disconnect the batteries.
4. Disconnect the electrical connector from the blower motor. See **Fig. 1**.



1. Electrical Connector
2. Blower Motor
3. Support Bracket
4. Blower Motor Tube

Fig. 1, Electrical Connector

5. Disconnect the blower motor tube from the blower motor.
6. Remove the screw that attaches the support bracket to the blower motor and remove the support bracket.
7. Remove the screws that secure the blower motor and remove the blower motor.
8. Remove and discard the retaining clip that secures the blower motor fan to the blower motor. See **Fig. 2**.

NOTE: The retaining clip that secures the blower motor fan to the blower motor is a single-use item. If the blower motor and blower motor fan are separated, a new retaining clip must be used.

9. Using a new retaining clip, install the blower motor fan.

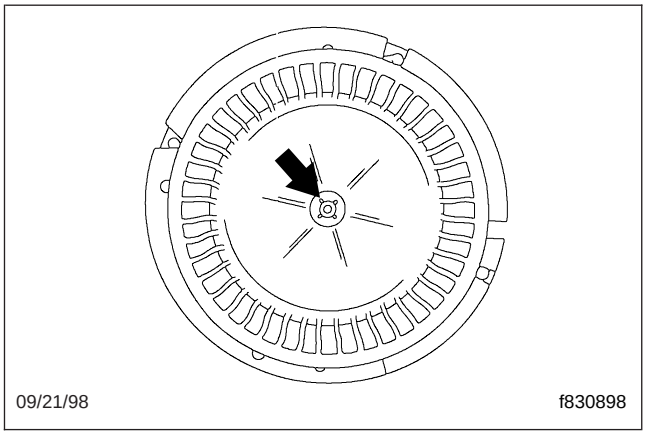


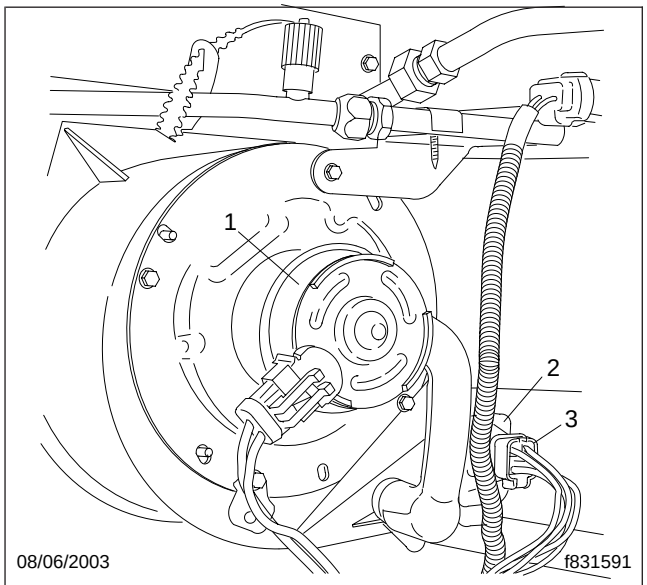
Fig. 2, Retaining Clip

10. Using screws, install the blower motor.
11. Using a screw, install the support bracket on the blower motor.
12. Install the blower motor tube on the blower motor.
13. Connect the electrical connector to the blower motor.
14. Return the hood to the operating position.
15. Connect the batteries.
16. Remove the chocks from the tires.

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Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Open the hood.
4. Disconnect the electrical connector from the resistor. See **Fig. 1**.



1. Blower Motor
2. Resistor
3. Electrical Connector

Fig. 1, Blower Motor Resistor

5. Remove the screws that secure the resistor, and remove the resistor.
6. Inspect the gasket on the resistor flange on the blower motor before installing the resistor. If the gasket is damaged, replace the gasket, or seal the resistor mounting flange using silicone rubber.
7. Using screws, install the resistor. Torque the screws 18 to 27 lbf·in (200 to 300 N·cm).
8. Connect the electrical connector to the resistor.
9. Connect the batteries.
10. Return the hood to the operating position.
11. Remove the chocks from the tires.

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Evaporator Housing Removal and Installation

Removal

WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

1. Turn off the engine, apply the parking brakes, and chock the tires.

WARNING

The engine must be off and fully cooled, and the cooling system fully depressurized before disconnecting any heater water hoses. Failure to comply with these warnings can result in serious personal injury from hot liquid escaping from the engine cooling system.

2. Open the hood.
3. Disconnect the batteries.
4. Recover the refrigerant from the air conditioning system. For instructions, see Subject 280.
5. If necessary, remove the blower motor. For instructions, see Subject 110.
6. From inside the vehicle, remove the bolts and nuts that attach the dash panel support brace to the vehicle, and remove the support brace. See Fig. 1.

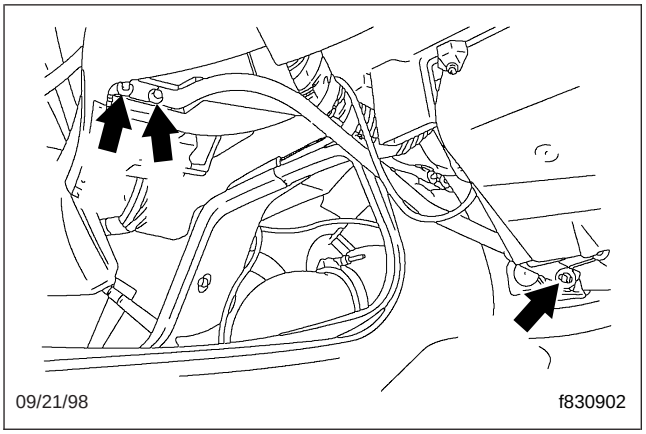


Fig. 1, Dash Panel Support Brace Fasteners

7. Remove the nuts that attach the evaporator housing to the dash panel.
8. If not already done, disconnect all electrical connectors from the blower motor and resistor.
9. Remove the nut that attaches the evaporator housing to the frontwall.
10. Remove the capscrews that attach the evaporator bracket to the frontwall. See Fig. 2.

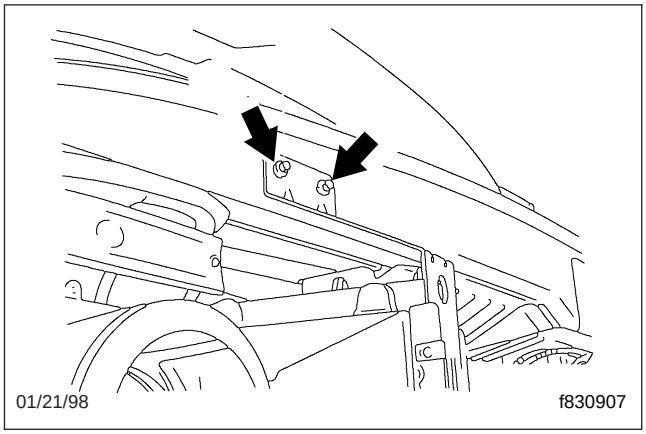


Fig. 2, Evaporator Bracket Capscrews

11. Remove the evaporator housing. See Fig. 3.

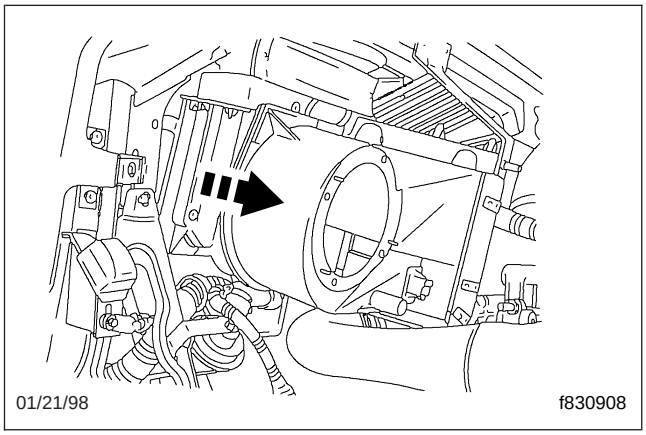


Fig. 3, Evaporator Housing

Installation

NOTE: If a new evaporator housing is to be installed, the blower motor and wheel, blower motor tube, blower motor resistor, evaporator bracket, fresh air filter, and evaporator must be

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Evaporator Housing Removal and Installation

transferred to the new evaporator housing. To ease installation, install these components prior to installing the evaporator housing.

1. Place the evaporator housing in the HVAC assembly.
2. Install the capscrews that attach the evaporator bracket to the frontwall.
3. Install the nut that attaches the evaporator housing to the frontwall.
4. Install the nuts that attach the evaporator housing to the dash panel.
5. Using bolts and nuts, attach the dash panel support brace to the vehicle.
6. If the blower motor was removed, install the blower motor. For instructions, see **Subject 110**.

   If the blower motor was not removed, connect the electrical connectors to the blower motor and resistor.
7. Charge the air conditioning system. For instructions, see **Subject 280**.
8. Connect the batteries.
9. Close the hood.
10. Remove the chocks from the tires.

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Evaporator Replacement

WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

Replacement

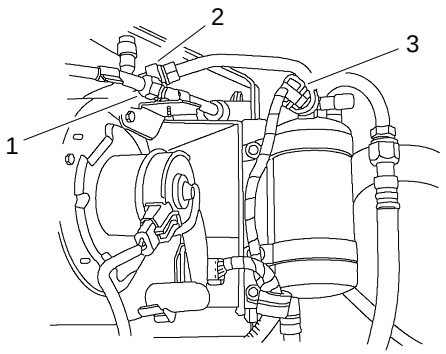
WARNING

The engine must be off and fully cooled, and the cooling system fully depressurized before disconnecting any heater water hoses. Failure to comply with these warnings can result in serious personal injury from hot liquid escaping from the engine cooling system.

1. Recover the refrigerant from the air conditioning system. For instructions, see Subject 280.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

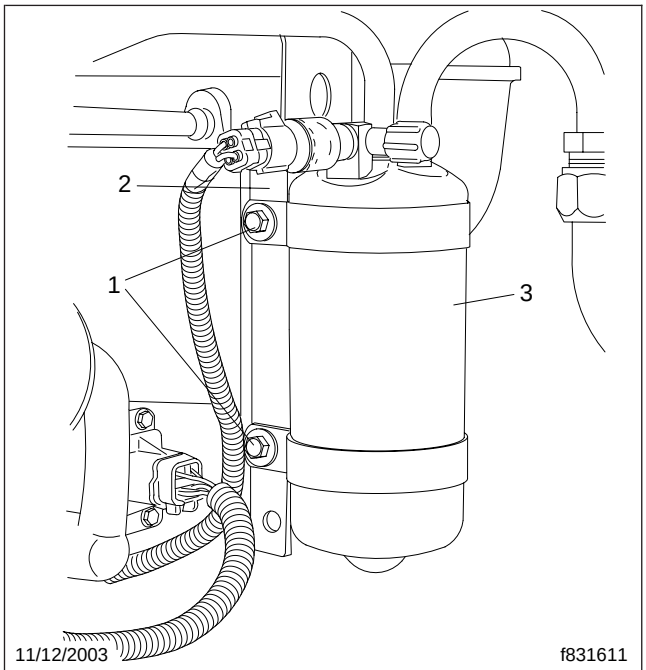
2. Disconnect the refrigerant lines from the evaporator. See Fig. 1.



1. Refrigerant Inlet Line
2. Refrigerant Outlet Line
3. Electrical Connector

Fig. 1, Disconnect the Refrigerant Lines

3. Disconnect the electrical connector from the refrigerant compressor cycling switch on the accumulator.
4. Remove the screws that attach the accumulator to the bracket, and remove the accumulator. See Fig. 2.



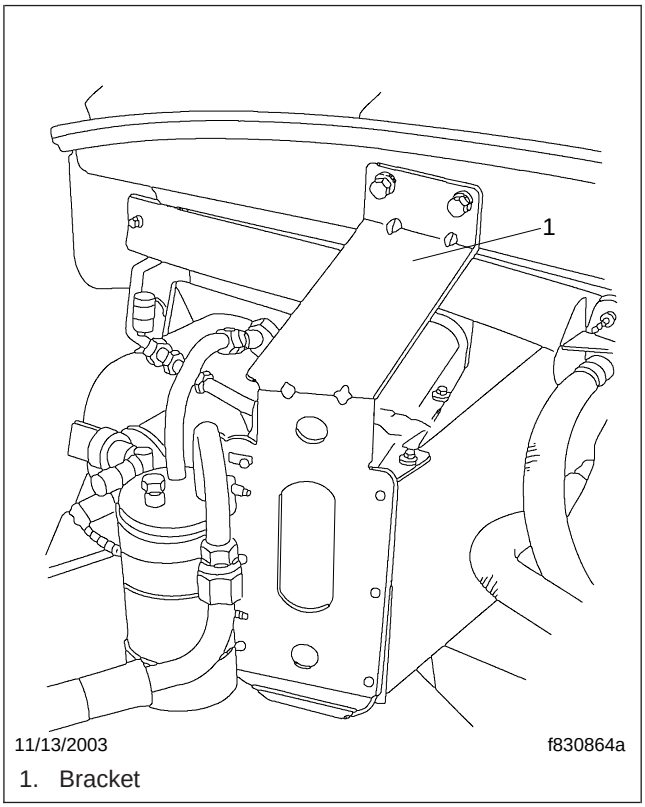
1. Screw
2. Bracket
3. Accumulator

Fig. 2, Accumulator

5. Remove the screws that attach the bracket to the evaporator case cover and the frontwall, and remove the bracket. See Fig. 3.
6. Remove the screws on top of the evaporator case cover and remove the case cover. See Fig. 4.
7. Remove the evaporator and O-rings.
8. Install a new evaporator and new O-rings. Lubricate the O-rings with mineral oil before installing.
9. Using screws, install the evaporator case cover.
10. Using screws, attach the accumulator and bracket to the evaporator case cover.
11. Connect the refrigerant lines to the evaporator.

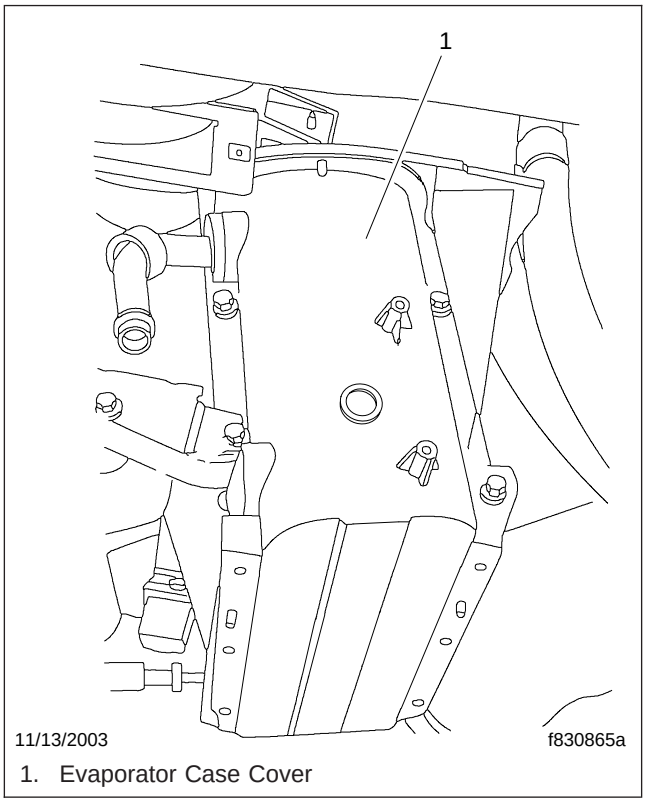
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Evaporator Replacement



1. Bracket

Fig. 3, Remove the Bracket



1. Evaporator Case Cover

Fig. 4, Remove the Evaporator Case Cover

12. Connect the electrical connector to the refrigerant compressor cycling switch on the accumulator.
13. Evacuate, leak check, and charge the air conditioning system. For instructions, see **Subject 280**.

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⚠ WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 280**.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through the refrigerant lines since shop air is wet (humid).

3. Disconnect the refrigerant line at the orifice tube fitting. See **Fig. 1**.

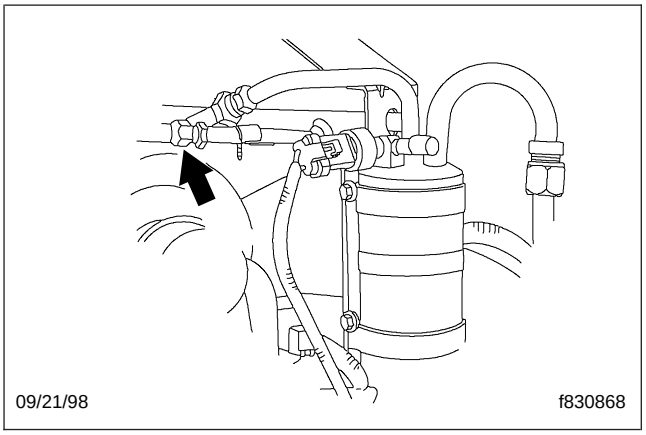


Fig. 1, Orifice Tube Fitting

4. Remove the orifice tube.
5. Install a new orifice tube.
6. Replace the O-ring in the fitting. Lubricate the O-ring with mineral oil before installing the O-ring.
7. Connect the refrigerant line to the orifice tube fitting. Torque the fitting 15 to 20 lbf·ft (20 to 27 N·m).
8. Evacuate and charge the air conditioning system. For instructions, see **Subject 280**.
9. Leak check the orifice tube fitting.
10. Remove the chocks from the tires.

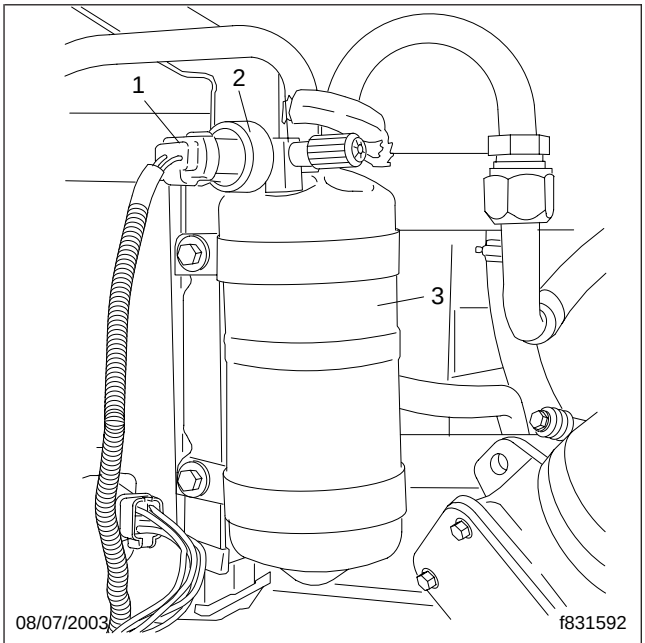
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Replacement

WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 280**.
4. Disconnect the electrical connector and the refrigerant compressor cycling switch from the accumulator. See **Fig. 1**.



1. Electrical Connector
2. Refrigerant Compressor Cycling Switch
3. Accumulator

Fig. 1, Accumulator

5. Disconnect the refrigerant lines from the accumulator. Quickly cap the refrigerant lines.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

6. Remove the capscrews that attach the accumulator to the mounting bracket and remove the accumulator.
7. Drain the refrigerant oil from the accumulator.
   - 7.1 Drill one or two 1/2-inch (13-mm) holes in the bottom of the accumulator that was just removed.
   - 7.2 Drain the refrigerant oil from the accumulator into a calibrated container. Record the amount of oil recovered and properly dispose of the recovered oil.
8. Add the same amount of clean refrigerant oil that was drained from the accumulator, plus two additional fluid ounces (59 mL), to the new accumulator.
9. Using capscrews, install the new accumulator on the mounting bracket.
10. Uncap the refrigerant lines, and remove and discard the O-rings.
11. Lubricate new O-rings with mineral oil, then install them on the refrigerant lines.
12. Connect the refrigerant lines to the accumulator. Torque the fittings on the refrigerant lines 25 to 30 lbf·ft (34 to 41 N·m).
13. Connect the refrigerant compressor cycling switch and the electrical connector to the accumulator. Tighten the cycling switch by hand only.
14. Evacuate the air conditioning system, then charge it with refrigerant. For instructions, see **Subject 280**.
15. Return the hood to the operating position.
16. Remove the chocks from the tires.

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Condenser Removal and Installation

Removal

WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 280**.
4. Disconnect the refrigerant lines from the condenser. Quickly cap the condenser inlet and outlet ports if the condenser will be reinstalled, and cap the refrigerant lines.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

5. Remove the fasteners that attach the condenser to the radiator, and remove the condenser.

Installation

1. Using fasteners, install the condenser on the radiator. Torque the fasteners 26 to 34 lbf·ft (35 to 46 N·m).
2. Uncap the inlet and outlet ports on the condenser and uncap the refrigerant lines.
3. On refrigerant line connections that have a Mini Stat-O-Seal assembly, install new Mini Stat-O-Seals. **Do not** lubricate Mini Stat-O-Seals prior to installation. Use **only** a Mini Stat-O-Seal on a Mini Stat-O-Seal assembly.

   On refrigerant line connections that have threaded fittings, install new O-rings on the fittings. Lubricate the O-rings with mineral oil before installing.
4. Connect the refrigerant lines to the condenser.

   On refrigerant lines that have a Mini Stat-O-Seal assembly, torque the bolt on the retaining plate 11 to 15 lbf·ft (15 to 20 N·m).

   On refrigerant lines that have threaded fittings, torque the fittings 10 to 15 lbf·ft (14 to 20 N·m).
5. Evacuate, leak test, and charge the air conditioning system. For instructions, see **Subject 280**.
6. Return the hood to the operating position.
7. Remove the chocks from tires.

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Replacement

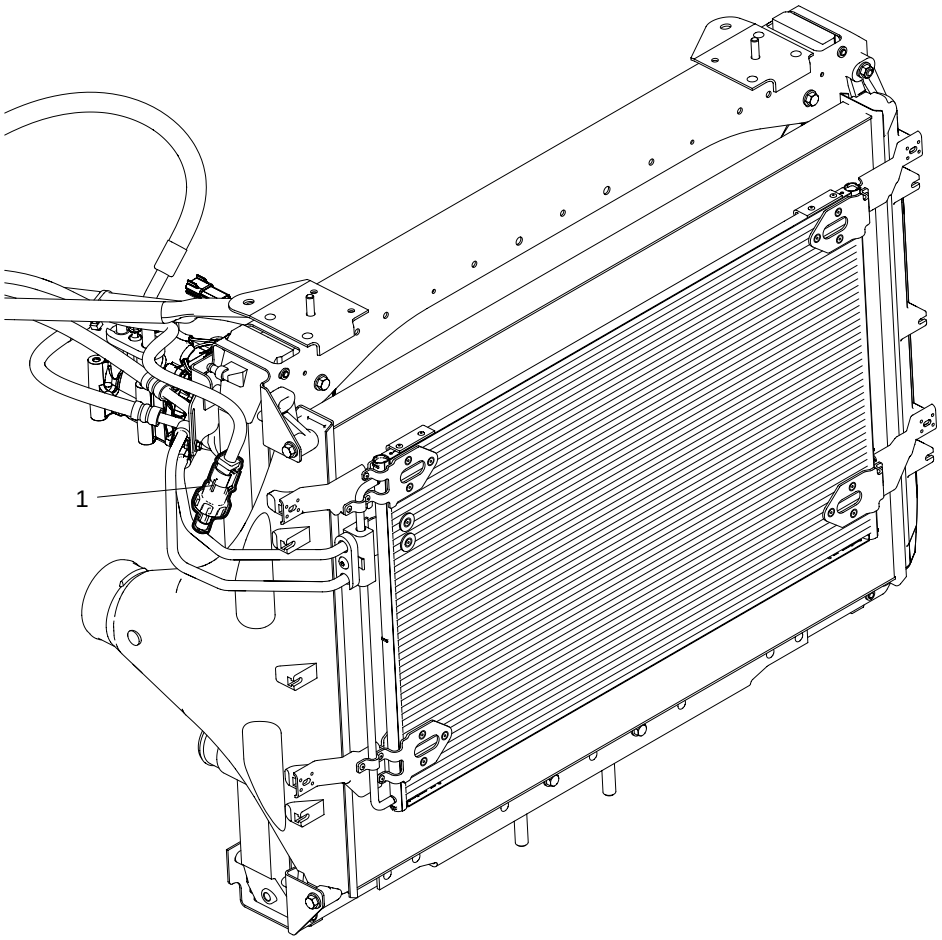
WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Disconnect the electrical connector from the engine fan cycling switch. See Fig. 1.
4. Remove the cycling switch.
5. Check the condition of the O-ring before installing the cycling switch. If necessary, replace the O-ring. Lubricate the O-ring with mineral oil before installing.
6. Install a new engine fan cycling switch. Tighten the switch by hand only.
7. Connect the electrical connector to the cycling switch.
8. Return the hood to the operating position.
9. Remove the chocks from the tires.

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Engine Fan Cycling Switch Replacement



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1. Engine Fan Cycling Switch

Fig. 1, Location of the Engine Fan Cycling Switch

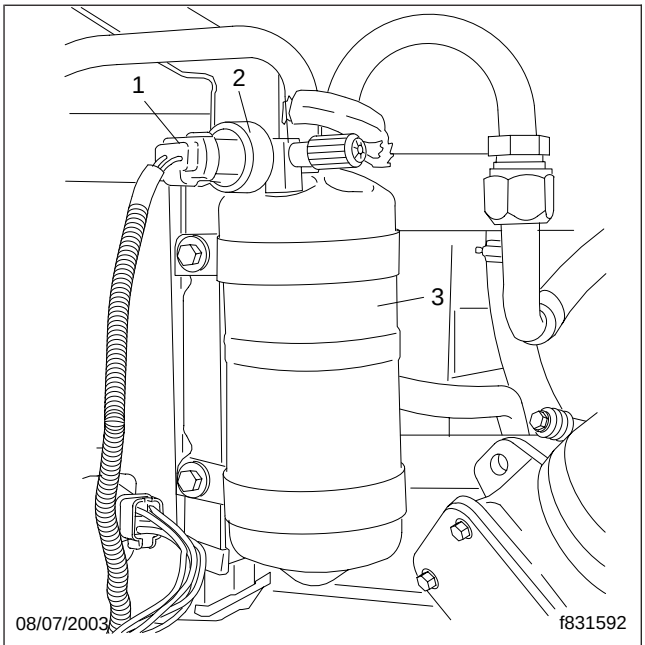
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Replacement

WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Disconnect the electrical connector from the refrigerant compressor cycling switch. See **Fig. 1**.
4. Remove the cycling switch.



1. Electrical Connector
2. Refrigerant Compressor Cycling Switch
3. Accumulator

Fig. 1, Refrigerant Compressor Cycling Switch

5. Check the condition of the O-ring before installing the cycling switch. If necessary, replace the O-ring. Lubricate the O-ring with mineral oil before installing.
6. Install a new cycling switch. Tighten the switch by hand only.
7. Connect the electrical connector to the cycling switch.
8. Return the hood to the operating position.
9. Remove the chocks from the tires.

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Climate Control Panel (Front Control Unit) Removal and Installation

Removal

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the auxiliary finish panel. For instructions, see **Group 60**.
4. Remove the screws that attach the climate control panel to the dash panel.
5. Pull the climate control panel away from the dash panel and disconnect the electrical connectors.
6. Remove the climate control panel.

Installation

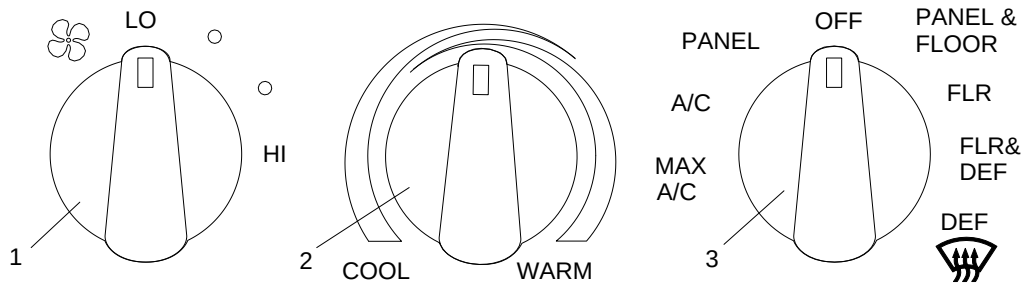
1. Connect the electrical connectors to the climate control panel.
2. Using screws, attach the climate control panel to the dash panel.
3. Install the auxiliary finish panel. For instructions, see **Group 60**.
4. Connect the batteries.
5. Remove the chocks from the tires.

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Fan, Temperature Control, and Air Selection Switches Replacement

Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the fan switch, temperature control switch, or air selection switch knob by pulling it off the climate control panel. See **Fig. 1**.
4. Remove the climate control panel. For instructions, see **Subject 210**.
5. Remove the screw that attaches the switch to the climate control panel. Rotate and remove the switch.
6. Using a screw, install a new switch on the climate control panel.
7. Install the climate control panel. For instructions, see **Subject 210**.
8. Install the fan switch, temperature control switch, or air selection switch knob by pushing it on the switch.
9. Connect the batteries.
10. Remove the chocks from the tires.



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1. Fan Switch Knob
2. Temperature Control Switch Knob
3. Air Selection Switch Knob

Fig. 1, Climate Control Panel

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Temperature/Blend Air Actuator Replacement

NOTE: The temperature/blend air actuator is referred to as the blend door actuator on the wiring schematic, drawing number D06-39579.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the screws that attach the heater core cover to the heater core housing, and remove the cover. See **Fig. 1**.
4. Disconnect the electrical connector from the temperature/blend air actuator. See **Fig. 2**.
5. Remove the screws that attach the temperature/blend air actuator to the HVAC assembly, and remove the actuator.
6. Using screws, install a new temperature/blend air actuator on the HVAC assembly.
7. Connect the electrical connector to the actuator.
8. Using screws, attach the heater core cover to the heater core housing.
9. Connect the batteries.
10. Remove the chocks from the tires.

Defrost/Panel Actuator Replacement

NOTE: The defrost/panel actuator is referred to as mode #3 module on the wiring schematic, drawing number D06-39579.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the actuator trim cover from the instrument panel. See **Fig. 3**.
4. Disconnect the control arms from the defrost/panel actuator.
5. Disconnect the electrical connector from the actuator.
6. Remove the screws that attach the defrost/panel actuator to the HVAC assembly, and remove the actuator. See **Fig. 1**.
7. Connect the electrical connector to a new defrost/panel actuator and position the actuator where it is to be installed on the HVAC assembly.
8. Connect the control arms to the actuator.
9. Using screws, attach the actuator to the HVAC assembly.
10. Install the actuator trim cover on the instrument panel.
11. Connect the batteries.
12. Remove the chocks from the tires.

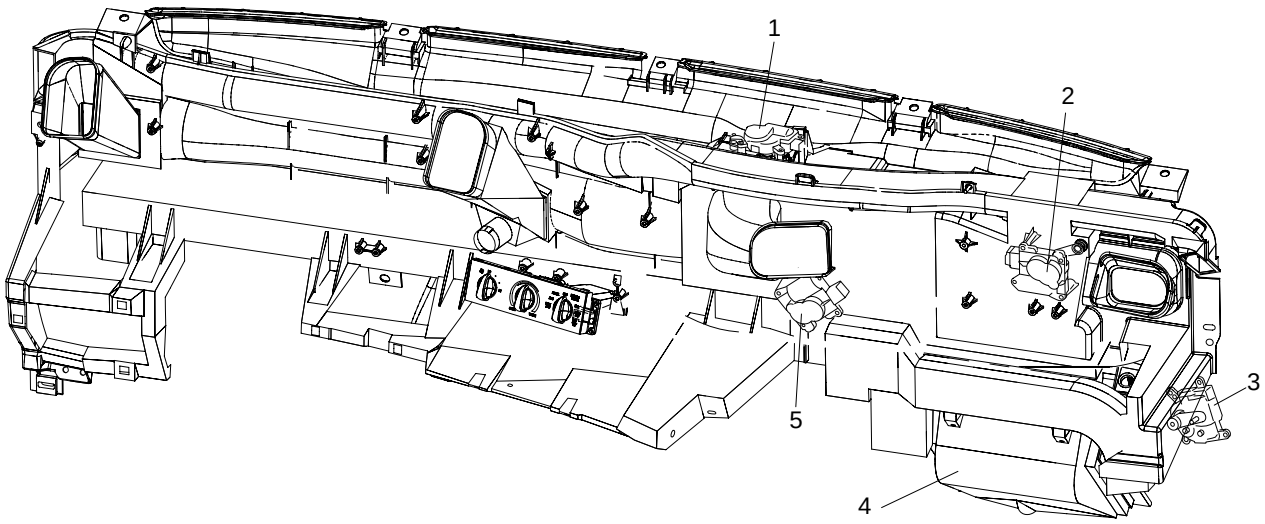
Fresh Air/Recirculation Actuator Replacement

NOTE: The fresh air/recirculation actuator is referred to as re-circ on the wiring schematic, drawing number D06-39579.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the screws that attach the heater core cover to the heater core housing, and remove the cover. See **Fig. 1**.
4. Disconnect the control arms from the fresh air/recirculation actuator.
5. Disconnect the electrical connector from the actuator.
6. Remove the screws that attach the fresh air/recirculation actuator to the HVAC assembly, and remove the actuator. See **Fig. 1**.
7. Connect the electrical connector to a new fresh air/recirculation actuator and position the actuator where it is to be installed on the HVAC assembly.
8. Connect the control arms to the actuator.
9. Using screws, attach the actuator to the HVAC assembly.
10. Using screws, attach the heater core cover to the heater core housing.
11. Connect the batteries.

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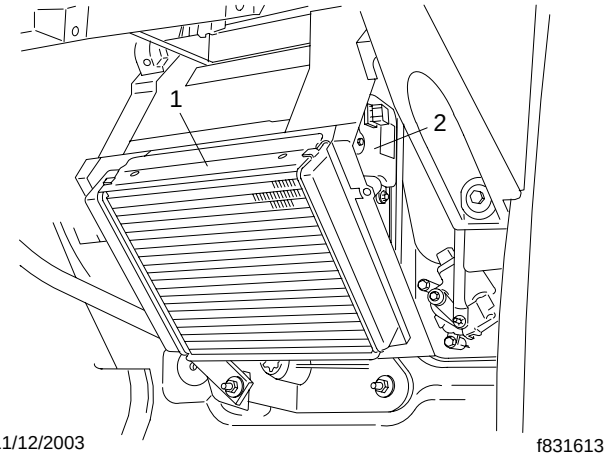
Actuator Replacement



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1. Defrost/Panel Actuator
2. Right-Side Panel/Demist Actuator
3. Fresh Air/Recirculation Actuator
4. Heater Core Cover
5. Panel/Floor Actuator

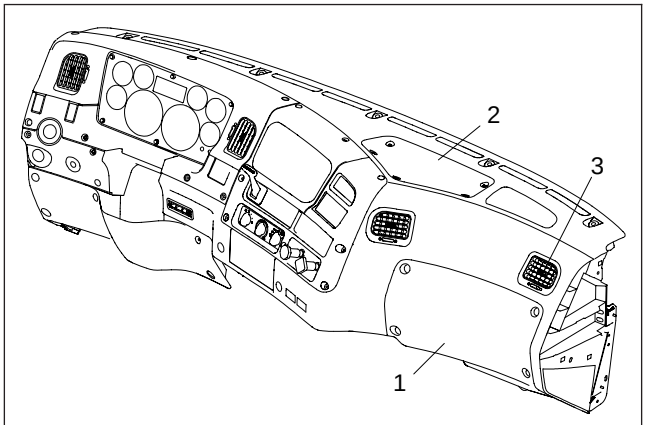
Fig. 1, Actuator Locations



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1. Heater Core
2. Temperature/Blend Air Actuator

Fig. 2, Location of Temperature/Blend Air Actuator



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1. Power Distribution Module Cover
2. Actuator Trim Cover
3. Louvers and Louver Housing

Fig. 3, Instrument Panel

12. Remove the chocks from the tires.

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Panel/Floor Actuator Replacement

NOTE: The panel/floor actuator is referred to as mode #2 module on the wiring schematic, drawing number D06-39579.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the power distribution module cover from the instrument panel. See **Fig. 3**.
4. Remove the screws that attach the power distribution module separator to the instrument panel, and remove the separator.
5. Remove the screws that attach the power distribution module to the instrument panel, and move the module to the cab floor.
6. Disconnect the electrical connector from the panel/floor actuator. See **Fig. 1**.
7. Remove the screws that attach the panel/floor actuator to the HVAC assembly, and remove the actuator.
8. Using screws, install a new panel/floor actuator on the HVAC assembly.
9. Connect the electrical connector to the actuator.
10. Using screws, install the power distribution module.
11. Using screws, install the power distribution module separator.
12. Install the power distribution module cover on the instrument panel.
13. Connect the batteries.
14. Remove the chocks from the tires.

Right-Side Panel/Demist Actuator Replacement

NOTE: The right-side panel/demist actuator is referred to as mode #1 module on the wiring schematic, drawing number D06-39579.

NOTE: The right-side panel/demist actuator can be removed by removing the right-side louvers and the louver housing, or by removing the power distribution module cover.

Louver Removal Method

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Access the tabs on the lower portion of the louver housing by moving the bottom of the louvers back. Use a screwdriver to release the tabs and pull the louvers and louver housing out of the dash panel. See **Fig. 3**.
4. Remove the screws that attach the actuator to the HVAC assembly, and remove the actuator. See **Fig. 1**.
5. Disconnect the electrical connector from the right-side panel/demist actuator.
6. Connect the electrical connector to the new actuator.
7. Using screws, install a right-side panel/demist actuator on the HVAC assembly.
8. Install the louvers and louver housing in the instrument panel.
9. Connect the batteries.
10. Remove the chocks from the tires.

Power Distribution Module Cover Removal Method

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the power distribution module cover from the instrument panel. See **Fig. 3**.
4. Disconnect the electrical connector from the right-side panel/demist actuator. See **Fig. 1**.
5. Remove the screws that attach the actuator to the HVAC assembly, and remove the actuator.
6. Using screws, install a new right-side panel/demist actuator on the HVAC assembly.

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Actuator Replacement

7. Connect the electrical connector to the actuator.
8. Install the power distribution module cover on the instrument panel.
9. Connect the batteries.
10. Remove the chocks from the tires.

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Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.

⚠ WARNING

The engine must be off and fully cooled, and the cooling system fully depressurized before disconnecting any heater water hoses. Failure to comply with these warnings can result in serious personal injury from hot liquid escaping from the engine cooling system.

3. Drain the coolant from the cooling system. For instructions, see **Group 20**.
4. Loosen the hose clamps on the heater hoses.
5. Remove the heater hoses.

⚠ CAUTION

Install the heater hoses so that they are not pinched and do not contact any part of the exhaust system. Doing so will prevent the hoses from being damaged.

NOTE: Cut new hoses of the same diameter to the same length as the old hoses.

6. Install the heater hoses.
7. Tighten the hose clamps on the heater hoses.
8. Fill the cooling system with coolant. For instructions, see **Group 20**.
9. Return the hood to the operating position.
10. Remove the chocks from the rear tires.

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Heater Core Shutoff Valve Replacement

Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.

⚠ WARNING

The engine must be off and fully cooled, and the cooling system fully depressurized before disconnecting any heater water hoses. Failure to comply with these warnings can result in serious personal injury from hot liquid escaping from the engine cooling system.

3. Drain the coolant from the cooling system. For instructions, see **Group 20**.

NOTE: There are two heater core shutoff valves on the vehicle.

4. Loosen the heater hose clamp and remove the heater hose from the heater core shutoff valve.
5. Remove and discard the shutoff valve.
6. Apply pipe sealant with Teflon® (D8AZ-19554-A or equivalent) to the threads on the new shutoff valve.
7. Install the heater hose on the shutoff valve.
8. Tighten the hose clamp on the heater hose.
9. Fill the cooling system with coolant. For instructions, see **Group 20**.
10. Return the hood to the operating position.
11. Remove the chocks from the tires.

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Replacement

1. Remove the heater core. For instructions, see **Subject 270**.
2. Remove the evaporator housing. For instructions, see **Subject 140**.
3. Disconnect the electrical connector.
4. Remove the nuts that attach the heater core housing to the firewall, and remove the heater core housing. See **Fig. 1** and **Fig. 2**.

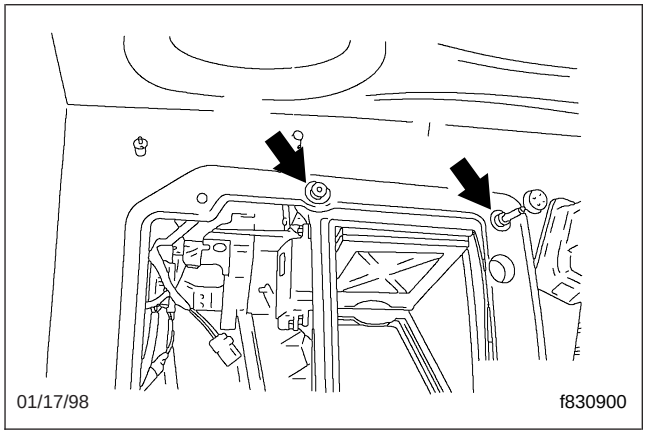


Fig. 1, Heater Core Housing Nuts

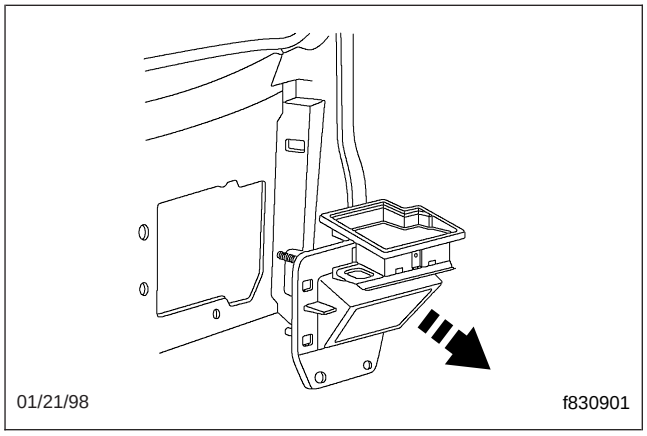


Fig. 2, Heater Core Housing

5. Using nuts, install a new heater core housing on the firewall.
6. Connect the electrical connector.
7. Install the evaporator housing. For instructions, see **Subject 140**.
8. Install the heater core. For instructions, see **Subject 270**.

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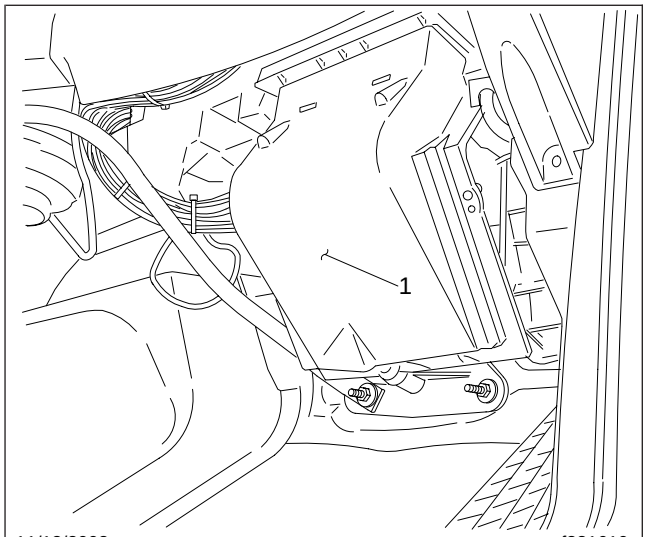
Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.

⚠ WARNING

The engine must be off and fully cooled, and the cooling system fully depressurized before disconnecting any heater water hoses. Failure to comply with these warnings can result in serious personal injury from hot liquid escaping from the engine cooling system.

3. Close the heater core shutoff valves or clamp the heater hoses.
4. Loosen the heater hose clamps and remove the heater hoses from the heater core.
5. Remove the screws that attach the heater core cover to the heater core housing, and remove the cover. See **Fig. 1**.

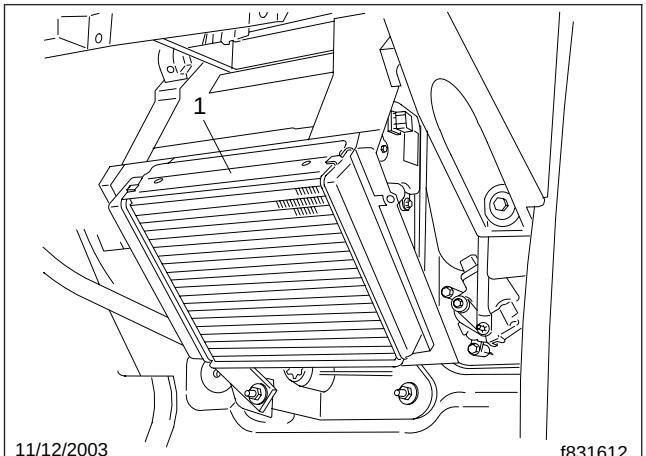


1. Heater Core Cover

Fig. 1, Heater Core Cover

IMPORTANT: A small amount of antifreeze may be present in the heater core. Protect the interior of the vehicle to prevent any damage from an antifreeze spill.

6. Wearing protective gloves, remove the heater core and drain any remaining coolant from the heater core. See **Fig. 2**.



1. Heater Core

Fig. 2, Heater Core

7. Apply rubber suspension insulator lube or its equivalent to the heater core tubes and to the frontwall seals to allow the heater core tubes to pass easily through the frontwall during installation.
8. Wearing protective gloves, install a new heater core in the heater core housing.
9. Using screws, attach the heater core cover to the heater core housing.
10. Attach the heater hoses to the heater core and tighten the hose clamps.
11. Open the heater core shutoff valves or remove the clamps from the heater hoses.
12. Add coolant to the cooling system to replace the amount that was lost during the replacement procedure. For instructions, see **Group 20**.
13. Return the hood to the operating position.
14. Remove the chocks from the tires.

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Manifold Gauge Set Connection

WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

CAUTION

The air conditioning refrigerant in all vehicles must be identified and analyzed prior to refrigerant recovery. Failure to do so can contaminate the shop bulk refrigerant and other vehicles.

1. Turn both valves on the R–134a manifold gauge set all the way to the left to close the low- and high-pressure hoses to the center manifold and center hose. See **Fig. 1**.

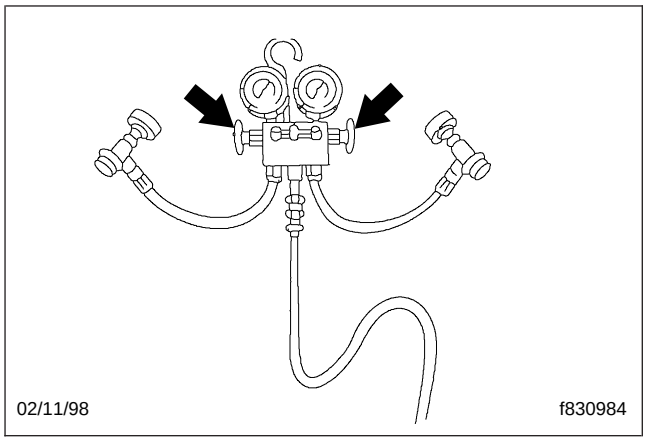


Fig. 1, Closing the Valves

2. Remove the air conditioning charging valve caps from the low- and high-pressure service gauge port valves. See **Fig. 2**.
3. Connect the low-pressure hose and an R–134a low-side quick disconnect to the low-pressure service gauge port valve. See **Fig. 3**.
4. Connect the high-pressure hose and an R–134a high-side quick disconnect to the high-pressure service port valve. See **Fig. 4**.

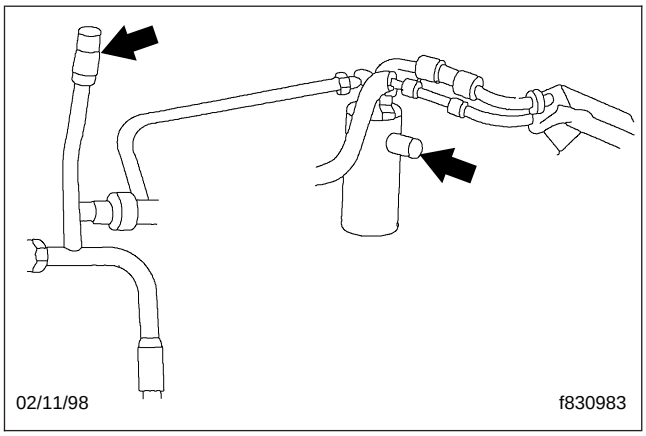


Fig. 2, Charging Caps

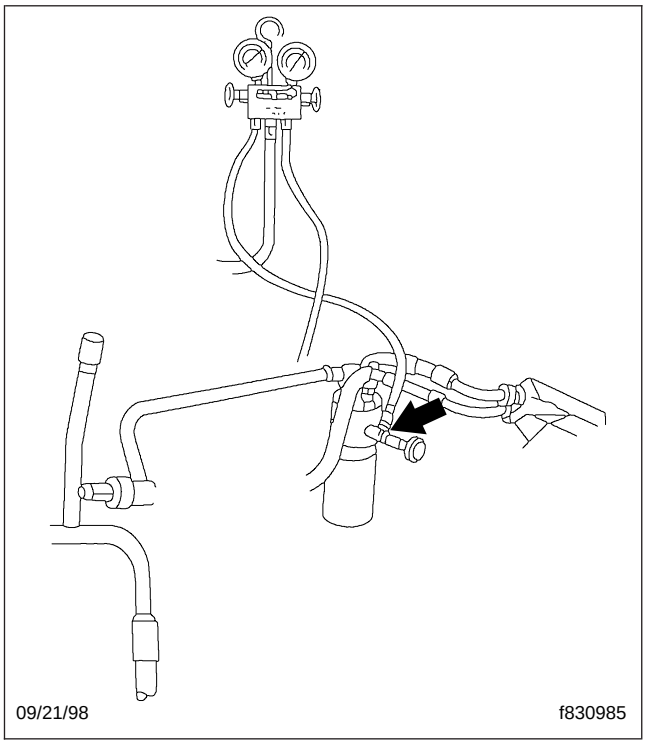


Fig. 3, Low-Pressure Connection

5. Connect the center hose to the vacuum pump or the R–134a tank. See **Fig. 5**.

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Refrigerant Service Operations

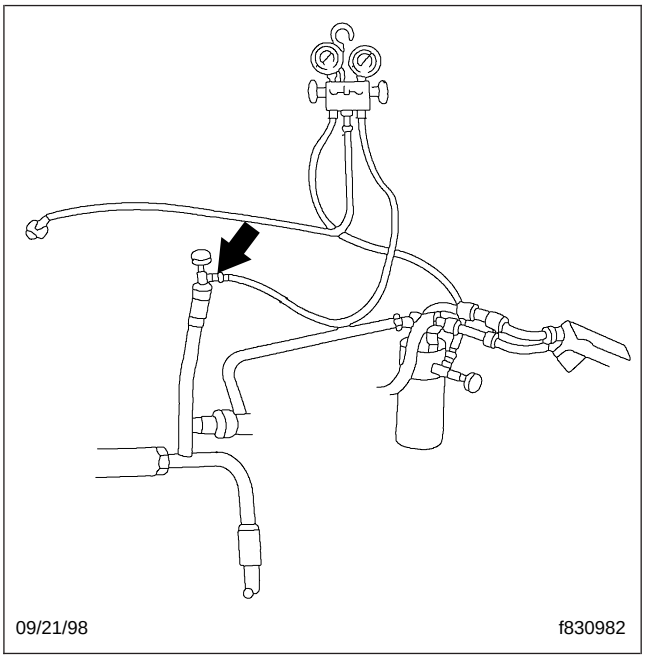


Fig. 4, High-Pressure Connection

Refrigerant Identification Testing

Use the air conditioning refrigerant analyzer to identify the refrigerant type and purity. Refer to the manufacturer's operating instructions.

- If the purity percentage of the R–134a is 98 percent or greater by weight, a green PASS LED will light. Proceed with the refrigerant recovery.
- If the R–134a does not meet 98 percent purity, a red FAIL LED will light. Proceed with the refrigerant recovery.
- Levels of R–22 and flammable hydrocarbons above two percent will light the red FAIL LED. Refer to "Contaminated Refrigerant" under the "Recovery" heading in this subject.
- If a flammable hydrocarbon is detected above five percent, both the FAIL and HYDROCARBON LEDs will light and an alarm will sound.

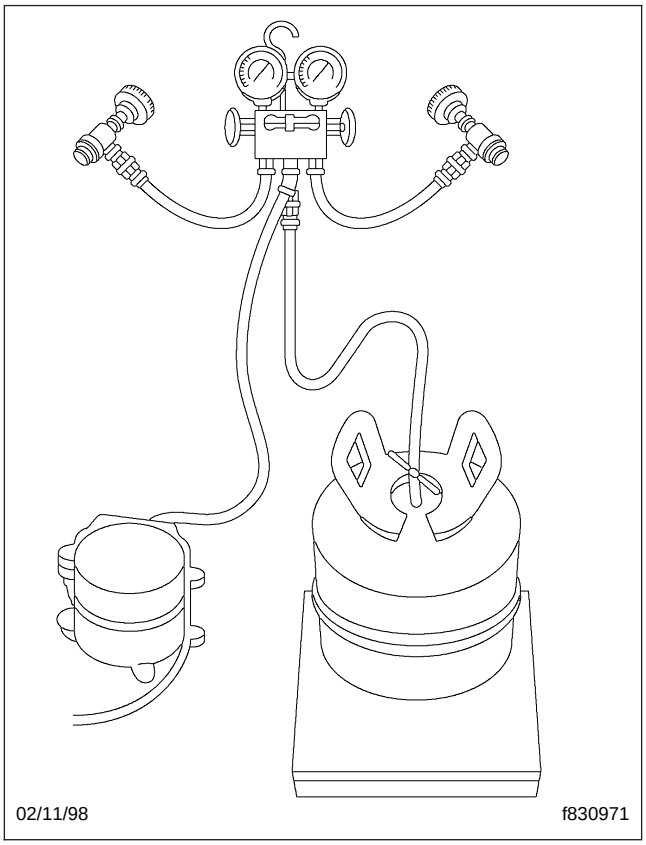


Fig. 5, Connecting the Vacuum Pump

Recovery

System Refrigerant

⚠ WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

NOTE: Sterling supports the efficient use, recovery, and recycling of R–134a used in tractor and truck air conditioners. Sterling recommends the use of a UL® approved recovery/recycling device such as an R–134a service center that meets SAE Standard J1991, during any air conditioning system repair and charge procedure

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that requires the air conditioning system to be recovered.

CAUTION

The air conditioning refrigerant in all vehicles must be identified and analyzed prior to refrigerant recovery. Failure to do so can contaminate the shop bulk refrigerant and other vehicles.

1. Analyze and identify the refrigerant in the air conditioning system.

NOTE: The hoses should have shutoff devices or check valves within 12 inches (305 mm) of the end of the hose to minimize the introduction of noncondensable gases (air) into the recycling station, and to minimize the amount of refrigerant released when the hoses are disconnected.

NOTE: Some R–134a service centers require the use of an air conditioning manifold gauge set.

2. Connect the R–134a service center hoses to the vehicle air conditioning service gauge ports.
3. Recover the refrigerant until the R–134a service center pressure goes into a vacuum. Refer to the equipment manufacturer's procedures and instructions for the use of the R–134a service center.

NOTE: Some R–134a service centers have a low-pressure switch in the electrical circuit to automatically shut off the pump. On other service centers, the pump may have to be shut off manually.

4. Shut off the pump.
5. If equipped with a service center inlet valve, close the valve.
6. Turn the R–134a service center power off.
7. Allow the vehicle air conditioning system to remain closed for approximately two minutes and observe the air conditioning system vacuum.
   - 7.1 If the system does not lose vacuum, disconnect the service center hoses.
   - 7.2 If the system loses vacuum, then repeat this procedure until the vacuum remains stable for two minutes.
8. Perform the required repairs. Evacuate and charge the air conditioning system.

Contaminated Refrigerant

1. Repeat the refrigerant identification.

NOTE: The customer may want to return to the facility responsible for the last air conditioning system service.

2. Advise the customer of the contaminated air conditioning system and any additional costs to repair the system.

CAUTION

This equipment must only be used to recover contaminated refrigerant to prevent the spread of contaminated refrigerant to other vehicles. As an alternative, contact an air conditioning service facility in your area that is equipped to handle contaminated air conditioning systems.

3. Recover the contaminated refrigerant using suitable recovery-only equipment designed for the recovery of contaminated refrigerant.
4. Determine the cause of the failure.
5. Determine which parts will need to be replaced.

NOTE: If the vehicle is equipped with an auxiliary HVAC system, the air conditioning evaporator must also be flushed to prevent system recontamination.

6. Flush the heat exchangers.
7. Install a new accumulator.
8. Add the necessary amount of refrigerant oil.
9. Evacuate the air conditioning system for 45 minutes.
10. Charge the air conditioning system.
11. Dispose of the contaminated refrigerant in accordance with all federal, state, and local laws and regulations.

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Evacuating/Recycling

Evacuation Using Vacuum Pump

⚠ WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

NOTE: Sterling supports the efficient usage, recovery, and recycling of R-134a used in tractor and truck air conditioners. Sterling recommends the use of a UL approved recovery/recycling device such as an R–134a service center that meets SAE Standard J1991, during any air conditioning system repair and charge procedure that requires the air conditioning system to be recovered.

1. Recover the refrigerant from the air conditioning system.
2. Connect the manifold gauge set with the center hose connected to the vacuum pump.
3. Evacuate the air conditioning system.
   - 3.1 Open the manifold gauge set valves.
   - 3.2 Start the vacuum pump.

   NOTE: The vacuum should be as close to 30 inHg (762 mmHg) as possible.
   - 3.3 Evacuate the system until the low-pressure gauge is between 25 to 30 inHg (635 to 762 mmHg).
   - 3.4 Operate the vacuum pump for an additional 45 minutes, or 65 to 75 minutes if a component of the air conditioning system has been replaced.
   - 3.5 Close the manifold gauge set valves.
   - 3.6 Turn the vacuum pump off.
   - 3.7 Observe the low-pressure side gauge to make sure it will hold a vacuum for five minutes.

     If the air conditioning system holds a vacuum, then proceed with air conditioning system charging.

     If the air conditioning system leaks, then leak test the system, repair any leak(s), and evacuate the system.

Evacuation Using Air Conditioning Service Center

NOTE: Some R–134a service centers require the use of an air conditioning manifold gauge set.

1. Connect the air conditioning service center hoses to the service gauge access ports.
2. The vacuum should be as close to 30 inHg (762 mmHg) as possible. Evacuate the system until the low-pressure gauge is between 25 to 30 inHg (635 to 762 mmHg). Refer to the equipment manufacturer's operating instructions.
3. Operate the vacuum pump for an additional 45 minutes or 65 to 75 minutes if a part of the air conditioning system has been replaced.
4. Turn the vacuum pump off.
5. Observe the low-pressure side gauge to make sure it will hold a vacuum for 5 minutes.
   - 5.1 If the air conditioning system holds a vacuum, then proceed with air conditioning system charging.
   - 5.2 If the air conditioning system leaks, then leak test the system, repair any leak(s), and evacuate the system.

Flushing

⚠ WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

Flushing removes moisture-laden oil and some contamination, such as dirty oil and some particles. When a part is flushed, liquid refrigerant is forced

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through it. The liquid picks up the contaminants and flushes them out.

Whether to flush or replace a part depends on how much contamination there is, as previously described.

Normally, the system always has pressure in it. Some loss of refrigerant from one season to the next is normal, and does not mean that the system is dirty. If refrigerant parts show signs of internal corrosion and grit, the system is contaminated.

If the system is contaminated with moisture, flush all sections of the system. Then change the oil in the compressor, and replace the receiver-drier prior to evacuating and charging the system.

If the system is heavily contaminated or if desiccant has circulated through the system, replace the receiver-drier, expansion valve(s), and inspect the compressor.

Do not flush the receiver-drier or the compressor.

Flush the system in segments to lessen the chance of blowing deposits against a port.

Flush the system in the opposite direction of refrigerant flow.

Flushing parts with refrigerant, requires a refrigerant recovery and charging machine.

Flushing Procedure

Method 1

NOTE: Use this method when the recovery and charging machine is equipped with a flush cycle.

1. Recover the refrigerant from the air conditioning system.
2. Disconnect both ends of the line or part(s) being flushed. Tightly cap the lines to the rest of the system.

NOTE: You must remove the expansion device(s), receiver-drier, and compressor(s) when flushing. These components must be removed and bypassed when performing a system flush.

3. Install the flushing adaptors and an inline filter and follow the instructions from the manufacturer of the recovery and charging machine to perform the flush. When flushing the entire system, use an adaptor that fits where the compressor was located, and backflush.
4. Remove the adaptors and bypass devices and install the expansion device(s), the compressor, and a new receiver-drier.
5. If installing the existing compressor, remove the oil in it and replace the oil with new oil. New compressors may or may not have a full charge of oil.
6. Charge the system with refrigerant and check the system performance.

Method 2

NOTE: Use this method when two recovery and charging machines are available.

1. Recover the refrigerant from the air conditioning system.
2. Disconnect both ends of the line or part(s) being flushed. Tightly cap the lines to the rest of the system.

NOTE: You must remove the expansion device(s), receiver-drier, and compressor(s) when flushing. These components must be removed and bypassed when performing a system flush.

3. Install the flushing adaptors and an inline filter. When flushing the entire system, use an adaptor that fits where the compressor was located, and backflush.
4. Charge the part with 2 pounds (0.9 kg) of refrigerant or the system with 5 pounds (2.3 kg) of refrigerant, then recover the refrigerant with a second machine. It is desirable to start the recovery slightly before the charge cycle is done, since this helps to push fluid through the system. Repeat the process several times until you think that all the oil has been removed.
5. Remove the adaptors and bypass devices and install the expansion device(s), the compressor(s), and a new receiver-drier.
6. If installing the existing compressor, remove the oil in it and replace the oil with new oil. New compressors may or may not have a full charge of oil.
7. Charge the system with refrigerant and check the system performance.

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Charging

WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

NOTE: Before charging, the system must be recovered and evacuated with the recovery and recycling station connected to the service and discharge port connections.

1. Obtain enough refrigerant to fully charge the system. Refer to the Air Conditioner label on the air intake plenum for the amount of refrigerant needed to fully charge the system.
2. Set the tank on a scale and weigh it so that the correct amount of refrigerant enters the system. This prevents overcharging which could damage the compressor.
3. Charge the system.

NOTE: If using a recovery, recycling, and recharging station, charge the system on the high side following the manufacturer's instructions. If charging from a bulk container, do the following.

4. Turn the tank (bulk container) upside down.
5. With the engine off, open the high-side valve. **Do not** open the low-side valve.
6. Allow refrigerant to enter the system until the correct charge (by weight) has entered. Then close the high-side valve.
7. Start the engine and run it at 1500 rpm. Set the cab air conditioner controls at maximum cooling and fan speed. The refrigerant compressor must engage.
8. If a full charge did not enter the system, place the tank (bulk container) in the upright position, then open the low-side valve to draw vapor into the system. Leave the valve open until the correct weight of refrigerant has entered the system, then close the low-side valve.

NOTE: If refrigerant is slow to enter the system because of low outside temperatures, vaporization can be quickened by placing the refrigerant tank in a tub of water no warmer than 125°F (52°C).

9. While the compressor is engaged, check the operating pressures at the suction and discharge ports. Refer to the applicable refrigerant compressor section in this manual. If the operating pressures are not acceptable, refer to **Troubleshooting 310** for possible causes.
10. Disconnect the high-side hose. With the engine running, open the low-side and high-side hose valves to recover the refrigerant from the lines.
11. Shut down the engine.

Leak Testing Methods

General Information

WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions, and to take precautions against the dangers involved when working with refrigerant, could lead to serious personal injury.

Refrigerant is odorless. As a result, all of it may leak away and not be noticed until the system stops cooling. All vehicle refrigerant systems lose some refrigerant, depending on the condition of the system. Higher loss rates signal a need to locate and repair the leaks.

Leaks are most often found at the compressor hose connections and at the various fittings and joints in the system. If unapproved replacement hoses are installed, refrigerant can be lost through hose permeation.

There are two leak testing methods that can be used to detect leaks in the A/C system: UV (ultraviolet) dye leak detection and electronic leak detection. Daimler Trucks North America LLC recommends using the UV dye leak detection method whenever possible, even though there are some limitations to using this method. A leak on the front seal of the compressor **must** be verified using a heated diode leak detector and the instructions in this subject. Visible dye on the front of the compressor clutch **does not** verify that there is a leak at the front seal.

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Evaporator leaks may not show up with dye, and must be checked using a heated diode leak detector if dye is not present at the condensate drain.

Determine If the A/C System Contains UV Dye

IMPORTANT: Always wear UV-blocking protective eyewear when using the UV dye leak detection method. Always wear nonleather gloves and protective eyewear when servicing the air conditioning system.

NOTE: Acterra vehicles with A/C systems have UV dye installed in them at the truck manufacturing plant and in replacement accumulators. If it is determined that more UV dye needs to be added to the A/C system because a large amount of oil has been replaced, or because there is no UV dye present after performing the following procedures, add dye according to the dye manufacturer's instructions.

1. Remove the low-side service port sealing cap, and direct the UV lamp to the stem area.
2. If UV dye is observed in the low-side service port, assume that a UV dye is in the system, and leak test the A/C system using the UV dye leak detection method.
3. If UV dye is not observed, depress the valve stem for an instant to bring some of the lubricant and dye out of the system. This can be safely accomplished using a modified service valve cap. See the instructions in "Modify the Service Valve Cap."

NOTE: Clean the modified valve cap after finding dye to avoid contaminating the next vehicle.

4. If no UV dye is observed in the low-side service port, use an electronic leak detector to leak test the A/C system, or add UV dye to the A/C system using the dye manufacturer's instructions.
5. If UV dye is being added to the A/C system, use the following instructions.
    - 5.1 Inject the amount of dye recommended by the dye manufacturer into the A/C system.
    - 5.2 Place a label under the hood, preferably next to the charge label, that indicates dye has been added to the A/C system.
    - 5.3 Verify that the A/C system has the correct amount of refrigerant.
    - 5.4 Run the air conditioner for at least 15 minutes to find large leaks. It may take as long as two weeks to detect small leaks using the UV dye leak detection method.

UV Dye Leak Detection

IMPORTANT: Always wear UV-blocking protective eyewear when using the UV dye leak detection method. Always wear nonleather gloves and protective eyewear when servicing the air conditioning system.

1. Inspect the A/C system for leaks using a UV lamp.
    - 1.1 Inspect the entire A/C system under low lighting using a UV lamp. Low lighting will increase the apparent brightness of the UV dye at leak sights.
    - 1.2 Move the UV lamp along the entire refrigerant system, looking for signs of damage or corrosion on the fittings, hose-to-line crimps, switch ports, service ports with caps installed (dye inside the port is not an indication of a leak), brazed or welded areas, and around all connections. Check for evaporator leaks by illuminating the condensate drain tube or hole using the UV lamp.
    - 1.3 Move the UV lamp along the refrigerant system following a continuous path, so that no potential leak sites are missed. If a leak is found, continue to check the remainder of the system since other leaks may be present.
2. After repairing a leak, remove all UV dye residue remaining on the outside of the A/C system using the cleaner provided by the dye manufacturer, or a comparable cleaner. Use a spray bottle of cleaner, a toothbrush, and a spray bottle of clean water for hard-to-reach areas.

NOTE: Minor UV dye residue, or residue that is impossible to reach, will lose its fluorescence over time.

3. See **Table 1** for a list of products that have been tested and approved for use by Sterling dealers.

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Refrigerant Service Operations

Approved Products for UV Dye Leak Detection				
Type of Refrigerant Oil	**Product Description**	**Vendor Part Number**	**Freightliner Part Number**	**Web Site Address**
PAG	Tracerline BigEZ Kit – Can be injected without discharging the system. • Each kit includes one 4-oz (118-mL) cartridge and an injection tool.	TP-9741CS	ABP N83 327911	www.tracerline.com
	• A 4-oz (118-mL) replacement cartridge services 16 vehicles.	TP-9760-0004CS	ABP N83 327961	
	• An 8-oz (237-mL) replacement cartridge services 32 vehicles.	TP-9760-0108	ABP N83 327951	
—	Tracerline Optimax UV Lamp	TP-8680	ABP N83 327985	www.tracerline.com
—	Bright Solutions UV Lamp	BSL760	ABP N83 327967	www.brightsol.com
—	Service Valve Cap	—	PH 660412	—

Table 1, Approved Products for UV Dye Leak Detection

Modify the Service Valve Cap

Use the following instructions to modify a service valve cap that will depress a Schrader valve.

1. Purchase a low-side service valve cap, part number PH 660412.
2. Locate the small, 0.145-inch diameter (3.7-mm) barrel inside the cap.
3. Fill the barrel to within 0.25 inch (6 mm) of its rim with epoxy, felt material, or wadded paper.
4. Mark the cap with the words "Do Not Use."

Electronic Leak Detection

When checking for leaks, move the probe all the way around the fitting or suspected leak.

NOTE: Do not try to use a leak tester immediately after connecting or disconnecting service hoses. Traces of refrigerant at the fittings can falsely signal a leak. Always verify a leak by blowing shop air in to the area of the suspected leak and checking the area again.

Daimler Trucks North America LLC recommends using only the heated diode type of electronic leak detector. This type of detector can be identified by its construction and power supply. It has a heated element which requires periodic replacement, and uses either a 12V DC or 120V AC power supply, or has a rechargeable battery. The heated diode type detector is sensitive only to gases containing halogen, such as R–134a and R–12 refrigerants. It will not detect other substances and is more likely to detect all of the leaks in a system. This type has both visual and audio indicators and self-tests to confirm operation.

Recommended electronic heated diode type leak detectors are available from their manufacturers. See **Table 2**.

Another type of detector, the corona discharge type, is the kind most commonly found in service and repair shops. This detector requires very little power and can operate on as few as four AA alkaline batteries. The corona discharge detector is not sufficiently sensitive and will create false alarms by detecting moisture and antifreeze or solvent vapors. This type of detector is specifically **not recommended**.

Use the following procedures to locate A/C system refrigerant gas leaks using a heated diode type electronic leak detector.

1. Operate the electronic leak detector in accordance with the manufacturer's instructions.

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Electronic Leak Detectors		
Designation	**Manufacturer**	**Comments**
D-TEK, D-Tek Select, and TekMate	Leybold Inficon 2 Technology Place East Syracuse NY 13057 (315) 434–1144	• Rechargeable battery • Hand-held design • Simple to operate
H–10 Professional	Bacharach Inc. c/o Yokogawa Corp. of America 2 Dart Road Newnan GA 30265 (800) 850–0044	• Rechargeable battery • Carrying case with strap • Calibration leak bottle • Manual sensitivity control • Most sensitive available
J 39400	SPX Kent-Moore 28635 Mound Road Warren MI 48092–3499 (800) 328–6657	• 12V DC or 120V AC • Carrying case with strap • Calibration leak bottle • Manual sensitivity control • Manual balance control

Table 2, Electronic Leak Detectors

2. Leak test with the engine turned off.
3. Charge the air conditioning system with sufficient refrigerant to indicate a gauge pressure of at least 50 psi (345 kPa) with the system not operating. It may not be possible to produce this amount of pressure and measure leakage if the ambient temperature is less than 59°F (15°C).
4. If the part being tested is not clean, be careful not to contaminate the detector probe tip. Wipe the part off with a dry shop towel, or blow it off with shop air. Do not use cleaners or solvents, as many detectors are sensitive to their chemical ingredients.
5. Visually inspect the entire refrigerant system. Look for air conditioning lubricant leakage and corrosion or damage to lines, hoses, and all other components. Inspect each questionable location carefully with the detector probe. Check all fittings, couplings, refrigerant controls, service ports (with caps installed), brazed or welded areas, and areas around attachment points and hold-downs.
6. Follow the path of the refrigerant system methodically so that no leaks are missed. If a leak is found, continue to test the rest of the system.
7. Inspect an area of possible leakage slowly and close to the part, moving completely around the part. Move the probe no faster than one to two inches (25 to 50 mm) per second and no farther away than 1/4 inch (6 mm) from the part.
8. If a large leak is present in either the system being serviced or the service equipment, the surrounding air will be saturated with refrigerant gas. In this situation the leak detector operates erratically and will indicate leakage, without being near a possible leak source. Place a large fan so that a light breeze blows through the work area. Verify a leak by blowing shop air into the area and repeating the inspection. Pinpoint a large leak by blowing out the area often.
9. You may test the evaporator core while it is in its housing. Turn on the blower motor for a minimum of 15 seconds. Shut off the blower and wait for refrigerant gas to accumulate in the housing. Follow the detector instructions for the specific length of time to wait for the gas to accumulate. Insert the detector probe into the blower resistor block, or condensate drain tube if no water is present. If this is not possible insert the probe into the closest opening to the evaporator, such as a heater or vent duct.

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Refrigerant Service Operations

NOTE: The presence of water in the condensate drain tube can be determined by inserting the eraser end of a pencil in the drain tube. Inserting the pencil will break the surface tension of any water near the opening of the drain tube and allow the water to drain out before inserting the probe tip. It is only necessary to break the plane of the drain tube with the probe tip. It doesn't need to be inserted far into the tube.

10. Leak test the front seal area of the compressor. Blow shop air into the cavities in and around the clutch for at least 15 seconds. Let the compressor stand for one minute and then test for leakage. Inspect axial-type compressors (Sanden or Sel-Tec) by placing the probe near the holes at the front of the clutch. See **Fig. 6**. Inspect two-cylinder reciprocating type compressors (Climate Control) by placing the probe between the clutch coil and the compressor. See **Fig. 7**.

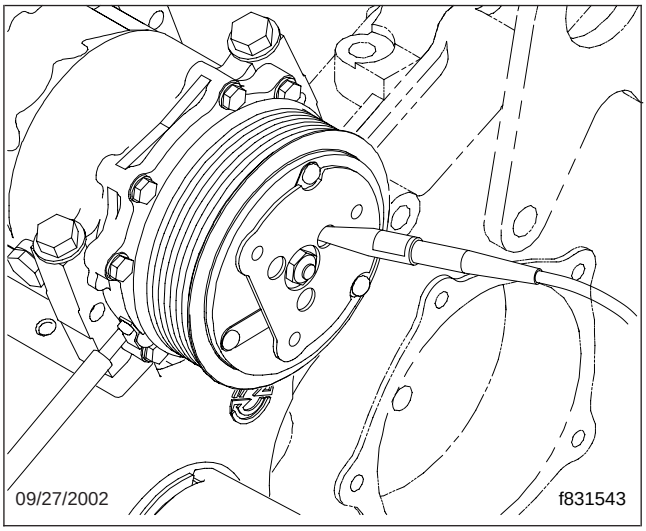


Fig. 6, Axial-Type Compressor

IMPORTANT: Be careful not to damage the clutch bearing seal with high pressure shop air.

11. Leak test repaired areas of the system after repairs have been performed. Leak test the service ports (with caps installed) after any service which disturbs the refrigerant system.

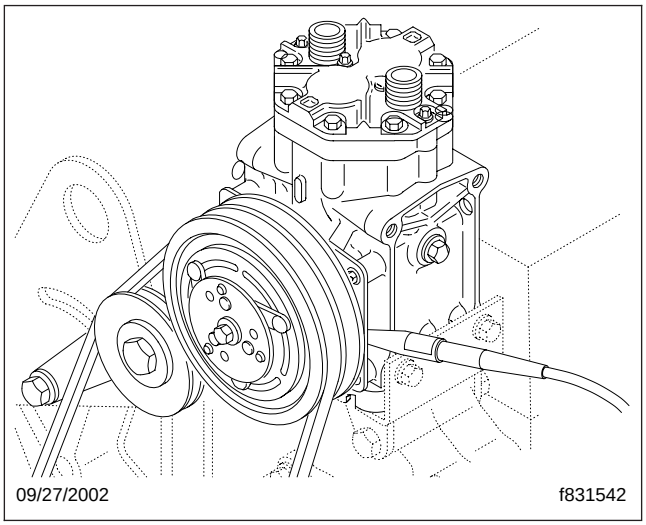


Fig. 7, Two-Cylinder Reciprocating Compressor

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General Information

The cab heating, ventilating, and air conditioning (HVAC) system is an electronically-controlled blend air system. On vehicles equipped with air conditioning, all airflow is routed through the evaporator. A blend air door is used to control the amount of air that is routed through the heater core. The amount of air directed through the heater core is dependent on the temperature control switch setting. Electric actuators control the position of the four mode doors, and thus the airflow, within the HVAC system. The actuators are controlled by the control panel module located on the back of the climate control panel. The speed of the blower motor is controlled by reducing the current through a resistor block.

The cab heater and air conditioner consists of a blower motor, evaporator, heater core, and five electric actuators that control the temperature control doors, the air selection mode doors, and the recirculation door. All electric actuators, except the temperature/blend air actuator, are controlled by the control panel module. The temperature/blend air actuator is controlled by a potentiometer on the climate control panel.

- The temperature/blend air actuator controls temperature by controlling the airflow through the heater core.
- The fresh air/recirculation actuator allows fresh air into the cab or allows the air in the cab to be recirculated.
- The panel/floor actuator controls the airflow to the floor outlets and to the instrument panel outlets, with the exception of the right-side instrument panel outlet.
- The right-side panel/demist actuator controls the airflow to the right-side instrument panel outlet and demist outlet.
- The defrost/panel actuator controls the airflow to the defrost outlets and to the instrument panel outlets, with the exception of the right-side instrument panel outlet.

See **Table 1** for the location of the air selection switch positions.

HVAC System Troubleshooting Tables

See **Table 2** to determine which troubleshooting table to refer to for the problem area of the HVAC system.

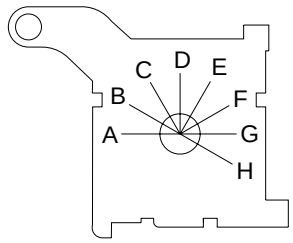
Air Selection Switch Positions				
Figure	Switch Position	HVAC Option		
		Heater (–000)	A/C (–001)	Max A/C (–002)
	A	Not Available	MAX A/C	MAX A/C
	B	PANEL	A/C	MAX A/C
	C	PANEL & FLOOR	PANEL	PANEL
	D	OFF	OFF	OFF
	E	FLR	PANEL & FLOOR	PANEL & FLOOR
	F	FLR & DEF	FLR	FLR
	G	DEF	FLR & DEF	FLR & DEF
	H	Not Available	DEF	DEF

Table 1, Air Selection Switch Positions

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Troubleshooting the HVAC System

General Diagnosis	
General Problem Area	**Action**
Air Distribution	See **Table 6**.
Blower	See **Table 9** and **Table 10**.
Little or No Cooling	See **Table 3**.
Little or No Heating	See **Table 4**.
Fresh Air/Recirculation	See **Table 12**.
Backlighting	See **Table 5**.
A/C Clutch Not Engaging	See **Table 16**.
CHECK A/C Indicator Illuminated*	See **Table 17**.

* Only vehicles built with pre-2004 engines have a CHECK A/C indicator.

Table 2, General Diagnosis

Little or No Cooling Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Does A/C clutch engage?	Yes	**Go to test no. 2.**
		No	See **Table 16** for diagnosis.
2	Temporarily pinch off the hoses going to the heater core. Is the outlet temperature now acceptable?	Yes	See **Table 7** for diagnosis of temperature/ blend air actuator.
		No	See **Subject 310** for the Refrigerant System Diagnosis procedures.

Table 3, Little or No Cooling Diagnosis

Little or No Heating Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Check engine coolant level.	OK	**Go to test no. 2.**
		Not OK	Check for coolant leaks. Repair as necessary. If vehicle still has a heating problem, **go to test no. 2.**
2	Check heater hose temperatures entering and exiting the heater core: • Set the temperature control switch to full hot. • Set the blower speed to HI. • Set the mode control to PANEL. • Bring engine to operating temperature. Feel both heater hoses going in to and out of the heater core.	Both hot	Check for possible blend door malfunction. See **Table 7** for diagnosis of temperature/ blend air actuator.
		One hot, one cool	Possible plugged heater core. Flush or replace as necessary.
		Both cool to lukewarm	Check engine thermostat for proper operation. Check for closed heater hose valves, if equipped.

Table 4, Little or No Heating Diagnosis

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Backlighting Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Check power and ground to control panel: • Gain access to back of control panel. • Remove the AC2 connector. See **Subject 400** for wiring diagrams. • Turn headlight switch ON. Measure voltage across pins 1 and 2 of the AC2 connector.	Approx. 12V	Replace bulb(s). If backlightling still does not work, replace the control panel.
		0V	Check backlighting circuit 29A and ground for open.

Table 5, Backlighting Diagnosis

Air Distribution Diagnosis	
Symptom	**Action**
No air flow from defrost outlets	Does air come out of floor outlets in defrost mode? Yes—**go to Table 14** for diagnosis. No—**go to Table 13** for diagnosis.
No airflow from floor outlets	**Go to Table 14** for diagnosis.
No airflow from panel outlets, except right-side outlet	Does air come out of the floor outlets in PANEL mode? Yes—**go to Table 14** for diagnosis. No—**go to Table 13** for diagnosis.
No airflow from right-side outlet	**Go to Table 15** for diagnosis.
Airflow from floor outlets in all mode positions	**Go to Table 14** for diagnosis.
Airflow from defrost and panel outlets in all mode positions, except floor	**Go to Table 13** for diagnosis.
No recirc or fresh air	**Go to Table 12** for diagnosis.

Table 6, Air Distribution Diagnosis

Temperature/Blend Air Actuator Electrical Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Check fuse/circuit breaker no. 18.	OK	**Go to test no. 2**.
		Not OK	Check circuit 220 for short to ground. Repair as necessary. If OK, replace actuator.

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Troubleshooting the HVAC System

Temperature/Blend Air Actuator Electrical Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
2	Disconnect the temperature potentiometer connector AC3. • Turn ignition ON. Measure voltage across pins 1 and 3 of the temperature potentiometer connector (harness side). NOTE: Connect electrical connector when test is complete. Leave connector accessible. It may require removal in later tests.	Approx. 10V	**Go to test no. 4**.
		Much less than 10V	**Go to test no. 3**.
3	Disconnect the connector to the temperature/blend air actuator. See **Fig. 7**. • Turn ignition ON. Measure voltage across pins 1 and 2 at the actuator connector (harness side). NOTE: Connect electrical connector when test is complete.	Approx. 12V	Check circuits 98K1 and 98K2 for open. Repair as necessary. See **Subject 400** for wiring diagrams. If circuits are okay, replace actuator.
		Much less than 12V	Check circuit 220 and actuator ground circuit for open. Repair as necessary. See **Subject 400** for wiring diagrams.
4	Disconnect the temperature potentiometer connector AC3. • Turn ignition OFF. Measure resistance across pins 1 and 2 of the temperature potentiometer connector (harness side). NOTE: Connect electrical connector when test is complete. Leave connector accessible. It may require removal in later tests.	Approx. 195k ohms	**Go to test no. 6**.
		Much greater than 195k ohms	**Go to test no. 5**.
5	Remove the temperature/blend air actuator. See **Fig. 7**. Measure resistance across pins 5 and 6 at the actuator connector (actuator side).	Approx. 195k ohms	Check circuits 98K2 and 98K3 for open. Repair as necessary. See **Fig. 1**. See **Subject 400** for wiring diagrams.
		Much greater than 195k ohms	Replace actuator.
6	Disconnect the temperature potentiometer connector AC3. • Turn ignition OFF. Measure resistance between harness side of pin 1 and a known good ground. NOTE: Connect electrical connector when test is complete. Leave connector accessible. It may require removal in later tests.	Less than 1 ohm	**Go to test no. 7**.
		More than 1 ohm	Check actuator ground circuit. Repair as necessary. See **Subject 400** for wiring diagrams.

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Temperature/Blend Air Actuator Electrical Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
7	Temperature potentiometer resistance check: • Disconnect the temperature control potentiometer connector AC3 (back of HVAC control panel). Measure resistance at the potentiometer as follows. See **Fig. 1**. • Across pins 1 and 3: should be approx. 5000 ohms • Across pins 1 and 2: should be approx. 80 ohms (cold) and approx. 5150 ohms (hot).	OK	**Go to test no. 8**.
		Not OK	Replace temperature potentiometer.
8	Remove the temperature/blend air actuator. See **Fig. 7**. Move the temperature door arm and check for obstruction or mechanical problem, such as binding.	OK	Replace actuator.
		Not OK	Mechanical problem. Repair as necessary.

Table 7, Temperature/Blend Air Actuator Electrical Diagnosis

Actuator Function Logic						
Air Selection Switch Setting*	**Actuator†**				**A/C 001 and 002 only**	**Blower**
	No. 1 Right-Side Panel/Demist	**No. 2 Panel/Floor**	**No. 3 Defrost/Panel**	**No. 4 Fresh Air/ Recirc‡**		
MAX A/C	CW	CCW	CCW	CW	X	On
A/C	CW	CCW	CCW	CCW§	X	On
PANEL	CW	CCW	CCW	CCW	§	On
OFF	Middle§	Middle§	CCW	CW§		Off§
PANEL & FLOOR	Middle	Middle	CCW	CCW§	X§	On§
FLR	CCW§	CW§	CW§	CCW	§	On
FLR & DEF	CCW	Middle§	CW	CCW	X§	On
DEF	CCW	CCW§	CW	CCW	X	On

* Use this table by starting with the switch at MAX A/C and moving through the settings as listed in the column.

† See **Fig. 7**.

‡ With the ignition off, the fresh air/recirc actuator drives recirc clockwise from any mode.

§ A change in state has occurred.

Table 8, Actuator Function Logic

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Troubleshooting the HVAC System

Blower Motor Diagnosis—Blower Does Not Operate at Any Speed			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Before proceeding, perform test in **Table 18**. If this does not correct the problem, return to this table, step 2.		
2	Check if blower relay is switching on: • Disconnect the blower motor connector. • Set the blower speed switch to any speed. • Set the mode control switch to any position except OFF. • Turn ignition ON. Measure voltage between pin 1 (circuit 98FA) of the blower motor connector (harness side) and a known good ground. See **Subject 400** for wiring diagrams.	Approx. 12V	**Go to test no. 8**.
		Less than 1V	**Go to test no. 3**.
3	Check voltage to the coil side of the blower motor relay: • Remove blower motor relay (relay 8). • Turn ignition ON. Measure voltage between the relay cavity in the PDM that mates with pin 1 of the relay and a known good ground.	Approx. 12V	**Go to test no. 4**.
		Less than 1V	Check circuit breaker 18 in cab PDM. Check circuit 220 (305 on vehicles with a 2004 engine) for open or short. Repair as necessary. See **Subject 400** for wiring diagrams.
4	Check if the control panel is providing ground to switch the blower motor relay on: • Turn ignition ON. Measure voltage between relay cavities in the PDM that mate to pins 1 and 2 of the blower motor relay. Check for the following: • When the mode control switch is in the OFF position, the voltage reading should be approx. 6V. • When the mode control switch is in any position except OFF, the voltage reading should be approx. 12V.	OK	**Go to test no. 5**.
		Not OK	Check circuit 98Z for open, check power and ground circuits to HVAC control panel. Repair as necessary. See **Subject 400** for wiring diagrams. If circuits are okay, replace the control panel.

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Blower Motor Diagnosis—Blower Does Not Operate at Any Speed			
Test No.	**Test Procedure**	**Test Result**	**Action**
5	Check relay coil resistance. Check resistance across pins 1 and 2 of the blower motor relay. NOTE: If the resistance is approximately 680 ohms, the relay coil is open. If the resistance is approximately 70 ohms, the surge suppression resistor is open. In either case the relay should be replaced.	Approx. 62 to 64 ohms	**Go to test no. 6**.
		Greater than 64 ohms	Replace the relay.
6	Check for voltage at the high side of the blower motor relay. Measure voltage between the relay cavity in the PDM that mates to pin 3 of the blower motor relay (relay 8) and a known good ground.	Approx. 12V	**Go to test no. 7**.
		Less than 1V	Check circuit breaker G in the engine compartment PDM. Check for open/short in circuit 210G that supplies power to the high side of the blower motor relay. Repair as necessary. See **Subject 400** for wiring diagrams.
7	Check continuity in circuit 98FA between blower motor relay and blower motor: • Disconnect blower motor connector. Check continuity between relay cavity in the PDM that mates to pin 5 of the blower motor relay, and pin 1 of the blower motor connector.	Continuity	Check for stuck relay contacts. If OK, check same circuit 98FA using a voltage drop test to confirm circuit. Voltage drop should be less than 1V. Repair as necessary.
		No continuity	Circuit 98FA is open. Repair as necessary.
8	Check voltage drop across blower motor: • Install blower motor relay (relay 8). • Connect blower motor connector. • Turn ignition ON. • Turn fan to HI. • Set mode control switch to any position except OFF. Measure the voltage drop across the blower motor connector (leave connector plugged in) by backprobing the two pins.	More than 10V	Replace blower motor.
		Less than 10V	Check circuit 98FA using a voltage drop test to confirm circuit between blower motor relay and the blower motor. Voltage drop should be less than 1V. If circuit 98FA is OK, perform same check on ground circuit between the blower motor and splice S2. Repair as necessary. See **Subject 400** for wiring diagrams.

Table 9, Blower Motor Diagnosis—Blower Does Not Operate at Any Speed

Blower Motor Diagnosis—Blower Does Not Work in One or Multiple Speed Settings			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Does the blower motor work in one or more speed settings?	Yes	**Go to test no. 2**.
		No	See **Table 9**, Blower Motor Diagnosis—Blower Does Not Operate at Any Speed.

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Troubleshooting the HVAC System

Blower Motor Diagnosis—Blower Does Not Work in One or Multiple Speed Settings			
Test No.	**Test Procedure**	**Test Result**	**Action**
2	Does the blower operate in LO speed?	Yes	**Go to test no. 6**.
		No	**Go to test no. 3**.
3	Check the blower resistor block: • Unplug resistor block. Measure resistance across the following pins. See **Fig. 2**. Pins 1 and 3: approx. 0.4 ohm Pins 3 and 4: approx. 1 ohm Pins 2 and 3: approx. 3 ohms If any of the readings are significantly higher than the values shown (meter reads OL), or if any of the readings are zero, then the result is not OK. NOTE: Plug connector back into resistor block when test is complete.	OK	**Go to test no. 4**.
		Not OK	Replace blower resistor block.
4	Check circuit 98F between blower motor and resistor block: • Turn ignition ON. • Set blower speed to MED-HI. • Set mode control switch to any position except OFF. Measure voltage drop between pin 2 (circuit 98F) of the blower motor connector and pin 3 (circuit 98F) of the resistor block by backprobing the connectors. NOTE: Connectors must be plugged in when performing this test.	Less than 0.25V	**Go to test no. 5**.
		More than 0.25V	Repair circuit 98F between blower motor and resistor block.
5	Check resistor block ground circuit: • Turn ignition ON. • Set blower speed to LO. • Set mode control switch to any position except OFF. Measure voltage drop between pin 2 of the resistor block (by backprobing) and the battery negative terminal. NOTE: Connectors must be plugged in when performing this test.	Less than 0.25V	No problem found. Repeat tests.
		More than 0.25V	Locate open or source of high resistance in resistor block ground circuit. Repair as necessary.

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Blower Motor Diagnosis—Blower Does Not Work in One or Multiple Speed Settings			
Test No.	**Test Procedure**	**Test Result**	**Action**
6	Check blower motor switch: • Remove blower motor switch connector from the control panel. Check continuity of the switch as follows. See **Fig. 3**. LO: pin 1 to pins 2 through 4—No continuity MED-LO: pin 1 to pin 3—Continuity MED-HI: pin 1 to pin 4—Continuity HI: pin 1 to pin 2—Continuity NOTE: Connect blower switch connector when test is complete.	OK	**Go to test no. 7**.
		Not OK	Replace blower speed switch.
7	Check blower speed switch ground circuit: • Turn ignition ON. • Set blower speed to HI. • Set mode control switch to any position except OFF. Measure voltage drop between pin 1 (GND) of the blower switch (by backprobing) and the battery negative terminal. NOTE: Connectors must be plugged in when performing this test.	Less than 0.25V	Depending on which speed does not work, check the following circuits: For MED-LO: 98A For MED-HI: 98B For HI: 98F between splice S2 and blower switch
		More than 0.25V	Repair blower switch ground circuit.

Table 10, Blower Motor Diagnosis—Blower Does Not Work in One or Multiple Speed Settings

HVAC Control Panel Pinout		
Pin	**Description**	**Circuit**
1	Not used	—
2	Mode no. 1 and no. 2 actuator position sensor ground	GND1
3	Mode no. 2 actuator position sensor feedback	338F2
4	Recirc actuator–open	338E
5	Mode no. 3 actuator–open	338C–
6	Mode no. 2 actuator–CW	338B–
7	Mode no. 1 actuator–CW	338A–
8	Blower motor relay control	98Z
9	Ground	GND2
10	+12V battery	97A
11	Mode no. 2 actuator position sensor +5V reference	338H

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Troubleshooting the HVAC System

HVAC Control Panel Pinout		
Pin	**Description**	**Circuit**
12	Mode no. 1 actuator position sensor +5V reference	338G
13	Mode no. 1 actuator position sensor feedback	338F1
14	Recirc actuator–closed	338D
15	Mode no. 3 actuator–closed	338C+
16	Mode no. 2 actuator–CCW	338B+
17	Mode no. 1 actuator–CCW	338A+
18	A/C clutch relay control	97
19	Not used	—
20	+12V ignition switched	220

Table 11, HVAC Control Panel Pinout

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Fresh Air/Recirculation Actuator No. 4 Circuit Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Check for signal from control panel: • Disconnect the fresh air/recirc actuator connector. See **Fig. 7**. • Turn ignition ON. Set DMM to read voltage, then place meter leads in harness side of actuator connector as follows: • (+) lead in pin 4 (circuit 338D) • (–) lead in pin 2 (circuit 338E) Start with the mode control switch in the OFF position. Then set the mode switch as follows and observe the voltage readings: MAX A/C: –10.5V± then 0V A/C: +10.5V± then 0V PANEL: +10.5V± then 0V OFF: –10.5V± then 0V PANEL & FLOOR: +10.5V± then 0V FLR: 0V FLR & DEF: 0V DEF: 0V If working correctly, the voltages listed should be present for a few seconds, then go to zero. For example, when the mode is switched to MAX A/C, the voltage should be approximately –10.5 V for a few seconds, then it will go to zero. NOTE: The voltage readings listed may range from approximately ±9 to 11V.	OK	Check for mechanical problem, such as binding. Repair as necessary If no mechanical problem is present, replace the fresh air/recirc actuator.
		Not OK	Check circuits 338D and 338E between control panel and recirc actuator for open or short circuit. Repair as necessary. If circuits 338D and 338E are OK, replace the control panel. NOTE: Assumes control panel is getting power/ground.

Table 12, Fresh Air/Recirculation Actuator No. 4 Circuit Diagnosis

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Troubleshooting the HVAC System

Defrost/Panel Actuator No. 3 Circuit Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Check for signal from control panel: • Disconnect the defrost/panel actuator connector. See **Fig. 7**. • Turn ignition ON. Set DMM to read voltage, then place meter leads in actuator connector as follows: • (+) lead in pin 4 (circuit 338C+) • (–) lead in pin 2 (circuit 338C–) Start with the mode control switch in the OFF position. Then set the mode switch as follows and observe the voltage readings: MAX A/C: 0V A/C: 0V PANEL: 0V OFF: 0V PANEL & FLOOR: 0V FLR: –10.5V± then 0V FLR & DEF: 0V DEF: 0V OFF: +10.5V± then 0V If working correctly, the voltages listed should be present for a few seconds, then go to zero. For example, when the mode is switched to FLOOR, the voltage should be approximately –10.5 V for a few seconds, then it will go to zero. NOTE: The voltage readings listed may range from approximately ±9 to 11V.	OK	Check for mechanical problem, such as binding. Repair as necessary If no mechanical problem is present, replace the defrost/panel actuator.
		Not OK	Check circuits 338C+ and 338C– between control panel and defrost/panel actuator no. 3 for open or short circuit. Repair as necessary. If circuits 338C+ and 338C– are OK, replace the control panel. NOTE: Assumes control panel is getting power/ground.

Table 13, Defrost/Panel Actuator No. 3 Circuit Diagnosis

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Panel/Floor Actuator (Mode No. 2) Circuit Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Check for actuator position sensor reference voltage and ground: • Disconnect the electrical connector at the actuator. See **Fig. 7**. • Turn ignition ON. Measure voltage across pins 2 and 3 of the actuator connector. See **Fig. 4**.	Approx. 5V	**Go to test no. 2**.
		Approx. 0V	Check circuit 338H (5V ref.) and actuator sensor ground circuit for open or short. Repair as necessary. If the circuits are OK, check power and ground circuits to control panel. If these are also OK, replace the control panel.
2	Check for actuator drive signal from the control panel: • Disconnect the electrical connector at the actuator. See **Fig. 7**. • Turn mode control switch to OFF. • Turn ignition ON. Measure voltage across pins 1 and 6 as follows. See **Fig. 4**. • (–) lead on pin 1 • (+) lead on pin 6 Observe the voltage. The voltage should briefly read approximately 10 to 12V, then go to zero. This repeats approximately every 10 seconds. If the meter observation is as listed, then the signal is OK.	OK	**Go to test no. 4**.
		Not OK	**Go to test no. 3**.
3	Check actuator drive circuit: • Turn ignition OFF. • Gain access to the back of the control panel and disconnect the electrical connector. • Disconnect the actuator connector. See **Fig. 7**. Check continuity in circuit 338B+ between control panel connector pin 16 and the actuator connector pin 6. See **Fig. 4** and **Fig. 5**. Check continuity in circuit 338B– between control panel connector pin 6 and the actuator connector pin 1.	OK	Check power and ground circuits to control panel. Repair as necessary. If the power and ground circuits are OK, replace the control panel.
		Not OK	Repair circuit 338B+ or 338B– as necessary.

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Troubleshooting the HVAC System

Panel/Floor Actuator (Mode No. 2) Circuit Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
4	Check actuator position sensor feedback voltage: • Make sure actuator and mode module connectors are plugged in. • Turn ignition ON. Measure voltage between mode module connector pin 3 (by backprobing) and a known good ground. The voltage should be approx. between 0.5V and 4.5V. See **Fig. 5**.	OK	**Go to test no. 5**.
		Not OK	Check circuit 338F2 for open or short. Repair as necessary. If circuit 338F2 is OK, replace the actuator.
5	Check actuator drive motor resistance: • Remove actuator. See **Fig. 7**. Measure resistance across pins 1 and 6 of the actuator. See **Fig. 4**.	Approx. 96 ohms	**Go to test no. 6**.
		Approx. 0 ohm or meter reads OL	Replace actuator.
6	Check for mechanical problem: • Remove actuator. See **Fig. 7**. Attempt to turn the panel/floor door by hand. Check for binding or obstruction.	OK	Replace actuator.
		Not OK	Repair mechanical problem as necessary.

Table 14, Panel/Floor Actuator (Mode No. 2) Circuit Diagnosis

Right-Side Panel/Demist Actuator (Mode No. 1) Circuit Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Check for actuator position sensor reference voltage and ground: • Disconnect the electrical connector at the actuator. See **Fig. 7**. • Turn ignition ON. Measure voltage across pins 2 and 3 of the actuator connector. See **Fig. 6**.	Approx. 5V	**Go to test no. 2**.
		Approx. 0V	Check circuit 338G (5V ref.) and actuator sensor ground circuit for open or short. Repair as necessary. If the circuits are okay, check power and ground circuits to control panel. If these are also okay, replace the control panel.

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Right-Side Panel/Demist Actuator (Mode No. 1) Circuit Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
2	Check for actuator drive signal mode module: • Disconnect the electrical connector at the actuator. See **Fig. 7**. • Turn mode control switch to OFF. • Turn ignition ON. Measure voltage across pins 1 and 6 as follows. See **Fig. 6**. • (–) lead on pin 1 • (+) lead on pin 6 Observe the voltage. The voltage should briefly read between approximately –10 to –12V, then go to zero. This repeats approx. every 10 seconds. If the meter observation is as listed, then the signal is okay.	OK	**Go to test no. 4**.
		Not OK	**Go to test no. 3**.
3	Check actuator drive circuit: • Turn ignition OFF. • Gain access to the back of the control panel and disconnect the electrical connector. • Disconnect the actuator connector. See **Fig. 7**. Check for continuity in circuit 338A+ between control panel connector pin 17 and the actuator connector pin 6. Check for continuity in circuit 338A– between control panel connector pin 7 and the actuator connector pin 1.	OK	Check power and ground circuits to control panel. Repair as necessary. If the power and ground circuits are OK, replace the control panel.
		Not OK	Repair circuit 338A+ or 338A– as necessary.
4	Check actuator position sensor feedback voltage: • Make sure actuator and control panel connectors are plugged in. • Turn ignition ON. Measure voltage between control panel connector pin 13 (by backprobing) and a known good ground. The voltage should be approx. between 0.5V and 4.5V.	OK	**Go to test no. 5**.
		Not OK	Check circuit 338F1 for open or short. Repair as necessary. If circuit 338F1 is okay, replace the actuator.

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Troubleshooting the HVAC System

Right-Side Panel/Demist Actuator (Mode No. 1) Circuit Diagnosis			
Test No.	**Test Procedure**	**Test Result**	**Action**
5	Check actuator drive motor resistance: • Remove actuator. See **Fig. 7**. Measure resistance across pins 1 and 6 of the actuator. See **Fig. 6**.	Approx. 96 ohms	**Go to test no. 6**.
		Approx. 0 ohm or meter reads OL	Replace actuator.
6	Check for mechanical problem: • Remove actuator. See **Fig. 7**. Attempt to turn the right-side panel/demist door by hand. Check for binding or obstruction.	OK	Replace actuator.
		Not OK	Repair mechanical problem as necessary.

Table 15, Right-Side Panel/Demist Actuator (Mode No. 1) Circuit Diagnosis

A/C Compressor Clutch Circuit Diagnosis (clutch does not engage)			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Does the blower also not work?	Yes	See **Table 18**. If this does not correct the problem, return to this table, step no. 2, or to **Table 9**.
		No	**Go to test no. 2**.
2	Check for voltage to A/C compressor clutch: • Disconnect the A/C clutch 2-pin electrical connector. • Turn ignition ON. • Set the mode control switch to MAX A/C. Measure voltage across the two A/C clutch connector pins (harness side).	Approx. 12V	**Go to test no. 3**.
		0V	**Go to test no. 4**.
3	Check voltage drop at A/C clutch: • Connect the A/C clutch 2-pin connector. • Turn ignition ON. • Set the mode control switch to MAX A/C. Measure voltage across the two A/C clutch connector pins by backprobing.	10.5V or more	Replace A/C compressor
		Less than 10.5V	Check entire circuit between A/C clutch and A/C relay and A/C clutch ground circuit for source of high resistance. Use voltage drop measurements to isolate problem. Repair as necessary. See **Subject 400** for wiring diagrams.

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A/C Compressor Clutch Circuit Diagnosis (clutch does not engage)			
Test No.	**Test Procedure**	**Test Result**	**Action**
4	Check for voltage to A/C compressor upstream of thermal switch: • Disconnect 4-pin connector near A/C compressor. • Turn ignition ON. • Set the mode control switch to MAX A/C. Measure voltage across pins 1 and 4 of the 4-pin connector (harness side). NOTE: Connect 4-pin connector when test is complete.	Approx. 12V	Thermal switch or wiring between 4-pin and 2-pin connector is open. Replace compressor.
		0V	**Go to test no. 5**.
5	Check for voltage on 97C at A/C clutch: • Disconnect the A/C clutch 2-pin connector. • Turn ignition ON. • Set mode control switch to MAX A/C. Measure voltage between pin B (circuit 97C) and a known good ground.	Approx. 12V	Check ground circuit to A/C clutch. Repair as necessary.
		0V	**Go to test no. 6**.
6	Check continuity across the low pressure (clutch cycling) switch: • Disconnect low pressure switch. See **Fig. 8**. Measure continuity across low pressure switch terminals. NOTE: See **Subject 400** for A/C Clutch Cycling Pressure Switch Specifications.	Continuity	**Go to test no. 7**.
		No continuity	Check refrigerant temperature/pressure relationship. If pressure is low, check refrigerant charge and repair as necessary. If temperature/pressure relationship is okay and pressure is above 42 psi (290 kPa), replace the low pressure switch (clutch cycling switch).
7	Check voltage to low pressure (clutch cycling) switch: • Disconnect low pressure switch. See **Fig. 8**. • Turn ignition on. • Set mode control switch to MAX A/C. Measure voltage between low pressure switch connector pin 2 (circuit 97F) and a known good ground.	Approx. 12V	**Go to test no. 8**.
		0V	**Go to test no. 9**.

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Troubleshooting the HVAC System

A/C Compressor Clutch Circuit Diagnosis (clutch does not engage)			
Test No.	**Test Procedure**	**Test Result**	**Action**
8	Check continuity across the high pressure switch: • Disconnect high pressure switch. See **Fig. 9**. Measure continuity across high pressure switch terminals. NOTE: See **Subject 400** for High Pressure Cutout and Fan Cycling Pressure Switch Specifications.	Continuity	Check circuits 97C and 97E between the low pressure switch and A/C clutch for open. Repair as necessary. See **Subject 400** for wiring diagrams.
		No continuity	Replace high pressure switch.
9	Check for control voltage to A/C clutch relay: • Disconnect the A/C clutch relay. • Turn ignition ON. • Set mode control switch to MAX A/C. Measure voltage across the connector pins that correspond to relay pins 1 and 2 (circuits 220 and 97).	Approx. 12V	**Go to test no. 11**.
		0V	**Go to test no. 10**.
10	Check for ignition supply voltage to control side of A/C clutch relay: • Disconnect the A/C clutch relay. • Turn ignition ON. Measure voltage between connector pin that corresponds to relay pin 1 and a known good ground.	Approx. 12V	Check circuit 97 between relay and control panel. Repair as necessary. If circuit 97 is okay, replace the control panel. See **Subject 400** for wiring diagrams.
		0V	Check circuit 220 (ignition supply) for open. Repair as necessary. See **Subject 400** for wiring diagrams.
11	Check voltage to common pin of relay: • Disconnect the A/C clutch relay. Measure voltage between connector pin that corresponds to relay pin 3 (circuit 97A) and a known good ground.	Approx. 12V	**Go to test no. 12**.
		0V	Check circuit 97A and fuse. Repair as necessary. See **Subject 400** for wiring diagrams.
12	Bypass relay: • Disconnect the A/C clutch relay. Insert a jumper wire between connector pins that correspond to pins 3 and 5 of the relay (circuits 97A and 97F).	Clutch engages	Replace relay.
		Clutch does not engage	Check connections and wiring between relay and low pressure switch for open or high resistance. Repair as necessary. See **Subject 400** for wiring diagrams.

Table 16, A/C Compressor Clutch Circuit Diagnosis (clutch does not engage)

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CHECK A/C Indicator Illuminated*			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Does the CHECK A/C indicator come on intermittently, or does it stay on all the time?	Stays on all the time	Check compressor clutch ground circuit for open or poor connections. Repair as necessary. If OK, thermal switch is probably stuck open. If thermal switch is stuck open, replace the compressor. See **Subject 400** for wiring diagrams.
		Comes on intermittently	System is probably low on refrigerant, thus causing thermal switch to open intermittently. Check refrigerant charge. If low, repair all leaks. NOTE: See **Subject 400** for Compressor Thermal Protection Switch Specifications.

* Vehicles with 2004 engines do not have a CHECK A/C indicator.

Table 17, CHECK A/C Indicator Illuminated

Troubleshooting Control Panel Software Lockup

On vehicles built from July 2000 through May 2004, the software for the HVAC control panel may lock up. This is most likely to occur when the battery voltage is low and the weather is cold. When the software locks up, the blower motor will not run and the refrigerant compressor clutch will not engage. Beginning June 1, 2004, production made a change to the HVAC control panel to protect it from the effects of a low-voltage start up.

The following control panel part numbers are known to be prone to software lockup:

- A22-51035-000 through -002
- A22-52746-000 through -002
- A22-57400 through -002

Use the test procedure in **Table 18** to determine if the control panel software is locked up. If software lockup is confirmed, replace the control panel with the latest version available.

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Troubleshooting the HVAC System

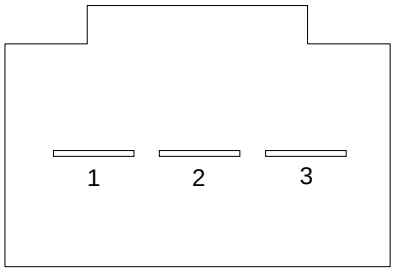
Checking for Control Panel Software Lockup			
NOTE: Control panels may exhibit software lockup which results in the following symptoms: blower is inoperable, and, if equipped with A/C, the A/C compressor clutch will not engage.			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	If blower does not work at all, and the A/C compressor clutch does not engage (if equipped with A/C), do the following: Turn ignition OFF. Remove the fuse that supplies constant battery power to the control panel for at least 5 seconds, then install it. NOTE: For fuse location, see **Table 19**. Turn ignition ON. Start engine only if equipped with A/C. Does the blower now work and the A/C clutch engage (if equipped with A/C)?	Yes	Replace the existing control panel with the most current version available. For instructions, see **Subject 210**.
		No	For blower not working, see **Table 9**. For blower not working **and** A/C clutch not engaging, see **Table 9** and **Table 16** for diagnosis.

Table 18, Checking for Control Panel Software Lockup

Fuse Location–Constant Battery Supply to Control Panel			
Model	**Build Date**	**Fuse ID**	**Fuse Location**
Acterra	Built through February 22, 2001	G	Under hood PDM
	Built from February 23, 2001, through September 14, 2003	3	Cab PDM
	Built on or after September 15, 2003	31	
L-Line and A-Line	Built from July 1, 2000 through September 14, 2003	3	
	Built on or after September 15, 2003	31	

Table 19, Fuse Location–Constant Battery Supply to Control Panel

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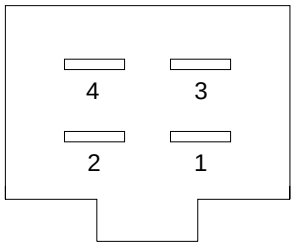


04/15/2004 f544452

NOTE: As seen looking toward the potentiometer.

1. Pin 1, Ground, 98K2
2. Pin 2, Wiper, 98K3
3. Pin 3, +12V, 98K1

Fig. 1, Temperature Potentiometer Connector AC 3 Pinout

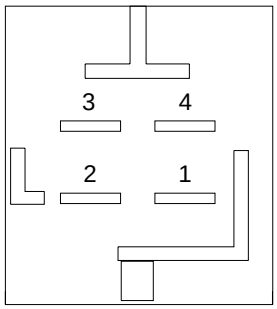


04/15/2004 f544453

NOTE: As seen looking toward the resistor block.

1. Pin 1, 98B
2. Pin 2, GND
3. Pin 3, 98F
4. Pin 4, 98A

Fig. 2, Blower Motor Resistor Block Pinout

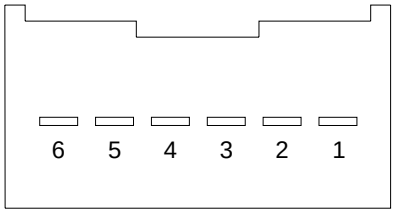


04/15/2004 f544454

NOTE: As seen looking toward the switch.

1. Pin 1, GND
2. Pin 2, 98F
3. Pin 3, 98A
4. Pin 4, 98B

Fig. 3, Blower Motor Switch Pinout

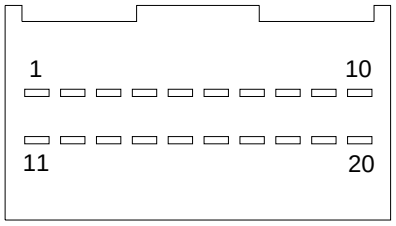


07/27/2004 f544457

NOTE: As seen looking toward the actuator.

1. Pin 1, Motor (–), 338B–
2. Pin 2, Position Sensor 5V Reference, Pot (+), 338H
3. Pin 3, Position Sensor Ground, Pot (–), GND1
4. Pin 4, Position Sensor Feedback, 338F2
5. Pin 5, Not Used
6. Pin 6, Motor (+), 338B+

Fig. 4, Panel/Floor Actuator (Mode No. 2) Pinout



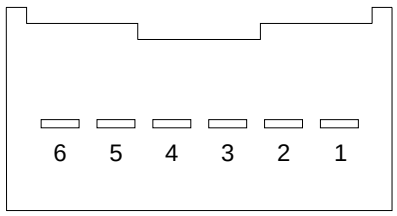
04/15/2004 f544455

NOTE: As seen looking toward the control panel. See **Table 11** for pin numbers, circuit numbers, and descriptions.

Fig. 5, HVAC Control Panel Pinout

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Troubleshooting the HVAC System

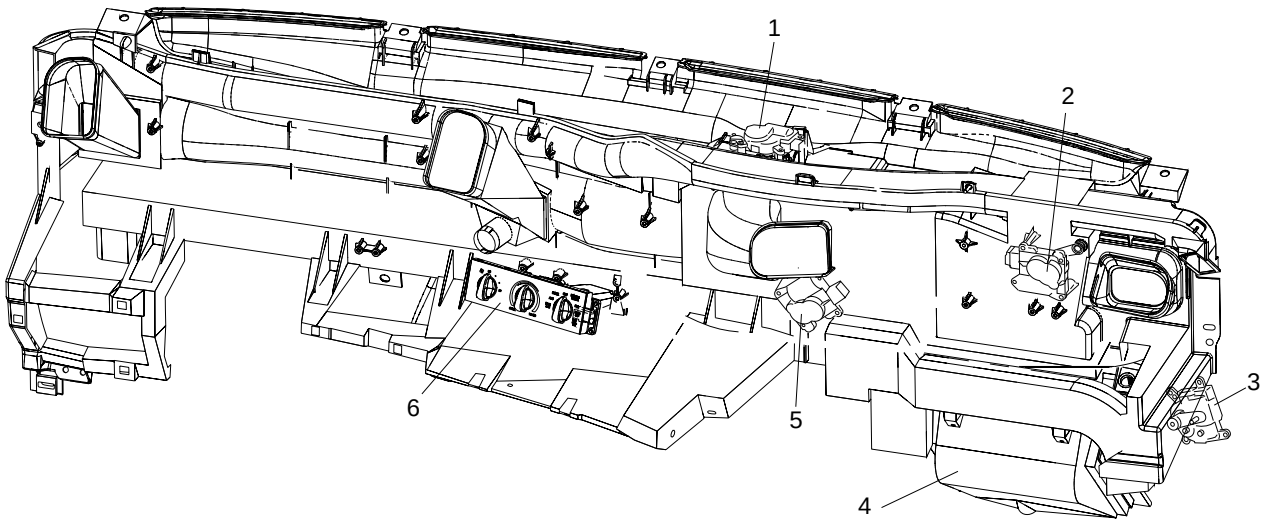


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NOTE: As seen looking toward the actuator.

1. Pin 1, Motor (–), 338A–
2. Pin 2, Position Sensor 5V Reference, Pot (+), 338G
3. Pin 3, Position Sensor Ground, Pot (–), GND1
4. Pin 4, Position Sensor Feedback, 338F1
5. Pin 5, Not Used, NA
6. Pin 6, Motor (+), 338A+

Fig. 6, Right-Side Panel/Demist Actuator (Mode No. 1) Pinout

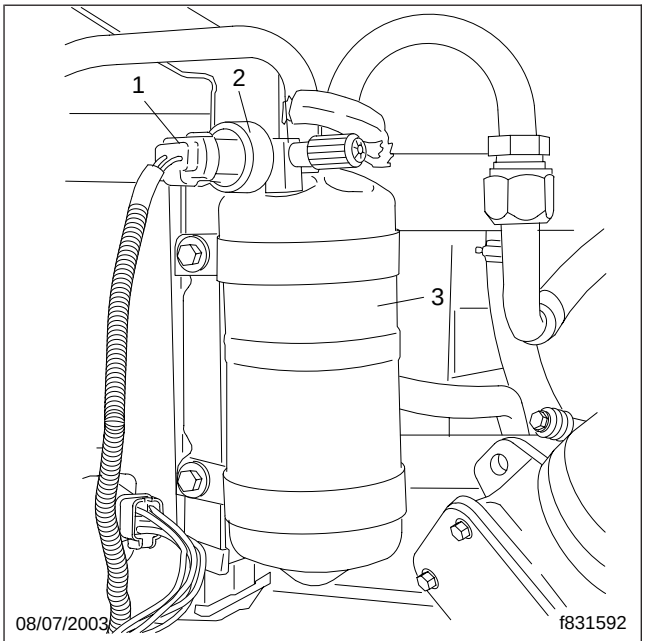


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1. Defrost/Panel Actuator
2. Right-Side Panel/Demist Actuator
3. Fresh Air/Recirculation Actuator
4. Heater Core Cover
5. Panel/Floor Actuator
6. Climate Control Panel

Fig. 7, Actuator Locations

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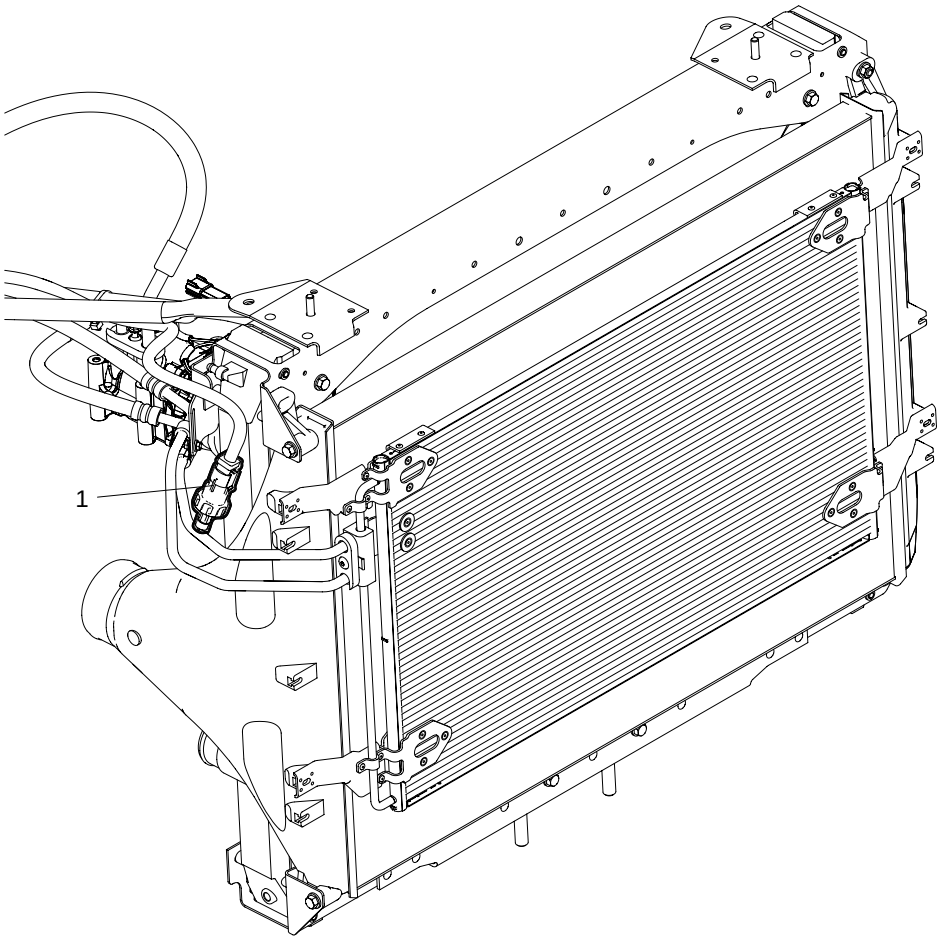


1. Electrical Connector
2. Low Pressure (clutch cycling) Switch
3. Accumulator

Fig. 8, Low Pressure (clutch cycling) Switch

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Troubleshooting the HVAC System



1. High Pressure Cut-out/Fan Cycling Switch

Fig. 9, High Pressure Cut-out/Fan Cycling Switch

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General Information

Before testing the A/C system performance, check the following conditions and correct any problems before proceeding with performance testing:

- A/C compressor drive belt worn or slipping
- A/C clutch slipping

Connect pressure gauges to the service ports and insert a thermometer into the center dash outlet. Operate the A/C system until the engine is warm and the temperature on the thermometer stabilizes. Then compare the test data with the temperature pressure specifications in the appropriate table in **Subject 400**.

When performance testing the refrigerant system, be sure the test conditions are the same as those that were used when the temperature pressure specifications were developed. The test conditions are stated at the bottom of the temperature pressure specifications tables.

If the dash outlet temperature or service port pressures do not agree with the specified values, see **Table 1** for possible cause and correction.

Refrigerant System Troubleshooting Table

Refrigerant System Diagnosis for a Vehicle With a Sanden Compressor				
High Side Pressure	**Low Side Pressure**	**Possible Symptoms**	**Probable Cause(s)**	**Correction**
High	High	Compressor running continuously	Inadequate airflow across condenser	Check engine fan operation, and repair as necessary.
			Restricted airflow across condenser	Clean or remove debris from condenser.
High	Normal to High	Compressor running continuously	Engine overheating	Check engine cooling system and repair as necessary.
Normal to High	Normal	Compressor running continuously	Air in refrigerant	Recover, evacuate, and charge the system.
			High ambient temperature or humidity	Not a problem.
Normal	High	Compressor running continuously	Missing orifice tube	Replace the orifice tube.
		Compressor cycling, excessive on and off time	A/C clutch cycling switch cut in pressure too high	Check A/C clutch cycling switch and replace as necessary.
Normal to Low	High	Compressor running continuously	Low compressor performance	Replace the compressor.
Normal	Low	Compressor cycling, excessive on and off time	A/C clutch switch cutout pressure too low	Check A/C clutch cycling switch and replace as necessary.
Normal to Low	Normal to High	Compressor running continuously	Restriction between evaporator and compressor inlet (lines or accumulator)	Locate restriction and replace as necessary.

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Troubleshooting the Refrigerant System

Refrigerant System Diagnosis for a Vehicle With a Sanden Compressor				
High Side Pressure	**Low Side Pressure**	**Possible Symptoms**	**Probable Cause(s)**	**Correction**
Normal to Low	Normal	Compressor cycling on and off quickly, shorter than normal run time	Low airflow across evaporator	Check evaporator for debris accumulation, frozen core, or faulty blower motor. Repair as necessary.
			Restriction	Locate restriction and repair as necessary.
		Compressor cycling on and off quickly, shorter than normal run and off time	Low refrigerant charge	Recover system. If amount of refrigerant recovered indicates low charge, leak check entire system and repair leaks. Then evacuate and charge the system.
		Compressor cycling on and off quickly, longer than normal off time	Restricted or plugged evaporator core	Locate restriction and repair as necessary.
Normal to Low	Low	Compressor running continuously	Restriction between evaporator and compressor inlet (lines or accumulator)	Locate restriction and repair as necessary.
			A/C clutch cycling switch sticking closed	Check A/C clutch cycling switch and repair as necessary.
Low	Normal	Compressor cycling on and off quickly, shorter than normal run and off time	A/C clutch cycling switch cut in cutout pressure range too close	Check A/C clutch cycling switch and replace as necessary.
Normal	Normal	Compressor running continuously or run time excessively long if cycling	Moisture in system	Recover, evacuate, and charge the system.
			Excessive refrigerant oil in the system	Flush system with refrigerant to remove oil. Add proper quantity of oil, evacuate and charge the system.
		Compressor cycling on and off quickly, shorter than normal run and off time	A/C clutch cycling switch cut in cutout pressure range too close	Check A/C clutch cycling switch and replace as necessary.

Table 1, Refrigerant System Diagnosis for a Vehicle With a Sanden Compressor

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⚠ WARNING

R–134a is the only refrigerant that is approved for use on Sterling vehicles. Several companies offer less expensive, hydrocarbon-based refrigerant, such as propane and methane. Use of these refrigerants will void the warranty on the air conditioning system, cause damage to the air conditioning system, and possibly result in personal injury or property damage. Leaking air conditioning systems charged with hydrocarbon-based refrigerants pose a serious risk of fire or explosion under the hood, or inside the passenger compartment. No vehicle built by Sterling Trucks can be safely charged with hydrocarbon-based refrigerants, regardless of what the refrigerant supplier states.

When servicing an air conditioning system, be sure to use a refrigerant identifier to ensure that the system has not been charged with something other than R–134a. This should be standard practice since there is no way to tell what services have been previously performed. Identification by service technicians will help to avoid the risk of explosion and guard against contamination of equipment when refrigerant is recovered and recycled.

Refrigerant recover/charge stations can be purchased from:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092-3499
(800) 328-6657

See **Fig. 1** for a full view of the heater and air conditioner system wiring. See **Fig. 2**, **Fig. 3**, and **Fig. 4** for details of the heater and air conditioner system wiring.

See **Fig. 5** for a partial view of the heater and air conditioner system wiring. See **Fig. 6** and **Fig. 7** for details of the heater and air conditioner system wiring.

See **Fig. 8** for a partial view of the heater and air conditioner system wiring. See **Fig. 9** and **Fig. 10** for details of the heater and air conditioner system wiring.

A/C Clutch Cycling Pressure Switch Specifications*				
Color	**Type of A/C Compressor**	**Part No.**	**Contacts Close Pressure psi (kPa)**	**Contacts Open Pressure psi (kPa)**
White	Sanden	VST95BW19E561AA	36 to 42 (248 to 290)	21 to 23 (145 to 159)

* Some early production vehicles with 2004 engines were equipped with a blue, YC2H 19D561 AA pressure switch. If the vehicle has this switch and is having a problem with A/C performance, replace it with a VST95BW19E561AA pressure switch.

Table 1, A/C Clutch Cycling Pressure Switch Specifications

High Pressure Cut Out and Fan Cycling Pressure Switch Specifications						
Color	**Part No.**	**Type of Fan**	**Engine Cooling Fan psi (kPa)**		**High Pressure Cut Out psi (kPa)**	
			Fan On	**Fan Off**	**Cut Out**	**Cut In**
Green	06-35209-000	On/Off Fan	310 to 340 (2137 to 2344)	255 to 295 (1758 to 2034)	435 to 475 (2999 to 3275)	220 to 280 (1517 to 1931)
Black/Yellow	F3AH 19D594 CA	Viscous	—	—	460 to 490 (3172 to 3378)	230 to 290 (1586 to 1999)

Table 2, High Pressure Cut Out and Fan Cycling Pressure Switch Specifications

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Specifications

Compressor Thermal Protection Switch Specifications*	
Thermal Switch Cut Out Temperature	**Thermal Switch Reset Temperature**
235.4 to 246.2°F (113 to 119°C)	203 to 224.6°F (95 to 107°C)

* All vehicles have a thermal protection switch. Only vehicles with a pre-2004 engine have a CHECK A/C indicator.

Table 3, Compressor Thermal Protection Switch Specifications

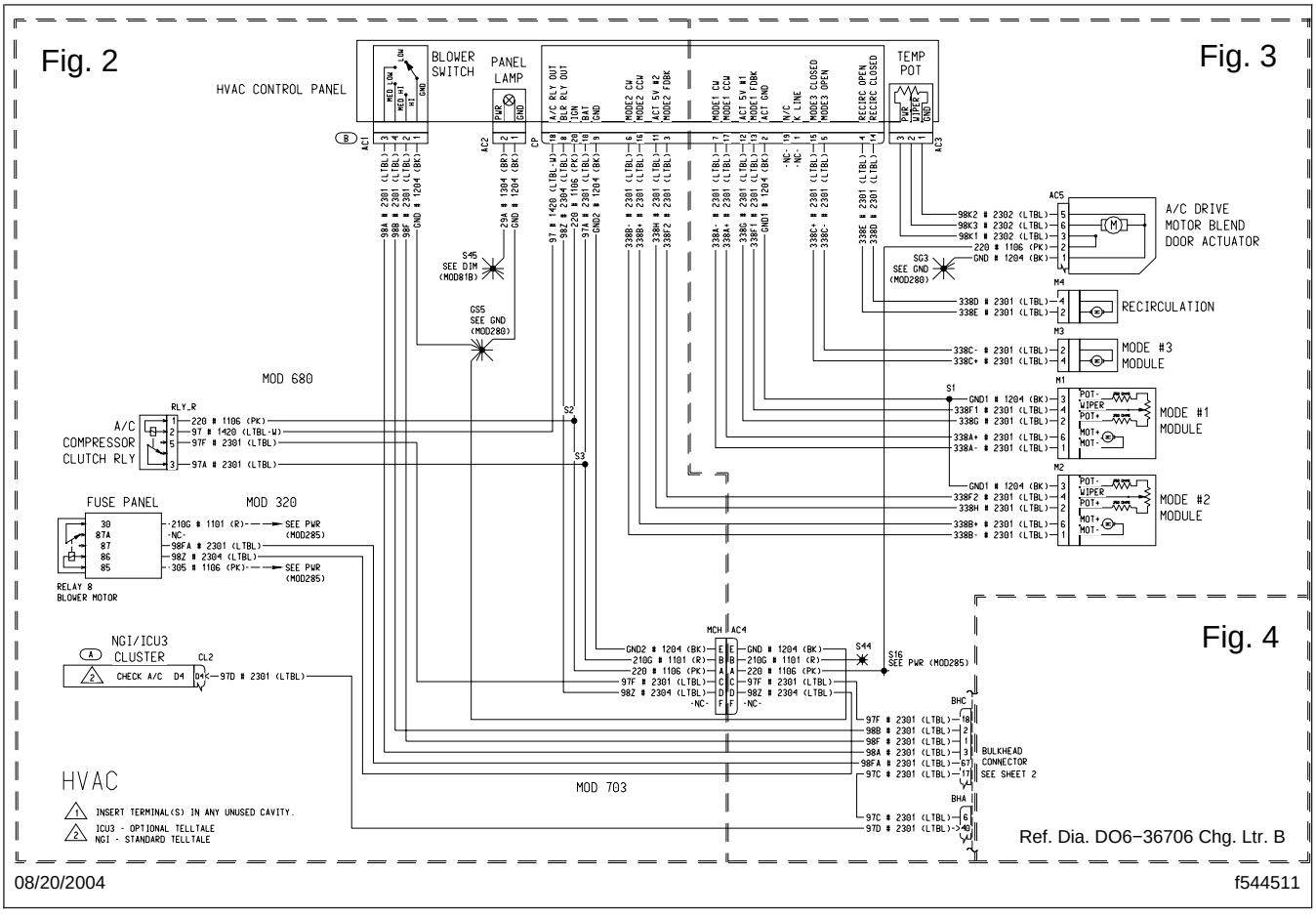


Fig. 1, Heater and Air Conditioner System Wiring (full view) for Vehicles Built On or Before September 11, 2003

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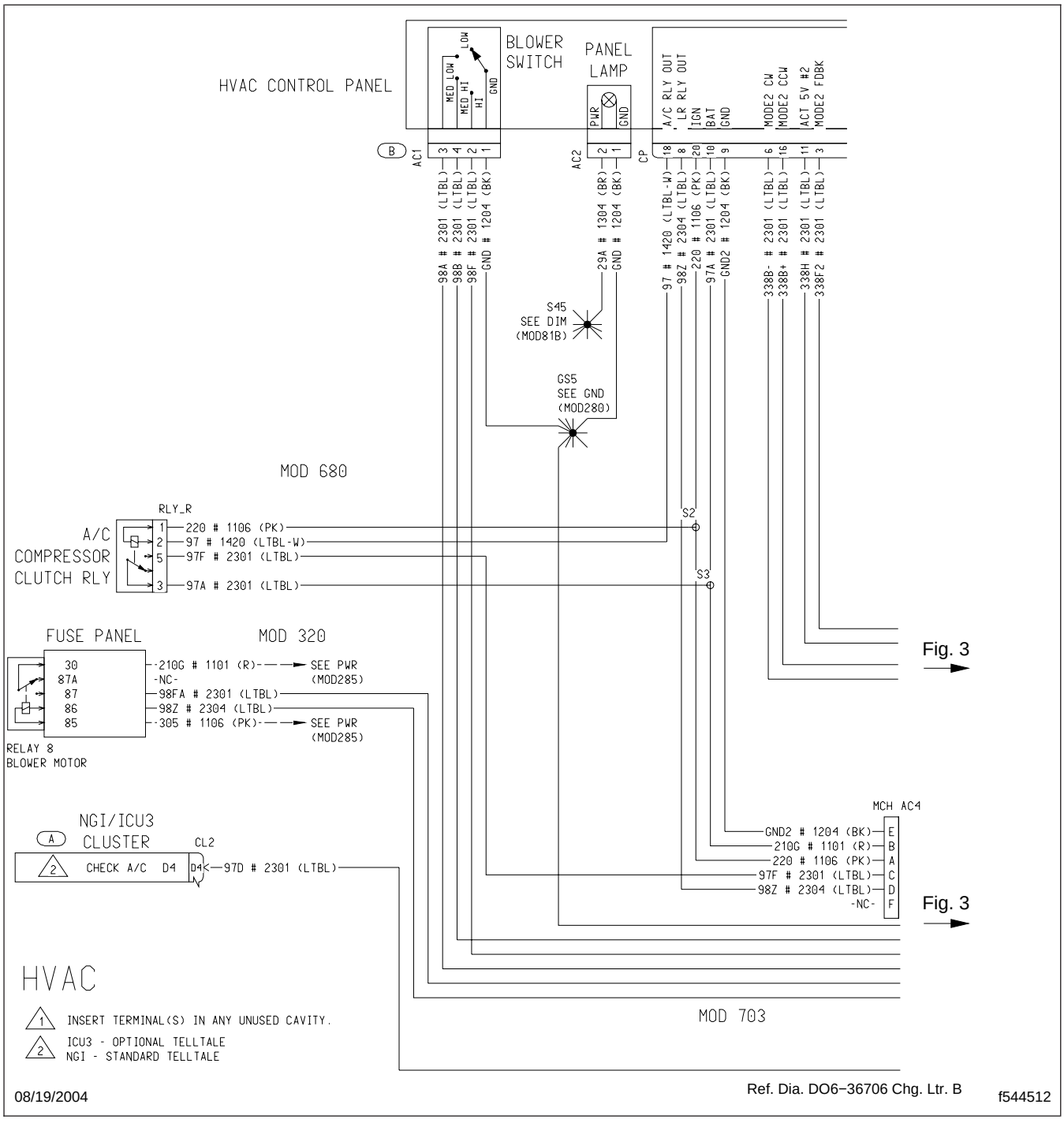


Fig. 2, Heater and Air Conditioner System Wiring (detail) for Vehicles Built On or Before September 11, 2003

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Specifications

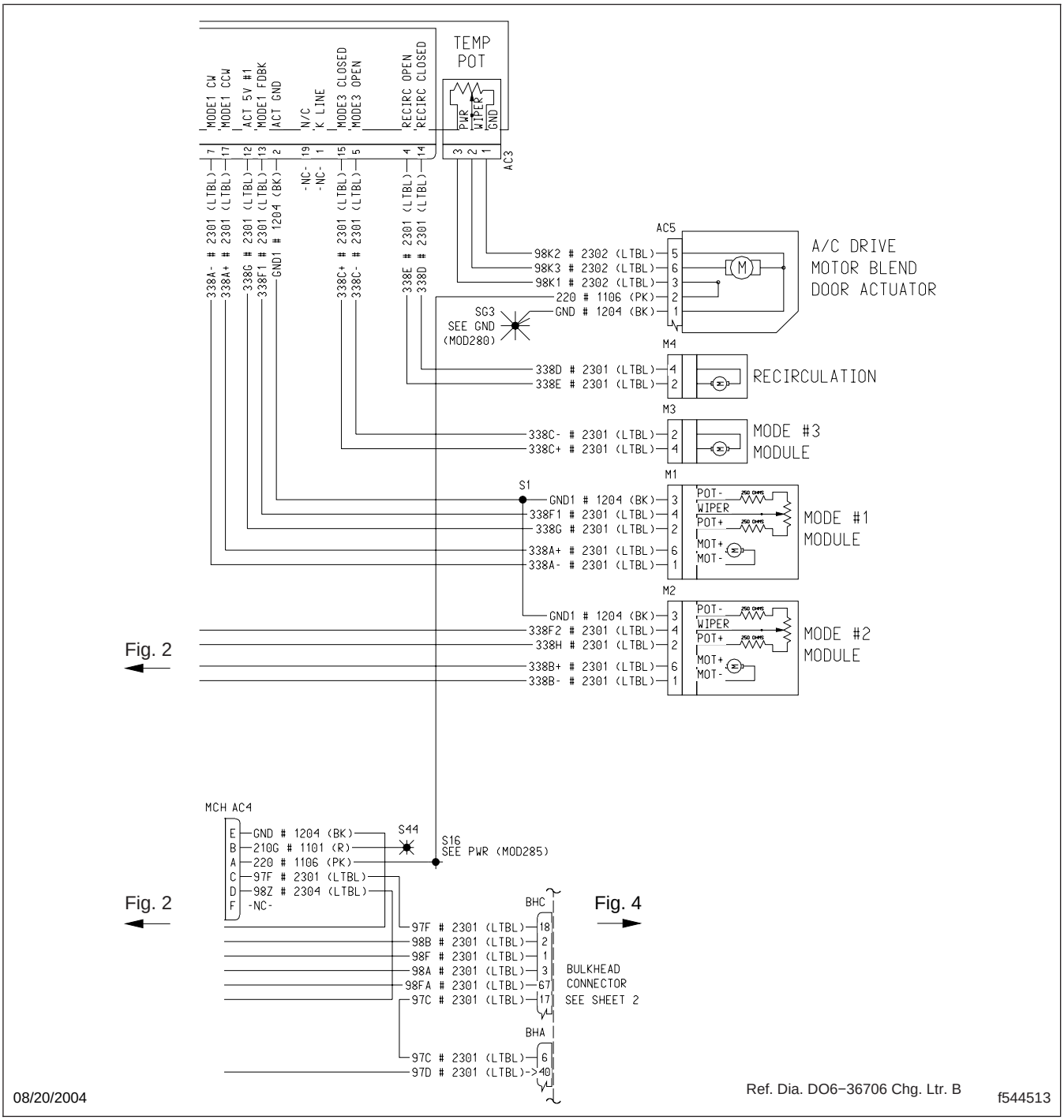


Fig. 3, Heater and Air Conditioner System Wiring (detail) for Vehicles Built On or Before September 11, 2003

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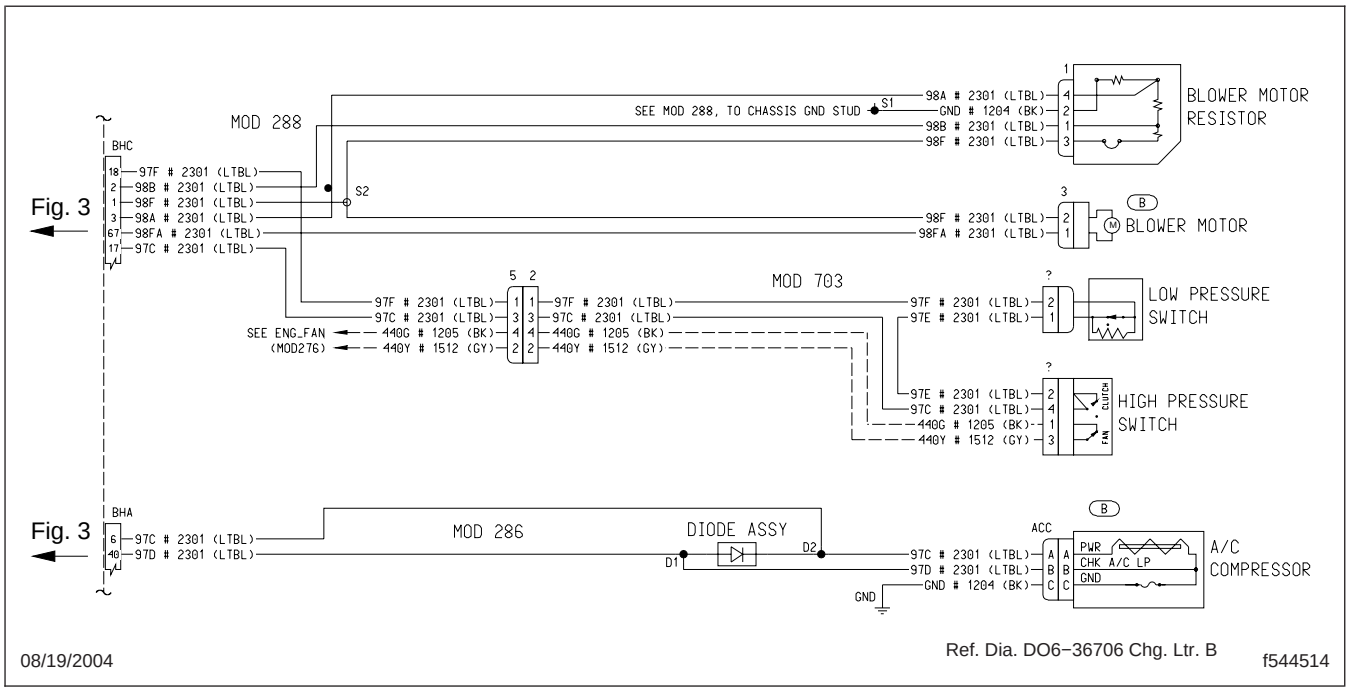


Fig. 4, Heater and Air Conditioner System Wiring (detail) for Vehicles Built On or Before September 11, 2003

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Specifications

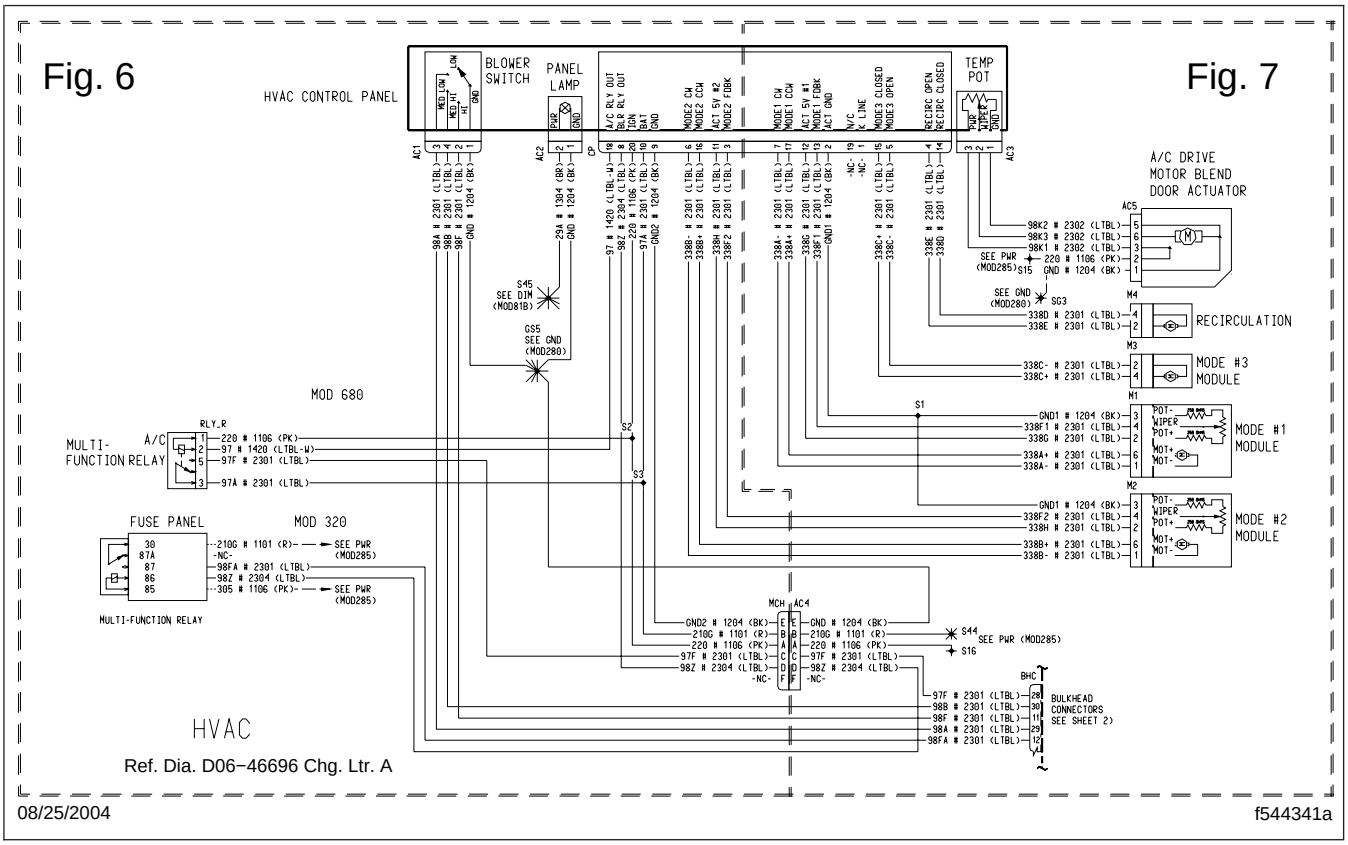


Fig. 5, Heater and Air Conditioner System Wiring (partial view) for Vehicles Built On or After September 12, 2003

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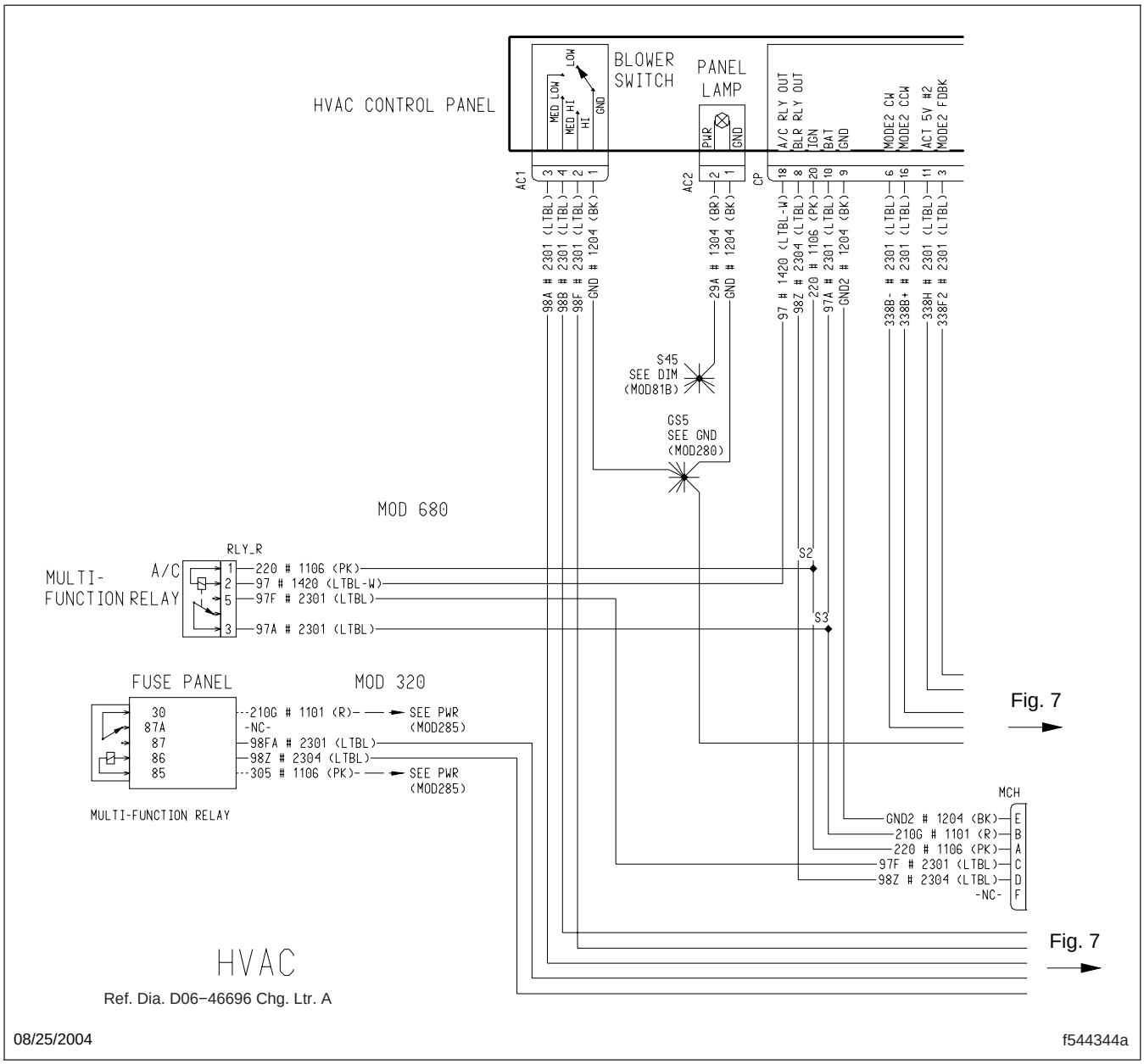


Fig. 6, Heater and Air Conditioner System Wiring (detail) for Vehicles Built On or After September 12, 2003

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Specifications

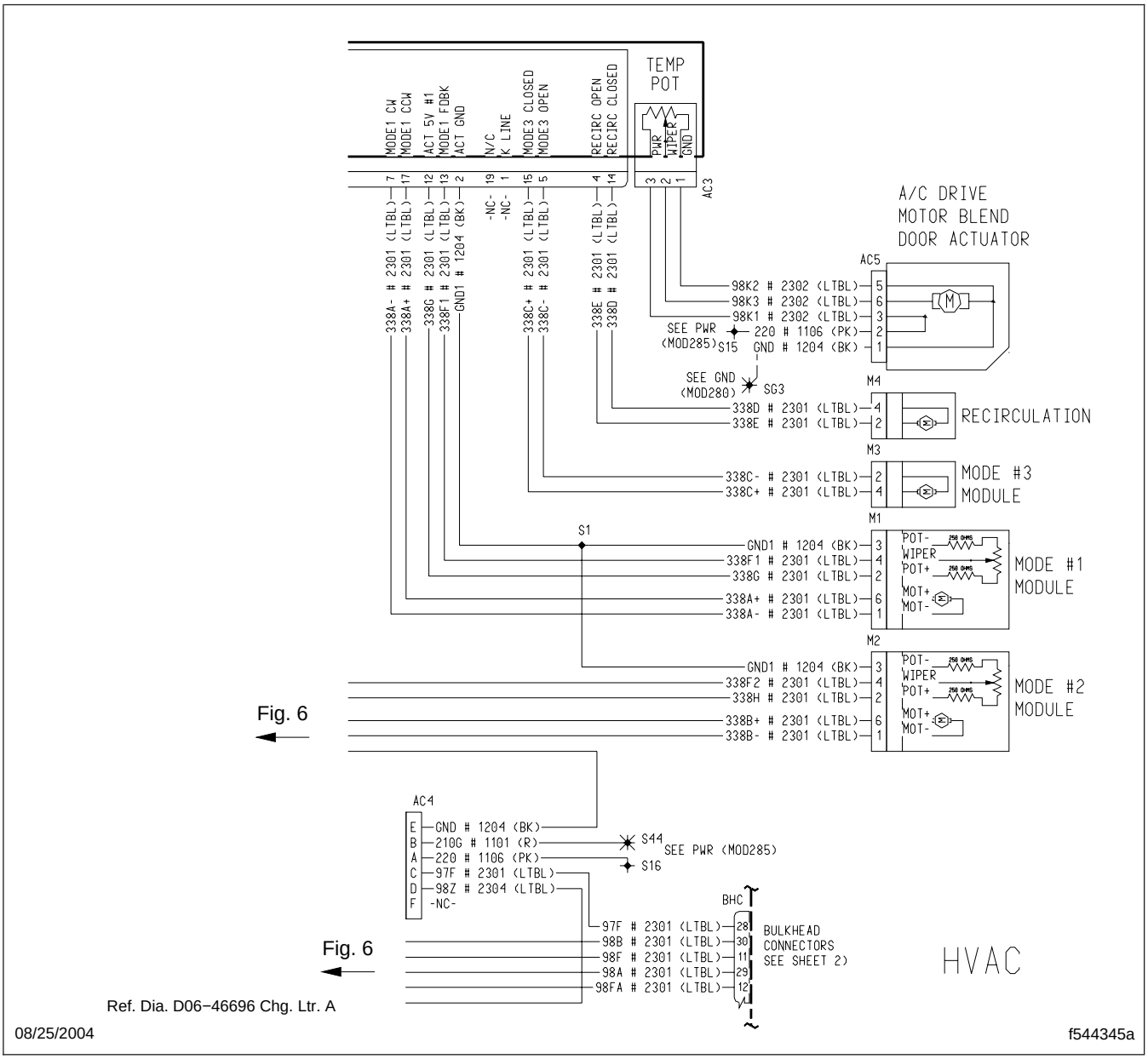


Fig. 7, Heater and Air Conditioner System Wiring (detail) for Vehicles Built On or After September 12, 2003

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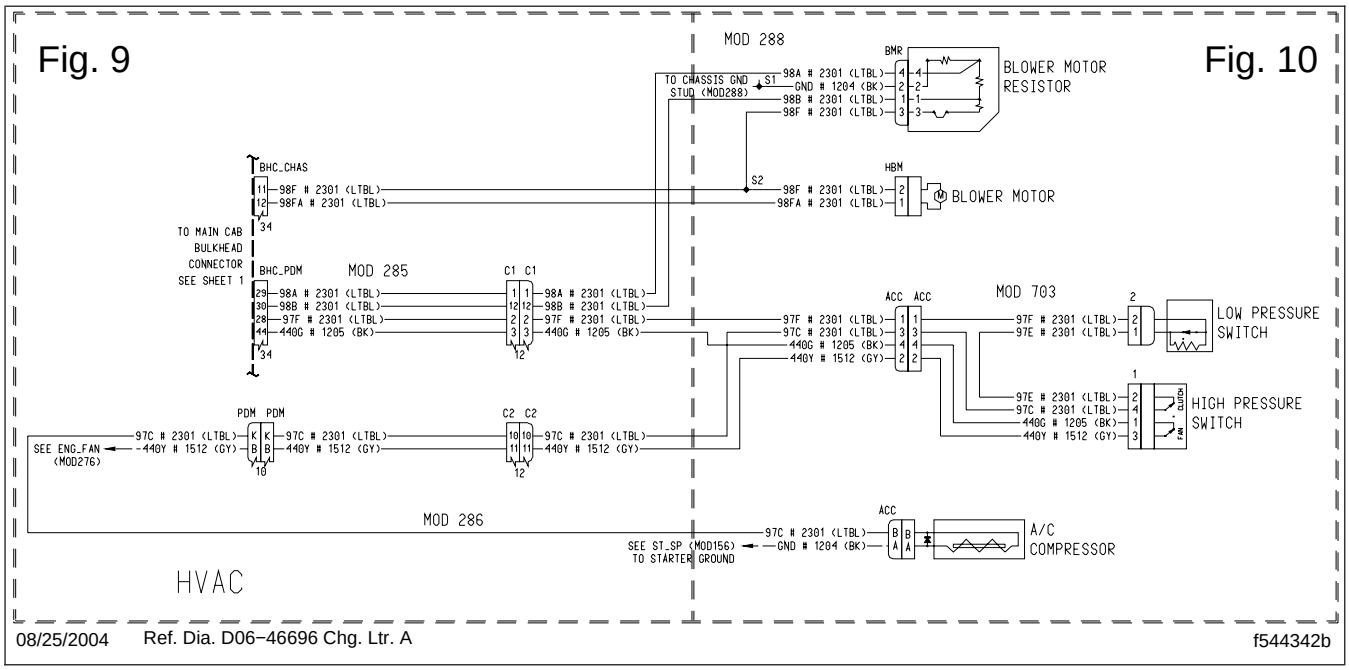


Fig. 8, Heater and Air Conditioner System Wiring (partial view) for Vehicles Built On or After September 12, 2003

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Specifications

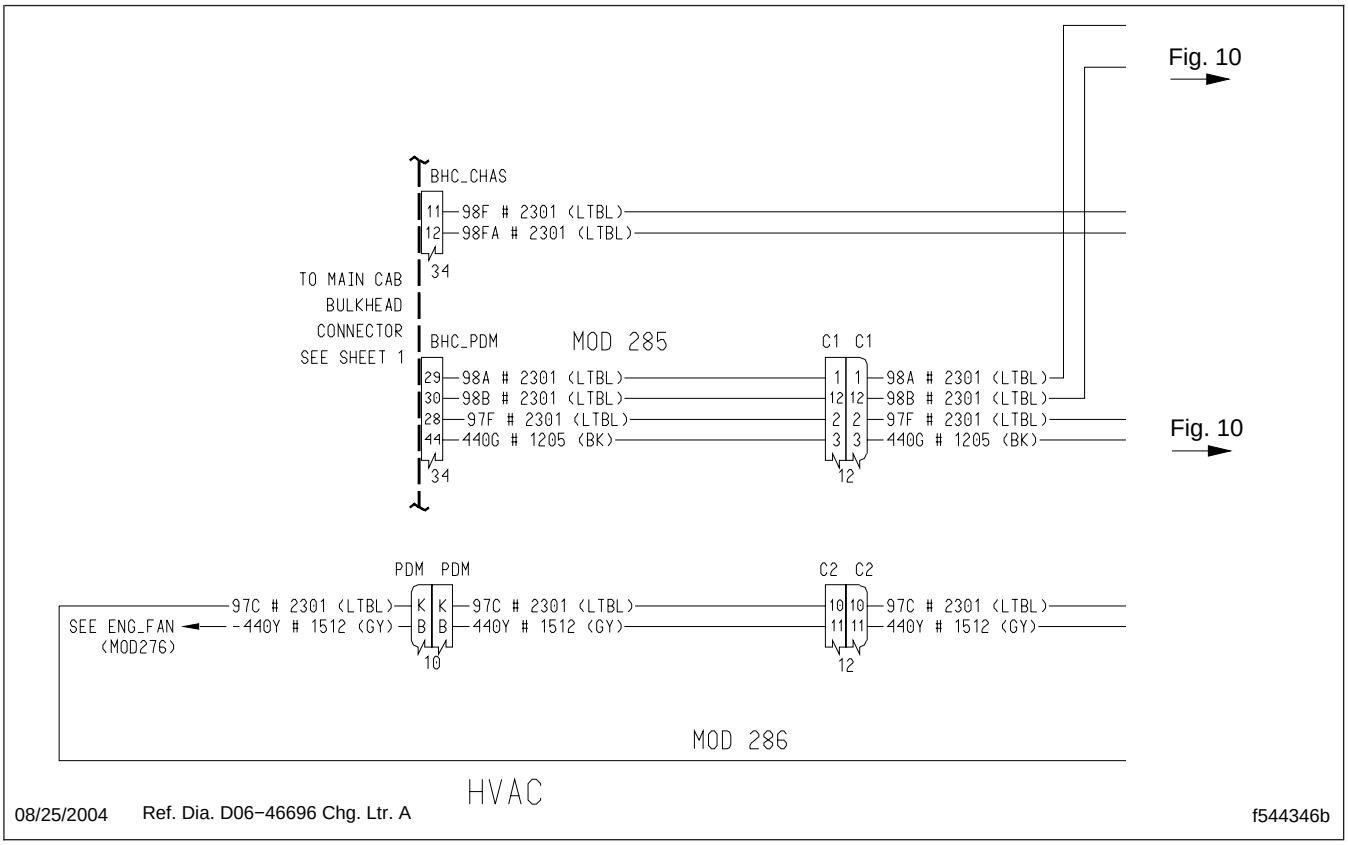


Fig. 9, Heater and Air Conditioner System Wiring (detail) for Vehicles Built On or After September 12, 2003

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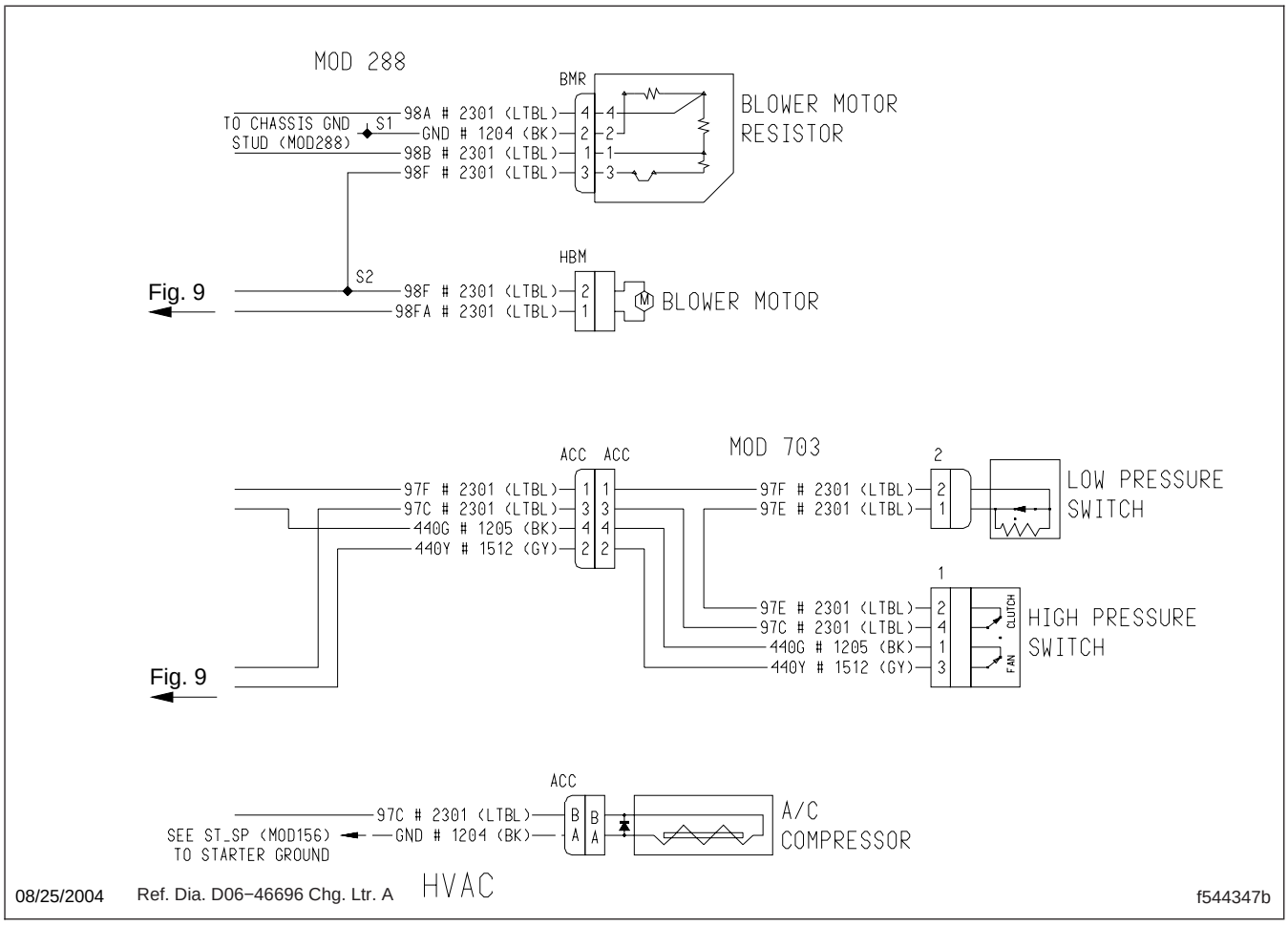


Fig. 10, Heater and Air Conditioner System Wiring (detail) for Vehicles Built On or After September 12, 2003

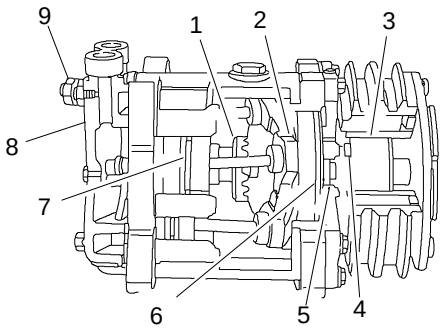
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General Information

Compressor

Acterra vehicles use the SD–7H15 compressor. **See Fig. 1**. This compressor has:

- An axial design with mounting brackets for radial mounting;
- Seven cylinders;
- Reed-type suction and discharge valve plates located between the cylinder assembly and the head;
- An integral cycling-type magnetic clutch with a compressor clutch field coil.



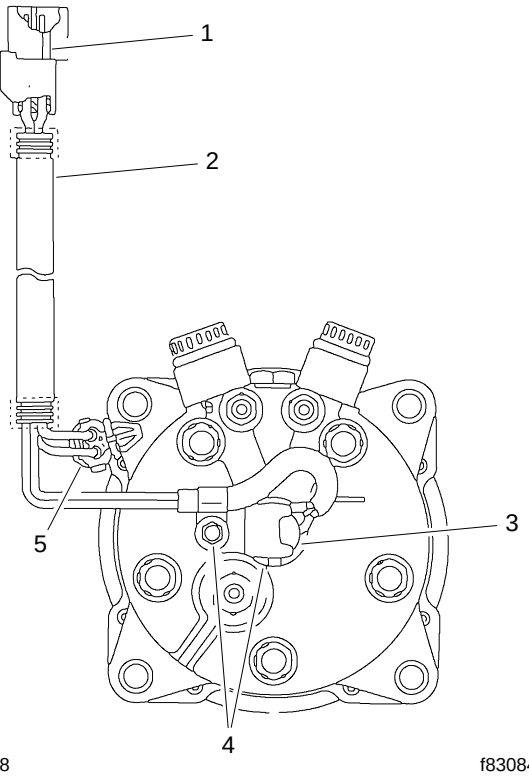
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1. Anti-Rotation Gear
2. Wobble Plate
3. Clutch Bearings
4. Shaft Seal
5. Front Housing and O-Ring
6. Needle Thrust Bearing
7. Piston
8. Compressor
9. Pressure Relief Valve

Fig. 1, Compressor (side view)

The compressor is engine mounted in line with a drive belt. The drive belt rotates the compressor clutch. When the compressor clutch field coil is energized, it causes the compressor clutch hub to magnetically draw inward against the pulley. This magnetic force locks the clutch plate and hub assembly against the pulley which then drives the compressor main shaft causing the piston to draw the refrigerant through the compressor and circulate through the system.

On some engines, the compressor is equipped with a thermal protection switch (TPS). See **Fig. 2**. The TPS shuts down the compressor and turns on a warning light in the instrument cluster when the compressor temperature exceeds approximately 240°F (116°C). The compressor restarts and the warning light turns off when the compressor temperature drops to approximately 210°F (99°C).



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1. Compressor Harness Connector (gray)
2. Compressor Harness
3. Thermal Protection Switch
4. Retaining Plate and Screw
5. Compressor Clutch Connector (white)

Fig. 2, Compressor (rear view)

Compressor Pressure Relief Valve

Under extreme pressure conditions, the compressor pressure relief valve will momentarily open, allowing refrigerant vapor to escape. This relieves excessive pressure that may damage the compressor. The valve closes as soon as pressure is lower than the

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General Information

relief setting. This prevents complete loss of the refrigerant charge. The compressor pressure relief valve is located in the rear of the compressor.

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Removal

Mercedes-Benz and Caterpillar™ Engines

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Open the hood.
3. Disconnect the batteries.
4. Discharge the system. For instructions, see **Section 83.00**.
5. Disconnect the electrical connector.

NOTE: All open refrigerant lines and connections must be capped or plugged to prevent dirt and moisture from entering and contaminating the system during repair.

6. Disconnect the lines.
   - 6.1 Disconnect the evaporator-to-compressor suction line.
   - 6.2 Disconnect the compressor-to-condenser discharge line.
7. Remove the compressor drive belt.
   - 7.1 Pivot the automatic belt tensioner to loosen the drive belt.
   - 7.2 Remove the drive belt from the compressor pulley.
   - 7.3 Release the automatic belt tensioner.
8. Remove the compressor.
   - 8.1 For Mercedes-Benz engines, remove the four capscrews and washers. See **Fig. 1**.
   - 8.2 For Caterpillar engines, remove the three capscrews, washers and nuts. See **Fig. 2**.
   - 8.3 Remove the compressor.

Cummins Engines

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Open the hood.
3. Disconnect the batteries.
4. Discharge the system. For instructions, see **Section 83.00**.
5. Disconnect the electrical connector.

NOTE: All open refrigerant lines and connections must be capped or plugged to prevent dirt and moisture from entering and contaminating the system during repair.

6. Disconnect the lines.
   - 6.1 Disconnect the evaporator-to-compressor suction line.
   - 6.2 Disconnect the compressor-to-condenser discharge line.
7. Remove the compressor drive belt. See **Fig. 3**.
   - 7.1 Loosen the 12 mm hexnut on the adjusting rod.
   - 7.2 Loosen the 10 mm hexnut on the adjusting link.
   - 7.3 Loosen the 10 mm hexhead capscrew holding the compressor to the mounting bracket.
   - 7.4 Pivot the compressor to loosen the drive belt.
   - 7.5 Remove the drive belt.
8. Remove the compressor. See **Fig. 4** or **Fig. 5**
   - 8.1 Remove the two hexhead capscrews, washers and nuts.
   - 8.2 Remove the compressor.

Installation

Mercedes-Benz and Caterpillar Engines

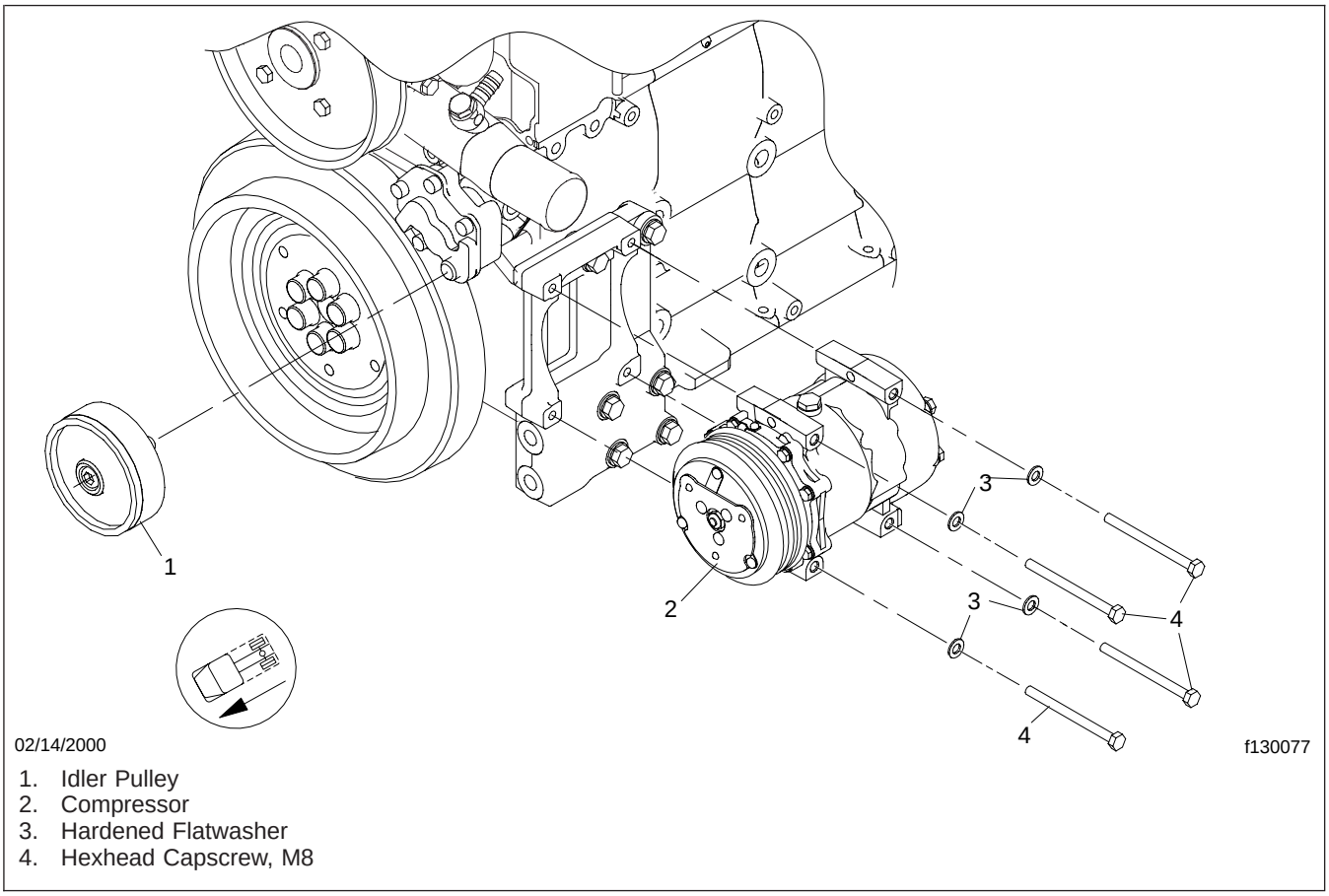
NOTE: If the compressor has been repaired or is being replaced, see **Subject 110** for refrigerant oil replacement procedures.

NOTE: When the air conditioning system connections have been opened, the O-ring seals must be replaced with new special green O-rings lubricated in clean refrigerant oil.

1. Install the compressor.
   - 1.1 Position the compressor.

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Compressor Removal and Installation



1. Idler Pulley
2. Compressor
3. Hardened Flatwasher
4. Hexhead Capscrew, M8

Fig. 1, Compressor Mounting, Mercedes-Benz MBE900 Engine

1.2 For Mercedes-Benz engines, install the four capscrews and washers. Tighten to 13 lbf·ft (18 N·m).

1.3 For Caterpillar engines, install the three capscrews, washers and nuts. Tighten phosphate and oil fasteners 33 to 41 lbf·ft (45 to 56 N·m). Tighten zinc fasteners 29 to 37 lbf·ft (39 to 50 N·m).

2. Install the compressor drive belt.

2.1 Pivot the automatic belt tensioner to loosen the drive belt.

2.2 Install the drive belt on the compressor pulley.

2.3 Release the automatic belt tensioner.

3. Connect the air conditioning lines.

3.1 Connect the evaporator-to-compressor suction line and tighten 21 to 27 lbf·ft (28 to 37 N·m).

3.2 Connect the compressor-to-condenser discharge line and tighten 15 to 20 lbf·ft (20 to 27 N·m).

4. Connect the electrical connector.

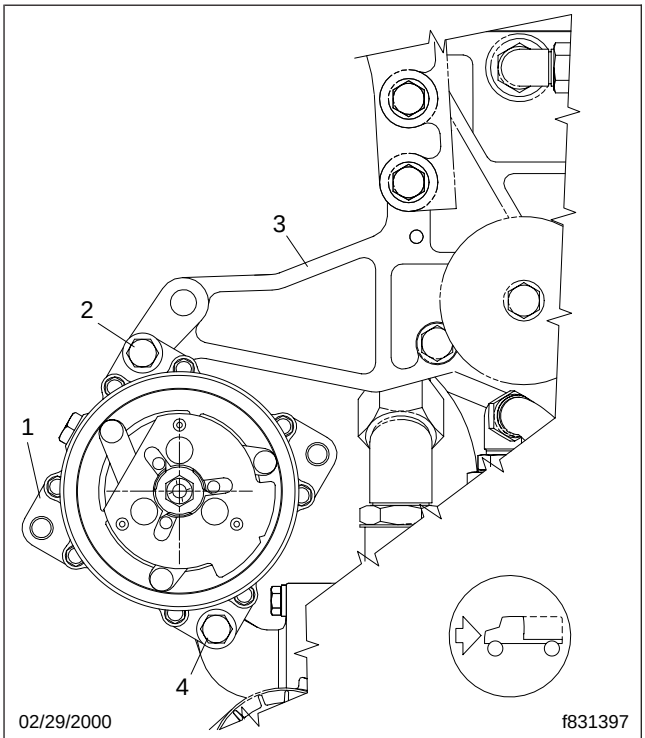
5. Evacuate, leak check and charge the system. For instructions, see **Section 83.00**.

6. Connect the batteries.

7. Close the hood.

8. Remove the chocks from the tires.

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1. Compressor
2. Hexhead Capscrew, 3/8–16 x 2.25
3. Mounting Bracket
4. Hexhead Capscrew, 3/8–16 x 1.75

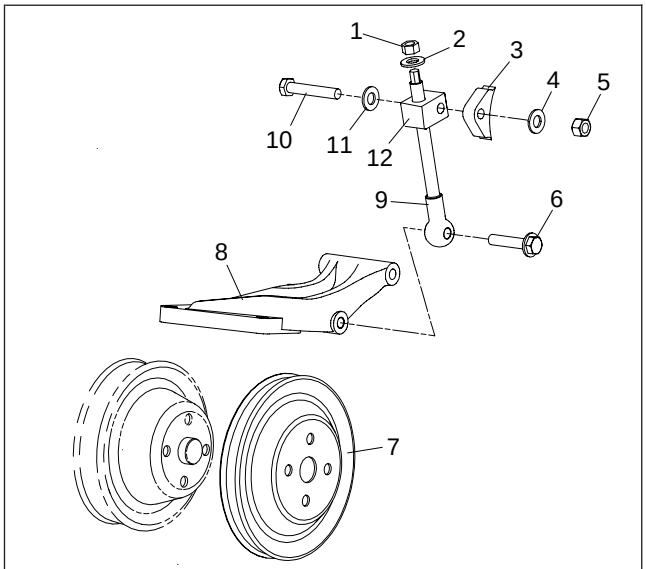
Fig. 2, Compressor Mounting, Caterpillar 3126B Engine

Cummins Engines

NOTE: If the compressor has been repaired or is being replaced, see **Subject 110** for refrigerant oil replacement procedures.

NOTE: When the air conditioning system connections have been opened, the O-ring seals must be replaced with new special green O-rings lubricated in clean refrigerant oil.

1. Install the compressor.
   - 1.1 Position the compressor.
   - 1.2 Position the two hexhead capscrews, washers and nuts.
2. Install the compressor drive belt.
   - 2.1 Position the drive belt.



1. Hexnut, M12
2. Washer
3. Compressor Ear
4. Hardened Washer
5. Hexnut, M10
6. Hexhead Capscrew, M10
7. Drive Pulley
8. Mounting Bracket
9. Adjusting Link
10. Hexhead Capscrew, M10
11. Hardened Washer
12. Adjusting Link End

Fig. 3, Adjusting Rod

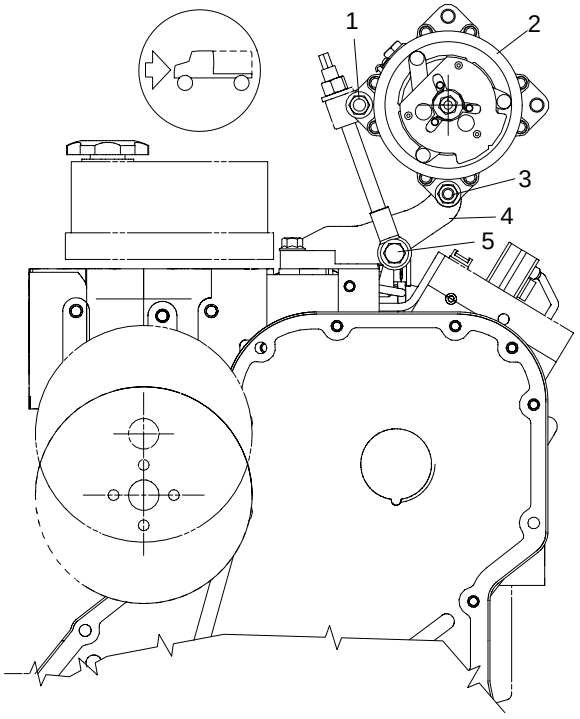
- 2.2 Pivot the compressor to tighten the drive belt.
- 2.3 Install a belt tension gauge at the center of the belt's longest free-span.
- 2.4 Tighten the compressor belt by turning the adjusting rod hexnut to rotate the compressor up and away from the fan pulley. Tighten the belt to 100 lb (45 kg).

IMPORTANT: Do not overtighten the belts. Too much tension shortens belt and bearing life.

- 2.5 Tighten the 10 mm hexnut on the adjusting link 30 to 40 lbf·ft (41 to 54 N·m).
- 2.6 Tighten the 12 mm hexnut on the adjusting rod 37 to 47 lbf·ft (50 to 64 N·m).

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Compressor Removal and Installation



1. Hexnut, M10
2. Compressor
3. Hexhead Capscrew, M10 x 130
4. Mounting Bracket
5. Hexhead Capscrew, M10 x 50

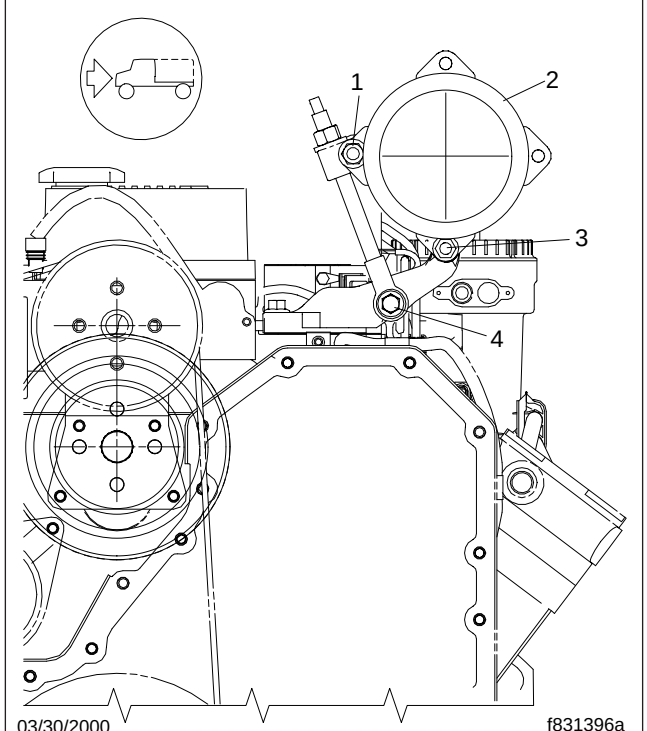
Fig. 4, Compressor Mounting, Cummins ISC Engine

2.7 Tighten both 10 mm hexhead capscrews holding the compressor to the mounting bracket 30 to 40 lbf·ft (41 to 54 N·m).

3. Check the belt tension again and adjust if needed.
4. If installing a new compressor belt, operate the engine for about 20 minutes. Check the belt tension. All new belts will lose tension after 20 minutes of operation.

   If necessary, adjust the belt to 100 lb (45 kg).
5. Connect the air conditioning lines.

   5.1 Connect the evaporator-to-compressor suction line and tighten 21 to 27 lbf·ft (28 to 37 N·m).



1. Hexnut, M10
2. Compressor
3. Hexhead Capscrew, M10 x 130
4. Hexhead Capscrew, M10 x 50

Fig. 5, Compressor Mounting, Cummins ISB Engine

5.2 Connect the compressor-to-condenser discharge line and tighten 15 to 20 lbf·ft (20 to 27 N·m).

6. Connect the electrical connector.
7. Evacuate, leak check and charge the system. For instructions, see **Section 83.00**.
8. Connect the batteries.
9. Close the hood.
10. Remove the chocks from the tires.

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⚠ WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant could lead to serious personal injury.

General Information

Compressors are charged with 10 fl oz (296 mL) of refrigerant oil. When the air conditioning system is operating, some refrigerant oil leaves the compressor and is circulated through the system with the refrigerant, but the refrigerant oil cannot leave the system except when there is a leak, when the refrigerant is recovered, or when a system part is replaced.

It is important that the air conditioning system has the correct amount of refrigerant oil for proper operation. Too little oil will result in compressor failure. Too much oil will degrade the performance of the air conditioner and may cause damage to the compressor.

IMPORTANT: Whenever the air conditioning system is discharged or recovered, the recovered oil, from the charging machine, must be measured in order to know how much oil must be returned to the system. When a system component is replaced, a quantity of new oil equal to the recovered oil plus the oil coating the inside of the component must be returned to the system. New oil must be from a container that has not been opened or that has been tightly sealed since its last use.

Order Sanden PAG oil SKI 7803 1997 (type SP–20) for an 8.45-ounce (250-mL) can of refrigerant oil from your local Daimler parts distribution center. Tubing, funnels, or other equipment used to transfer the oil should be very clean and dry.

When handling refrigerant oil:

- Be sure that the oil is free of water, dust, metal powder, and other foreign substances;
- Do not mix the refrigerant oil with other types or viscosities of oil;
- Quickly seal the oil container after use. Refrigerant oil absorbs moisture when exposed to the air for any period of time.

Checking and Adding Refrigerant Oil

⚠ WARNING

Do not remove the oil fill plug on the refrigerant compressor without first recovering the system. Failure to recover the system could cause uncontrolled release of high-pressure refrigerant, which can freeze skin and eye tissue causing serious injury or blindness.

1. Before beginning the refrigerant recovery process, make sure that the oil accumulator and oil drain bottle on the recovery/recycle machine are emptied of oil from previous repairs.
2. Recover all of the refrigerant from the system. For instructions, see **Section 83.00, Subject 280**.
3. Drain the recovered oil into the calibrated drain bottle of the recovery/recycle machine. Record the amount of oil recovered.
4. Inspect the refrigerant oil. If the oil has any of the following characteristics, flush and charge the system with 10 fl oz (296 mL) of oil.
   - silver or black oil—indicates metal in the air conditioning system due to compressor wear
   - milky oil—may indicate moisture in the system
   - grit or debris in the oil
5. Properly dispose of the recovered oil.
6. After repairs are finished, refer to **Table 1** and use the following equation to determine the quantity of refrigerant oil that needs to be added to the system.

   [Quantity Recovered] + [Quantity for All Replaced Components] = [Quantity to add to the System]

   Table 1 provides the quantities of oil that need to be added to the system for each component that was replaced. Add the quantities listed in the table for each component that was replaced. Use the sum of the quantities or 6 fl oz (177 mL), whichever is less.

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Refrigerant Oil Replacement

Refrigerant Oil Quantities for Replaced Components	
Add the quantities listed in this table for each component that was replaced. Use the sum of the quantities or 6 fl oz (177 mL), whichever is less.	
Component	**Quantity: oz (mL)**
High Pressure Line (main A/C)	1 (30)
Low Pressure Line (main A/C)	2 (59)
High Pressure Line (auxiliary A/C)	1 (30)
Low Pressure Line (auxiliary A/C)	3 (89)
Condenser	1 (30)
Evaporator (main A/C)	3 (89)
Evaporator (auxiliary A/C)	2 (59)
Receiver-Drier	3 (89)
Minor Leak at Connector Only	0.5 (15)
Major Leak at Connector Only	2 (59)

Table 1, Refrigerant Oil Quantities for Replaced Components

7. Remove the oil fill plug on the refrigerant compressor and add the refrigerant oil. Never add more than 8 fl oz (237 mL) to the system unless the system has been flushed.
8. Evacuate, charge, and leak test the refrigerant system. See **Section 83.00, Subject 280** for instructions.

Adjusting the Refrigerant Oil Level in a New Compressor

Sanden refrigerant compressors are charged with 10 fl oz (296 mL) of refrigerant oil. If the air conditioning system has been flushed, the compressor will need a 10-ounce charge. If the system has not been flushed, use the following procedure to adjust the oil level in the compressor.

Use the "Worksheet for Adjusting the Refrigerant Oil Level in a New Compressor" shown in **Fig. 1** to adjust the refrigerant oil level in a new compressor.

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Worksheet for Adjusting the Refrigerant Oil Level in a New Compressor

1. Drain the oil from the old compressor.
   - 1.1 Remove the oil plug and drain as much oil as possible into a clean, calibrated container.
   - 1.2 If there are caps on the suction and discharge ports, remove them.
   - 1.3 Drain the oil from the suction and discharge ports into the container while turning the shaft clockwise using a socket wrench on the armature retaining nut.
   - 1.4 Enter the amount of oil that was drained from the compressor. 1. ☐
2. See Table 1 of this subject to determine the total amount of refrigerant oil that is needed for each component that was replaced. Enter the amount, up to 6 fl oz (177 mL), here. 2. ☐
3. Add the amounts from steps 1 and 2 and enter the total. 3. ☐
4. Subtract the total in step 3 from 10 and enter that number. For example, if the total in line 3 was six, the calculation would be 10 − 6 = 4. 4. ☐
5. Refer to the table below for the amount of oil that must be drained from the new compressor.

If the number in step 4 is:	Drain this amount from the new compressor:
a negative number(−)	2 fl oz (59 mL)
0	2 fl oz (59 mL)
1	2 fl oz (59 mL)
2	2 fl oz (59 mL)
3	3 fl oz (89 mL)
4	4 fl oz (118 mL)
5	4 fl oz (118 mL)
6	4 fl oz (118 mL)
7	4 fl oz (118 mL)
8	4 fl oz (118 mL)
9	4 fl oz (118 mL)
10	4 fl oz (118 mL)

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Fig. 1, Worksheet for Adjusting the Refrigerant Oil Level in a New Compressor

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Compressor Clutch and Pulley Removal and Installation

Removal

NOTE: The compressor may have a spline shaft or a keyed shaft. The spline shaft can be identified by the unthreaded holes in the clutch plate. See **Fig. 1**. The keyed shaft can be identified by the threaded holes in the clutch plate.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.

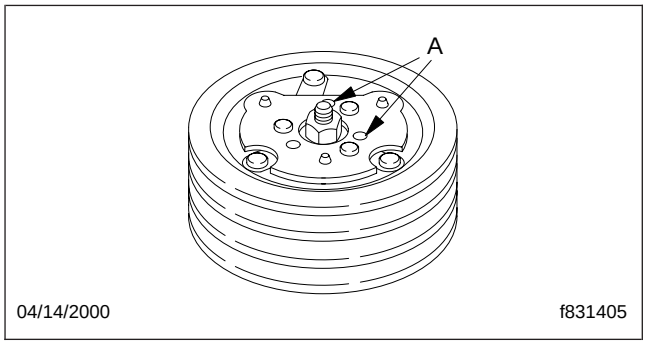


Fig. 1, Spline Shaft Clutch Plate

2. Open the hood.
3. Disconnect the batteries.
4. Remove the compressor. For instructions, see **Subject 100**.
5. Place the compressor in a bench mounted holding device.
6. Hold the clutch plate stationary using a suitable spanner wrench and remove the hexnut. See **Fig. 2**.

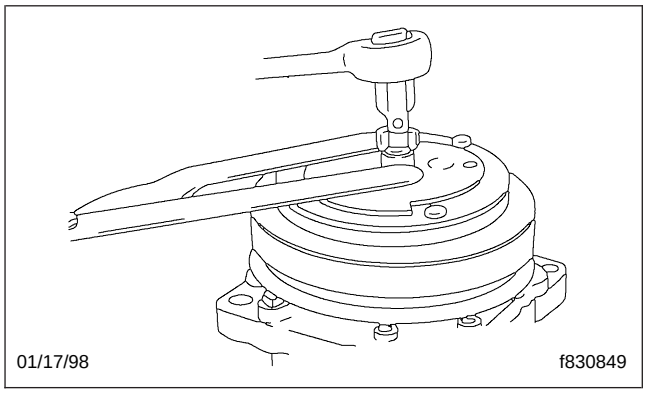


Fig. 2, Clutch Plate Hexnut

7. For a keyed shaft, using a suitable puller, remove the clutch plate from the compressor shaft. See **Fig. 3**.

   For a spline shaft, lift off the clutch plate with your fingers. If the plate does not come off easily, spray an anti-sieze oil into the shaft to loosen it. The plate can also be loosened by gently prying between the rotor and the plate with two slotted screwdrivers. See **Fig. 4**.

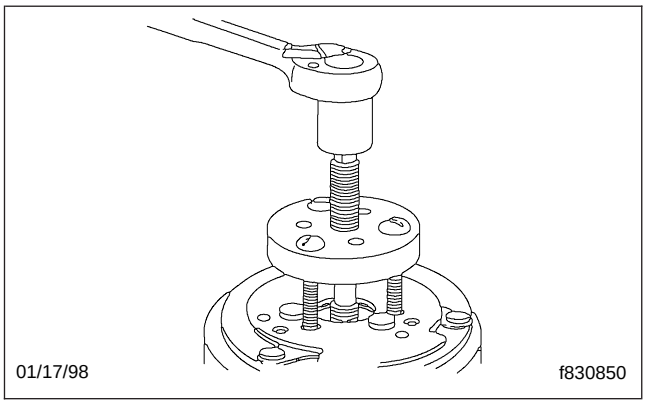


Fig. 3, Keyed Shaft Clutch Plate

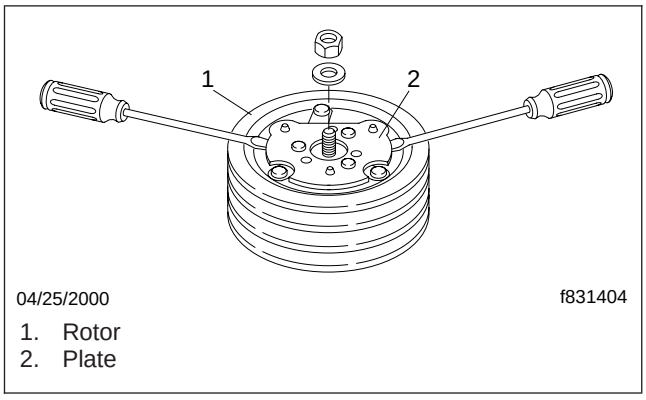


Fig. 4, Spline Shaft Clutch Plate

8. Carefully remove the bearing dust cover. See **Fig. 5**.
9. For a keyed shaft only, carefully tap the shaft key loose using a hammer and slotted screwdriver and remove the shaft key. See **Fig. 6**.
10. Remove the snap ring. See **Fig. 7**.
11. Remove the second snap ring. See **Fig. 8**.
12. Install the pulley remover. See **Fig. 9**.
13. Remove the pulley.

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Compressor Clutch and Pulley Removal and Installation

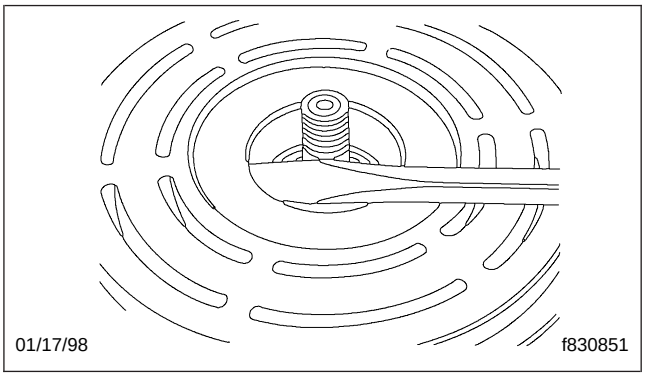


Fig. 5, Bearing Dust Cover

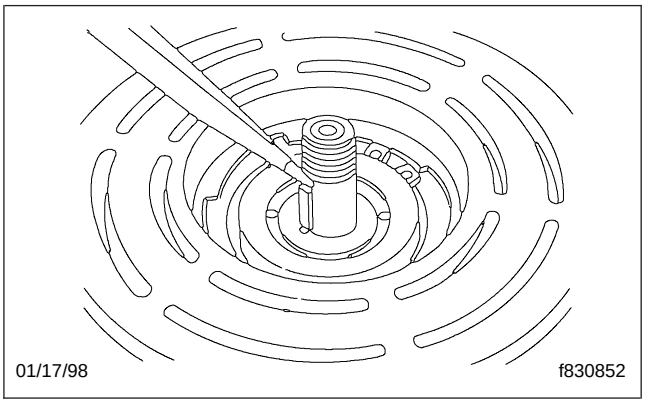


Fig. 6, Shaft Key

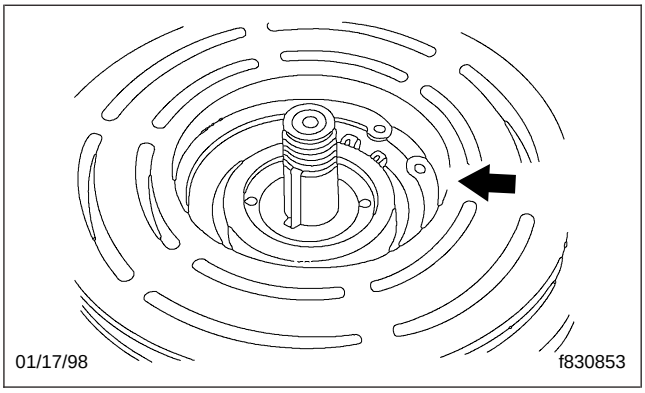


Fig. 7, Snap Ring

Installation

1. Align the pulley squarely on the compressor housing hub. See **Fig. 10**.
2. Install the pulley. See **Fig. 11**.

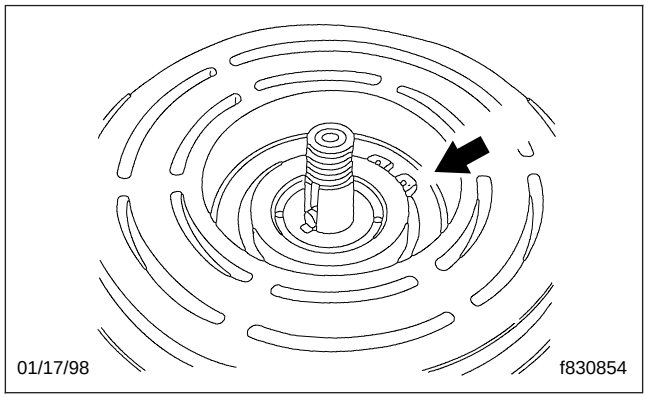


Fig. 8, Second Snap Ring

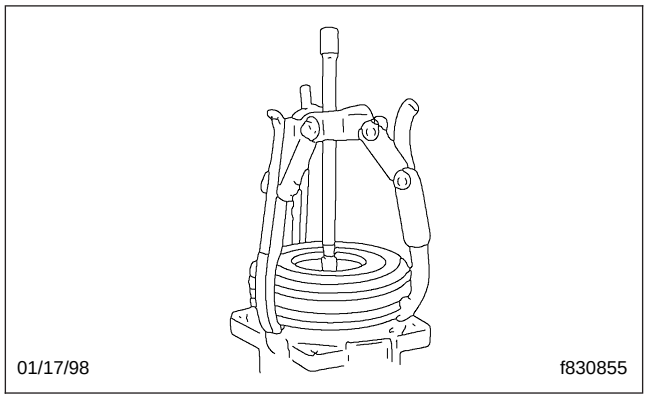


Fig. 9, Pulley Remover

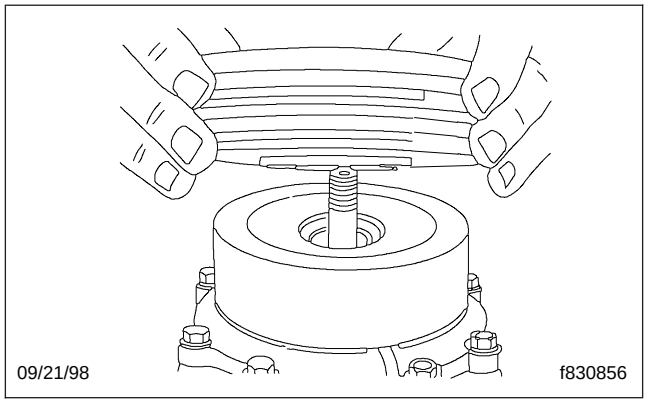
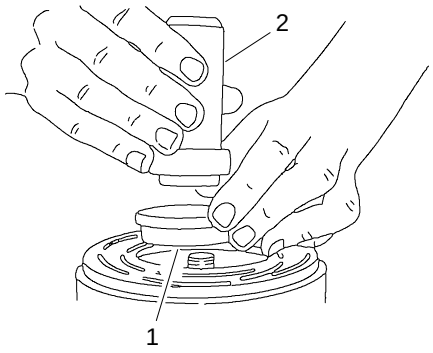


Fig. 10, Aligning the Pulley

2.1 Place the installer ring into the bearing cavity.

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Compressor Clutch and Pulley Removal and Installation

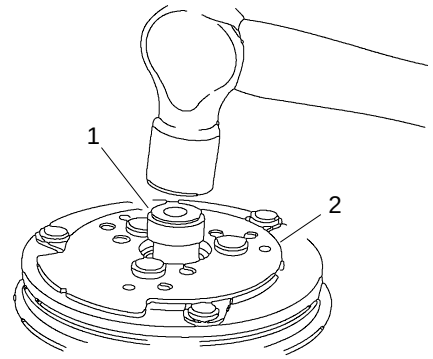


1. Installer Ring
2. Installer Driver

Fig. 11, Installing Pulley

2.2 Place the installer driver into the installer ring and carefully drive the pulley using a hammer until fully seated on the compressor.

3. Install the snap rings.
4. Install the bearing dust cover.
5. Install the clutch plate.
6. For a keyed shaft, align the clutch plate keyway with the compressor shaft keyway and install the compressor shaft key. Seat the clutch plate by positioning the shaft protector and carefully driving the clutch plate onto the compressor until it is fully seated. See **Fig. 12**.



1. Shaft Protector
2. Clutch Plate

Fig. 12, Seating Clutch Plate

7. For a splined shaft, align the slot in the clutch plate with the locator tooth on the shaft. Press the clutch plate toward the rotor by hand until the plate seats.
8. Install the clutch plate nut. Tighten the nut 25 to 30 lbf·ft (34 to 40 N·m). See **Fig. 13**.

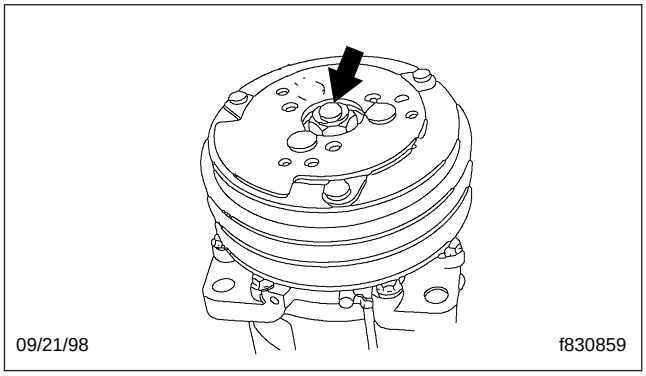


Fig. 13, Tightening Nut

9. Check the compressor air gap using a 0.016- to 0.031-inch feeler gauge, between the clutch plate and pulley surface in three locations equally spaced around the pulley. See **Fig. 14**.
10. Rotate the compressor pulley one-half turn (180 degrees) and repeat the air gap measurement. The smallest air gap measurement must be within specified limits for the air gap.
11. Install the compressor. For instructions, see **Subject 100**.
12. Connect the batteries.
13. Close and latch the hood.
14. Remove the chocks from the tires.

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Compressor Clutch and Pulley Removal and Installation

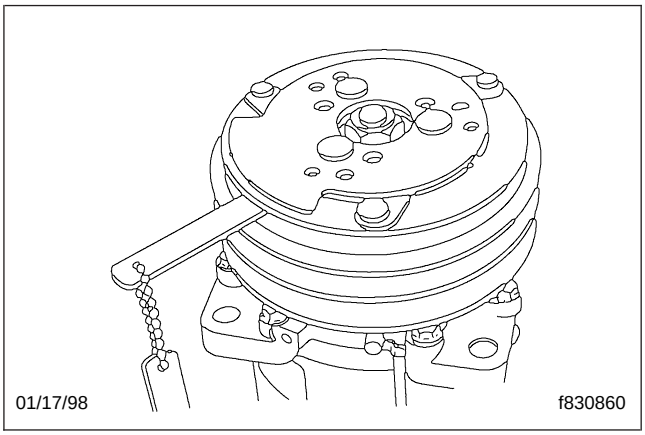


Fig. 14, Checking Air Gap

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Replacement

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Open the hood.
3. Disconnect the batteries.
4. Recover the air conditioning system. For instructions, see **Section 83.00**.
5. Remove the compressor. For instructions, see **Subject 100**.
6. Remove the clutch and pulley.
7. Remove the coil lead wire clip. See **Fig. 1**.

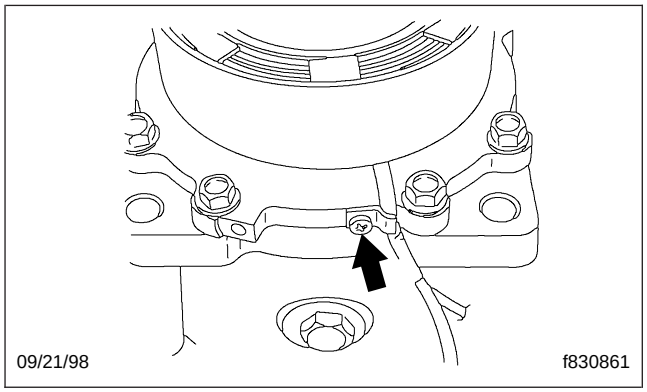
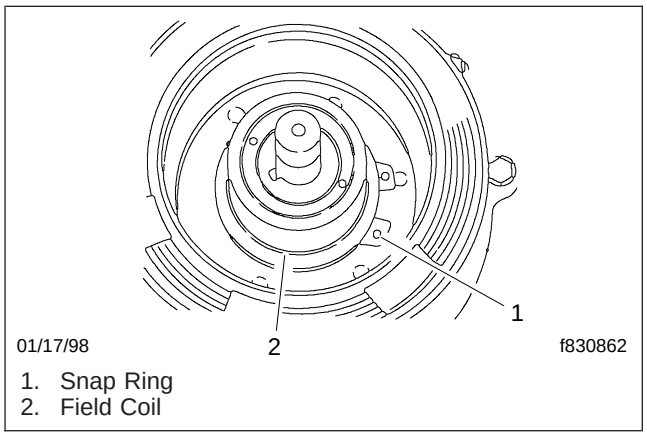


Fig. 1, Coil Lead Wire Clip

8. Remove the field coil. See **Fig. 2**.



1. Snap Ring
2. Field Coil

Fig. 2, Field Coil

8.1 Remove the snap ring.

8.2 Remove the field coil.

9. Install the field coil. See **Fig. 2**.
   9.1 Install the field coil.
   9.2 Install the snap ring.
10. Install the coil lead wire clip. See **Fig. 1**.
11. Install the clutch and pulley.
12. Install the compressor. For instructions, see **Subject 100**.
13. Charge the system. For instructions, see **Section 83.00**.
14. Connect the batteries.
15. Close the hood.
16. Remove the chocks from the tires.

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Adjustment

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Open the hood.
3. Check the clutch air gap at three equally spaced places between the clutch hub and the clutch pulley. See **Fig. 1**.

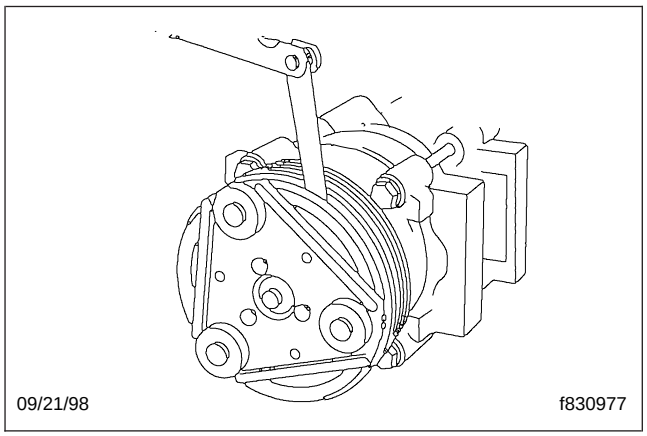


Fig. 1, Checking Air Gap

4. Add or remove shims between the clutch and the compressor shaft until the clearance is within 0.016 to 0.031 inch (0.40 to 0.80 mm).
5. Close the hood.
6. Remove the chocks from the tires.

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Recommended Refrigerant Oil	
Item	**Specification**
R–134a Refrigerant Oil-YN13 (SP-20)	EST-M1C231-B2

Table 1, Recommended Refrigerant Oil

Torque Specifications	
Description	**lbf·ft (N·m)**
Evaporator-to-Compressor Suction Line (Compressor End)	21–27 (28–37)
Compressor-to-Condenser Discharge Line (Compressor End)	15–20 (20–27)
Pressure Relief Valve	9–13 (12–18)
Clutch Plate Nut	25–30 (30–40)

Table 2, Torque Specifications

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Hood Removal and Installation

Removal

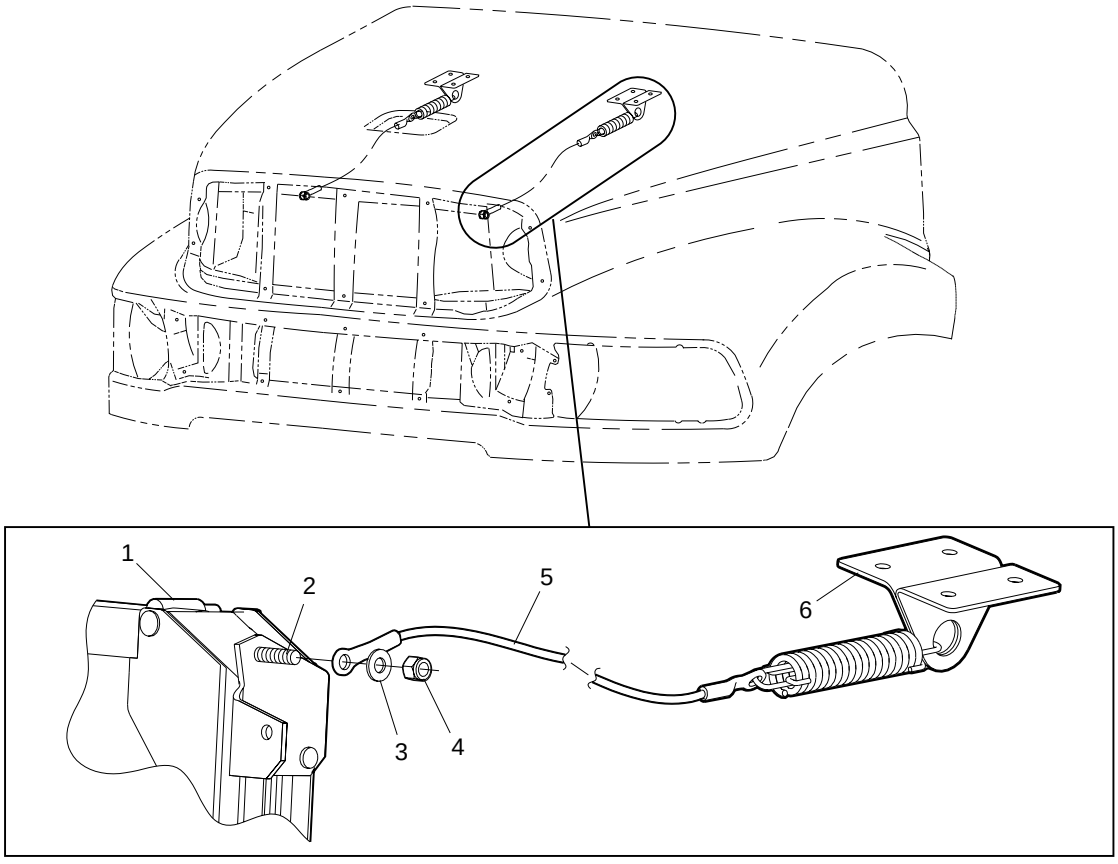
1. With the vehicle parked, apply the parking brakes and chock the tires.
2. Open the hood.
3. Place a support in front of the vehicle, and pad the support and the front bumper.
4. Disconnect the electrical connector(s) from the front lamps.
5. Disconnect the hood check cables, as follows. See **Fig. 1**.

5.1 Have an assistant close the hood one-fourth of the way, and support it in that position from the front.

5.2 With the assistant supporting the hood in position, remove the nuts and washers that attach the hood cables to the radiator.

⚠ CAUTION

Do not support the hood by the grille or the headlamp surface; this could cause damage to the grille or the headlamp surface.



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1. Radiator
2. Stud
3. Washer
4. Nut
5. Hood Check Cable
6. Bracket

Fig. 1, Hood Check Cables

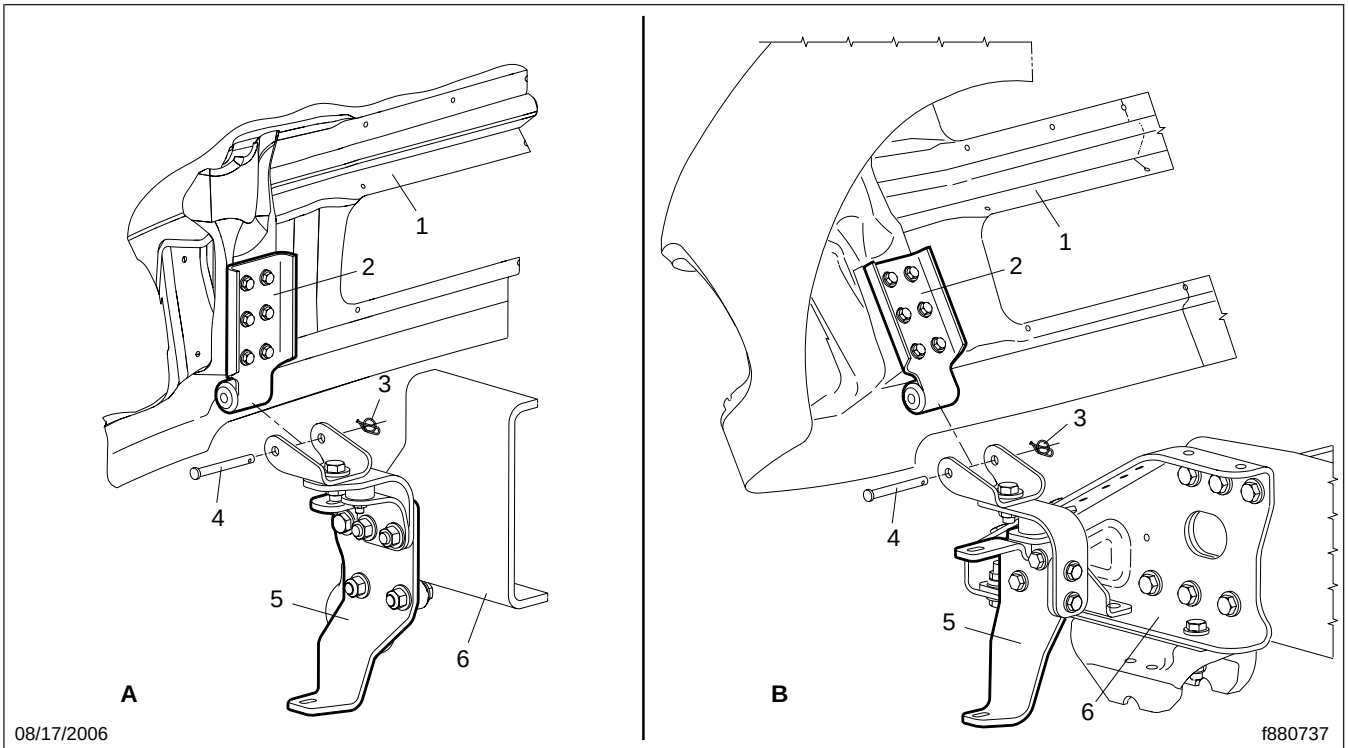
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Hood Removal and Installation

6. Tilt the hood fully open, and rest it on the support so that most of the weight is on the hood structure.
7. Using a hammer, remove the cotter pins from the hinge pins; see **Fig. 2**.
8. With two assistants holding the hood, one per side, remove the hinge pins from the hinge brackets.
9. Position the hood carefully on the support.

Installation

1. With the tires chocked, and two assistants holding the hood, one per side, install the hinge pins in the hinge brackets; see **Fig. 2**.
2. Install new cotter pins in the hinge pins.
3. Connect the hood check cables, as follows. See **Fig. 1**.
   - 3.1 Have an assistant close the hood one-fourth of the way, and support it in that position from the front.
   - 3.2 With the assistant supporting the hood in position, install the nuts and washers that attach the hood cables to the radiator.
4. Close and latch the hood.
5. Connect the electrical connector(s) to the front lamps.
6. Remove the chocks.
7. Align the hood, if necessary; see **Subject 110**.



A. Vehicles with Engines Built Through December 31, 2006

1. Hood
2. Hood-Mounted Bracket
3. Cotter Pin
4. Hinge Pin
5. Frame-Mounted Bracket
6. Frame

B. Vehicles with EPA07 Compliant Engines

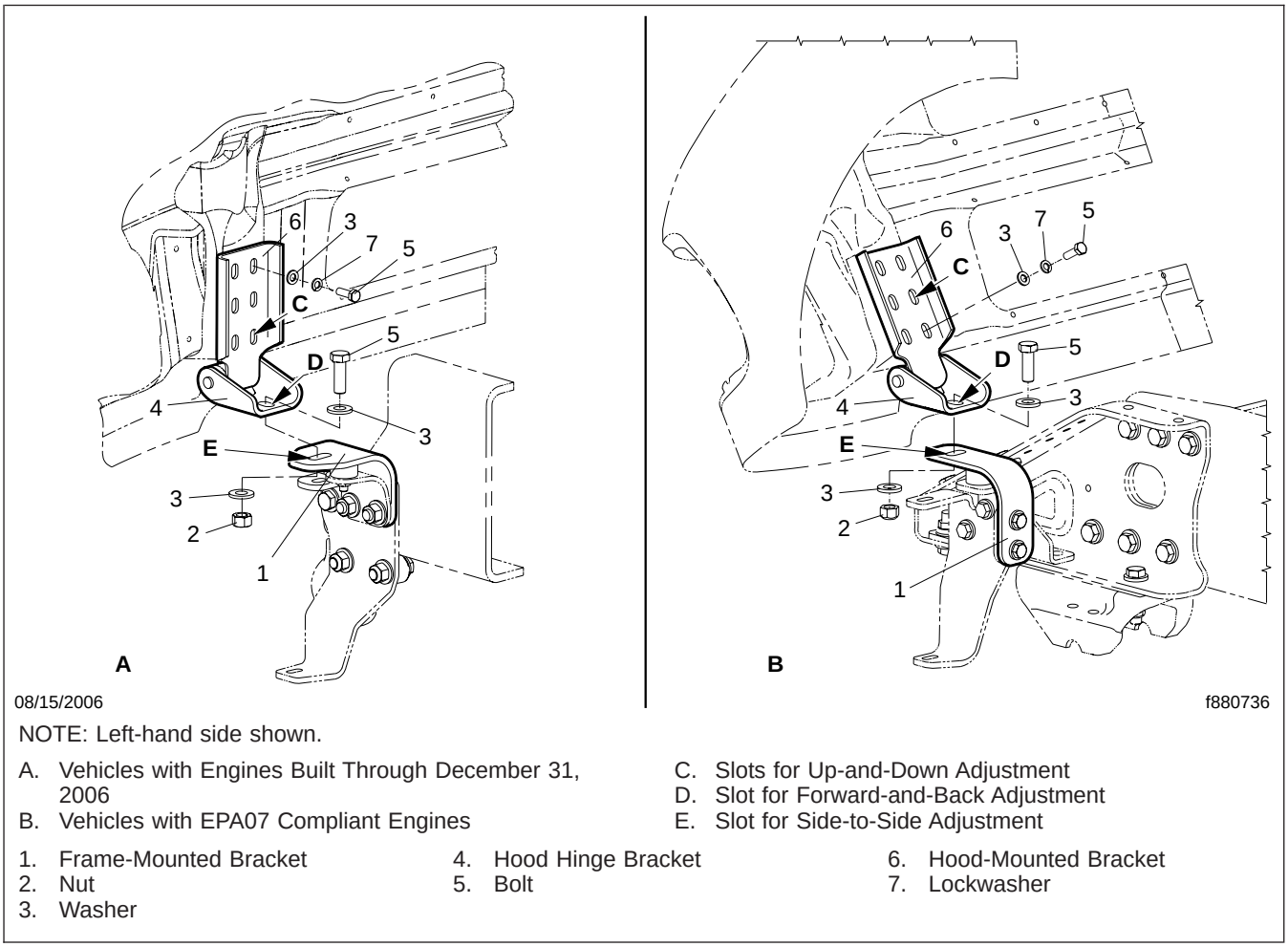
Fig. 2, Hood Hinge Installation

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Alignment

NOTE: The frame-mounted portion of the hood hinge assembly provides forward-and-back and side-to-side adjustment; see **Fig. 1**, Ref. D and Ref. E. The hood-mounted brackets provide up-and-down adjustment at the front of the hood; see **Fig. 1**, Ref. C. The cab-mounted hood stabilizers provide up-and-down adjustment and side-to-side adjustment at the rear of the hood; see **Fig. 2**. To correct a misaligned hood, measure the clearances between the panels to determine in which directions, and how far, to move the hood.

1. Drive the vehicle back and forth to settle the frame and suspension. Park the vehicle on a flat, level surface. Shut down the engine, apply the parking brakes, and chock the tires.
2. Adjust the hood-to-fender clearance at the latch pocket to 1-1/4 to 1-1/2 inches (32 to 38 mm); see **Fig. 3**.
3. Adjust the hood-to-cowl panel clearance to 1-1/2 to 2 inches (38 to 51 mm); see **Fig. 4**.
4. Adjust the hood-to-bumper clearance at the vehicle center to 3-1/16 to 3-5/16 inches (78 to 84 mm); see **Fig. 5**.



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NOTE: Left-hand side shown.

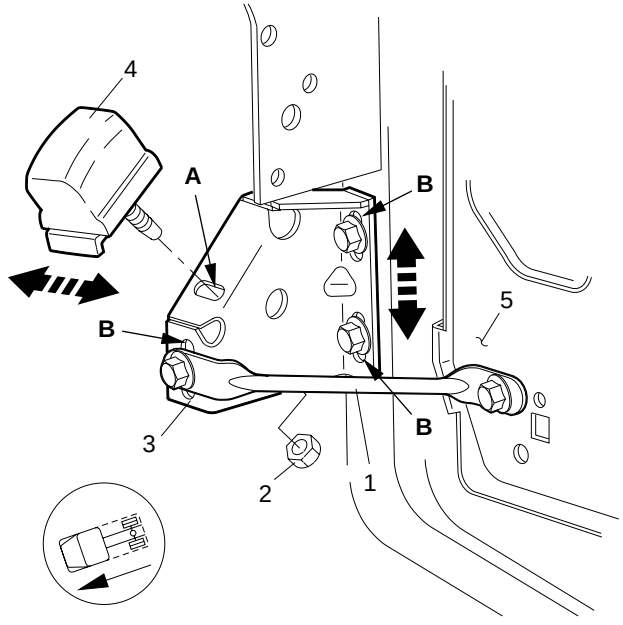
A. Vehicles with Engines Built Through December 31, 2006
B. Vehicles with EPA07 Compliant Engines
C. Slots for Up-and-Down Adjustment
D. Slot for Forward-and-Back Adjustment
E. Slot for Side-to-Side Adjustment

1. Frame-Mounted Bracket
2. Nut
3. Washer
4. Hood Hinge Bracket
5. Bolt
6. Hood-Mounted Bracket
7. Lockwasher

Fig. 1, Hood Alignment at Hood Hinge

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Hood Alignment



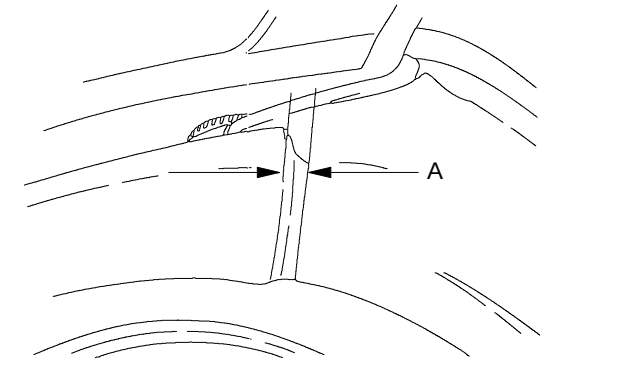
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NOTE: Right-hand side shown.

A. Slot for Side-to-Side Adjustment
B. Slots for Up-and-Down Adjustment

1. Hood Stabilizer Brace
2. Nut
3. Hood Stabilizer Bracket
4. Isolator
5. Cab Front Wall

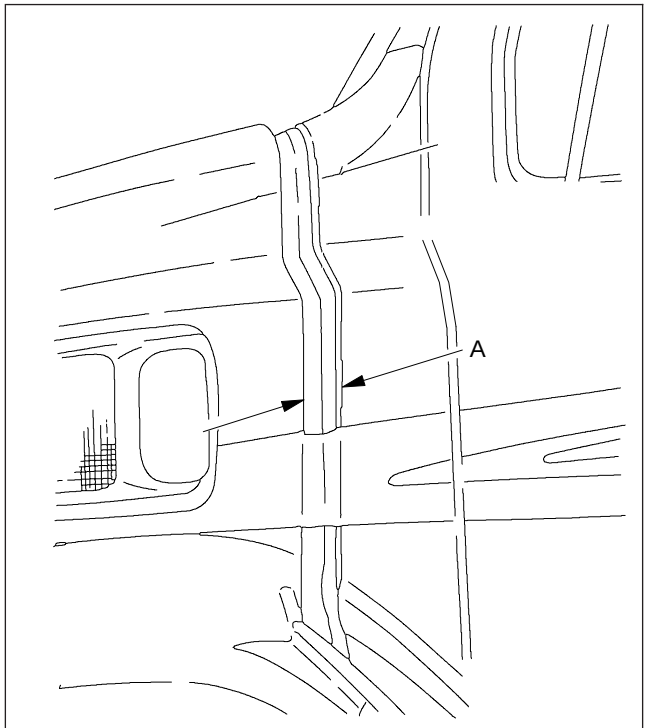
Fig. 2, Hood Alignment at Cab-Mounted Hood Stabilizer



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A. 1-1/4 to 1-1/2 in (32 to 38 mm)

Fig. 3, Hood-to-Fender Clearance at Latch Pocket



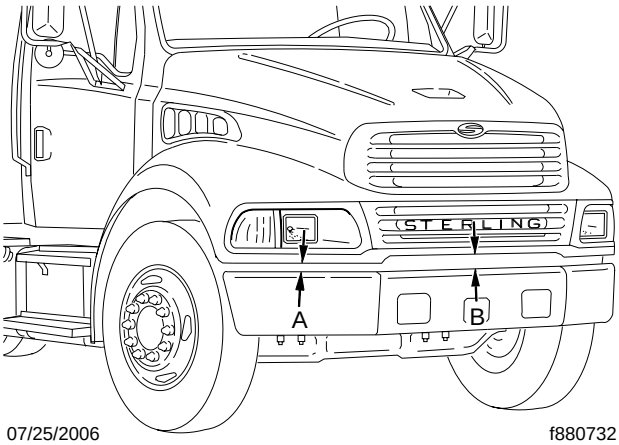
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A. 1-1/2 to 2 in (38 to 51 mm)

Fig. 4, Hood-to-Cowl Panel Clearance

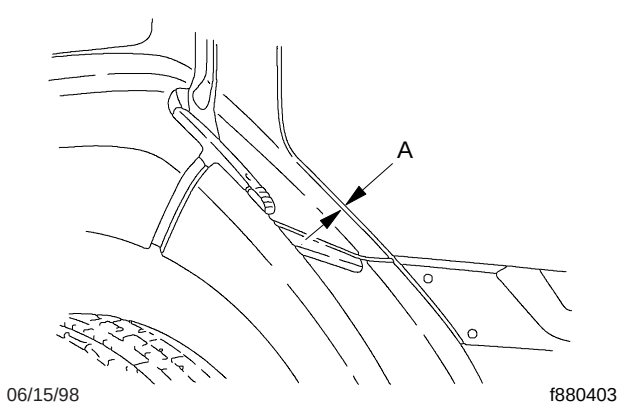
5. Adjust the hood-to-bumper clearance under the headlamp to 1-13/16 to 2-1/16 inches (46 to 52 mm).
6. Adjust the door-to-cowl clearance to 3/16 to 1/4 inch (5 to 7 mm); see **Fig. 6**.
7. Adjust the cowl panel-to-fender clearance to 3/16 to 1/4 inch (5 to 7 mm).
8. For hood adjustment at the rear of the hood, loosen the hood stabilizer bracket bolts and slide the bracket up-and-down, or loosen the isolator and slide it side-to-side; see **Fig. 2**.
9. Lubricate the hood stabilizer on the top face with fluorinated grease.
10. Loosen the bolts in the hood-mounted brackets, move the hood up-and-down as far as required, then tighten the bolts. See **Fig. 1**.
11. Loosen the nuts that secure the hood hinges to the frame-mounted brackets. Move the hood side-to-side or front-and-back as far as required, then tighten the nuts.

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A. 1-13/16 to 2-1/16 in (46 to 52 mm)
B. 3-1/16 to 3-5/16 in (78 to 84 mm)

Fig. 5, Hood-to-Bumper Clearance



A. 3/16 to 1/4 in (5 to 7 mm)

Fig. 6, Door-to-Cowl Clearance

12. If the hood cannot be adjusted to the specified clearances, the hood hinges, the hood-mounted brackets, or the frame-mounted brackets may be damaged. Inspect all hood-mounting components and replace any damaged components.
13. Remove the chocks.

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Grille Removal and Installation

Removal

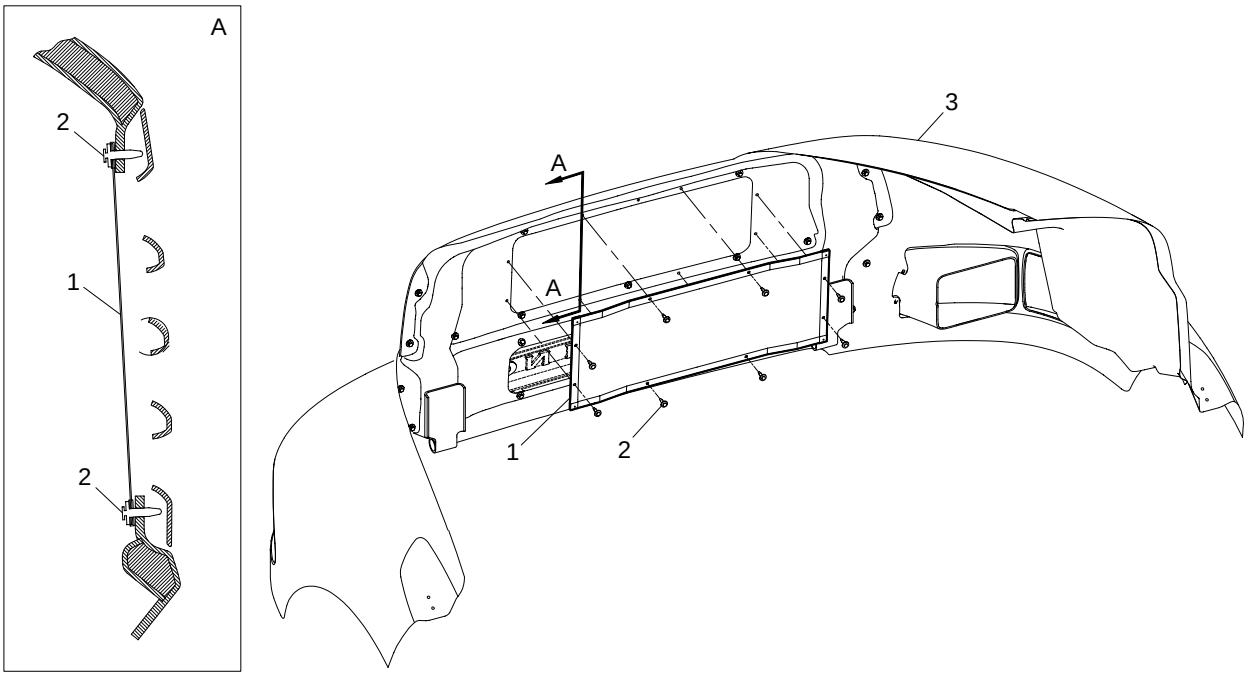
1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Remove the engine splash panel to provide access to the grille.

NOTE: Use care when removing the upper screen/mesh fasteners. They are reusable.

4. From under the hood, remove the fasteners around the upper screen/mesh, if equipped. Use a flat-blade screwdriver placed into the slot under the fastener head to remove the fasteners. Remove the upper screen/mesh. See **Fig. 1**.
5. Remove the fasteners holding the upper grille to the hood. Remove the upper grille. See **Fig. 2**.
6. Remove the fasteners holding the lower grille and letter mesh to the hood. Remove the lower grille and letter mesh. See **Fig. 3**.

Installation

1. Place the letter mesh into the lower grille. The vertical bars on the lower grille have tabs on the rear that align the letter mesh and the grille mounting holes.
2. Position the lower grille and letter mesh on the hood.
3. Align the lower grille and letter mesh fasteners and washers with the holes.
4. Tighten the lower grille and letter mesh fasteners 25 to 35 lbf·in (280 to 380 N·cm).
5. Position the upper grille on the hood.



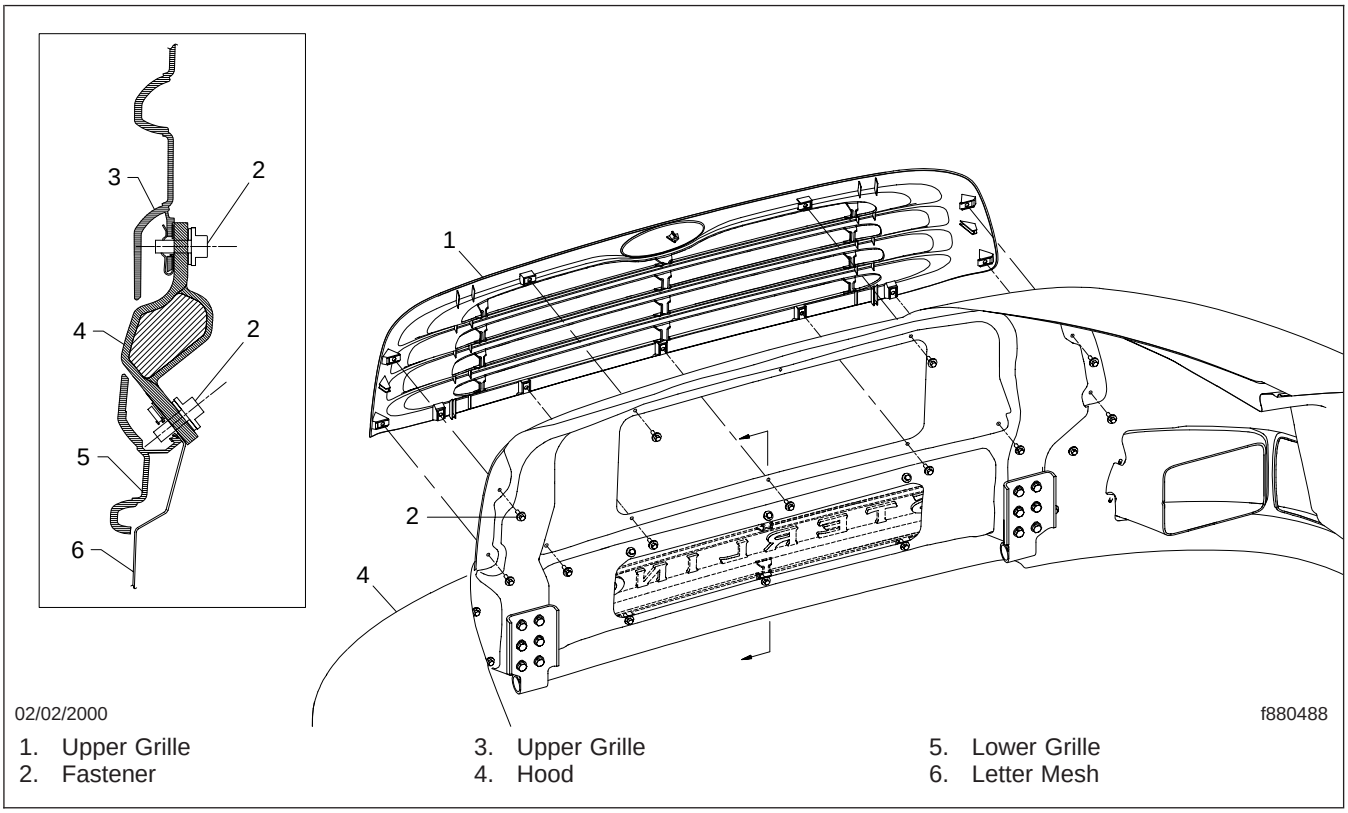
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A. Fastener Detail
1. Upper Screen/Mesh
2. Fastener
3. Hood

Fig. 1, Upper Screen/Mesh

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Grille Removal and Installation



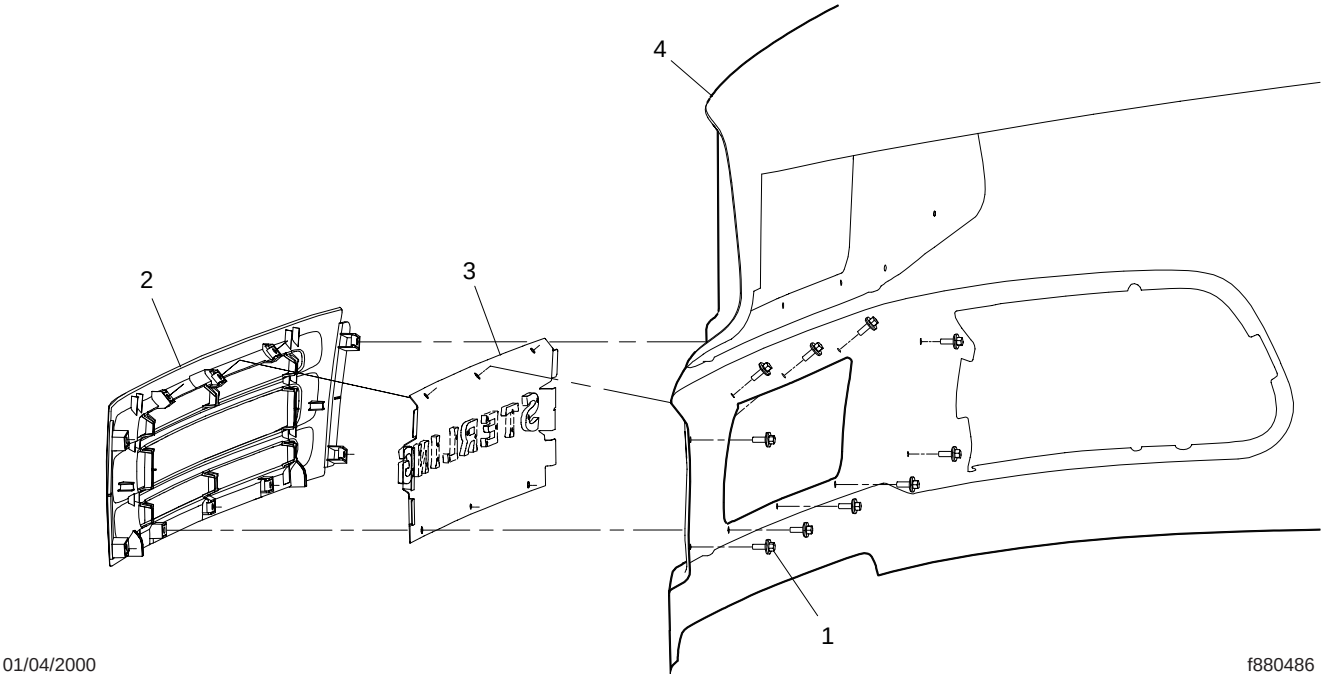
1. Upper Grille
2. Fastener
3. Upper Grille
4. Hood
5. Lower Grille
6. Letter Mesh

Fig. 2, Upper Grille

6. Align the upper grille fasteners and washers with the holes.
7. Tighten the upper grille fasteners 25 to 35 lbf·in (280 to 380 N·cm).
8. From under the hood, install the upper screen/ mesh, if equipped, and tighten the fasteners.
9. Install the engine splash panel.
10. Close and latch the hood.
11. Remove the chocks from the rear tires.

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Grille Removal and Installation



1. Fastener
2. Lower Grille
3. Letter Mesh
4. Hood

Fig. 3, Lower Grille and Letter Mesh

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General Description

The Twinflow midship-mounted fire pump is a centrifugal pumping system designed to deliver large volumes of water under pressure. See **Fig. 1**.

Generally, the pump consists of the following major components:

- cast-iron pump body
- bronze impeller(s) and a stainless steel shaft
- pump gear box
- priming system
- pressure control device
- valves

There are numerous other components, such as the AutoLube and the mechanical seal.

Pump type is determined by the number of impellers on a common shaft. The impeller, which is mounted on a shaft rotated by the vehicle's engine via the driveline, provides velocity to the water causing it to build enough pressure and volume to be used for firefighting applications. See **Fig. 2**.

Bearings support and align the impeller shaft and other components. The bearings must be maintained on a scheduled basis.

The pump body is split horizontally in two sections for the ease of removal of the impeller assembly, including the bearings and the clearance rings.

The pump gear box and the impeller assembly are removable from the bottom of the vehicle in order to avoid interference with the pump plumbing and control mechanisms.

The pump has two large suction inlets, one on each side of the vehicle, though other inlets may be present. The inlets and the internal pump outlets are on opposite sides of the pump to balance forces caused by the intake and the discharge of water.

The AutoLube is built into the pump assembly to continuously force oil to the impeller shaft bushing to lubricate and cool the impeller bushing.

Principles of Operation

A centrifugal pump such as the Twinflow fire pump operates on the principle wherein centrifugal force is created by a rapidly spinning disk, or impeller. Water is routed to the center of the impeller, which throws the water outward from the center of the impeller. When water is confined in a closed container, in this instance, the pump body, the water pressure increases. The pressure level depends on how fast the impeller is rotating.

Water enters the spinning impeller at the intake and is confined by shrouds and vanes in the impeller, which, in turn, builds pressure.

The vanes guide the water away from the inlet to the discharge to reduce the water's turbulence and to move the water toward the outer edge of the impeller.

The shrouds serve as the sides of the impeller and confine the water to the centrifugal acceleration.

Single-stage pumps provide the same operating and rating-test pressures as a two-stage pump, but the two-stage pump offers additional operating (water) pressure.

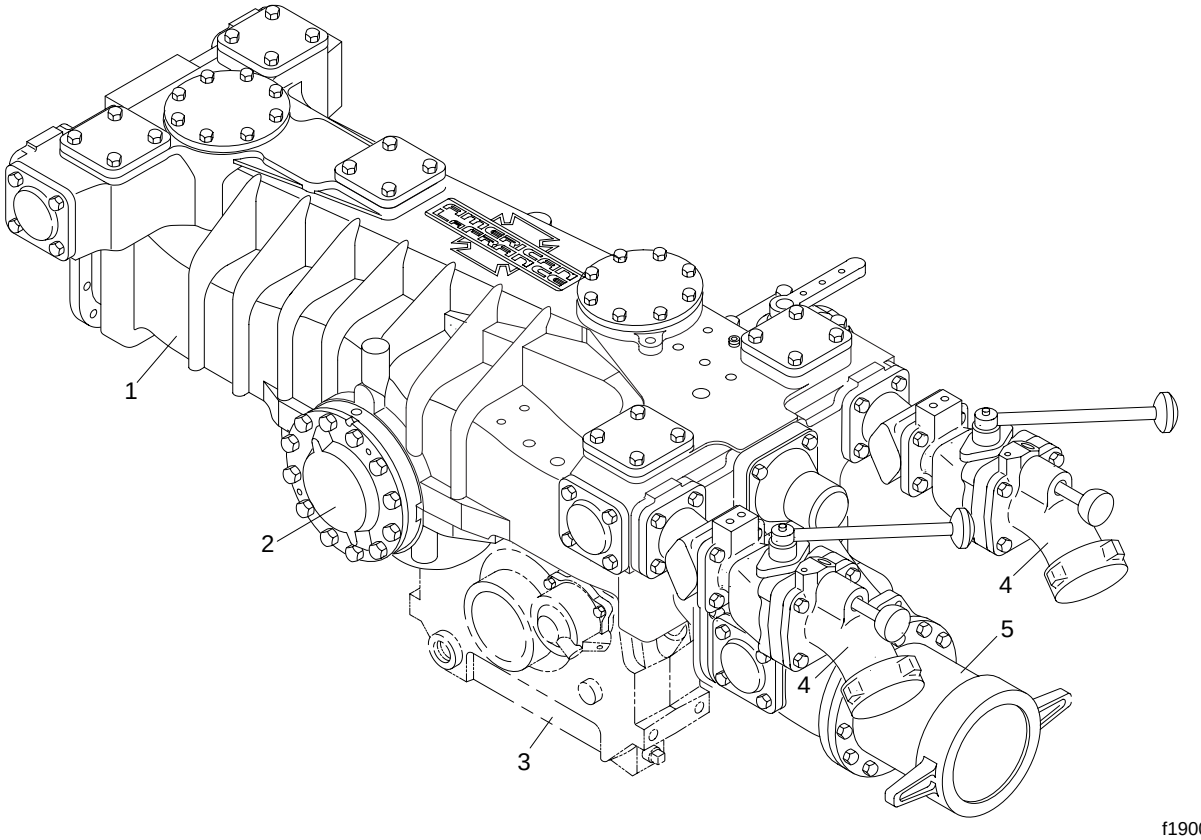
The primary difference between a single-stage and a two-stage pump is that the single-stage has only one impeller and no transfer valve to switch between volume and pressure operation. A transfer valve is a two-position valve that permits the impellers in a two-stage pump to operate in parallel (volume) or series (pressure).

In two-stage pumps, the volume operation results in the pressure at the pump intake being added to the equal pressure developed by the impellers, and the amount of water sent to the discharge being the sum of the flows of the two impellers. The pressure operation features the impellers operating in series, or the output of the primary impeller supplied from the pump intake is supplied to the input of the secondary impeller. Thus, the pressure at the pump discharge is the sum of the pressures of the two impellers plus the pressure at the intake. The flow is then half of the volume operation.

In both types of pumps, the pressurized water is prevented from returning to the intake of the impeller(s) by clearance rings. Centrifugal pumps have clearance rings mounted between the spinning impeller and the pump body. Clearance rings and the hubs of the impeller(s) will, over time, become worn or pitted and may need to be replaced or machined to a smaller diameter.

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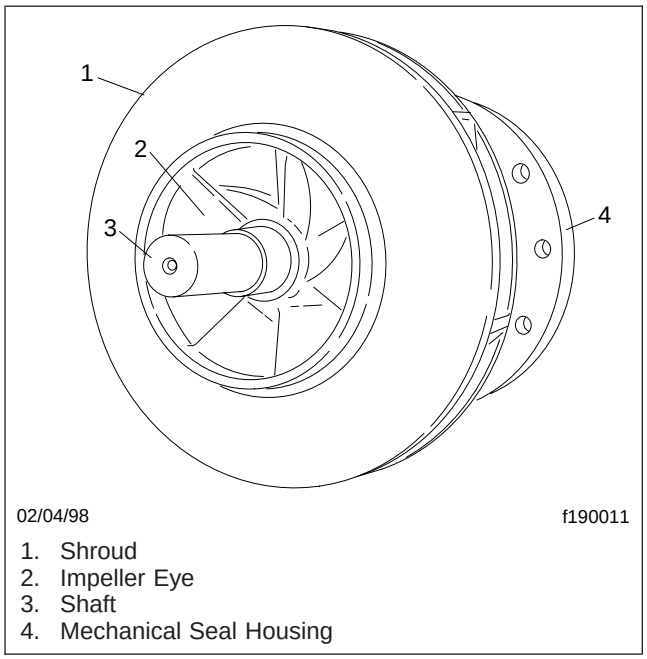
General Information



1. Pump Body
2. AutoLube
3. Gear Box
4. Discharge
5. Intake

Fig. 1, Twinflow Fire Pump (single-stage shown)

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1. Shroud
2. Impeller Eye
3. Shaft
4. Mechanical Seal Housing

Fig. 2, Twinflow Fire Pump Gear Box

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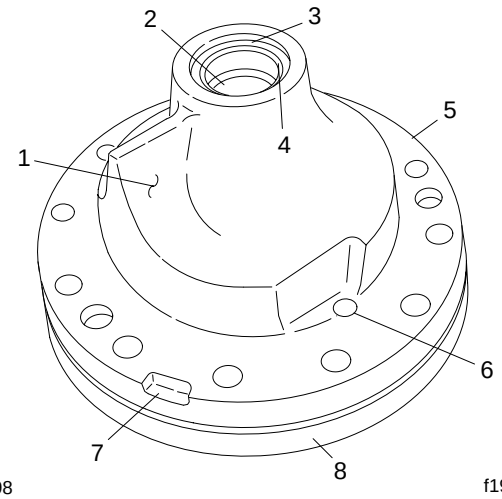
Replacement

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Drain the water from the pump.
3. Remove the fill and drain plugs from the AutoLube reservoir and drain the oil.
4. Use a center punch to mark the AutoLube cover and the front bearing housing for proper alignment during assembly.

CAUTION

Do not use a chisel to separate the AutoLube from the pump body because the mating surfaces may be scratched or gouged, which could result in a leak. The AutoLube is manufactured from cast metal and if it becomes necessary to pry the AutoLube apart from the pump body, pry between the AutoLube and the pump body or at the AutoLube notches.

5. Remove the 1/2–13 x 2 capscrews attaching the AutoLube to the pump body and gently pry the AutoLube from the pump body and impeller shaft.
6. Place the AutoLube face down on a work bench and remove the two 3/8–16 x 3/4 allen-head capscrews from the impeller side. Separate the two halves and remove the diaphragm.
7. Remove the seal lock ring.
8. Remove the oil seal from the inner half of the AutoLube.
9. Check the impeller shaft bushing for wear.
10. Clean the inner and outer halves of the AutoLube.
11. Clean the gasket surfaces of the AutoLube and the pump body.
12. Check for restrictions in the water passages to the rear half of the AutoLube.
13. If it is necessary to replace the impeller shaft bushing, press the bushing from the inner side of the inner half of the AutoLube (on the side opposite of the impeller). Install the bushing from the impeller side of the inner half of the AutoLube. See **Fig. 1**.



1. Cut Water
2. Bushing
3. Lock Ring
4. Seal
5. Front Bearing Housing
6. Water Passage
7. Pry Notches
8. AutoLube Cover

Fig. 1, Impeller Shaft Bushing

CAUTION

The impeller shaft bushing seats against a shoulder in the inner half of the AutoLube and can only be removed and installed as described or the AutoLube may be damaged.

14. Install the new oil seal in the inner half of the AutoLube.
15. Install the seal lock ring.
16. Position the diaphragm on the inner half of the AutoLube.
17. Line up the marks and place the outer half of the AutoLube onto the inner half. Apply Loctite® 242 to the two 3/8–16 x 3/4 allen-head capscrews. Tighten 30 lbf·ft (41 N·m).
18. Install the new gasket on the AutoLube and position the assembly (with the top up) onto the impeller shaft. Attach the AutoLube with 1/2–13 x 2 capscrews and tighten 80 lbf·ft (108 N·m).

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AutoLube Seal Replacement

⚠ CAUTION

Do not damage the oil seal. A damaged oil seal could result in damage to the AutoLube assembly as well as the pump.

19. To fill the AutoLube with 90w oil, pump the oil in from the bottom plug opening until the oil spills from the top opening. This eliminates air pockets and false readings.

⚠ CAUTION

Purge the air from the AutoLube while filling it with oil or a "false-fill" situation will develop, which could cause damage to the AutoLube and other components.

20. Add water to the pump.
21. Operate the fire pump and check the AutoLube for water or oil leaks.
22. Remove the tire chocks.

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Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

Removal

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Drain the water from the pump.
3. Drain the gearbox lubricant to prevent contamination.
4. Disconnect the pressure lubrication line to the gearbox cover. Keep the line primed with lubricant.
5. Disconnect the drive shafts from the gearbox.
6. Disconnect the electrical switches and the air lines. Mark the switches and air lines for assembly.
7. Disconnect the pump gearbox cooling lines.

⚠ WARNING

The gearbox is heavy. Support the gearbox with a lifting or supporting device while removing it from the pump body. Failure to do so could result in the gearbox falling, which could result in personal injury or property damage.

NOTE: Before removing the gearbox, use a center punch to mark the rear bearing housing, the mechanical seal housing, the oil pump cover, and the pump body to ensure proper alignment during reassembly.

8. Support the gearbox with an appropriate device.
9. Remove the six 1/2–13 x 1-3/4 capscrews that attach the gearbox cover to the top of the gearbox.
10. Remove the 7/16–14 x 1-1/4 capscrews that attach the gearbox to the rear bearing housing.
11. Lower the gearbox. Be sure to balance the gearbox so that it does not tip from the lowering device. See **Fig. 1**.
12. Remove the gearbox cover.

NOTE: The threaded holes may need to be cleaned.

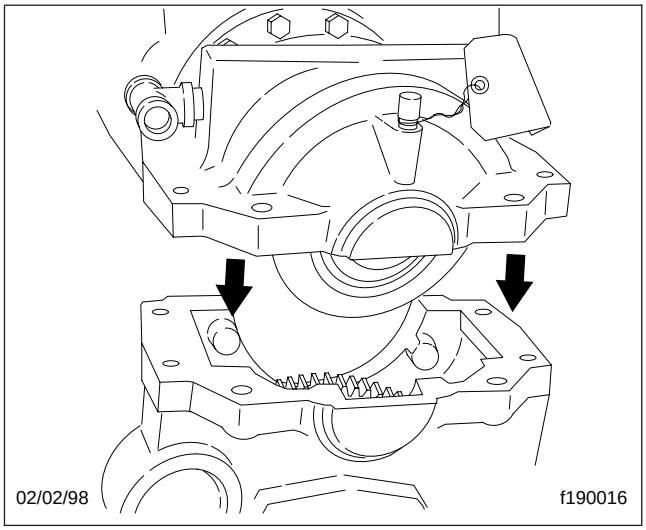


Fig. 1, Lowering the Fire Pump Gearbox

Disassembly

1. Remove and disassemble the intermediate shaft assembly.
   - 1.1 Disconnect the oil suction line from the lubrication pump.
   - 1.2 Remove the capscrews attaching the front bearing housing to the lubrication pump. Then remove the housing and pump assembly.

   NOTE: The rear bearing housing has threaded holes for 1/4–20 jackscrews to assist in removal.

   - 1.3 Remove the capscrews attaching the rear bearing housing to the lubrication pump.
   - 1.4 Reach into the top of the gearbox housing and remove the intermediate gear and shaft assembly. The bearing inner cups are pressed onto the shaft, so care must be taken not to damage the cups during removal.
   - 1.5 Using a bearing splitter, clamp the halves of the splitter onto the back edge of the intermediate shaft bearing cup. Attach a crossbar puller to the bearing splitter halves and remove the cup. Care must be taken when removing the cup not to damage the lubrication pump spline in the

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Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

center of the intermediate shaft. Repeat the procedure for the opposite side bearing cup.

1.6 Using a gear puller with reversed jaws, remove the intermediate shaft bearing cone from the intermediate shaft rear cover.

⚠ CAUTION

Lubrication pump impeller vanes are fragile and may break or chip. Impeller vanes are installed only one way. If removal of the vanes is necessary, note the installation direction of the vanes (rounded edge). Failure to install the vanes properly will result in pump gearbox failure.

1.7 When disassembling the lubrication pump, be sure to note the number of gaskets and shims that are under the cover. Set these components aside for reassembly.

1.8 Using a centerpunch, mark the lubrication pump position and remove the six 1/4–20 x 5/8 capscrews.

1.9 Remove the lubrication pump cover.

1.10 Remove the lubrication pump impeller and the shaft, being careful not to damage the impeller vanes.

1.11 Using a gear puller with reversed jaws, remove the intermediate shaft bearing cone from the intermediate shaft front cover. Care must be taken when removing the cup so as not to damage the lubrication pump spline in the center of the intermediate shaft cover.

2. Remove and disassemble the output shaft assembly.

2.1 Remove the manual shift eye from the rear of the shift yoke shaft.

2.2 Remove the detent allen-head screw, spring and detent ball from the top of the output shaft housing.

2.3 Remove the shift and interlock switches on the output shaft housing.

2.4 Remove the 7/16–14 x 2-1/4 capscrews retaining the output shaft and the housing to the gearbox housing. Carefully remove the output shaft housing by sliding the housing from the shift yoke shaft.

2.5 Remove the input shaft pilot bearing from the output shaft.

2.6 Remove the 3/4–10 x 1-1/2 capscrew retaining the rear driveline yoke to the output shaft and remove the yoke.

2.7 Remove the output shaft seal.

2.8 Remove the output shaft by sliding it from the output shaft housing from the rear to the front. Use caution when sliding the output shaft through the bearing cones and spacer(s).

⚠ CAUTION

Bearing cups, cones, and spacers are factory preset for end play and are only provided as a matched set. It is important that bearing cups, bearing cones, and spacers, when removed, be kept together in matched sets. Input and output shaft bearing and spacer sets are different. Failure to keep matched sets together or to not use factory preset and matched bearing and spacer sets will void warranty and may result in gearbox failure.

2.9 Remove the inner and outer bearing cones.

2.10 Using a brass drift, carefully drive out the outer bearing cup from the inside out. Remove the internal retaining ring and then the spacer(s).

2.11 Using a brass drift, carefully drive out the inner bearing cup from the outside in.

2.12 Remove the shaft seal from the output shaft housing.

3. Remove and disassemble the input shaft assembly.

3.1 Remove the three 5/16–18 x 1 capscrews from the shift cylinder and carefully slide the shift cylinder from the piston.

3.2 Remove the nut and then remove the piston from the shift shaft. Remove the seal ring from the piston.

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Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

⚠ CAUTION

Do not remove the piston from the shift yoke shaft unless it is damaged and replacement is mandatory. When installing a new piston, replace the locknut and tighten snugly, but do not overtighten as the nut can become distorted, which can cause shift failures.

3.3 Remove the shift shaft, the shift fork, and the shift ring assembly from the gearbox. Make sure the shift ring does not get dropped or damaged.

3.4 Note the location and orientation of the shift fork on the shaft, then remove the 3/8–16 x 1-1/4 screw from the shift fork and remove the fork from the shift shaft.

3.5 Remove the shift shaft support block. Then remove the seal from the support block.

NOTE: One ear of the shift yoke is machined and will fit one way. Make a note of the location of the machined ear when removing the shift yoke.

3.6 Remove the 3/4–10 x 1-1/2 capscrew attaching the front driveline yoke to the input shaft. Remove the yoke.

3.7 Remove the input shaft by sliding the input shaft from the output shaft housing opening at the rear of the gearbox. Use caution when sliding the input shaft through the bearing cones, the thrustwasher, and the drive gear. Place wooden blocks to support the drive gear and to protect the windage tray, and force the shaft loose.

⚠ CAUTION

Bearing cups, cones, and spacers are factory preset for end play and are only provided as a matched set. It is important that bearing cups, bearing cones, and spacers, when removed, be kept together in matched sets. Input and output shaft bearing and spacer sets are different. Failure to keep matched sets together or to not use factory preset and matched bearing and spacer sets will void warranty and may result in gearbox failure.

There are two bearings of different widths supporting the drive gear on the input shaft. It is important that these bearings be installed in the drive gear in the proper location. Note the location of the bearings when removed. Failure to install the bearings properly can result in gearbox failure.

3.8 Reaching through the top of the gearbox housing, carefully remove the drive gear, the inner bearing cone, and thrustwasher. Remove the drive gear bearings.

3.9 Using a magnet, remove the positioning pins from the windage tray. Then remove the windage tray and the positioning springs.

3.10 Remove the input shaft seal.

3.11 Remove the outer bearing cone.

3.12 Using a brass drift, carefully drive out the outer bearing cup from the inside out. Remove the internal retaining ring and the spacer(s).

3.13 Using a brass drift, carefully drive out the inner bearing cup from the outside in.

4. Inspect the cooling tube for damage and leaks.
5. Remove the gearbox lubrication oil filter from the suction inlet on the gearbox housing.
6. Clean and inspect each component of the gearbox assembly. Inspect the bearing cups and the cones for wear, pitting, and damage. Inspect the gear tooth surfaces for wear damage and pitting. Inspect the shift shaft block for wear. Inspect the gasket surfaces for nicks and gouges. Replace all components that are worn, damaged, or pitted.

Assembly

1. Install a new transmission lubrication oil filter.
2. Assemble and install the input shaft assembly.

⚠ CAUTION

Bearing cups, cones, and spacers are factory preset for end play and are only provided as a matched set. It is important that bearing cups, bearing cones, and spacers, when removed, be

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Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

kept together in matched sets. Input and output shaft bearing and spacer sets are different. Failure to keep matched sets together or to not use factory preset and matched bearing and spacer sets will void warranty and may result in transmission failure.

2.1 Using a brass drift or a bearing cup installation tool, install the inner bearing cup from the inside out. Then install the spacer(s) and insert the retaining ring.

2.2 Using a brass drift or a bearing cup installation tool, install the outer bearing cup from the outside in.

2.3 Coat the outer bearing cone with oil. Install the outer bearing cone.

2.4 Install the input shaft seal.

2.5 Install the windage tray positioning springs and windage tray. While holding the windage tray in place against the positioning springs, install the windage tray positioning pins.

⚠ CAUTION

There are two bearings of different widths supporting the drive gear on the input shaft. It is important that these bearings be installed in the drive gear in the proper location. The location of the bearings should have been noted when removed from the assembly. Make sure that the lubrication holes are aligned in the center of the larger bearing. Failure to install the bearings properly may result in transmission failure.

2.6 Coat the new drive bearings with oil and install in the drive gear.

2.7 Coat the inner bearing cone with oil and install. Then install the thrustwasher.

2.8 Reaching through the top of the transmission housing, install the drive gear into position against the thrustwasher, being careful not to dislodge the windage tray.

2.9 Slide the input shaft through the output shaft housing opening at the rear of the transmission through the drive gear, the thrustwasher, and the bearing cones and spacer(s).

2.10 Install the front driveline yoke on the input shaft, being careful to not damage the input shaft seal. Apply Loctite® 242 to the 3/4–10 x 1-1/2 yoke retaining capscrew. Then install the capscrew and washer and tighten 225 lbf·ft (305 N·m).

NOTE: Apply a coat of Loctite® to all screws prior to reassembly.

NOTE: One ear of the shift yoke is machined and it will only fit one way. Make sure the yoke is oriented on the shaft in the position noted during disassembly.

2.11 Make sure the shift fork is properly aligned (the machined side should be toward the threaded end of the shift shaft) and slide the new shift fork on the shift shaft. Align the shift fork with the groove in the shaft and secure the shift fork in place with a 3/8–16 x 1-1/4 screw. Tighten the screw 33 lbf·ft (45 N·m).

2.12 Install a new seal on the shift shaft support block. Install a new gasket on the shift shaft support block. Install the shift shaft support block and gasket in the gearbox using two 1/4–20 x 5/8 capscrews. Tighten the capscrews 96 lbf·in (1085 N·cm).

2.13 Place the shift ring into the shift fork grooves. While holding the shift ring in place, insert the shift shaft into the gearbox through the bushing. Make sure the teeth on the shift shaft ring line up with the teeth on the input shaft and gear.

2.14 Apply a light coating of grease to the new seal ring, then install the seal ring on the shift piston. Install the piston on the shift shaft end.

⚠ CAUTION

When installing the piston, use a new locknut and tighten snugly but do not overtighten. Overtightening the locknut may distort the piston and cause shift failures.

2.15 Secure the piston in place with a new locknut.

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Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

2.16 Apply a light coating of grease to the shift cylinder seal and install the seal in the groove on the shift cylinder.

2.17 Install the shift cylinder using three 5/16–18 x 1 screws. Tighten the screws 17 lbf·ft (23 N·m).

3. Assemble and install the output shaft assembly.

3.1 Install a new shift shaft seal in the output shaft housing.

⚠ CAUTION

Bearing cups, cones, and spacers are factory preset for end play and are only provided as a matched set. It is important that bearing cups, bearing cones, and spacers, when removed, be kept together in matched sets. Input and output shaft bearing and spacer sets are different. Failure to keep matched sets together or to not use factory preset and matched bearing and spacer sets will void warranty and may result in transmission failure.

3.2 Using a brass drift or a bearing cup installation tool, install the inner bearing cup from the inside out. Install the spacer(s). Then install the retaining ring.

3.3 Using a brass drift or a bearing cup installation tool, install the outer bearing cup from the outside in.

3.4 Coat the outer bearing cone with oil and then install it.

3.5 Install the output shaft seal.

3.6 Apply a coating of oil to the inner bearing cone and install.

3.7 Apply a coating of oil to the input shaft pilot bearing and then install the bearing into the output shaft.

3.8 Install the output shaft by sliding the shaft in through the output shaft housing from the front to the rear. Be careful when sliding the output shaft through the bearing cones and spacer(s).

3.9 Install the rear driveline yoke on the output shaft, taking care not to damage the output shaft seal. Apply Loctite® 242 to the 3/4–10 x 1-1/2 capscrew. Then install the capscrew and washer and tighten 225 lbf·ft (305 N·m).

3.10 Install a new gasket onto the output shaft housing.

3.11 Apply Loctite® 242 to the two 7/16–14 x 2-1/4 and the four 7/16–14 x 1-3/4 capscrews. Then install the output shaft and housing, sliding the housing onto the shift yoke shaft. Install and tighten the 2-1/4-inch capscrews 50 lbf·ft (68 N·m) and the 1-3/4-inch capscrews 53 lbf·ft (72 N·m).

3.12 Install the shift and interlock switches on the output shaft housing.

3.13 Apply Loctite® 242 to the detent allen-head screw and install the detent ball, spring, and allen-head screw.

3.14 Install the manual shift eye from the rear of the shift yoke shaft.

3.15 Rotate the input shaft to check for proper movement.

4. Assemble and install the intermediate shaft assembly.

4.1 Press a new bearing cone into the intermediate shaft rear cover, coat the cone with oil and install a new cover seal.

4.2 Press a new bearing cone into the intermediate shaft front cover, coat the cone with oil and install a new cover seal.

⚠ CAUTION

Lubrication pump impeller vanes are fragile and may break or chip. Impeller vanes are installed only one way. If removal of the vanes is necessary, note the installation of the vanes. Failure to install the vanes properly will result in transmission failure.

IMPORTANT: To ensure proper operation of the oil pump, use the same number of gaskets and shims that were removed when the oil pump was disassembled.

4.3 Install the lubrication pump impeller assembly, vanes, and shaft into the front cover aligning the matchmarks. Apply Loctite® 242 to the six 1/4–20 x 5/8 capscrews and tighten 8 lbf·ft (11 N·m).

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Fire Pump Gearbox Removal, Disassembly, Assembly, and Installation

4.4 Press the new bearing cups onto the intermediate shaft, one on each side of the intermediate gear.

4.5 Reaching through the top of the transmission housing, install the intermediate gear and shaft assembly taking care not to damage the bearing cups.

4.6 Holding the intermediate gear assembly in place, install the rear intermediate shaft cover. Apply Loctite® 242 to the three 7/16–14 x 1-1/4 capscrews and install but do not torque.

4.7 Install the front intermediate shaft cover, aligning the lubrication pump shaft spline with the intermediate shaft spline. Apply Loctite® 242 to the three 7/16–14 x 1-1/4 capscrews and tighten all six capscrews 53 lbf·ft (72 N·m).

4.8 Connect the oil suction line to the lubrication pump.

4.9 Rotate the input shaft and manually shift the transmission to check for proper movement and operation.

Installation

1. Install a new gasket on the seating surface of the rear bearing housing.

⚠ CAUTION

Properly align the rear bearing housing. If the rear bearing housing is not aligned with the matchmarks, the gear tooth mesh could be incorrect and may result in damage to the gearbox.

2. Using a lifting device, lift the gearbox into position (around the rear bearing housing). Apply Loctite® 242 to the six 1/2–13 x 1-3/4 capscrews and attach the gearbox cover to the gearbox. Tighten finger-tight, but do not torque.
3. Apply Loctite® 242 to the twelve 7/16–14 x 1-1/4 capscrews and insert the capscrews through the rear bearing housing cover and gasket into the gearbox. Tighten 53 lbf·ft (72 N·m).
4. Tighten the six 1/2–13 x 1-3/4 capscrews 65 lbf·ft (88 N·m).
5. Connect the pump gearbox cooling lines.
6. Connect the air lines and electrical switches.
7. Connect the drive shafts. Tighten the yoke fasteners 225 lbf·ft (305 N·m) and tighten the bearing retaining strap capscrews 40 to 48 lbf·ft (54 to 65 N·m).
8. Connect the lubrication line to the gearbox cover.
9. Fill the gearbox with the necessary lubricant.
10. Operate the pump and check for leaks. Verify the oil pressure at 25 to 35 psi (172 to 241 kPa) at the oil injection point.
11. Remove the chocks from the front and rear tires.

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Replacement

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Drain the water from the pump.

⚠ WARNING

The gearbox assembly is heavy. Support the lower gearbox assembly with a lifting device. Failure to do so could result in the assembly falling, which could result in personal injury or property damage.

3. Remove the gearbox. See **Subject 110** for information.
4. Remove the 5/8–11 x 1-1/4 capscrew and bearing retaining washer from the end of the impeller shaft.
5. Remove the twelve 1/2–13 x 1-3/4 capscrews that attach the rear bearing housing to the pump body.
6. Install two 1/2–13 x 3 jackscrews into the 1/2–13 threaded holes provided in the rear bearing housing. See **Fig. 1**.
7. Use a centerpunch to mark the rear bearing housing, the mechanical seal housing, and the pump body so that the components are properly aligned during assembly.
8. Turn the two jack screws evenly, clockwise, to push the rear bearing housing from the impeller shaft and pump body.

NOTE: To prevent damage to components as the rear bearing housing is pushed from the impeller shaft, place your hands under the gear opening to catch the gear, key, and bearings.

NOTE: It may be necessary to use pry bars to gently assist in removing the inner bearings and gear.

9. Remove the jack bolts.
10. Remove the slinger from the impeller shaft.
11. Remove the four 7/16–14 x 1-1/4 capscrews from the mechanical seal cover. See **Fig. 2**. Use a center punch to mark the seal cover for proper alignment during installation.
12. Use pry bars if necessary in the provided slots to loosen the mechanical seal cover from the impeller shaft and the pump body.
13. Remove the old mechanical seal, being careful not to damage the impeller shaft. Use two small hook-tools positioned about 180 degrees apart to pull the mechanical seal from the seal cavity if necessary.
14. Clean the seal cavity and the impeller shaft.
15. Inspect the retaining ring on the shaft.
16. Remove the burrs at the gear key slot and the bearing lands, and remove the oil seal in the rear bearing housing. See **Fig. 3**.

IMPORTANT: Always replace the entire mechanical seal with a new Twinflow mechanical seal assembly.

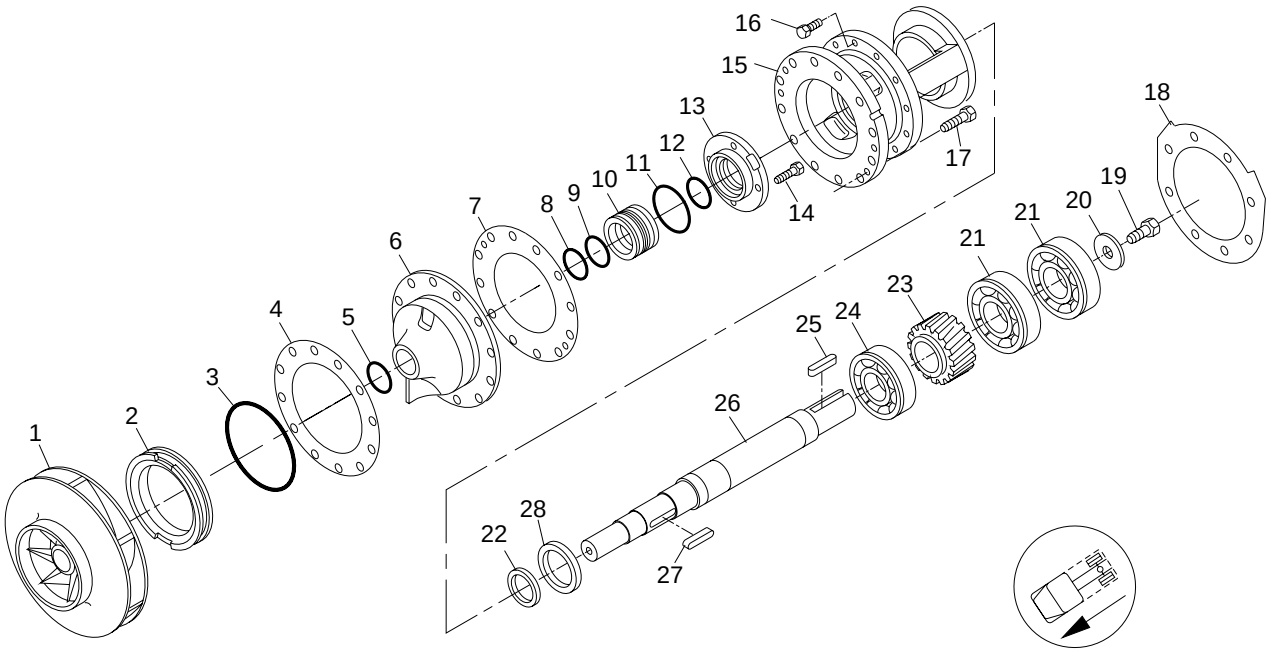
⚠ CAUTION

When installing a new mechanical seal do not touch the sealing surface of the carbon seal ring or the metal seat while handling or installing. Oil and grease can damage the bellows of the mechanical seal. Use only a soap-and-water solution to lubricate the mechanical seal.

17. Clean the housing and the impeller shaft, and lubricate the impeller shaft and the new mechanical seal with a soap-and-water solution.
18. Install the new mechanical seal bellows over the end of the impeller shaft with the spring oriented toward the impeller. Using a soft pusher tube and keeping your fingers away from the carbon seal, carefully push the mechanical seal assembly into the mechanical seal cavity. If binding occurs, apply more soap-and-water solution to the impeller shaft and the bellows.
19. Install the steel cup and seat it into the mechanical seal cover. Lubricate with a soap-and-water solution.
20. Remove and replace the seal rings in the mechanical seal cover. Apply the soap-and-water solution to the seal rings and then slide over the

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Mechanical Seal Replacement



1. Impeller
2. Clearance Ring
3. Rear Bearing Housing Seal
4. Bearing/Seal Housing Gasket (impeller side)
5. Shaft Retaining Ring
6. Mechanical Seal Housing
7. Bearing/Seal Housing Gasket (mechanical seal side)
8. Shaft Seal Ring
9. Shaft Retaining Ring
10. Mechanical Seal And Steel Cup Assembly
11. Mechanical Seal Piston Ring
12. Shaft Seal Ring
13. Mechanical Seal Cover
14. Hexhead Screw, 7/16–14 x 1-1/4
15. Rear Bearing Housing
16. Hexhead Screw, 7/16–14 x 1-1/2
17. Hexhead Screw, 1/2–13 x 1-3/4
18. Rear Bearing Housing Gasket
19. Hexhead Screw, 5/8–11 x 1-1/4
20. Rear Bearing Washer
21. Bearing (aft)
22. Pump Shaft Slinger
23. Pump Shaft Gear
24. Bearing (forward)
25. Pump Shaft Gear Key
26. Pump Shaft
27. Impeller Key
28. Drive Unit Oil Seal

Fig. 1, Impeller Shaft Assembly (exploded view)

end of the impeller shaft. Make sure the mechanical seal remains seated in the bore of the cover.

21. Insert the mechanical seal cover into the mechanical seal cavity aligning it with the bolt holes and the orientation marks.
22. Insert the bolts in the mechanical seal housing to prevent the housing from rotating.
23. Install the four 7/16–14 x 1-1/4 capscrews. Tighten 53 lbf·ft (72 N·m).
24. Install the new slinger onto the impeller shaft. Then remove the retaining bolts.
25. Install the new gasket and oil seal in the rear bearing housing. Slide the housing and front bearing onto the rear impeller shaft. The bearing is a press-fit onto the impeller shaft and slip-fit in the housing.

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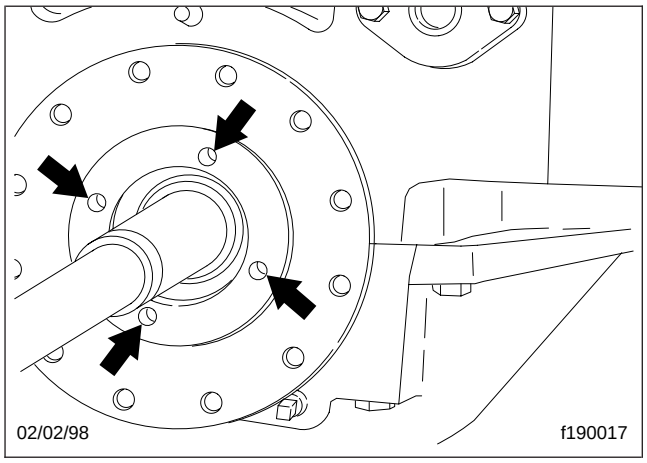
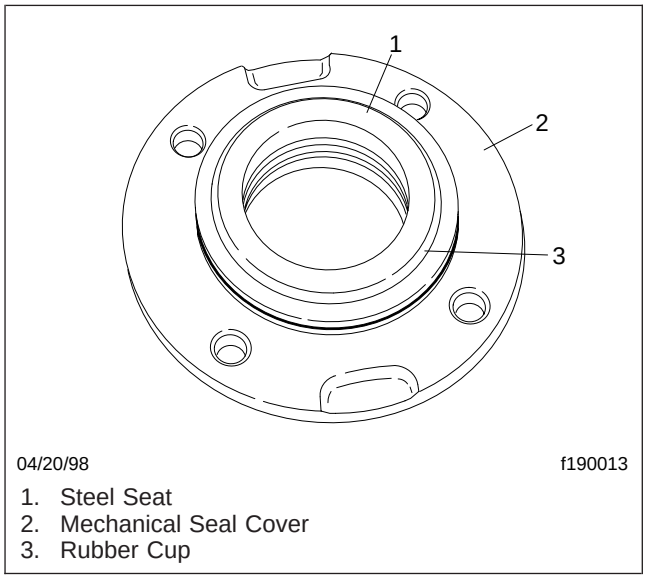


Fig. 2, Remove Four Capscrews



1. Steel Seat
2. Mechanical Seal Cover
3. Rubber Cup

Fig. 3, Mechanical Seal Assembly

IMPORTANT: Do not allow the weight of the rear bearing housing to rest on the oil seal.

26. Insert the gear through the opening in the housing and align it with the impeller shaft. Slide the housing, front bearing and gear onto the shaft. The front bearing will stop when the inner race contacts the seat on the impeller shaft.
27. Line up the keyway in the gear and install the key into the keyway.
28. Slide one of the two rear bearings onto the impeller shaft and into the housing. The rear bearings are a press-fit onto the shaft and a slip-fit in the housing.
29. Using a series of different length capscrews, install the rear bearing housing to the pump body. When it is possible, install the four capscrews (approximately 90 degrees apart). These bolts, in combination with the rear bearing, will center the housing. Double check to be sure the housing is centered and will clear the mechanical seal assembly.
30. Install the pusher bolt in the rear of the impeller shaft. Tighten the nut on the pusher bolt while holding the pusher bolt, pushing the rear bearing into the housing. Remove the pusher bolt and install the second of the two rear bearings. Then install the pusher bolt and tighten the nut while holding the pusher bolt to install the bearing.
31. Continue to tighten the nut on the pusher bolt while making sure the housing is aligned and centered. Once the pusher bolt is snug, the rear housing assembly, the gear, and the bearings should be in place. Remove the pusher bolt and rotate the impeller assembly by placing a large screwdriver between the housing and the gear. The impeller assembly should rotate.

NOTE: A new impeller will have some resistance when the impeller shaft is rotated.

32. Apply Loctite® 242 to the 5/8–11 x 1-1/4 bearing retainer capscrew. Install and tighten 80 lbf·ft (108 N·m).
33. Apply Loctite® 242 to the twelve 1/2–13 x 1-3/4 capscrews, install and tighten 80 lbf·ft (108 N·m).
34. Install the gearbox. See **Subject 110** for information.
35. Perform the annual service test on the pump. Check for leaks. Verify the oil pressure at 25 to 35 psi (172 to 241 kPa) at the oil injection point.
36. Remove the chocks from the front and rear tires.

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Impeller Assembly Removal and Installation

Removal

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Drain the water from the pump.

⚠ WARNING

The gearbox assembly is heavy. Support the lower gearbox assembly with a lifting device. Failure to do so could result in the assembly falling, which could result in personal injury or property damage.

3. Remove the gearbox. See **Subject 110** for information.

⚠ WARNING

The lower pump body is heavy. Support the lower pump body and impeller assembly with a lifting device. Failure to do so could result in the lower pump body and impeller assembly falling, which could result in personal injury or property damage.

4. Remove the drain lines from the lower pump body. See **Fig. 1**.
5. Drain the oil from the AutoLube and remove the 1/2–13 x 2 capscrews from the upper half of the AutoLube and pump body.
6. Remove the 7/16–14 x 1-1/2 capscrews from the upper half of the rear bearing housing and pump body.
7. Remove the 1/2–13 x 1-1/4 capscrews from the lower pump body.

⚠ WARNING

Do not remove the four capscrews, one in each corner of the lower pump body, until the lifting device is in position. Failure to do so could result in the lower pump body and impeller assembly falling, which could result in personal injury or property damage.

8. Position the lifting device into place with the lower pump body lifting adapter between the lifting device and the lower pump body.
9. Remove the 5/8–11 x 5 capscrews in each corner of the lower pump body.
10. Lower the lower pump body and impeller assembly. Be sure to balance the assembly so that it does not tip from the lifting device.
11. Remove the remaining capscrews from the lower half of the AutoLube, the rear bearing housing, and the lower pump body.

⚠ WARNING

The impeller assembly is heavy. Do not attempt to lift the assembly without the aid of another person or persons, or a lifting device. Failure to do so could result in the impeller assembly falling, which could result in personal injury or property damage.

12. Remove the remaining screws from the rear bearing housing and then from the lower pump body.
13. Lift the impeller assembly from the lower pump housing. See **Fig. 2**. Set the assembly aside.
14. Clean all gasket surfaces of the upper and lower pump bodies, as well as those on the AutoLube and the rear bearing housing face.
15. Clean the clearance ring and clearance ring seats in both the upper and lower pump body halves to remove all the buildup material so that the new clearance ring will seat properly.

NOTE: Pitting of the clearance rings may occur from the buildup material and the effects of corrosion. Once the seats are cleaned, any pitting on the clearance rings is considered normal.

Installation

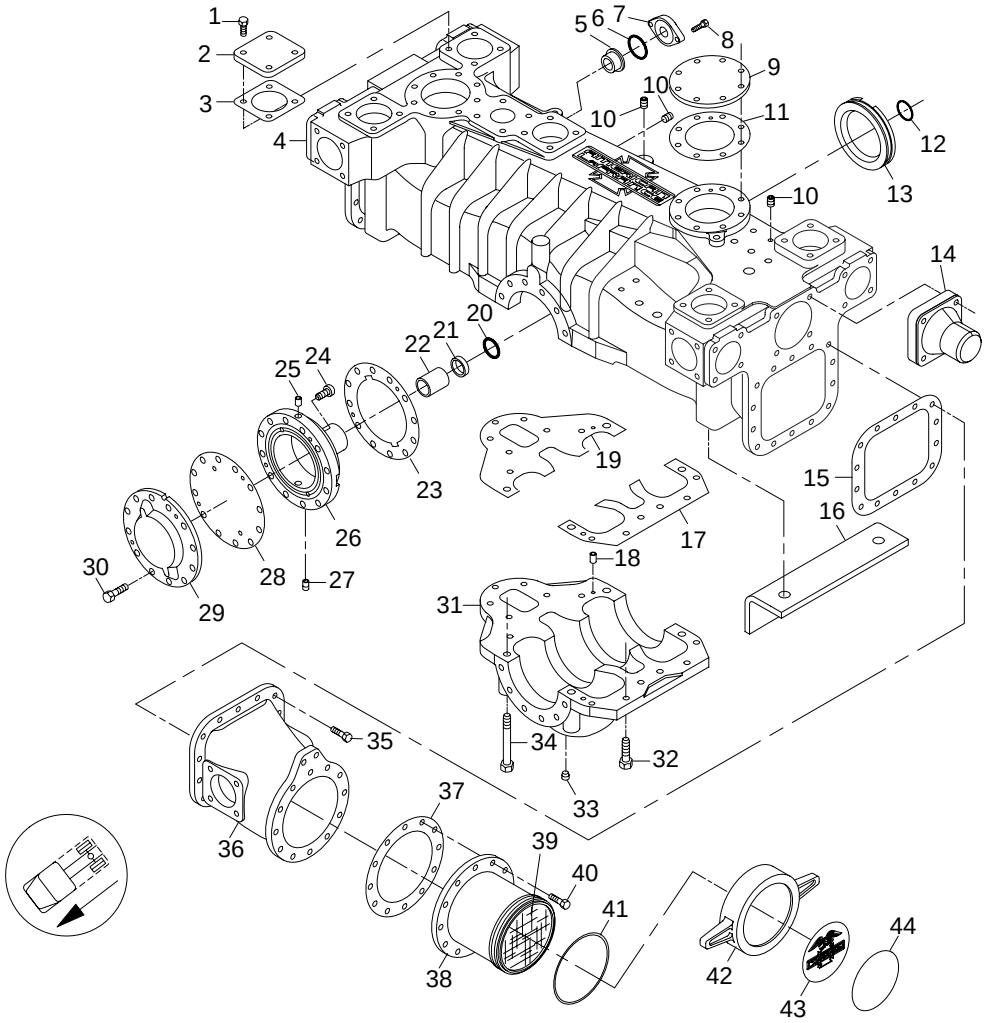
1. Install the pump body gaskets to the lower pump body, trimming as necessary to fit.

⚠ CAUTION

Failure to line up the clearance ring lock notches with the pump body tabs (as described in the next step) may result in pinched clearance rings, which could result in pump damage and pump failure.

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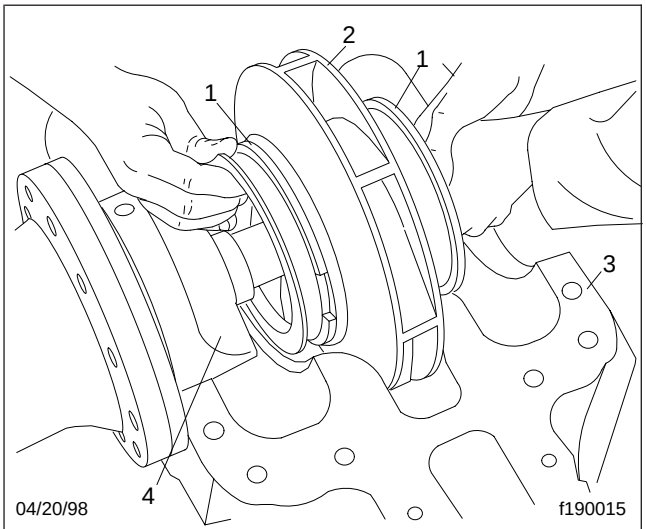
Impeller Assembly Removal and Installation



1. Hexhead Screw, 7/16–14 x 1-1/4
2. Blank Flange
3. Flange Gasket
4. Upper Pump Body
5. Priming Valve Strainer
6. Priming Valve Plate Seal Ring
7. Priming Valve Plate
8. Hexhead Screw, 7/16–14 x 1-1/4
9. Tank Connection Flange
10. Plug, 1/4-inch
11. Tank Connection Gasket
12. Impeller Retaining Ring
13. Clearance Ring
14. QD Relief Valve Assembly
15. Suction Tube Extension Gasket
16. Pump Mounting Bracket
17. Pump Body Gasket (left side)
18. Dowel Pin
19. Pump Body Gasket (right side)
20. Oil Seal Retaining Ring
21. Front Bearing Housing Oil Seal
22. Front Bearing
23. Bearing/Seal Housing Gasket
24. Allen-head Screw, 3/8–16 x 3/4
25. Brass Socket Plug, 1/4-inch
26. Front Bearing Housing Assembly
27. Brass Socket Plug, 1/4-inch
28. Front Bearing Diaphragm
29. Front Bearing Cover
30. Hexhead Screw, 1/2–13 x 2
31. Lower Pump Body
32. Hexhead Screw, 1/2–13 x 1-3/4
33. Plug, 1/2-inch
34. Hexhead Screw, 5/8–11 x 5
35. Hexhead Screw, 1/2–13 x 1-1/4
36. Suction Tube Extension
37. Suction Tube Round Gasket
38. Suction Tube, 6-inch
39. Suction Strainer, 6-inch
40. Hexhead Screw, 7/16–14 x 1-1/4
41. Suction Cap Washer
42. Suction Cap
43. Medallion
44. Medallion O-Ring

Fig. 1, Fire Pump Body Assembly (exploded view)

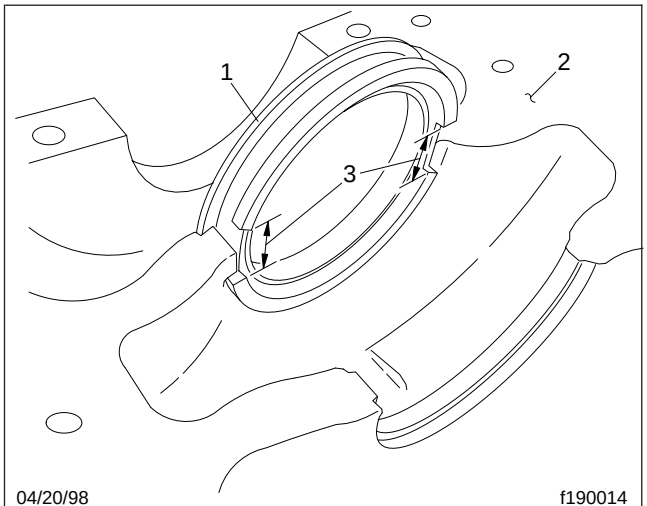
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1. Clearance Ring
2. Impeller
3. Lower Pump Housing
4. Cut Water

Fig. 2, Lifting the Impeller Assembly from the Lower Pump Housing

2. Install the impeller assembly into the lower pump housing carefully aligning the clearance ring lock-notch with the clearance ring lock tabs in the lower pump body. Then rotate the clearance rings to one side to open up lock notches to line up with the lock tabs in the upper pump body. See **Fig. 3**.
3. Install the 1/2–13 x 1-3/4 capscrews through the rear bearing housing and the mechanical seal housing. Do not tighten.
4. Make sure the dowel pins are in the upper pump body to assist in aligning the lower pump body with the upper pump body.
5. Using a lifting device, slowly raise the lower pump body and the impeller assembly into place, making sure that the lower pump body aligns with the dowel pins and the clearance ring notches align with the clearance ring lock tabs in the upper pump body.
6. Rotate the impeller and check for freedom of movement when the lower pump body and the impeller assembly is in place.



1. Clearance Ring
2. Lower Pump Housing
3. Clearance Ring Notch

Fig. 3, Clearance Ring Mounted in Pump Housing

7. Apply Loctite® 242 and install the four 5/8–11 x 5 capscrews (one at each corner of the lower pump body). Tighten snug but do not fully torque.
8. Install the 1/2–13 x 1-3/4 screws in the rear bearing housing and mechanical seal housing. Tighten 53 lbf·ft (72 N·m).
9. Remove the lifting device.
10. Apply Loctite® 242 to the 1/2–13 x 1-3/4 lower pump body capscrews and install them. Tighten snug but do not torque.
11. Torque the 5/8–11 x 5 capscrews 150 lbf·ft (203 N·m) then, starting from the center and moving outward, tighten the lower pump body capscrews 65 lbf·ft (88 N·m).
12. Install the AutoLube. See **Subject 100** for instructions.
13. Install the gearbox. See **Subject 110** for instructions.
14. Operate the pump and check for leaks. Verify the oil pressure at 25 to 35 psi (172 to 241 kPa) at the oil injection point.
15. Remove the chocks.

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Single-Stage Pump

Disassembly

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Remove the AutoLube. See **Subject 100** for instructions.
3. Remove the fire pump gear box. See **Subject 110** for instructions.
4. Remove the impeller assembly. See **Subject 130** for instructions and see **Fig. 1** for an exploded view of the assembly.
5. Place the impeller shaft on a work bench.
6. Note the orientation of the impeller vanes.
7. Remove the outer retaining ring.

WARNING

Wear protective, heat-resistant gloves while heating the impeller to remove it from the impeller shaft. Heated metal can cause injury to your hands.

CAUTION

Do not overheat the impeller. The impeller is constructed of bronze. If the impeller is overheated and turns red or blue during removal from the shaft, it has been weakened and must be replaced.

8. Using an acetylene torch, carefully heat the "eye" of the impeller for approximately two minutes.
9. When heated properly, the impeller will slide free of the shaft. If the impeller moves but does not slide free, do not immediately reheat. Allow the complete assembly to cool to room temperature then reheat and remove the impeller.
10. Allow the components to cool to room temperature.
11. Remove the inner clearance ring.
12. Remove the key.
13. Remove the inner retaining ring and slide the mechanical seal housing from the impeller shaft

Assembly

1. Clean the impeller shaft, the keyway, and the mechanical seal housing and face.
2. Check the waterway in the mechanical seal housing for restrictions.
3. Install the mechanical seal housing onto the impeller shaft.
4. Install the inner retaining ring.
5. Install the new gasket on the mechanical seal housing face.
6. Install the key into the keyway.

CAUTION

If the impeller or clearance rings are dropped, damaged, or deformed, they will need to be replaced.

7. Install the inner clearance ring.

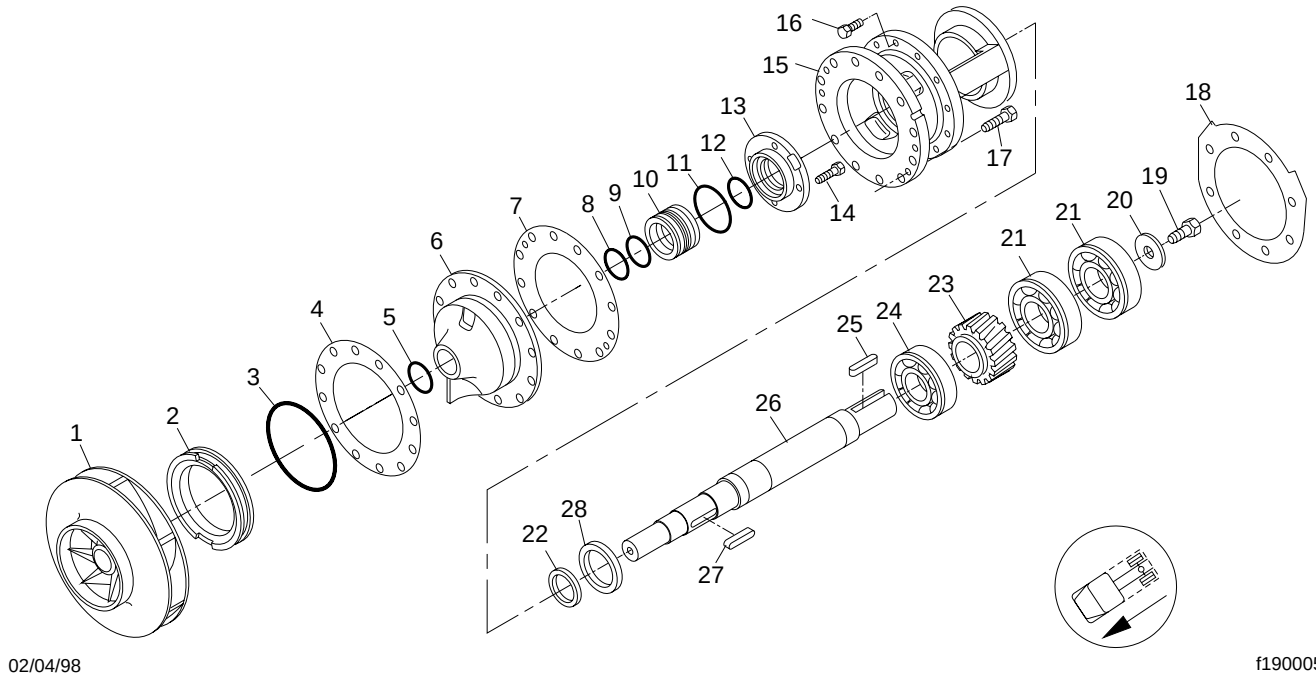
WARNING

Wear protective, heat-resistant gloves while heating the impeller to install it onto the impeller shaft. Heated metal can cause injury to your hands.

8. Using the torch, heat the "eye" of the new impeller for approximately two minutes. Then slide the impeller onto the shaft with vanes in proper orientation. If the impeller does not fully slide onto the shaft allow the assembly to cool to room temperature before reheating.
9. Install the outer retaining ring.
10. Install the impeller assembly. See **Subject 130** for instructions.
11. Install the outer clearance ring.
12. Install the impeller shaft assembly.
13. Install the fire pump gear box. See **Subject 110** for instructions.
14. Install the AutoLube. See **Subject 100** for instructions.
15. Remove the chocks from the front and rear tires.

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Impeller Shaft Disassembly and Assembly



1. Impeller
2. Clearance Ring
3. Rear Bearing Housing Seal
4. Bearing/Seal Housing Gasket (impeller side)
5. Shaft Retaining Ring
6. Mechanical Seal Housing
7. Bearing/Seal Housing Gasket (mechanical seal side)
8. Shaft Seal Ring
9. Shaft Retaining Ring
10. Mechanical Seal And Steel Cup Assembly
11. Mechanical Seal Piston Ring
12. Shaft Seal Ring
13. Mechanical Seal Cover
14. Hexhead Screw, 7/16–14 x 1-1/4
15. Rear Bearing Housing
16. Hexhead Screw, 7/16–14 x 1-1/2
17. Hexhead Screw, 1/2–13 x 1-3/4
18. Rear Bearing Housing Gasket
19. Hexhead Screw, 5/8–11 x 1-1/4
20. Rear Bearing Washer
21. Bearing (aft)
22. Pump Shaft Slinger
23. Pump Shaft Gear
24. Bearing (forward)
25. Pump Shaft Gear Key
26. Pump Shaft
27. Impeller Key
28. Drive Unit Oil Seal

Fig. 1, Impeller Shaft Assembly (exploded view)

Two-Stage Pump

Disassembly

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Remove the AutoLube. See **Subject 100** for instructions.
3. Remove the fire pump gear box. See **Subject 110** for instructions.
4. Remove the impeller assembly. See **Subject 130** for instructions.
5. Place the impeller shaft assembly on a work bench.
6. Note the position of the impeller vanes.

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7. Remove the inner and the outer retaining rings and then remove the mechanical seal housing.

WARNING

Wear protective, heat-resistant gloves while heating an impeller to remove it from the impeller shaft. Heated metal can cause injury to your hands.

CAUTION

Do not overheat the impeller. An impeller is constructed of bronze. If the impeller is overheated and turns red or blue during removal from the shaft, it has been weakened and must be replaced.

8. With an acetylene torch, carefully heat the "eye" of the impellers for approximately two minutes.

IMPORTANT: Mark the impellers as to whether they are the primary or secondary impeller in relation to the AutoLube. Improper or backward installation of the impellers affects pump performance.

9. When heated properly, an impeller will slide free of the shaft. If the impeller moves but fails to slide free, do not immediately reheat. Allow the complete assembly to cool to room temperature then reheat and remove the impellers. Heat the secondary impeller and remove. Then rotate the impeller shaft assembly end for end and heat and remove the primary impeller.
10. Remove the center support bearing.
11. Remove mechanical seal housing and then the inner clearance ring.
12. Remove the key.
13. Remove the inner retaining ring and slide the mechanical seal housing from the impeller shaft.

Assembly

1. Clean the impeller shaft, the keyway, and the mechanical seal housing and face.
2. Check the waterway in the mechanical seal housing for restrictions.
3. Install the new gasket on the mechanical seal housing face.
4. Install the key into the keyway.

CAUTION

If the impellers or the clearance rings are dropped, damaged, or deformed, they require replacement.

5. Install the inner clearance ring.

WARNING

Wear protective, heat-resistant gloves while heating the impeller to install it onto the impeller shaft. Heated metal can cause injury to your hands.

6. Using the torch, heat the "eye" of each impeller for approximately two minutes. Then slide the individual impellers onto the shaft. If an impeller does not fully slide onto the shaft allow the assembly to cool to room temperature before reheating.
7. Install the outer retaining ring.
8. Install the outer clearance ring.
9. Install the impeller assembly. See **Subject 130** for instructions.
10. Install the mechanical seal housing onto the impeller shaft.
11. Install the impeller shaft assembly.
12. Install the fire pump gear box. See **Subject 110** for instructions.
13. Install the AutoLube. See **Subject 100** for instructions.
14. Remove the chocks from the front and rear tires.

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Valve Removal, Disassembly, Assembly and Installation

Pilot Valve

Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.

1. Drain the fire pump.
2. Rotate the adjustment handwheel counterclockwise to remove the spring tension.
3. Remove the capscrew and nut attaching the adjustment handwheel to the adjustment shaft. Then remove the handwheel.

⚠ CAUTION

Identify and mark the line connections on the control body before removing. Improper connection of lines may result in the failure of the pilot valve, which could cause damage to the fire pump.

4. Remove the pump discharge pressure line and the relief valve line from the control body of the pilot valve.
5. While holding the pilot valve, remove the four 1/4–20 x 5/8 machine screws attaching the valve and cover plate to the Pump Operator's Panel, and separate the valve, plate, and the relief valve setting indicator (if equipped with PMD) from the panel.
6. Disassemble the pilot valve.
   - 6.1 Remove the four 5/16–18 x 1 allen-head capscrews securing the control body to the rear of the spring housing. Then remove the control body.

⚠ CAUTION

Do not use pliers to unscrew the control valve from the diaphragm clamp. Damage to the control valve will render the pilot valve inoperative.

   - 6.2 Unscrew the control valve from the diaphragm clamp. Remove the diaphragm washer and the diaphragm.
   - 6.3 Remove the retaining ring, the seal, and the bearing.

⚠ WARNING

Use a spring compressor to remove the pilot valve spring. The spring is under compression and could become uncompressed, which could result in personal injury.

   - 6.4 Turn the adjustment handwheel clockwise to unscrew the adjustment shaft from the adjustment nut. From the handwheel end, remove the adjustment shaft from the spring housing.
   - 6.5 Remove both springs, the adjustment nut, and diaphragm clamp as an assembly from the spring housing and then separate.
7. Clean all the pilot valve components. Inspect and lubricate with grease the threads on the adjustment shaft.
8. Assemble the pilot valve.

⚠ WARNING

Use a spring compressor to install the pilot valve spring. The spring is under compression and could become uncompressed, which could result in personal injury.

⚠ CAUTION

Always remove the pilot valve discharge pressure inlet screen, which is located in the top of the discharge side of the pump. Clean or replace as necessary. Failure to do so could render the pilot valve inoperative.

   - 8.1 Combine both springs, the adjustment nut and the diaphragm clamp as an assembly and install into the spring housing. Align the guide pin-in adjustment nut with the slot in the spring housing and the indicator plate on the PMD.
   - 8.2 Slide the adjustment shaft into the spring housing from the handwheel end. Turn the adjustment handwheel counterclockwise in order to screw the adjustment shaft into the adjustment nut until it bottoms in the diaphragm clamp. Do not put the springs under tension.

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Valve Removal, Disassembly, Assembly and Installation

8.3 Lubricate the new bearing and slide the new bearing and bearing washer over the adjustment shaft into the spring body housing. Install the retaining ring. Then install the new seal washer and rotate the adjustment shaft in both directions to check for freedom of movement.

8.4 Install the new diaphragm washer and diaphragm. Screw the control valve into the diaphragm clamp.

8.5 Install the control body. Apply Loctite® 242 to the four 5/16–18 x 1 allen-head capscrews attaching the control body to the rear of the spring housing.

9. Holding the pilot valve, align the cover plate and install the four 1/4–20 x 5/8 machine screws attaching the pilot valve and cover plate to the Pump Operator's Panel.
10. Install the pump discharge pressure line and relief valve line to the control body of the pilot valve.
11. Slide the adjustment handwheel onto the adjustment shaft and then install the retaining capscrew and nut.
12. Fill the pump and test the valve for proper operation and leaks.

Transfer Valve

See **Fig. 1** for an exploded view of the transfer valve.

1. Drain the fire pump.

IMPORTANT: The transfer valve is a timed device. It is therefore important during disassembly to note the location of the transfer bracket locating pin, the transfer drum stop pin, the transfer drum sleeve locating pin, and the transfer drum stem key. It is not necessary to remove the transfer bracket locating pin, the transfer drum sleeve locating pin, or the transfer drum stop pin during disassembly.

2. Turn the adjustment handwheel clockwise until it stops. The transfer indicator should be at the top of the slotted guide in the cover plate.
3. Remove the two allen-head set screws from the transfer indicator guide. Slide the transfer indicator guide (on an adjustment stem) towards the transfer valve.
4. Remove the stem drive gear lock pin. Slide the adjustment stem from the stem drive, the support, and the transfer indicator guide, being careful not to drop or damage the transfer indicator guide and transfer indicator.
5. Remove the four 7/16–14 x 1-1/4 capscrews retaining the transfer bracket assembly to the pump body. Carefully remove the transfer bracket and the transfer valve drum.
6. Disassemble the valve.

   6.1 Remove the locating pin that secures the countershaft in place.

   6.2 Remove the countershaft from the countershaft gear.

   6.3 Remove the countershaft gear and the countershaft gear spring from the transfer bracket assembly.

   6.4 Remove the allen-head set screw from the transfer drum gear. Slide the transfer drum gear from the drum stem. Remove the woodruff key from the transfer drum stem.

   6.5 Separate the transfer bracket from the transfer drum by sliding it from the transfer drum stem.

   6.6 Slide the transfer drum from the transfer sleeve.

7. Assemble the valve.

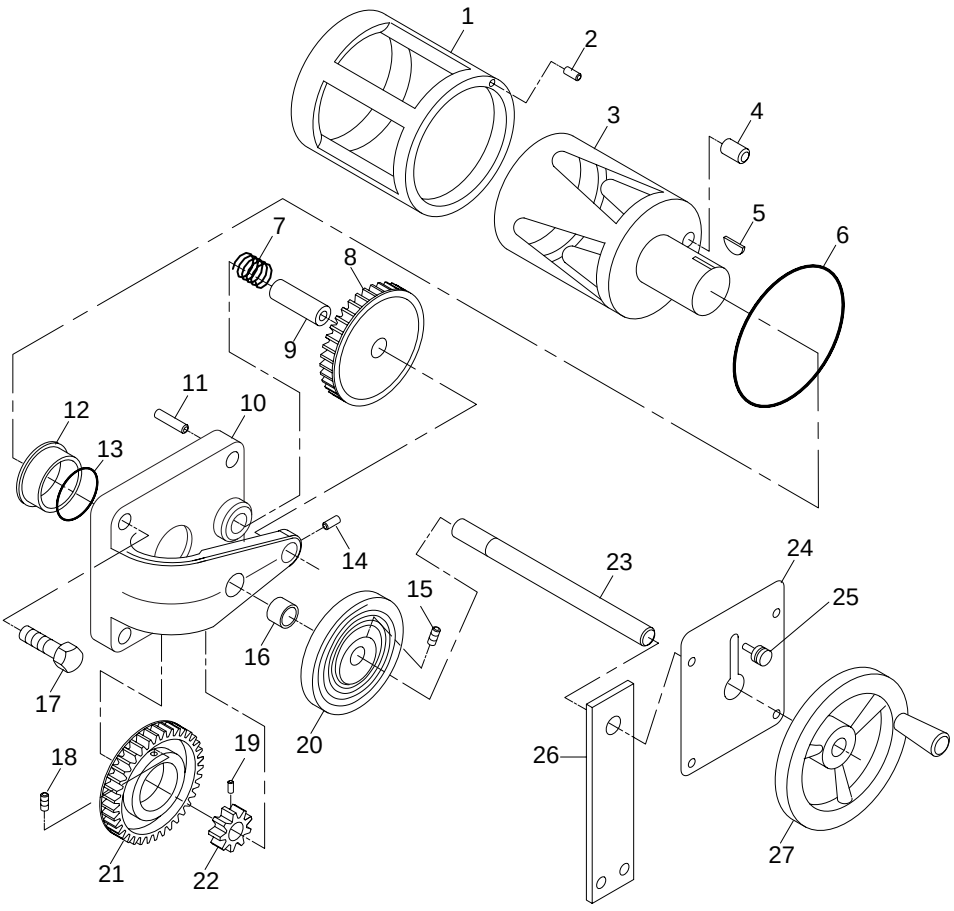
   7.1 Clean and inspect all sealing surfaces, the mating surfaces of the transfer valve drum and sleeve. Clean and inspect the transfer bracket bushings and bushing surface on the transfer valve stem and the transfer valve adjustment stem.

   7.2 Install new O-ring seals on the transfer valve drum stem and the transfer valve bracket.

   7.3 Slide the transfer drum into the transfer bracket, being careful not to damage the bearing surfaces. Then rotate the transfer drum until the drum stop pin is in the correct position.

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Valve Removal, Disassembly, Assembly and Installation



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1. Transfer Drum Sleeve
2. Locating Pin
3. Transfer Drum
4. Transfer Drum Stop Pin
5. Gear Key
6. Transfer Bracket Seal Ring
7. Countershaft Gear Spring
8. Transfer Valve Countershaft Gear
9. Transfer Countershaft
10. Transfer Bracket (with bearings) Assembly
11. Bracket Locating Pin
12. Drum Bracket Bearing
13. Transfer Drum Seal Ring
14. Locating Pin
15. Sockethead Setscrew, 1/4–20 x 3/8
16. Transfer Valve Stem Drive Gear
17. Hexhead Screw, 7/16–14 x 1-1/4
18. Sockethead Setscrew, #10–32 x 1/2
19. Gear Lock Pin
20. Transfer Indicator Guide
21. Transfer Valve Transfer Drum Gear
22. Transfer Stem Drive Gear
23. Transfer Stem
24. Instruction Plate
25. Transfer Indicator
26. Support Stem
27. Adjusting Wheel Assembly

Fig. 1, Transfer Valve

7.4 Install the woodruff key into the transfer drum stem. Install the transfer drum gear onto the transfer drum stem. Apply Loctite® 242 to the allen-head set screw and install the transfer drum gear.

7.5 Assemble the countershaft gear spring in the countershaft gear and position the assembly into place in the transfer bracket. Then install the countershaft and

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Valve Removal, Disassembly, Assembly and Installation

the countershaft locating pin to lock the countershaft in place.

8. Install the transfer valve.
   - 8.1 Align the transfer drum stop pin, the transfer bracket locating pin, and the transfer drum sleeve locating pin into proper position.
   - 8.2 Install the transfer valve drum and bracket assembly into the pump body.
   - 8.3 Apply Loctite® 242 to the four 7/16–14 x 1-1/4 transfer bracket capscrews and install and tighten 53 lbf·ft (72 N·m).
   - 8.4 Slide the adjustment stem through the cover plate, the transfer indicator guide, and the support and transfer bracket.
   - 8.5 Insert the stem drive gear into place in the transfer bracket and then slide the adjustment stem through the stem drive gear.
   - 8.6 Insert the stem drive gear lock pin into place, locking the stem drive gear onto the adjustment stem.
   - 8.7 Apply Loctite® 242 to the transfer indicator guide set screws and install. Do not tighten.
   - 8.8 Turn the adjustment handwheel counterclockwise until it stops. Make sure the transfer indicator is at the top of the slotted guide toward the transfer indicator, making certain that the transfer indicator engages the transfer indicator guide in the top groove. Then tighten the inside set screw in the transfer guide indicator.
   - 8.9 Rotate the adjustment handwheel from stop to stop. The transfer indicator should move freely from the top to the bottom of the slotted guide in the cover plate.
   - 8.10 Tighten the outside set screw in the transfer indicator guide, and recheck the movement of the transfer indicator.
9. Fill the pump and test the valve for proper operation and leaks.

Back Flow Valve

1. Drain the water tank and the pump.
2. Disconnect the control linkage at the Tank-to-Pump valve.
3. Disconnect both ends of the flexible hose connecting the water tank to the tank-to-pump valve. Then slide the flexible hose toward the water tank outlet or the tank-to-pump valve plumbing.

NOTE: If the tank-to-pump valve is air-operated, drain the vehicle's air system and disconnect the supply and the return line on the valve actuator, but do not remove the actuator from the valve. Also, the tank-to-pump valve may be connected to the pump body by capscrews or studs with nuts. If studs are used, it may be necessary to remove some or all of the studs to remove the valve. If so, remove only the studs necessary to remove the valve as any studs left will assist in realigning the valve during installation.

4. Remove the eight 7/16–14 x 1-1/2 capscrews retaining the tank-to-pump valve to the pump body.
5. Remove the tank-to-pump valve and associated plumbing.

NOTE: The back flow valve is a flat butterfly plate with two pivots attached at the top. These pivots fit into two open pivot sockets in the pump body. When the gasket is removed, the back flow valve may fall out.

6. Remove the old gasket from the pump body.
7. Remove the back flow valve.
8. To install the back flow valve, first clean all of the gasket surfaces on the pump body and the tank-to-pump flange.
9. Install the back flow valve. Using two fingers, hold the pivots in the pivot sockets and check the valve for freedom of movement.
10. Install a new gasket.
11. Apply Loctite® 242 to the eight 7/16–14 x 1-1/2 capscrews and attach the tank-to-pump valve to the pump body. Tighten 53 lbf·ft (72 N·m).

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12. Slide the flexible connection hose so it is evenly spaced and secured on the water tank outlet and the tank-to-pump valve plumbing.
13. Attach the tank-to-pump valve controls and linkage.
14. Fill the pump and test the valve for proper operation and leaks.

Sensing Valve

1. Disconnect the following lines at the sensing valve:
    - pilot valve discharge line
    - QG relief valve line
    - PG relief valve line
    - sensing valve pump suction line
    - drain lines
2. Remove the 7/16–14 x 2 sensing valve mounting capscrew.
3. Remove the four 5/16–18 x 1 capscrews attaching the control body to the rear of the spring housing. Remove the control body, being careful not to lose the sensing valve spring.
4. Remove the control valve from the sensing valve body.
5. Unscrew the sensing valve from the diaphragm, being careful not to damage the control valve. Remove the diaphragm.
6. Before installing the sensing valve, clean all components.

⚠ CAUTION

Always remove the sensing valve suction inlet screen. Clean or replace as necessary. The screen is located in the suction side of the pump. Failure to do so may render components inoperative.

7. Install a new diaphragm on the diaphragm clamp. Apply Loctite® to the threads on the control valve and install the control valve into the sensing valve body.
8. Install the sensing valve spring into the valve body cover.
9. Apply Loctite® 242 to the four 5/16–18 x 1 capscrews and attach the control body to the rear of the spring housing. Make sure that the sensing valve spring properly aligns with the diaphragm clamp.
10. Make sure the up arrow is aligned properly.
11. Apply Loctite® 242 to the 7/16–14 x 2 sensing valve mounting capscrew. Tighten 40 lbf·ft (54 N·m).
12. Connect all lines.
13. Fill the pump and test the valve for proper operation and leaks.

TPM Relief Valve

1. Disconnect the line to the sensing valve and drain the fire pump. Make note of the wire connections.
2. Disconnect the indicator light switch.
3. Remove the four 7/16–14 x 1-1/4 capscrews attaching the relief valve assembly to the pump body.
4. Using a twisting motion, remove the relief valve assembly.
5. To disassemble the valve, remove the indicator light switch and remove the cover retaining ring and slide the cover out of the relief valve body.
6. Apply a small amount of pressure to the relief valve piston and remove the piston retaining ring. Carefully release the pressure held to the piston by the spring.
7. Remove the relief valve from the opposite end, sliding the relief valve stem out of the piston.
8. Reach through the center hole of the piston and pull the piston out of the indicator switch end of the relief valve body. Then remove the piston spring.
9. To assemble and install the valve, first clean and inspect all components.
10. Clean all sealing surfaces and install new O-rings seals.
11. Install the relief valve into the relief valve body.

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Valve Removal, Disassembly, Assembly and Installation

12. Install the piston spring by sliding the piston into the relief valve body while at the same time sliding the piston onto the relief valve system.
13. Apply light pressure to the piston to compress the piston spring and install the piston retaining ring.
14. Slide the cover into the relief valve body. Then install the cover retaining ring.
15. Using a powered test light, screw the indicator light switch in until the light goes out. Then turn an additional 3/4 to 1-1/4 turn. Apply Loctite® to the jamnut and tighten.
16. Slide the relief valve assembly into the pump body with the side marked "top" up, being careful not to damage the O-rings.
17. Apply Loctite® 242 to the four 7/16–14 x 1-1/4 capscrews and install the assembly in the pump body. Tighten 53 lbf·ft (72 N·m).
18. Connect the indicator light switch.
19. Fill the pump and test the valve for proper operation and leaks.

QD Relief Valve

See **Fig. 2** for an exploded view of the QD relief valve.

1. Drain the pump.
2. Note the location of the wires and disconnect the indicator light switch.
3. Disconnect the relief valve supply line from the pilot valve and drain the line.
4. Remove the two 7/16–14 x 1-1/4 capscrews attaching the relief valve indicator light switch and the mounting bracket assembly to the relief valve cover. Remove the light switch and the bracket.
5. Compress the relief valve return spring by hand and remove the E-clip and washer. Then remove the return spring.
6. Remove the two remaining 7/16–14 x 1-1/4 capscrews retaining the relief valve cover to the pump body. Using a twisting motion, carefully remove the relief valve cover.

⚠ CAUTION

Do not push the relief valve too far into the pump body as it may fall into the pump body and become lodged or damaged. The relief valve is made of brass and is easily damaged by prying or hammering. Damaged valves must be replaced.

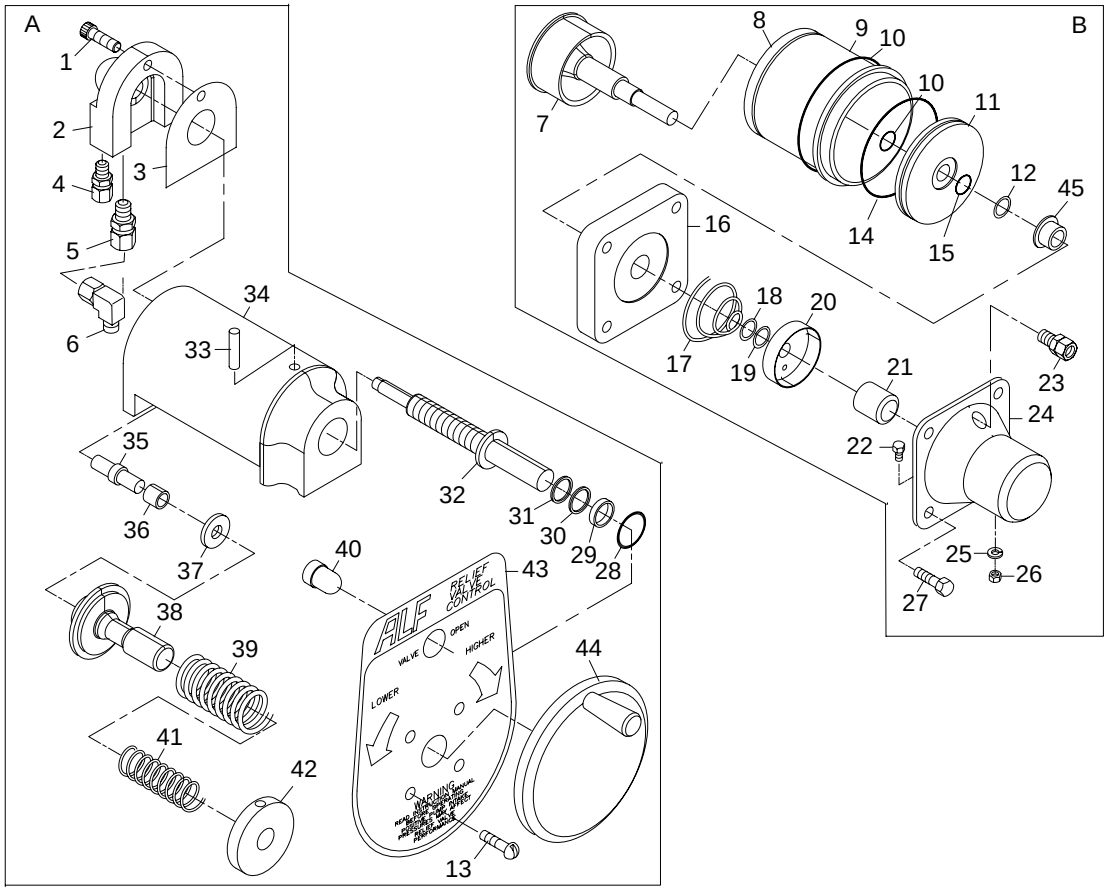
7. Remove the retaining ring securing the relief valve piston to the relief valve. Gently push the relief valve into the pump body approximately 1 inch (25 mm) and then pull it back out in a snap-motion. This should pop the relief valve piston out of the relief valve body. Repeat if necessary.

NOTE: It is not necessary to remove the relief valve unless it is damaged. To remove the relief valve, the relief valve body will have to be removed and the complete relief valve assembly will need to be replaced as it will be necessary to pry the relief valve body from the pump body, which will likely damage it.

8. Clean and inspect all of the relief valve assembly components.
9. Clean all sealing surfaces and install new O-rings and Quad-ring seals.
10. Install the relief valve piston in the stem of the relief valve. Do not push the relief valve into the pump body. As it is necessary to start the piston onto the relief valve stem, push the piston until you can grasp the relief valve stem. Then pull the relief valve stem outward while pushing on the relief valve piston. Once the relief valve piston is seated against the shoulder of the relief valve stem, install the retaining ring.
11. Operate the relief valve by hand to check for freedom of movement.
12. Slide the relief valve cover gasket and cover over the top of the relief valve stem to align the relief valve supply line from the pilot valve in the original position. Then apply Loctite® 242 to two 7/16–14 x 1-1/4 capscrews and install opposite of each other. Tighten, but do not torque.
13. Compress and install the return spring and secure it with a washer and E-clip.
14. Align the indicator light switch mounting bracket and switch with the two empty holes in the relief

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Valve Removal, Disassembly, Assembly and Installation



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A. PM Relief Valve Control Assembly
B. QD Relief Valve System Assembly

1. Sockethead Screw, 5/16–18 x 1
2. Control Body Assembly
3. PM Control Valve Diaphragm
4. Connector Tube, 1/8–3/4
5. Connector Tube, 1/4–3/8
6. Connector Strainer
7. Relief Valve
8. Valve Body Seal Ring
9. Relief Valve Body
10. Piston Seal Ring
11. Transfer/Relief Valve Piston
12. Piston Retaining Ring
13. Screw, 1/4–20 x 5/8
14. Cover and Piston Seal Ring
15. Cover Seal Ring
16. Relief Valve Cover
17. Valve Spring
18. Washer
19. Spring Retaining Ring
20. Switch Strap
21. Indicator Light Switch
22. Hexhead Screw, #10–32 x 1/2
23. Connector Tube, 1/4" x 3/8"
24. Switch Bracket
25. Lockwasher, #10
26. Hexnut, #10–32
27. Hexhead Screw, 7/16–14 x 2-1/4
28. Sealing Washer
29. Bearing Washer Retaining Ring
30. Bearing Washer
31. Thrust Bearing
32. Adjusting Stem
33. Indicator Pin
34. Spring Housing
35. Control Valve
36. Control Valve Bearing
37. Diaphragm Support Bearing
38. Diaphragm Clamp
39. Outside Spring
40. Light Bulb
41. Inside Spring
42. Adjusting Nut
43. Instruction Plate
44. Adjusting Wheel Assembly

Fig. 2, QD Relief Valve

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Valve Removal, Disassembly, Assembly and Installation

valve cover. Install the two remaining capscrews. Tighten all capscrews 53 lbf·ft (72 N·m).

15. Connect the relief valve supply line from the pilot valve. Also connect the drain line.
16. Connect the indicator light switch.
17. Fill the pump and test the valve for proper operation and leaks.

TPM Dump Valve

1. Drain the pump.
2. Disconnect the indicator light switch.
3. Disconnect the line to the sensing valve.
4. Remove one 7/16–14 x 2 sensing valve mounting capscrew.
5. Remove the four 7/16–14 x 1-3/4 capscrews retaining the relief valve assembly to the atmosphere dump.
6. Remove the four 7/16–14 x 1-1/2 relief valve mounting capscrews to remove the relief valve from the pump body.
7. Remove the relief valve assembly
8. Remove the four 7/16–14 x 1-3/4 capscrews retaining the relief valve cover to the relief valve body.
9. Remove the indicator light switch assembly.
10. Apply a small amount of pressure to the relief valve spring and remove the spring retaining ring and washer. Carefully release the pressure held on the spring and then remove the spring.
11. Remove the relief valve cover.
12. Remove the piston retaining ring.
13. Remove the relief valve from the opposite end, sliding the relief valve stem out of the piston.
14. Reaching through the center hole of the piston, gently pull the piston from the indicator switch end of the relief valve body.
15. Before assembling and installing the valve, clean and inspect all components of the relief valve assembly.
16. Clean all sealing gasket surfaces and install new O-rings and gaskets.
17. Install the relief valve into the relief valve body.
18. Slide the piston into the relief valve body while at the same time sliding the piston onto the relief valve stem. Then install the piston retaining ring.
19. Install the new gasket and then install the cover onto the relief valve body.
20. Install two 7/16–14 x 1-3/4 capscrews finger-tight to keep the relief valve cover aligned with the valve body.
21. Install the valve spring over the relief valve stem. Then apply pressure to the valve spring to compress the spring.
22. Install the spring washer and the retaining ring.
23. Remove the two 7/16–14 x 1-3/4 capscrews installed to keep the relief valve cover aligned with the valve body. Place the indicator switch assembly into position on the relief valve cover. Apply Loctite® 242 to the four capscrews, install, and tighten 53 lbf·ft (72 N·m).
24. Apply Loctite® 242 to the four 7/16–14 x 1-1/2 capscrews to install the new gasket for the relief valve to the pump surface.
25. Apply Loctite® 242 to the four 7/16–14 x 1-1/2 capscrews and install the new gasket and relief valve assembly to the atmosphere dump. Tighten 53 lbf·ft (72 N·m).
26. Apply Loctite® 242 to the 7/16–14 x 2 capscrew, install the sensing valve and tighten 40 lbf·ft (54 N·m). Make sure the arrow points upward.
27. Connect the indicator light switch.
28. Connect the line to the sensing valve.
29. Fill the pump and test the valve for proper operation and leaks.

Check Valves (two-stage only)

1. Drain the pump.

NOTE: There are two check valves (one on each side) in the suction side on the front of the two-stage pump body. The following procedure is used for both check valves.

2. Remove the four 1/2–13 x 1-1/4 capscrews from the check valve cover on the front side of the pump body.

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3. Remove the check valve.
4. Clean the gasket surfaces and inspect the check valve pivots and pivot sockets.
5. Install the check valve.
6. Install the new gasket in the pump body.
7. Apply Loctite® to the four capscrews and secure the check valve cover to the pump body with the capscrews, being careful to align the check valve pivot with the pivot socket in the check valve cover. Tighten 53 lbf·ft (75 N·m).
8. Fill the pump and test the valve for proper operation and leaks.

SPV Priming Valve

1. Drain the pump.
2. Disconnect the 3/4-inch (19 mm) vacuum hose connecting the priming valve to the primer.
3. Remove two 7/16–14 nuts attaching the priming valve to the studs in the pump body. If the studs are damaged, replace them with 7/16–14 x 1-3/4 zinc plated studs.

NOTE: If the valve strainer and O-ring seal remains on the pump body, remove it carefully for cleaning and installation. If the valve strainer is removed as part of the priming valve, remove it from the body and set it aside. Use care as the valve strainer is easily damaged.

4. Note the location of the drain hole on the diaphragm cover and then remove the eight 5/16–18 x 3/4 capscrews securing the diaphragm cover to the valve body. Remove the diaphragm cover and the diaphragm.
5. Hold pressure on the diaphragm washer to compress the valve spring then remove the diaphragm washer retaining screw. Remove the diaphragm washer and valve spring. From the opposite side of the valve body, remove the valve.
6. Clean all the components of the priming valve and mating surfaces. Inspect the valve seat and replace if worn or damaged.
7. Install the valve into the valve body from the pump side of the body.
8. Install the valve spring and diaphragm washer onto the valve. Apply Loctite® 242 to the diaphragm washer retaining screw, compress the valve spring with the diaphragm washer, and install the valve.
9. Align the diaphragm holes with the capscrew holes in the diaphragm cover. Apply Loctite® 242 to the eight 5/16–18 x 3/4 capscrews and install the diaphragm cover and diaphragm valve body. Tighten 17 lbf·ft (23 N·m).
10. Install the valve strainer and O-ring seal onto the pump side of the priming valve.
11. Apply Loctite® 242 on the two 7/16–14 priming valve mounting nuts and install the priming valve into the pump body. Tighten 40 lbf·ft (54 N·m).
12. Connect the vacuum hose to the primer.
13. Fill the pump and test the valve for proper operation and leaks.

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Troubleshooting

Lack of use causes many problems for fire pumps and fire pump components.

IMPORTANT: The entire pumping system should be exercised on a regular basis, at least weekly. This routine procedure should include all discharge valves and suction valves.

Abuse of the fire pump is rarely a problem. If the pump and pump components have been abused, indications of problems may be fairly obvious. For example, bent controls are a common indicator.

Simultaneous oil and water leaks are uncommon. Normally, a water leak indicates that a line has come loose or is broken. Gaskets are used between mating surfaces *without* sealant. If a leak is present at a gasket-mating surface, whether oil or water, the components should be disassembled and repaired.

Be certain when a device indicates it is not working that it is not asimple electrical problem, such as a burned-out indicator bulb.

Troubleshooting Tables

Problem—Pump Will Not Engage

Problem—Pump Will Not Engage	
Possible Cause	**Remedy**
Parking brake not set.	Set the parking brake.
Transmission not in neutral.	Shift transmission to neutral.
Insufficient air supply.	Repeat the recommended shift procedure: Check the air pressure gauges. This procedure requires at least 100 psi (689 kPa), and shut the engine down and check for air leaks.
Pump shift or application of parking brake attempted before apparatus was stopped.	Release the braking system momentarily and repeat the recommended shift procedure. *

* This condition is known as "Butt Tooth," which occurs when the transmission shifts and the shift gear-teeth and the teeth on the drive gear do not line up and butt up against each other. The Twinflow fire pump transmission is designed with a sliding shift collar. Therefore, the occurrence of "Butt Tooth" will be rare.

Problem—Pump Will Not Shift

Problem—Pump Will Not Shift	
Possible Cause	**Remedy**
Battery voltage low.	Turn off accessories. Check the charging system of the apparatus. Inspect the batteries. If okay, recharge and try shift again.
Interface/Interlock module not receiving proper inputs.	Check the Officers Information Center output.
Transmission not receiving lock-up input.	Check output to transmission with Prolink.

Problem—Pump Will Not Prime

Problem—Pump Will Not Prime	
Possible Cause	**Remedy**
Low battery voltage.	Increase the engine speed 1000 to 1200 rpm for temporary support for electrical system requirements and primer operation. *
Worn or damaged priming system.	Perform the "Dry Vacuum Test" which follows the troubleshooting tables in this subject. If pump is tight but primer develops less than 22 inches of vacuum, the primer pump, motor, or Priming Valve may be worn or damaged.

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Troubleshooting

Problem—Pump Will Not Prime	
Possible Cause	**Remedy**
Primer not operated long enough.	Operate for 30 seconds for pump up to 1250 gpm or for 45 seconds for 1500 and up gpm pump. Add 15 additional seconds if priming from front or rear suction. Do not run primer over 45 seconds. Stop and check for causes.
Suction lifts too high.	Do not attempt lifts exceeding 22 feet, except at low elevations.
Suction strainer blocked.	Check and clean.
Air pocket in suction hose or pump.	Place suction hose lower than suction intake. Slightly open a discharge valve momentarily to release trapped air.
Air leaks.	Perform the "Dry Vacuum Test" which follows the troubleshooting tables in this subject. Then shut engine off and listen for air leaks. Pressurize the discharge side of the pump with approximately 100 psi (689 kPa) from the hydrant and check for water leaks. Check connections and gaskets.

* Electric primer does not require engine speed to be increased for operation. A primer can and will draw in excess of 300 amps and primer operation can last 45 seconds.

Problem—Pump Loses Prime

Problem—Pump Loses Prime	
Possible Cause	**Remedy**
Suction lifts too high.	Do not attempt lifts exceeding 22 feet except at low elevations.
Suction strainer blocked.	Check and clean.
Air leaks.	Check all connections and gaskets. Perform the "Dry Vacuum Test" which follows the troubleshooting tables in this subject.
Pump pressure is too low when discharge appliance is opened.	Prime the pump again. Raise pump pressure higher and open the discharge appliance slowly.

Problem—Pump Primer Does Not Operate Properly

Problem—Pump Primer Does Not Operate Properly	
Possible Cause	**Remedy**
Does not operate electrically.	Check the battery, connections, primer, and primer control. Check the control switch and solenoid on the primer. If the primer has not been used recently, it could be frozen. It should, if contact is still being made internally, show heavy current draw.
Primer is slow or lower than normal.	Check batteries, wiring, and connections. A large quantity of suction hoses or suction pipes can exceed primer capabilities. Too small diameter or too long a length of piping between primer and pump can exceed primer capabilities. Lift not to exceed 20 feet (6 m) and 10 feet (3 m) for testing. The primer pump itself may be worn out.
Pulls some prime.	The primer pump could be in need of repairs or cleaning. Check for air leaks and verify that the Priming Valve is not sticking.
Pulls full prime.	Check for air leaks. Check for clogged inlet strainer and screens. Check that the suction hose is submerged in adequate water supply. Check for air pockets and air accumulation in piping. Check for turbulence in piping. The pump impeller may be damaged or severely worn.

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Problem—Insufficient Capacity or Pressure

Problem—Insufficient Capacity or Pressure	
Possible Cause	**Remedy**
Insufficient engine power.	Check engine performance.
Improperly set relief valve.	Readjust the relief valve to a higher pressure setting. If the relief valve is set too low it will open to relieve pressure and reduce capacity.
Transmission in incorrect range.	Check the transmission selector for correct range recommended for pumping procedure. Check that the Fourth range lockup has occurred. If the transmission shifts while increasing engine speed, lock up has not occurred. Check engine speed or drive shaft speed for correct transmission range and inaccurate tachometer.
Air leaks.	Perform the "Dry Vacuum Test" which follows the troubleshooting tables in this subject.
Transfer valve in incorrect position.	Transfer valve must be in the "parallel or volume" setting for capacity in the "series or pressure" setting for pressure. The transfer valve indicator may be out of adjustment. At idle, shift the transfer valve back and forth. You should hear the check valves close and see a change in pressure on the Master Pressure gauge.
Tank fill valve leaking.	Repair the leak.

Problem—Engine Speed Too High for Capacity or Pressure

Problem—Engine Speed Too High for Capacity or Pressure	
Possible Cause	**Remedy**
Impeller blockage.	Check and clean. Backflushing through the discharge side of the pump may clear the obstruction. It may require disassembly of the pump.
Worn impeller or clearance rings.	Overhaul the pump. All other possibilities should be eliminated before overhauling the pump.
Suction strainer blocked.	Clean and check.
Lift too high.	Lifts over 10 feet will cause higher engine speeds and vacuum.
Transmission in incorrect range.	Check the transmission selector for correct range for recommended pumping procedure. Check that Fourth range lockup has occurred. If the transmission shifts while increasing engine speed, lockup has not occurred. Check engine speed or drive shaft speed for correct transmission range and inaccurate tachometer.
Check Valves damaged or missing.	At idle, shift the transfer valve back and forth. You should detect a change in the engine/pump sound, hear the check valves close, and see a change in the pressure on the Master Pressure gauge. If no apparent change occurs, remove the suction inlet cap and visually inspect the check valves. Insert a broom handle in the suction inlet and gently push each check valve open and let it close. Check valves should move freely.
Tank fill valve leaking.	Repair the leak.

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Troubleshooting

Problem—Relief Valve Does Not Relieve When Valves are Closed

Problem—Relief Valve Does Not Relieve When Valves are Closed	
Possible Cause	**Remedy**
Incorrect pilot valve setting.	Repeat the proper procedure for setting the relief valve.
Pilot valve inoperative.	Disassemble, clean, and lubricate. Inspect the control valve diaphragm for wear or damage.
Relief valve inoperative.	Disassemble, clean, and lubricate.

Problem—Relief Valve Does Not Recover When Valves are Opened

Problem—Relief Valve Does Not Recover When Valves are Opened	
Possible Cause	**Remedy**
Dirt in system resulting in slow or sticky operation.	Disassemble, clean and lubricate.

Problem—Unable to Attain Proper Setting

Problem—Unable to Attain Proper Setting	
Possible Cause	**Remedy**
Incorrect procedure.	Check procedure and reset.
Blocked strainer.	Disconnect the pilot valve supply line from the discharge side of pump. Remove the 90-degree fitting where the supply line connects to the pump. The strainer is attached to this fitting. Clean or replace the strainer and fitting assembly.
Dirt in pilot valve.	Disassemble, clean, and lubricate.
Hunting condition.	Insufficient water supply to the pilot valve. Check strainer and supply lines. If there is dirt in the pilot valve, disassemble, clean, and lubricate.

Problem—TPM Valve Does Not Relieve

Problem—TPM Valve Does Not Relieve	
Possible Cause	**Remedy**
Sensing valve inoperative.	Disassemble, clean, and lubricate. Inspect the control valve diaphragm for wear or damage.
PG relief valve inoperative.	Disassemble, clean, and lubricate.
PG relief valve sluggish.	Check and clean the discharge and suction strainers in the pump body.

Problem—TPM Valve Does Not Recover

Problem—TPM Valve Does Not Recover	
Possible Cause	**Remedy**
Dirt in system resulting in slow or sticky operation.	Disassemble, clean, and lubricate. Check and clean the discharge and suction strainers in the pump body.

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Problem—AutoLube

Problem—AutoLube	
Possible Cause	**Remedy**
External leaks.	External leaks are the result of gasket failures. Disassemble and repair.
Internal leaks.	If water is leaking, replace the diaphragm. If oil is leaking, replace the AutoLube seal and the impeller bushing. Heavy oil usage by the AutoLube or oil present in the water when the pump master drain is opened indicates that the AutoLube seal and possibly the impeller bushing is damaged.

Problem—Mechanical Seal Leaks

Problem—Mechanical Seal Leaks	
Possible Cause	**Remedy**
Leak at mechanical seal.	If the mechanical seal is leaking it will have to be replaced. If properly cared for, the mechanical seal should be almost maintenance free. Water quality will greatly affect seal life. The most common failure of the mechanical seal is from thermal-shock. That is running the pump dry, heating up the seal and then opening to a cool or cold water supply. The seal may shatter. Check the AutoLube. If the bushing is worn or missing, the impeller shaft will wobble and fracture the mechanical seal.

Problem—Pump Gear Box Does Not Function Properly

Problem—Pump Gear Box Does Not Function Properly	
Possible Cause	**Remedy**
Water in gear box.	Locate and repair the leak. Remove and clean the gear box filter. Replace the transmission oil. Water leaking onto the input drive shaft of the pump gear box will actually be screwed into the pump transmission past the oil seals. This is not a seal problem. Be certain the slinger(s) are in place. Check the pump gear box cooling line for internal fractures. Pump gear box will fill with water and overflow through breather.
Whine in gear box.	Check the oil level. If oil is low, helical gears and/or tapered bearings will whine. Check oil pressure. If the filter is clogged, oil pressure will be low. Drain oil and check for metal. Remove filter and check for metal. If metal is detected, pump gear box will have to be disassembled for complete inspection and repairs.
Knock or rattle in gear box.	Check for gears missing teeth. Check for damaged bearings. Disassemble and repair. *

* The cause may include foreign objects, low or contaminated oil, or low oil pressure. Low oil level or pressure will result in the transmission being damaged due to overheating.

Dry Vacuum Test

1. Open all the intake valves.
2. Cap all intakes, and close and uncap all discharge valves.

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Troubleshooting

3. Using the pump's priming devices, develop a vacuum of at least 22 inHg (74.5 kPa) for 30 seconds for pumps up to 1250 gpm or 45 seconds for pumps 1500 gpm or greater.
4. Reduce the maximum vacuum attained by 1 inHg (3.4 kPa) for each 1,000 ft. (305 m) of elevation of the test site above 2,000 ft. (610 m).

NOTE: The vacuum should not drop more than 10 inHg (33.9 kPa) in five minutes. Do not operate the pump priming device once the five-minute test has begun.

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See **Fig. 1** for the fire pump wiring diagram.

See **Fig. 2** for the fire pump controls wiring diagram. See **Fig. 3** for a detailed view of the RH switch panel for the fire pump controls and **Fig. 4** for a detailed view of the electrical center.

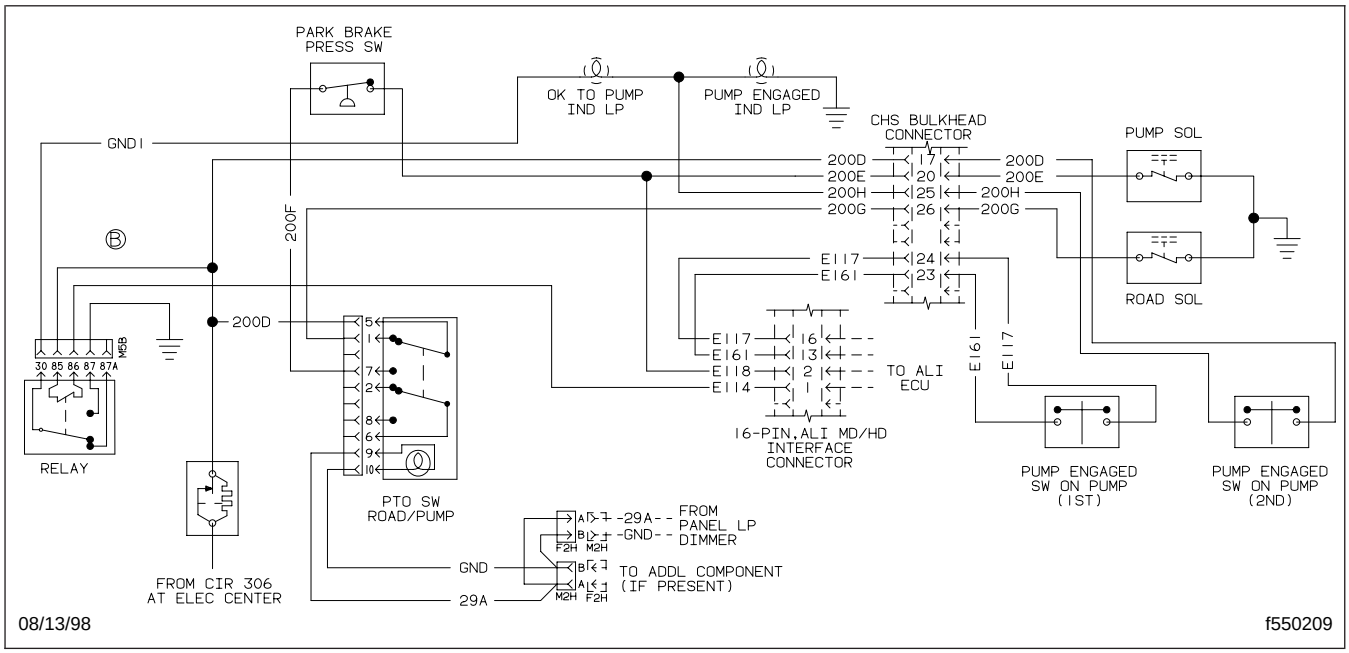


Fig. 1, Fire Pump Wiring Diagram

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Specifications

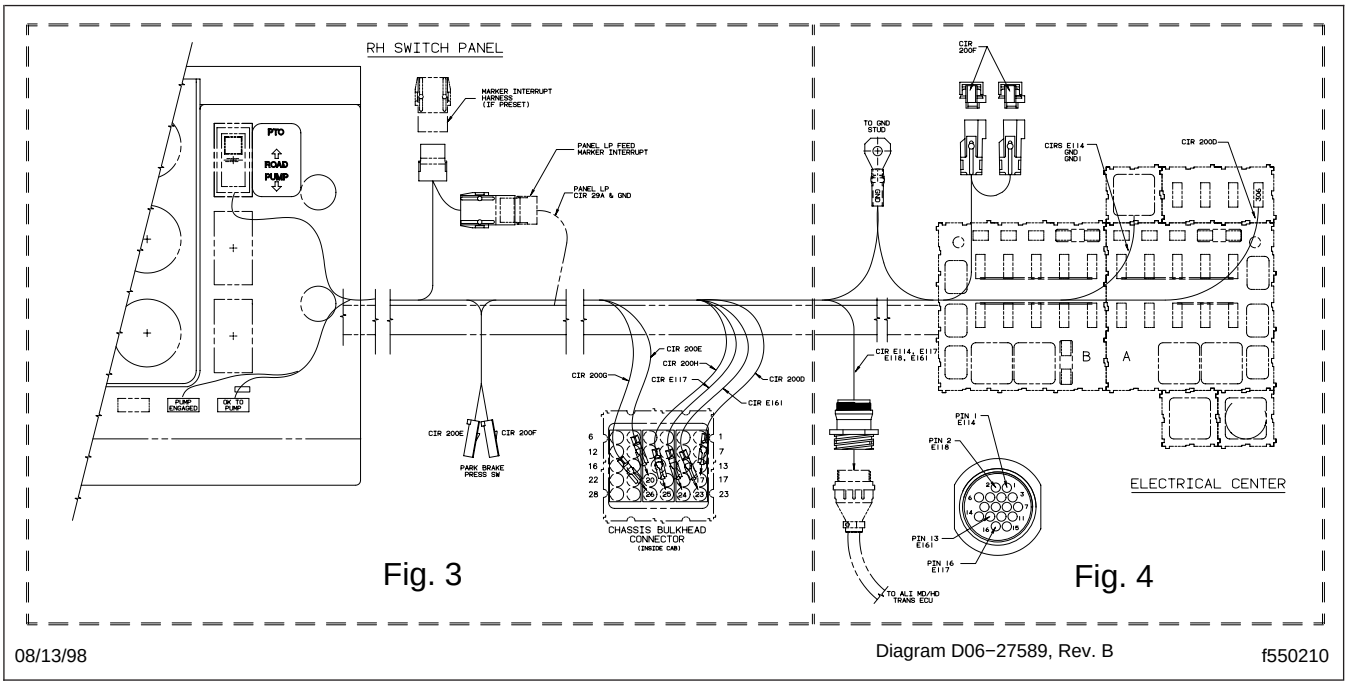


Fig. 2, Fire Pump Controls Wiring Diagram

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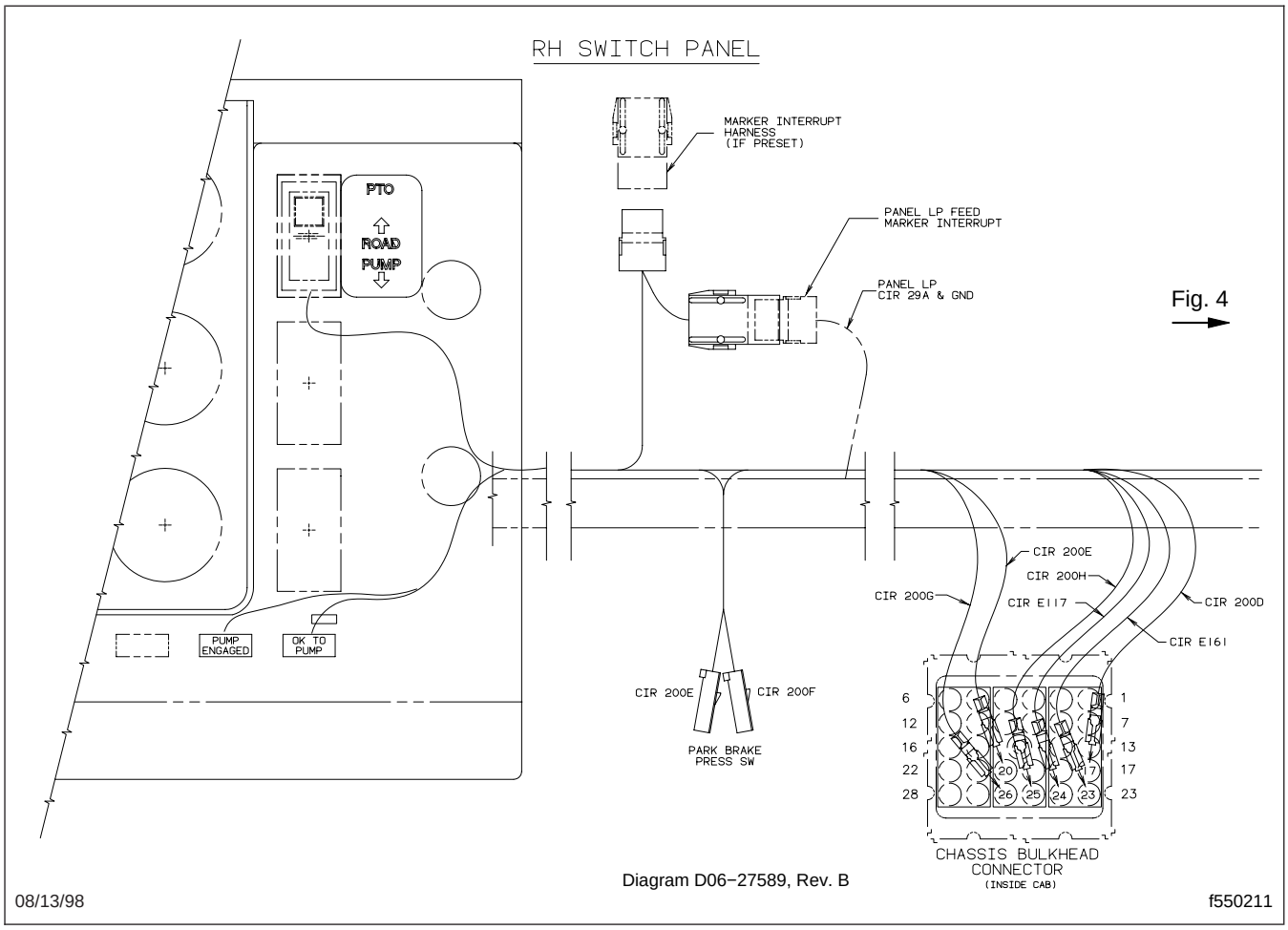


Fig. 3, Fire Pump Controls, RH Switch Panel

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Specifications

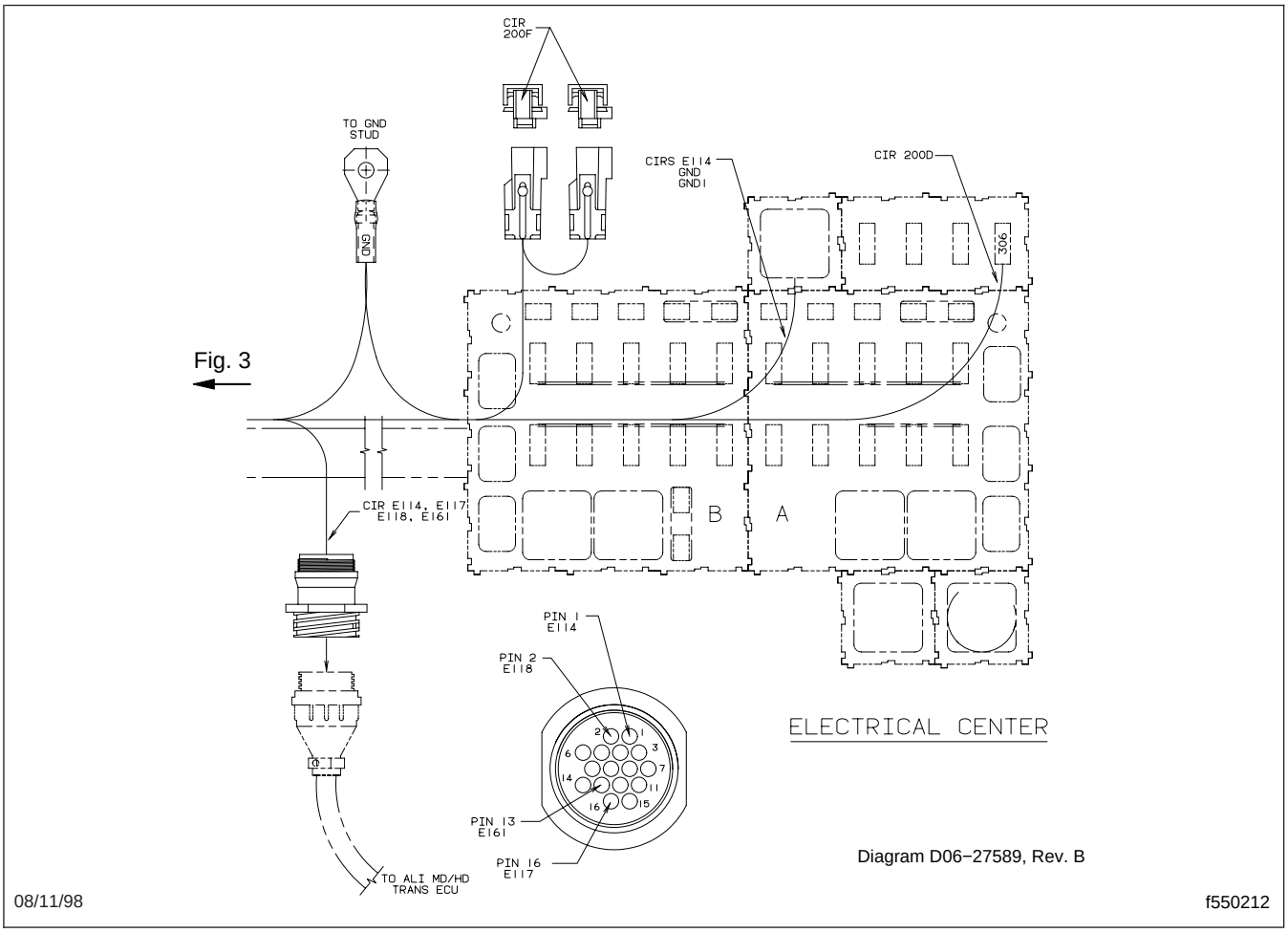


Fig. 4, Fire Pump Controls, Electrical Center

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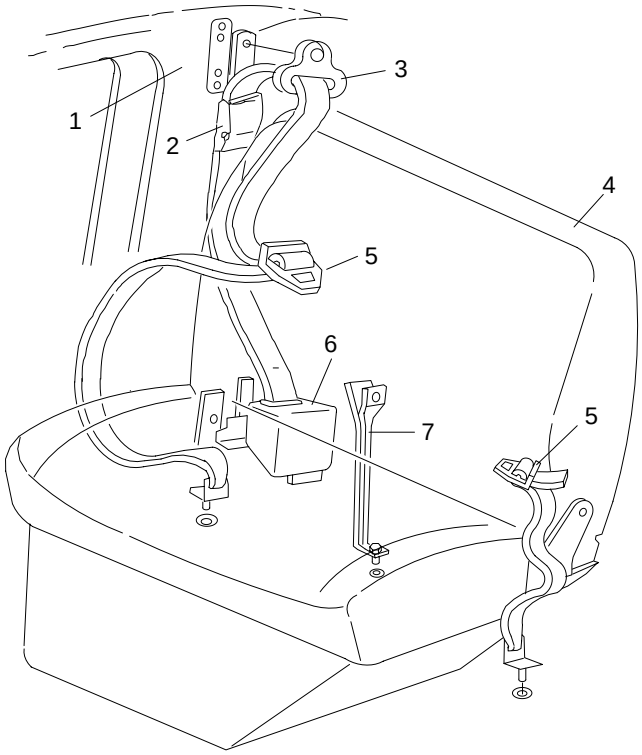
WARNING

Inspect and maintain seat belts. When any part of a seat belt system needs replacement, the entire seat belt must be replaced, both retractor and buckle side. Any time a vehicle is involved in an accident, and the seat belt system was in use, the entire vehicle seat belt system must be replaced before operating the vehicle. Do not attempt to modify the seat belt system; doing so could change the effectiveness of the system. Failure to replace worn or damaged seat belts, or making any modifications to the system, may result in personal injury or death.

Although the three-point seat belts (**Fig. 1**, **Fig. 2**, or **Fig. 3**) installed in Sterling vehicles appear similar to the seat belts used in passenger cars, there are some important differences that can affect service life:

- A heavy truck can travel more miles in a year than a car might go in its lifetime.
- There is more movement in a truck seat belt system, especially with air ride seats.
- Trucks often operate in more severe environments than cars, such as gravel pits, cement plants and grain elevators, where the belts are exposed to abrasive dirt and dust.

Because of these factors, truck seat belt systems need to be inspected regularly to ensure that they are in proper condition; see **Subject 140**.



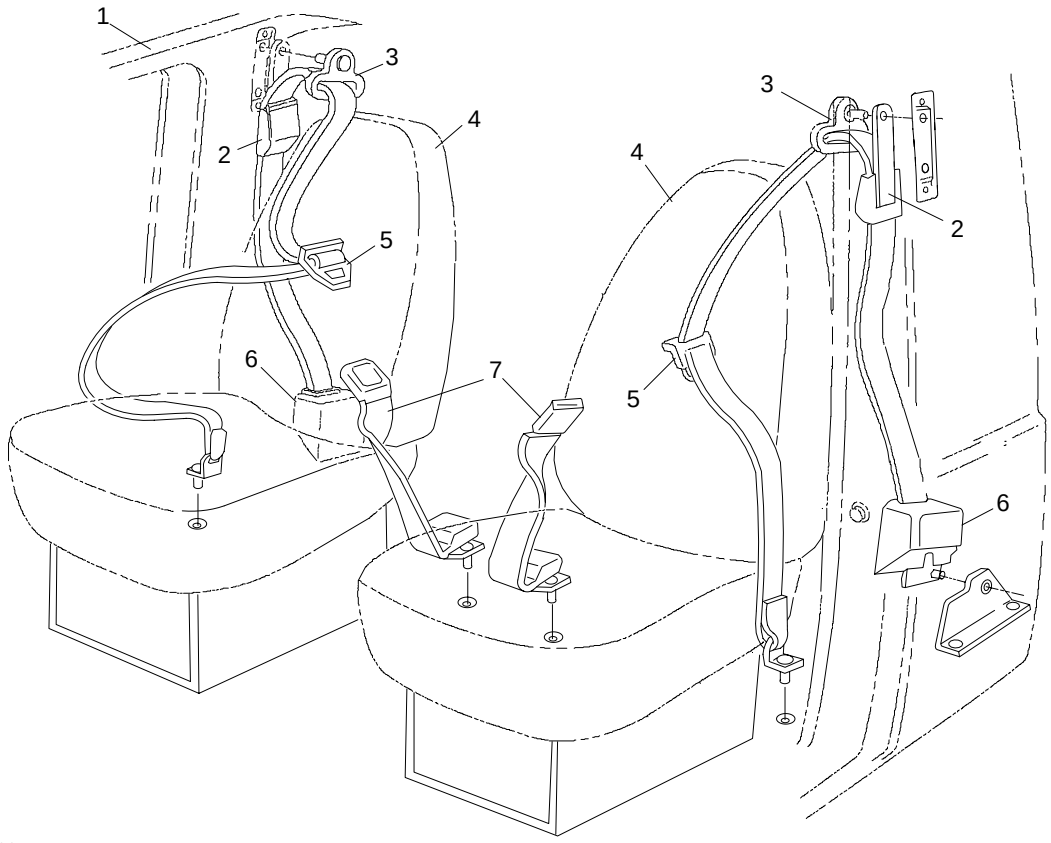
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1. Cab
2. Komfort Latch™
3. Fixed "D" Ring
4. Seat
5. Latch
6. Retractor
7. Buckle

Fig. 1, Bench Seat

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General Information

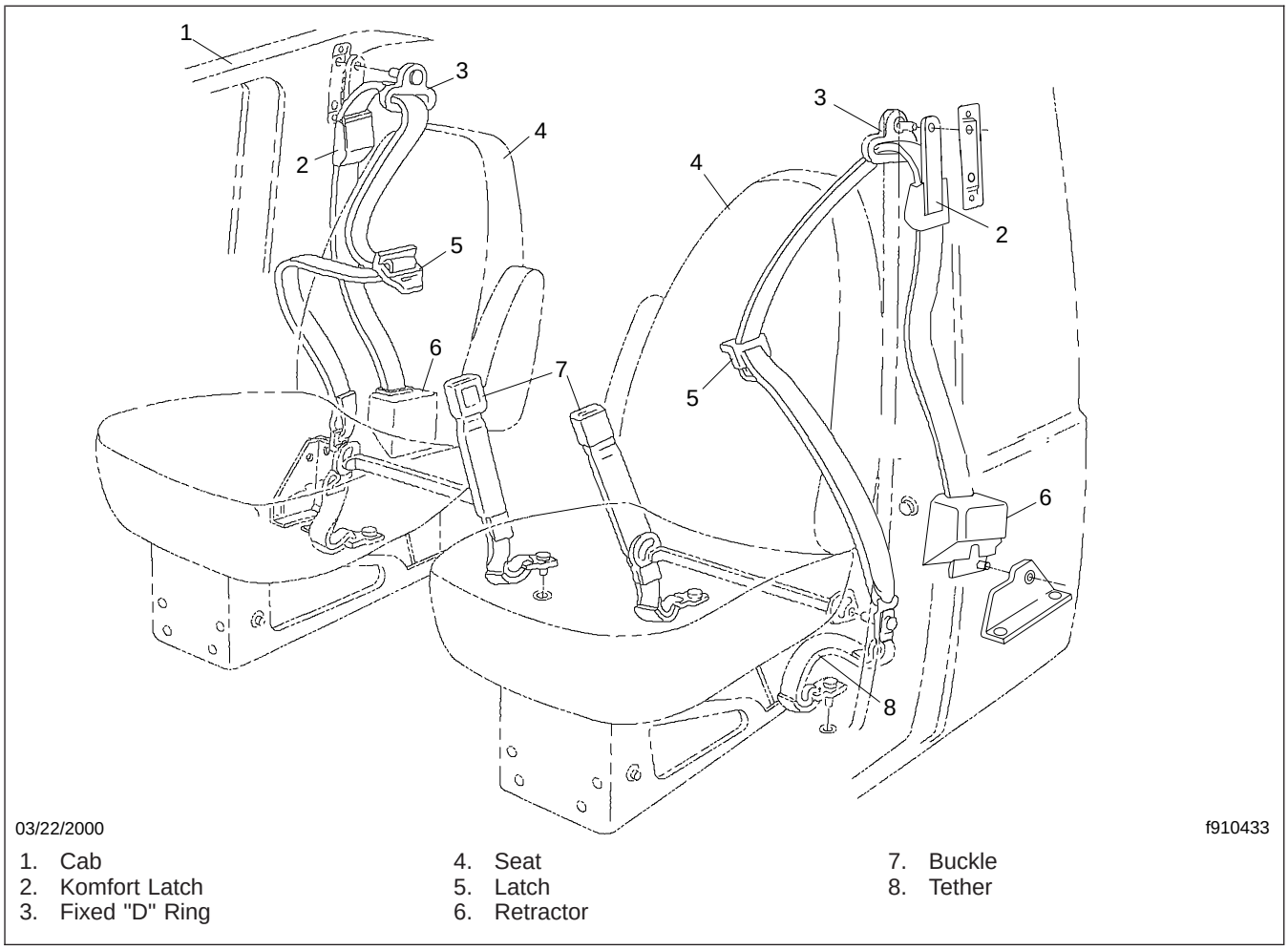


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1. Cab
2. Komfort Latch
3. Fixed "D" Ring
4. Seat
5. Latch
6. Retractor
7. Buckle

Fig. 2, Fixed Base Seats

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1. Cab
2. Komfort Latch
3. Fixed "D" Ring
4. Seat
5. Latch
6. Retractor
7. Buckle
8. Tether

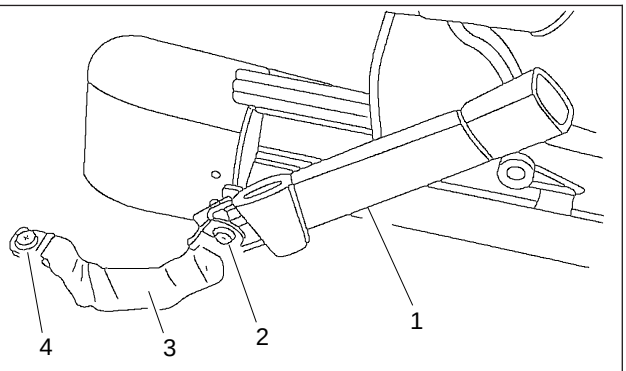
Fig. 3, Air Suspension Seats

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Replacement

IMPORTANT: When any part of a seat-belt system needs replacement, the entire seat-belt system must be replaced—both the retractor side and the buckle side and, if equipped, both tether belts.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. If the vehicle is equipped with air suspension seats, remove the seat anchor bolt. See **Fig. 1**.
3. Remove the floor anchor bolt.
4. Remove the safety belt buckle, and if so equipped, the tether.
5. If the vehicle is equipped with air suspension seats, attach the new safety belt buckle and tether to the seat with the seat anchor bolt. Tighten the bolt 22 to 32 lbf·ft (30 to 43 N·m).
6. Attach the safety belt buckle or tether (if so equipped) to the cab floor with the floor anchor bolt. Tighten the bolt 22 to 32 lbf·ft (30 to 43 N·m).



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1. Safety Belt Buckle
2. Seat Anchor Bolt
3. Safety Belt Tether
4. Floor Anchor Bolt

Fig. 1, Safety Belt Buckle Mounting (air suspension seat shown)

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Retractor Removal and Installation

Removal

IMPORTANT: When any part of a seat-belt system needs replacement, the entire seat-belt system must be replaced—both the retractor side and the buckle side and, if equipped, both tether belts.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. For vehicles with air suspension seats, remove the retractor-side safety belt seat anchor bolt. See **Fig. 1**.

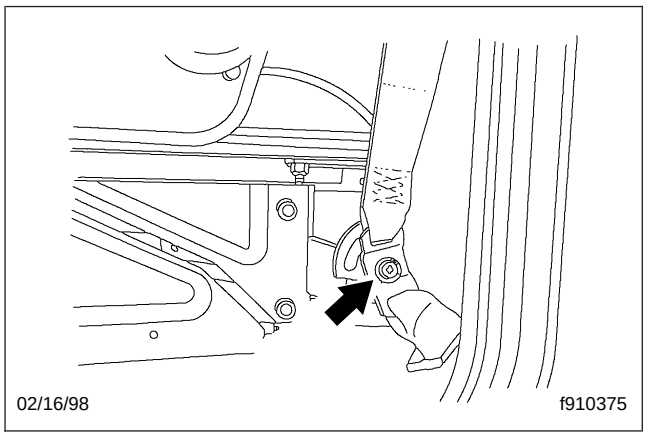
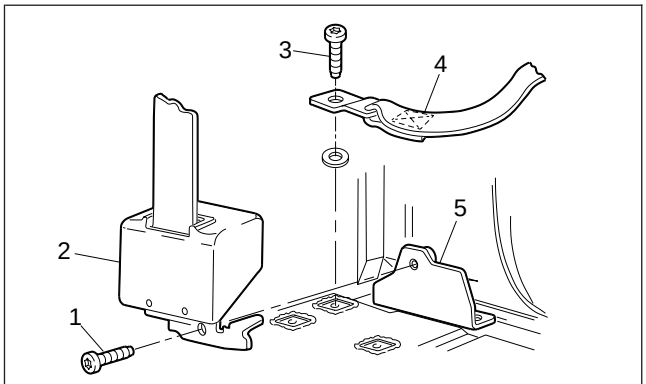


Fig. 1, Safety Belt Seat Anchor Bolt

3. Remove the retractor-side floor anchor bolt. See **Fig. 2**. Remove the tether, if so equipped.
4. Remove the safety belt retractor bolt.
5. Remove the shoulder strap guide cover. See **Fig. 3**.
6. Remove the shoulder strap guide nut.
7. Remove the safety belt retractor assembly.

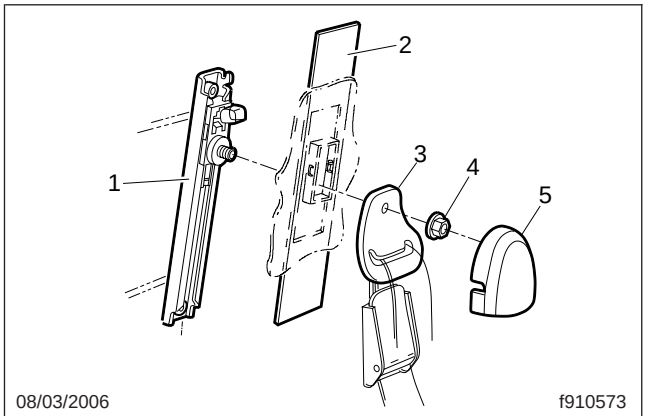
Installation

1. With the tires chocked, position the shoulder strap guide in place. Install the guide nut. See **Fig. 3**. Tighten the nut 22 to 32 lbf·ft (30 to 43 N·m).
2. Install the shoulder strap guide cover.



1. Retractor Bolt
2. Retractor
3. Floor Anchor Bolt
4. Safety Belt or Tether (if so equipped)
5. Retractor Mounting Bracket

Fig. 2, Safety Belt Retractor and Floor Anchor



1. Height Adjuster
2. Dust Cover
3. Shoulder Strap Guide
4. Guide Nut
5. Cover

Fig. 3, Shoulder Strap Guide Installation

3. Position the safety belt retractor in place, and install the bolt. See **Fig. 2**. Tighten the bolt 22 to 32 lbf·ft (30 to 43 N·m).
4. For vehicles with air suspension seats, attach the safety belt and tether to the seat with the seat anchor bolt. See **Fig. 1**. Tighten the bolt 22 to 32 lbf·ft (30 to 43 N·m).
5. Attach the safety belt or the tether (if so equipped) to the cab floor with the floor anchor

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Retractor Removal and Installation

bolt. See **Fig. 2**. Tighten the bolt 22 to 32 lbf·ft (30 to 43 N·m).

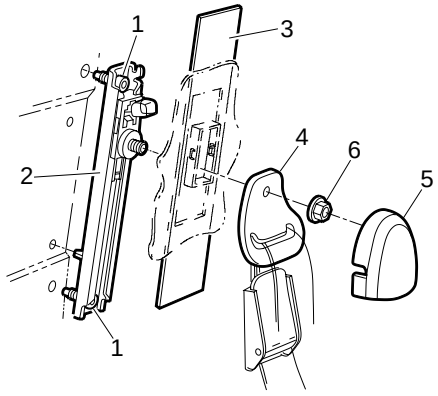
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Height Adjuster Removal and Installation

Removal

IMPORTANT: When any part of a seat-belt system needs replacement, the entire seat-belt system must be replaced—both the retractor side and the buckle side and, if equipped, both tether belts.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Remove the shoulder strap guide cover. See **Fig. 1**.



1. Height Adjuster Screw
2. Height Adjuster
3. Dust Cover
4. Shoulder Strap Guide
5. Cover
6. Guide Nut

Fig. 1, Height Adjuster Installation

3. Remove the shoulder strap guide nut.
4. Remove the height adjuster trim cover, if so equipped. See **Fig. 2**.
5. Remove the height adjuster dust cover. See **Fig. 1**.
6. Remove the height adjuster by removing the height adjuster screws.

Installation

1. With the tires chocked, position the height adjuster in place, and install the height adjuster screws. See **Fig. 1**. Tighten the screws 22 to 30 lbf·ft (30 to 40 N·m).

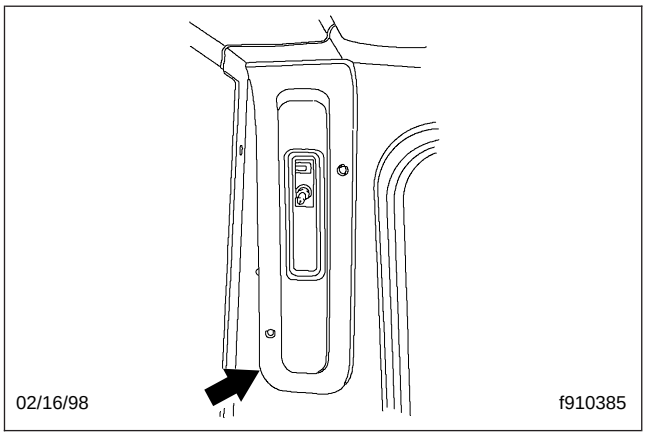


Fig. 2, Height Adjuster Trim Cover

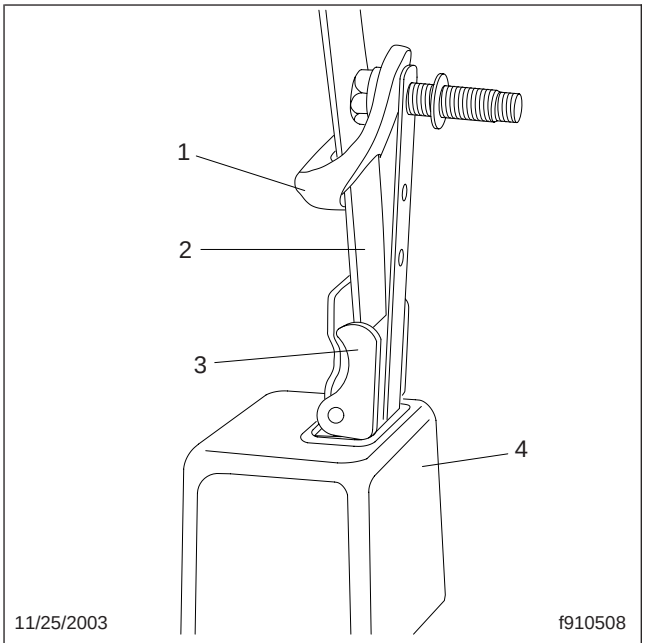
2. Install the height adjuster dust cover.
3. Install the height adjuster trim cover. See **Fig. 2**.
4. Install the shoulder strap guide and nut. See **Fig. 1**. Tighten the nut 22 to 32 lbf·ft (30 to 43 N·m).
5. Install the shoulder strap guide cover.

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Unlocking an Installed Retractor

Seat belt retractors are locking up and preventing the webbing from being extracted. This condition is known as reverse lock-up and is caused by excessive webbing spooling into the retractor before installation in the vehicle.

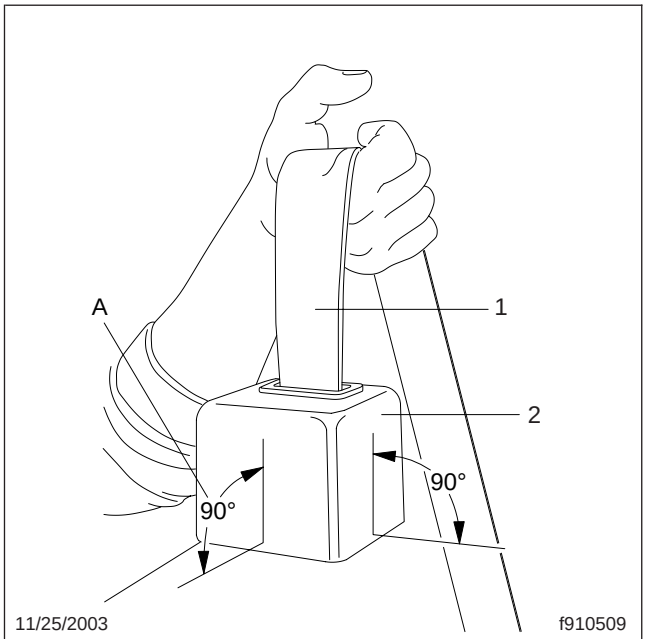
1. Park the vehicle, apply the parking brake, shut down the engine, and chock the front and rear tires.
2. Verify that the retractor is mounted in the 90-degree position. See **Fig. 1**.
3. Firmly grasp the web close to the retractor. See **Fig. 2**.



1. Web Guide Loop
2. Web
3. Komfort Latch®
4. Retractor Cover

Fig. 1, Retractor in the 90-Degree Position

4. Pull on the web with enough force to tighten the web onto the spool until the webbing locks back onto the retractor. The retractor should unlock when tension is released.
5. Remove the chocks from the tires.



A. Orient the retractor at a 90-degree angle.
1. Web
2. Retractor Cover

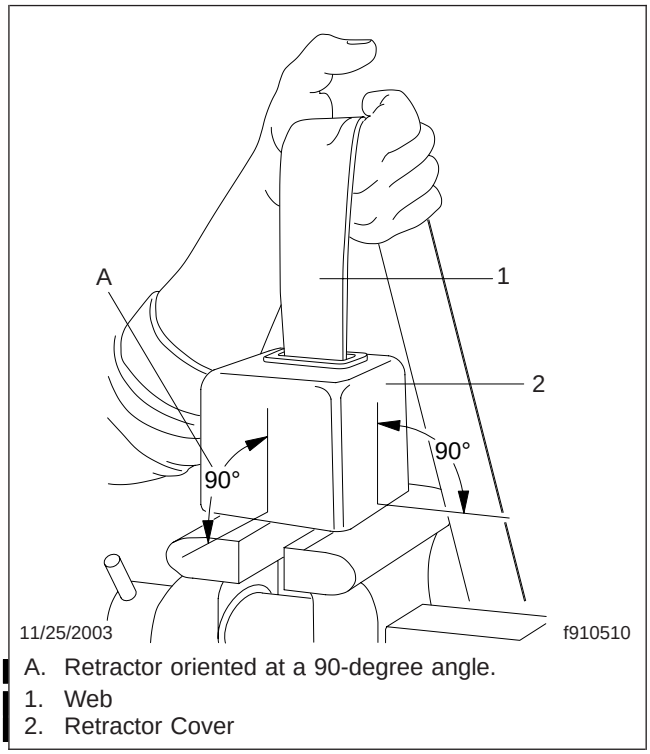
Fig. 2, Firmly Grasp the Webbing

Unlocking an Uninstalled Retractor

1. Clamp the retractor in a vice at a 90-degree angle. See **Fig. 3**.
2. Pull on the web with enough force to tighten the web onto the spool.
3. Release the web. This allows 1/2-inch (12.7-mm) of the webbing to feed back into the retractor storage housing and unlock the retractor.
4. Pull all the webbing out of the retractor, and allow only 12 to 15 inches (304 to 381 mm) to retract. Lock the Komfort Latch on the web. See **Fig. 4**.

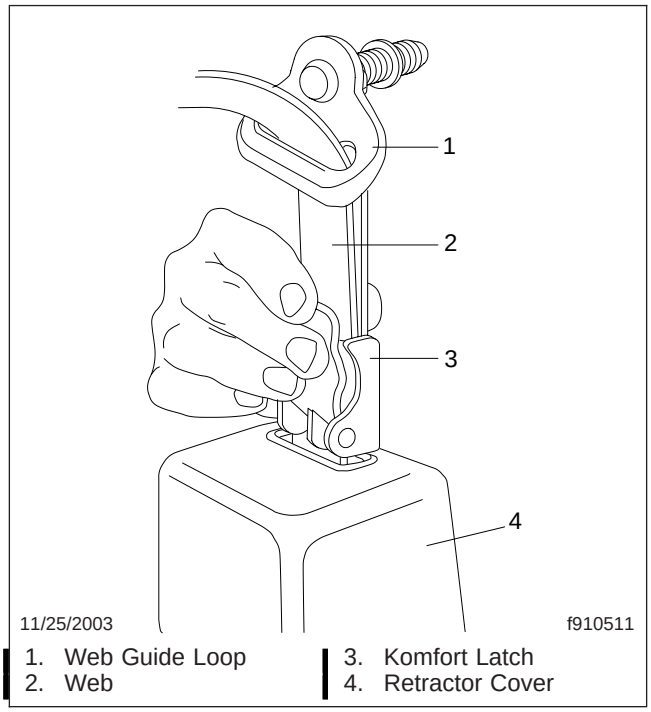
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Seat Belt Retractor Unlocking



A. Retractor oriented at a 90-degree angle.
1. Web
2. Retractor Cover

Fig. 3, Place the Retractor in a Vice



1. Web Guide Loop
2. Web
3. Komfort Latch
4. Retractor Cover

Fig. 4, Lock the Komfort Latch

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Inspection

⚠ WARNING

Inspect and maintain seat belts. When any part of a seat belt system needs replacement, the entire seat belt must be replaced, both retractor and buckle side. Any time a vehicle is involved in an accident, and the seat belt system was in use, the entire vehicle seat belt system must be replaced before operating the vehicle. Do not attempt to modify the seat belt system; doing so could change the effectiveness of the system. Failure to replace worn or damaged seat belts, or making any modifications to the system, may result in personal injury or death.

Seat belts and tether belts have a finite life which may be much shorter than the life of the vehicle. Regular inspections and replacement as needed are the only assurance of adequate seat belt security over the life of the vehicle.

1. Check the web for fraying, cuts, extreme dirt and dust, or for severe fading from exposure to sunlight, especially near the buckle latch plate and in the D-loop guide area.
2. Check operation of the buckle, latch, Komfort Latch or Sliding Komfort Latch (if equipped), web retractor, and upper seat belt mount on the door pillar. Check all visible components for wear or damage.
3. Check the seat belt and tether belt connection points, and tighten any that are loose.

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Troubleshooting

⚠ WARNING

Inspect and maintain seat belts. When any part of a seat belt system needs replacement, the entire seat belt must be replaced, both retractor and buckle side. Any time a vehicle is involved in an accident, and the seat belt system was in use, the entire vehicle seat belt system must be replaced before operating the vehicle. Do not attempt to modify the seat belt system; doing so could change the effectiveness of the system. Failure to replace worn or damaged seat belts, or making any modifications to the system, may result in personal injury or death.

Replace the entire seat belt system if any of the following problems exist:

- cuts, fraying or extreme wear of any area of the web (shoulder or lap belt)
- buckle and latch do not engage with a solid sounding "click" or do not release freely when the button is pushed
- Komfort Latch™ is broken or does not lock in place easily and does not release by tugging downward on the webbing
- retractor locks up at improper times or web does not flow freely to and from the retractor while vehicle is not moving
- seat belt web has been exposed to extreme sun light, dust or dirt, causing the web color to fade and deterioration of web physical strength
- molded plastic around the buckle is deformed, cracked or broken, exposing the internal mechanism
- molded plastic cover around the retractor is cracked or broken, exposing the internal mechanism or stored web
- metal or molded plastic area of latch is deformed, cracked, corroded or broken
- molded plastic D-loop is deformed, cracked or broken

If any of the following problems exist, replace hardware with authorized parts:

- tethers are missing, not attached to seat or hang extremely loose
- D-loop web guide does not rotate freely
- hardware is missing, rusted, corroded or damaged
- hardware does not appear to be tight

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Specifications

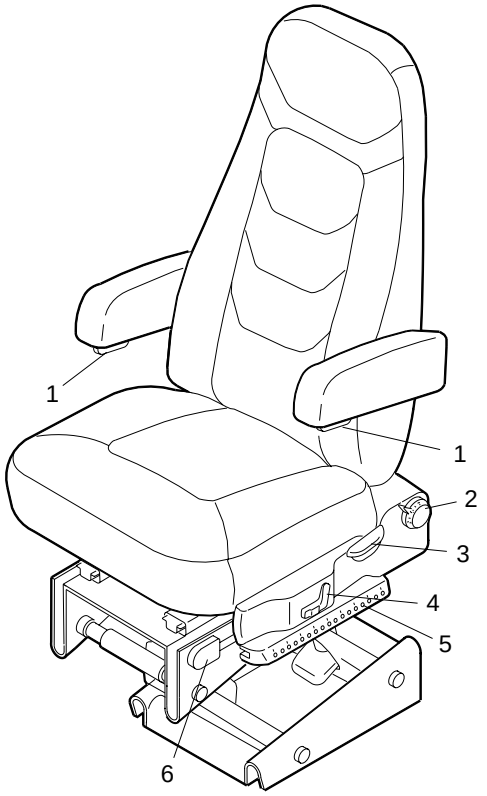
Torque Specifications	
Description	**lbf·ft (N·m)**
Height Adjuster Bolts	22–30 (30–40)
Anchor Bolts	22–32 (30–43)
Retractor Bolts	22–32 (30–43)
Shoulder Strap Guide Nut	22–32 (30–43)

Table 1, Torque Specifications

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General Information

EzyRider seats (see **Fig. 1**) offer adjustment features for height, fore and aft positioning, back cushion tilt, lumbar support, and seat cushion tilt. The air suspension and height-adjustment features are provided by an air spring that receives air pressure from the vehicle air system; pressure in the air spring is controlled by a switch attached to the seat frame. Each seat is equipped with a shock absorber to dampen unwanted up-and-down motion of the seat. An isolator reduces the amount of road shock by isolating the occupant from the motion of the vehicle. A lockout feature is used whenever the isolator is not desired.



06/24/2005 f910555

1. Armrest Adjustment Knob
2. Back Cushion Tilt Position Indicator
3. Back Cushion Tilt Lever
4. Height Adjustment and Lumbar Support Lever
5. Fore/Aft Seat Position Indicator
6. Isolator and Fore/Aft Seat Adjustment Lever

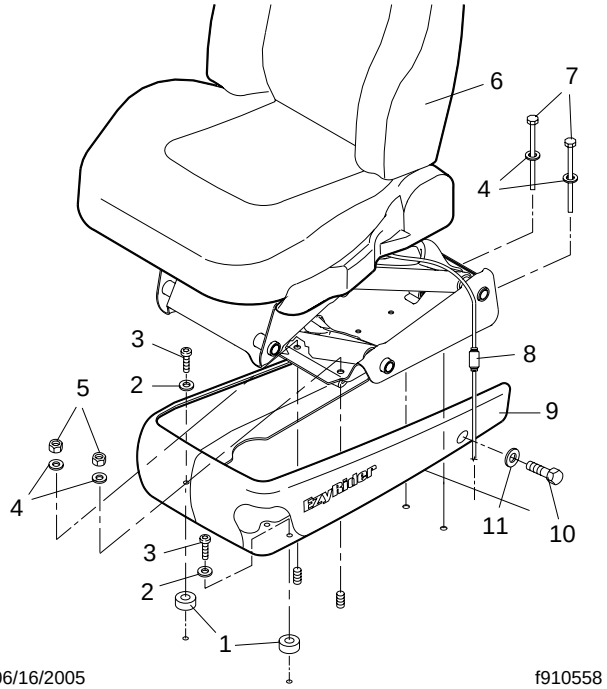
Fig. 1

For a complete description of, and operating instructions for, all seat adjustment features, refer to the vehicle driver's manual.

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Removal

1. Park the vehicle on a level surface, apply the parking brake, shut down the engine, and chock the front and rear tires.
2. Press the seat ride-height rocker switch until the seat is adjusted to its maximum height.
3. If so equipped, remove the seat suspension skirt. It is attached to the seat with 11 upholstery fasteners.
4. Cut a wooden block to the length required to support the seat at its maximum height, and place the block between the air suspension seat base and the rear crosstube of the lower arm.
5. Drain the vehicle air reservoirs. Then press the seat-height adjustment switch until all the air is exhausted from the air spring.
6. Remove the seat heel guard. See **Fig. 1**.
   - 6.1 Remove the two screws and washers that hold the heel guard to the sides of the seat base.
   - 6.2 Remove the two T20 Torx® capscrews and washers that attach the heel guard to the cab deck. Remove the two spacers under the heel guard.
   - 6.3 Loosen the fasteners (two nuts in the front and two capscrews in the rear) that attach the seat base to the cab deck.
   - 6.4 Slide the heel guard forward to unseat the bottom flange from under the outer edges of the seat base. Remove the heel guard.
7. Disconnect the air valve air-supply hose at the quick-connect union behind the seat.
8. Remove the Torx capscrews that attach the seat-belt straps to the intermediate-connecting-point threaded rod.
9. Remove the two capscrews and washers that attach the rear of the seat base to the cab deck, and the two nuts and washers that attach the front of the seat base to studs on the cab deck. Remove the seat from the cab.



06/16/2005 f910558

1. Spacers
2. Washer
3. Torx Capscrew, T20
4. Washers
5. Nuts
6. Seat
7. Capscrews
8. Air Supply Quick-Connect Union
9. Heel Guard
10. Screw
11. Washer

Fig. 1, EzyRider Seat Installation

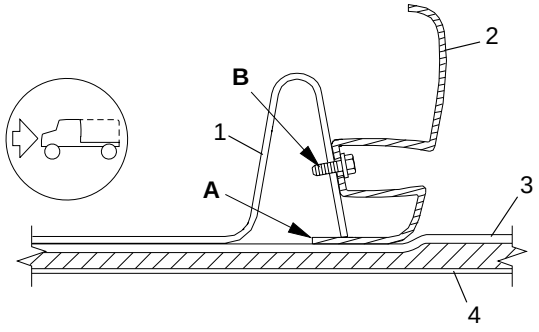
Installation

1. Position the seat on the cab deck, with the two cab-deck studs inserted through the holes in the front of the seat base. Install the two nuts and washers on the studs. Insert the two capscrews and washers through the holes in the rear of the seat base (see **Fig. 1**). Do not tighten the nuts or the capscrews until the heel guard is installed.
2. Attach the brackets of the seat-belt straps and tether straps to the intermediate-connecting-point threaded rod. Tighten the Torx capscrews 35 to 45 lbf·ft (47 to 61 N·m).

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Seat Removal and Installation

3. Connect the air valve air-supply hose by pressing the pneumatic tubing into the quick-connect union behind the seat.
4. Install the seat heel guard.
   4.1 Place the heel guard around the seat base, sliding it backward to seat the bottom flange under the outer edge of the seat base on both sides. See **Fig. 2**.



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A. Slide the bottom flange of the heel guard under the outer edge of the seat base.
B. Attach the heel guard to the seat base with the screws and washers.

1. Seat Base
2. Heel Guard
3. Floor Covering
4. Cab Deck

Fig. 2, Installing the Heel Guard

   4.2 Tighten the two capscrews and the two nuts that attach the seat to the cab deck 25 to 29 lbf·ft (34 to 39 N·m).
   4.3 Position the two spacers under the heel guard, then attach the front of the heel guard to the cab deck with the two T20 Torx capscrews and washers.
5. Start the engine and allow the air reservoirs to fill. Press the seat ride-height rocker switch until the seat is adjusted to its maximum height, then remove the wooden block that supports the seat suspension.
6. Install the seat suspension skirt.
7. Remove the chocks from the tires.

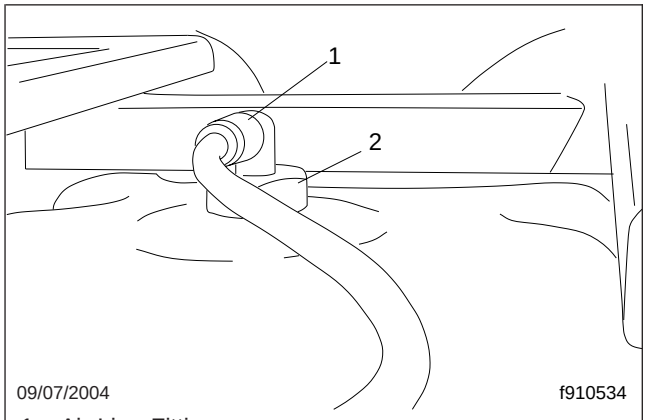
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Air Spring Replacement

1. Park the vehicle, apply the parking brakes, shut down the engine, and chock the front and rear tires.
2. Inflate the seat suspension to the maximum height.
3. Pull the slide lever, and slide the seat to the forward position.
4. Lift the suspension skirt up and out of the way.
5. Cut a wooden block to the length required to support the seat at its maximum height, and place the block between the air suspension seat base and the rear crosstube of the lower arm.

NOTE: The seat must be secured with a block when replacing the air spring.

6. Drain the vehicle air reservoirs. Then push in on the bottom of the seat ride-height rocker switch until all air is exhausted from the air spring.
7. Remove the air line from the air spring. See **Fig. 1**.



1. Air Line Fitting
2. Spring Plate Mounting Nut

Fig. 1, Air Line and Fitting

8. Remove the air fitting from the top of the air spring.
9. Remove the nut that secures the air spring to the spring plate.
10. Use a 9/16-inch socket wrench to remove the lower air spring bolt.
11. Remove the air spring.
12. Install the new air spring.
13. Install the spring plate mounting nut and torque it 130 lbf·in (1470 N·cm).
14. Install the air fitting and tighten securely. Make sure that the fitting is oriented forward.
15. Using a hose cutter, cut 1/4 inch (6 mm) off of the air line.
16. Insert the air line into the air fitting.
17. Apply Loctite™ 454 to the bottom six threads of the mounting bolt. See **Fig. 2**.

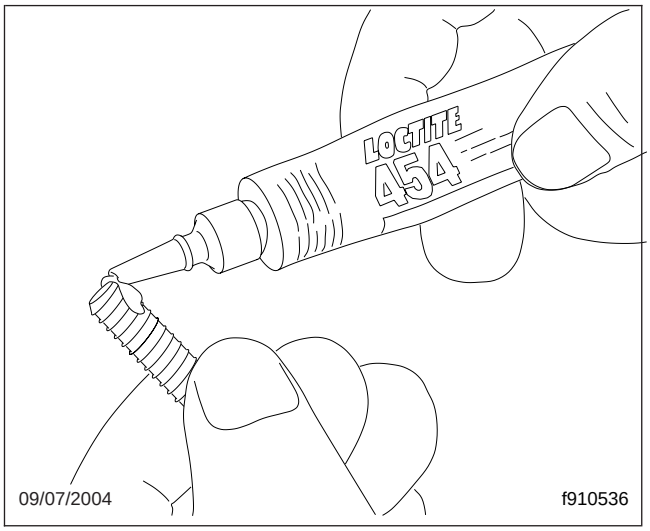


Fig. 2, Apply Loctite to the Bottom Six Threads

18. Install the bolt through the bottom casting of the seat to the air spring and tighten the bolt 45 lbf·in (510 N·cm).
19. Inflate the suspension.
20. Remove the block.
21. Remove the chocks from the tires.

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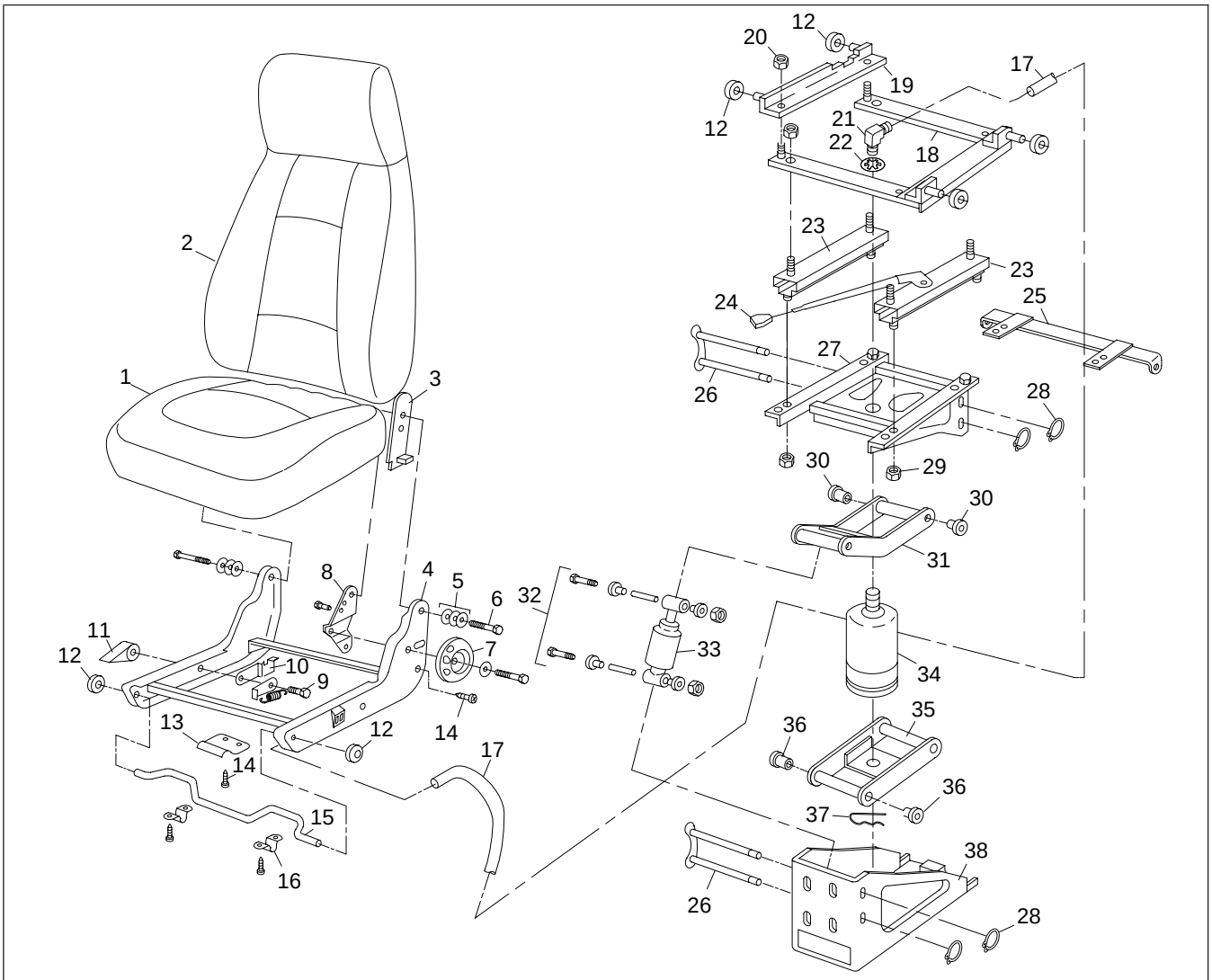
General Information

National Cush-N-Aire II air suspension seats offer adjustment features for height, fore/aft positioning, back cushion tilt, lumbar support, and seat cushion tilt. See **Fig. 1**. The air suspension and height-adjustment features are provided by an inflatable air spring (air bag) that receives air pressure from the vehicle air system; pressure in the air spring is controlled by a set of switches attached to the seat frame. Each seat is equipped with a shock absorber to dampen unwanted up and down motion of the seat. An isolator (Chugger-Snubber®) isolates the seat from the cab's forward and rearward movement; at the side of the seat's lower frame is an isolator lockout handle that can be used whenever the isolator feature is not desired.

For a complete description and operating instructions for all seat adjustment features, see Chapter 5 in the *Acterra Driver's Manual*.

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General Information



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1. Seat Cushion
2. Seat Back
3. Back Frame Bracket
4. Upper Seat Frame
5. Flatwashers
6. Back Frame Bolt
7. Back Recline Adjustment Knob
8. Back Limit Bolt Bracket
9. Cushion Adjustment Bolt
10. Cushion Adjustment Bracket
11. Cushion Adjustment Lever
12. Bearing
13. Adjustment Rod Bracket
14. Fastener
15. Adjustment Rod
16. Adjustment Rod Bracket
17. Air Hose
18. Isolator
19. Isolator Bar
20. Locknut
21. Hose Barbed Fitting
22. Retaining Ring
23. Track
24. Fore/Aft Adjustment Lever
25. Belt Bar
26. Connected Shaft
27. Seat Support
28. Snap Ring
29. Locknut
30. Bearing
31. Upper Arm
32. Shock Absorber Assembly
33. Shock Absorber
34. Air Spring
35. Lower Arm
36. Bearing
37. Pin Clip
38. Seat Base

Fig. 1, National Cush-N-Aire II Seat (exploded view)

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Removal (See Fig. 1)

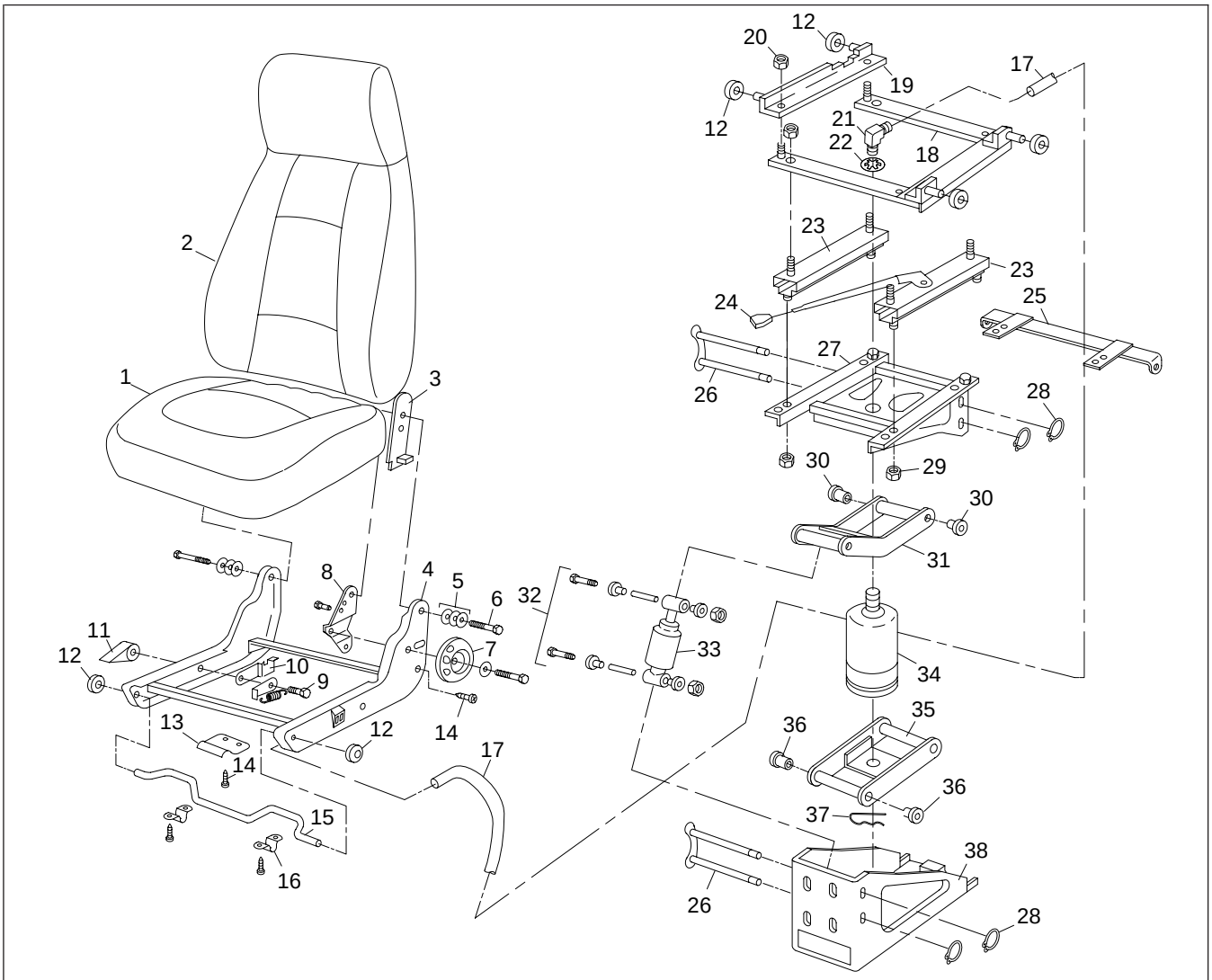
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the suspension shroud (if equipped) from the seat base.
3. Push on the top of the seat ride height rocker switch until the seat is adjusted to its maximum height.
4. Cut a wooden block to the length required to support the seat at its maximum height and place the block between the air suspension seat base and the rear crosstube of the lower arm.
5. Drain the vehicle air reservoirs. Push on the bottom of the seat ride height rocker switch until all air is exhausted from the air spring.
6. Disconnect the air valve air supply hose.
7. Unscrew the capscrews that attach the seat belt straps and tether straps.
8. Remove the capscrews and washers that attach the seat to the cab deck. Remove the seat from the cab.

Installation

1. Place the seat on the cab deck. Insert the capscrews through the washers and the seat base. Tighten the capscrews 25 to 29 lbf·ft (34 to 39 N·m).
2. Attach the brackets of the seat belt straps and tether straps. Tighten the capscrews 40 lbf·ft (54 N·m).
3. Attach the air valve air supply hose.
4. Start the engine and allow the air reservoirs to fill. Push on the top of the seat ride height rocker switch until the seat is adjusted to its maximum height. Remove the wooden block that supports the seat suspension.
5. Install the suspension shroud (if equipped) on the seat base.
6. Remove the chocks from the rear tires.

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Seat Removal and Installation



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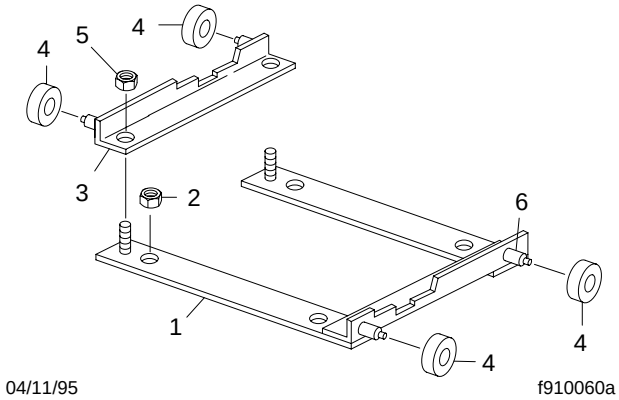
1. Seat Cushion
2. Seat Back
3. Back Frame Bracket
4. Upper Seat Frame
5. Flatwashers
6. Back Frame Bolt
7. Back Recline Adjustment Knob
8. Back Limit Bolt Bracket
9. Cushion Adjustment Bolt
10. Cushion Adjustment Bracket
11. Cushion Adjustment Lever
12. Bearing
13. Adjustment Rod Bracket
14. Fastener
15. Adjustment Rod
16. Adjustment Rod Bracket
17. Air Hose
18. Isolator
19. Isolator Bar
20. Locknut
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22. Retaining Ring
23. Track
24. Fore/Aft Adjustment Lever
25. Belt Bar
26. Connected Shaft
27. Seat Support
28. Snap Ring
29. Locknut
30. Bearing
31. Upper Arm
32. Shock Absorber Assembly
33. Shock Absorber
34. Air Spring
35. Lower Arm
36. Bearing
37. Pin Clip
38. Seat Base

Fig. 1, National Cush-N-Aire II Seat (exploded view)

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Isolator Assembly (Chugger-Snubber®) Replacement

Replacement (See Fig. 1)



1. Welded Bearing Support Frame
2. Locknut
3. Bearing Support Rail
4. Bearing
5. Hexnut
6. Bearing Stud

Fig. 1, Isolator Assembly

1. Remove the seat from the vehicle. For instructions, see **Subject 100**.
2. Remove the plastic tie strap that attaches the seat cushion to the upper seat frame assembly.
3. Cut off the air spring supply hose close to the barbed fitting; minimize hose length loss. Remove the scrap hose from the barbed fitting. Tape the hose and fitting ends to prevent dirt or other matter from entering.
4. Remove the hexnuts that attach the isolator bearing support rail to the studs on the isolator bearing support frame.
5. Lift up on the side of the seat's lower frame to slide the bearing support rail up and off the bearing support frame.

NOTE: Two of the isolator bearings will fall off when the bearing support rail is removed.

6. Push the upper seat frame toward the opposite side to remove the other two bearings. Remove the bearings and the unattached upper seat components.
7. Remove the four 5/16–18 locknuts from the bearing support frame. Remove the bearing support frame.
8. Using a multi-purpose chassis grease, lubricate the bearing cups and new isolator bearings.
9. Install the welded bearing support frame on the track assembly. Tighten the four 5/16–18 locknuts 15 lbf·ft (20 N·m).
10. Install two of the isolator bearings on the bearing studs of the bearing support frame. Align the bearing cups on the upper seat frame over the bearings.
11. Assemble the isolator bearing support rail and the two remaining isolator bearings. With the seat cushion tilted forward, install the support rail's bearings in the upper seat frame, and lower the seat frame and support rail assembly onto the isolator bearing support frame. Install the 5/16–18 hexnuts and finger-tighten them.

    Push the isolator assembly forward and rearward and check the position of the isolator bearing support rail before tightening the hexnuts. The isolator should be tight enough to eliminate side play without interfering with the forward and rearward movement of the seat. Tighten the 5/16–18 hexnuts 15 lbf·ft (20 N·m).
12. Install a new plastic tie strap to secure the seat cushion to the lower frame assembly.
13. Install the seat in the vehicle. For instructions, see **Subject 100**.

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Shock Absorber Removal and Installation

Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Move the fore/aft adjustment lever to the right and slide the upper seat assembly back as far as possible.
3. Raise the upper seat assembly to maximum height.
4. Remove the shock absorber, bushings and bearings.
   - 4.1 Remove the nuts and bolts that attach the shock absorber to the upper arm and the seat base. Remove the shock absorber.
   - 4.2 Remove the bushings and bearings from the shock absorber.

Installation

1. Check the operation of the shock absorber and replace it if needed.
2. Install the shock absorber and new bearings and bushings.
   - 2.1 Install new bearings and bushings in the shock absorber eyes.
   - 2.2 Position the shock absorber so its piston-rod end is in the mounting bracket of the upper arm. Install the bolt and locknut to attach the shock absorber to the bracket. Tighten the locknut 25 lbf·ft (34 N·m).
   - 2.3 Position the cylinder end of the shock absorber in the mounting bracket of the seat base. Attach the shock absorber to the seat base. Tighten the locknut 25 lbf·ft (34 N·m).
3. Remove the chocks from the rear tires.

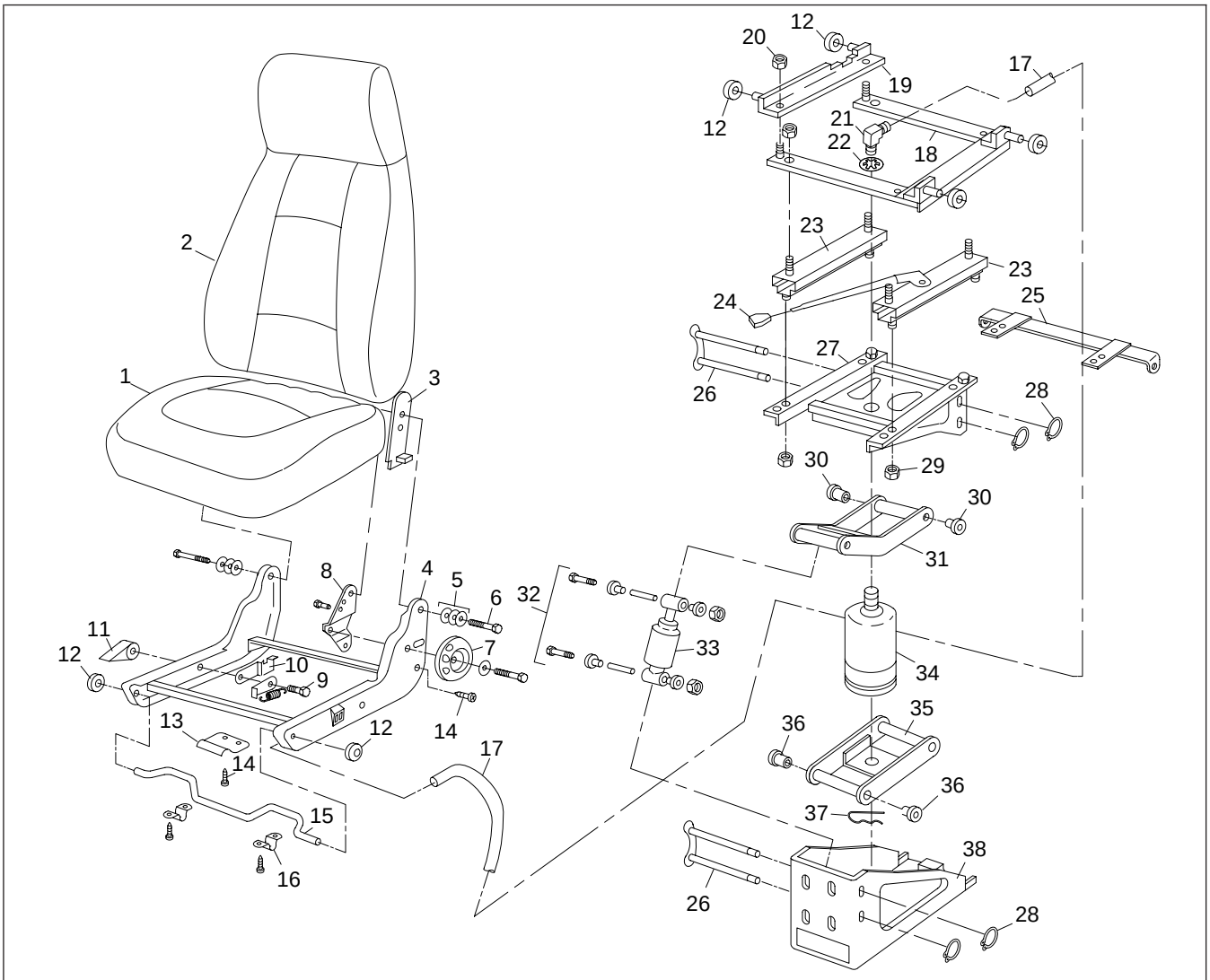
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Replacement (See Fig. 1)

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Raise the upper seat assembly to its maximum height. Support the seat in this position by placing a wooden block between the lower arm and the seat base.
3. Push on the bottom of the seat ride height rocker switch until all the air is exhausted from the air spring.
4. Remove as an assembly the fitting and the air hose from the air spring. Tape the end of the fitting to prevent dirt or other matter from entering.
5. Pry the pin clip from the bottom of the air spring.
6. Remove the retaining ring that secures the air spring to the seat support. Remove the air spring.
7. Position the new air spring in the lower arm and secure it with a new pin clip.
8. Insert the top of the air spring in the opening of the seat support. Install the retaining ring on the air spring.
9. Install the air spring fitting and air hose in the top of the air spring.
10. Push on the top of the seat ride height rocker switch until the seat is adjusted to its maximum height. Remove the wooden block that supports the seat.
11. Remove the chocks from the rear tires.

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Air Spring Replacement



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1. Seat Cushion
2. Seat Back
3. Back Frame Bracket
4. Upper Seat Frame
5. Flatwashers
6. Back Frame Bolt
7. Back Recline Adjustment Knob
8. Back Limit Bolt Bracket
9. Cushion Adjuster Bolt
10. Cushion Adjustment Bracket
11. Cushion Adjustment Lever
12. Bearing
13. Adjustment Rod Bracket
14. Fastener
15. Adjustment Rod
16. Adjustment Rod Bracket
17. Air Hose
18. Isolator
19. Isolator Bar
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21. Hose Barbed Fitting
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33. Shock Absorber
34. Air Spring
35. Lower Arm
36. Bearing
37. Pin Clip
38. Seat Base

Fig. 1, National Cush-N-Aire II Seat (exploded view)

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Base Assembly Bearing/Sleeve Replacement

Replacement (See Fig. 1)

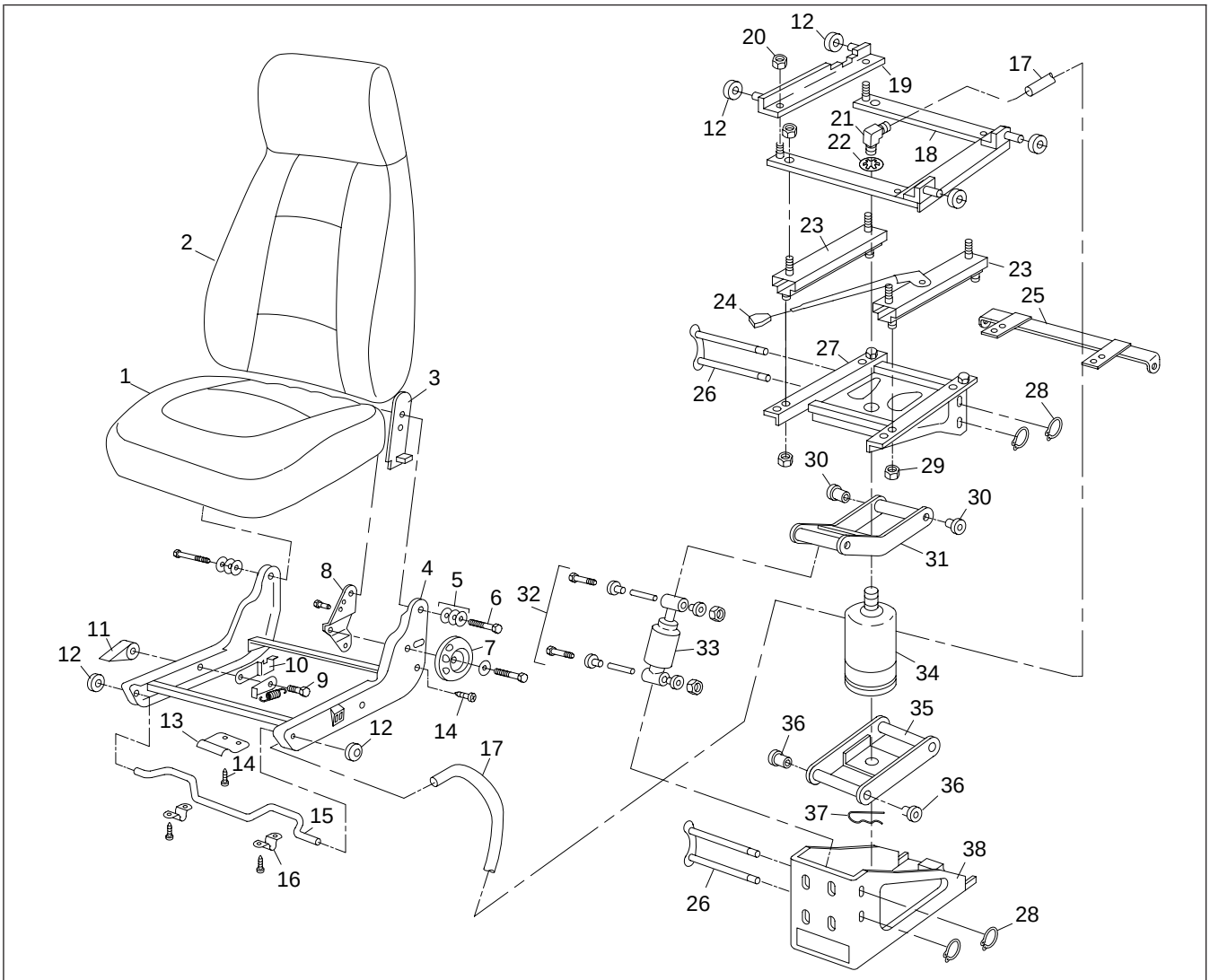
1. Remove the seat as instructed in **Subject 100**.
2. Remove the shock absorber as instructed in **Subject 120**.
3. Remove the air spring as instructed in **Subject 130**.
4. Remove the four locknuts that attach the track assemblies, seat track stop, belt bar and bearings and upper seat assembly to the seat support. Remove the upper seat assembly, track assemblies, seat track stop and belt bar and spacers.
5. Remove the bearings from the seat support and the seat base and the upper and lower arms.
   - 5.1 Use snap ring pliers to remove the four snap rings from the connected shaft assemblies. Using a drift punch, drive out the shaft assemblies from the seat support and the seat base.

   NOTE: Place the punch against the snap ring end of the shafts. Drive each shaft end a little at a time. The two shafts are connected to each other on the opposite side.

   - 5.2 Remove the seat support and the upper and lower arms from the seat base.
   - 5.3 Remove the bearings from the upper and lower arms. Discard the bearings.
   - 5.4 If so equipped, remove the bearings from the seat support and the seat base. Discard the bearings.
6. Install new bearings, as equipped.
   - 6.1 Install new bearings in the upper and lower arm tubes.
   - 6.2 If so equipped, install new bearings in the seat support and the seat base.
   - 6.3 Align the tubes of the lower and upper arms with the holes in the seat base. Be sure the notch in the lower arm is forward and up, and the notch in the upper arm is to the rear and down.
   - 6.4 Install the connected shaft assembly through the seat base and the upper and lower arm forward tubes.
   - 6.5 Align the holes of the seat support with the rear tubes of the lower and upper arms.
   - 6.6 Install the connected shaft assembly through the seat support and the upper and lower arm tubes.
   - 6.7 Use snap ring pliers to install the snap rings that secure the shafts and the arms to the seat base and the seat support.
7. Place the belt bar and bearings, seat track stop, track assemblies and upper seat assembly on the seat base. Install the locknuts and tighten 15 lbf·ft (20 N·m).
8. Install the air spring as instructed in **Subject 130**.
9. Install the shock absorber as instructed in **Subject 120**.
10. Install the seat as instructed in **Subject 100**.

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Base Assembly Bearing/Sleeve Replacement



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1. Seat Cushion
2. Seat Back
3. Back Frame Bracket
4. Lower Frame
5. Flatwashers
6. Back Frame Bolt
7. Back Recline Adjustment Knob
8. Back Limit Bolt Bracket
9. Cushion Adjustment Bolt
10. Cushion Adjustment Bracket
11. Cushion Adjustment Lever
12. Bearing
13. Adjustment Rod Bracket
14. Fastener
15. Adjustment Rod
16. Adjustment Rod Bracket
17. Air Hose
18. Isolator
19. Isolator Bar
20. Locknut
21. Hose Barbed Fitting
22. Retaining Ring
23. Track
24. Fore/Aft Adjustment Lever
25. Belt Bar
26. Connected Shaft
27. Seat Support
28. Snap Ring
29. Locknut
30. Bearing
31. Upper Arm
32. Shock Absorber Assembly
33. Shock Absorber
34. Air Spring
35. Lower Arm
36. Bearing
37. Pin Clip
38. Seat Base

Fig. 1, National Cush-N-Aire II Seat (exploded view)

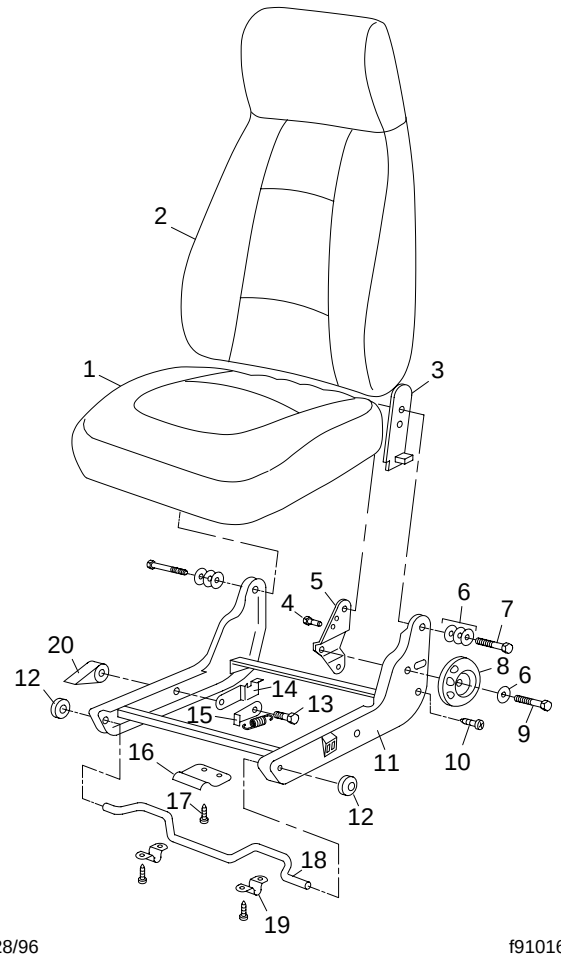
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Removal (See Fig. 1)

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the suspension shroud (if equipped) from the seat base.
3. Drain the vehicle air reservoirs. Push on the bottom of the seat ride height rocker switch until all the air is exhausted from the air spring.
4. Disconnect the air valve air supply hose.
5. Remove the plastic tie strap that attaches the seat cushion to the upper seat frame assembly.
6. Disconnect the air spring supply hose from the air spring.
7. Remove the four locknuts from under the top flange of the seat support assembly.
8. Remove the lower frame from the seat base.

Installation

1. Place the lower frame on the seat support assembly. Install the locknuts under the top flange of the seat support assembly. Tighten the locknuts 10 lbf·ft (15 N·m).
2. Attach the air spring supply hose to the air spring. Make sure that the air hose moves without any restrictions when the seat is moved forward or rearward.
3. Install a new plastic tie strap to secure the seat cushion to the lower frame assembly.
4. Attach the air valve air supply hose.
5. Start the engine and allow the air reservoirs to fill. Test the seat for proper operation.
6. Install the suspension shroud (if equipped) on the seat base.
7. Remove the chocks from the rear tires.



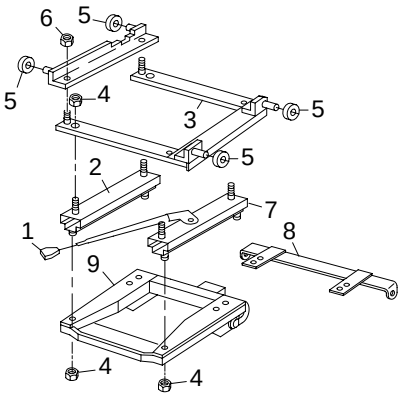
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1. Seat Cushion
2. Seat Back
3. Back Frame Bracket
4. Back Limit Bolt
5. Back Limit Bolt Bracket
6. Flatwashers
7. Back Frame Bolt
8. Back Recline Adjustment Knob
9. Hexbolt
10. Screw
11. Lower Frame
12. Bearing
13. Cushion Adjustment Bolt
14. Cushion Adjustment Bracket
15. Cushion Adjustment Spring Bracket
16. Adjustment Rod Bracket
17. Fastener
18. Adjustment Rod
19. Adjustment Rod Bracket
20. Cushion Adjustment Lever

Fig. 1, Upper Seat Frame Assembly (exploded view)

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Replacement (See Fig. 1)



1. Fore/Aft Adjustment Lever
2. Right-Side Track
3. Welded Bearing Support Frame
4. Locknut
5. Bearing
6. Hexnut
7. Left-Side Track
8. Belt Bar
9. Seat Support

Fig. 1, Track Assembly (exploded view)

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the suspension shroud (if equipped) from the seat base.
3. Drain the vehicle air reservoirs. Push on the bottom of the seat ride height rocker switch until all the air is exhausted from the air spring.
4. Disconnect the air valve air supply hose.
5. Pull up and support the rear edge of the seat cushion as needed to gain access to the isolator-assembly-to-track-assembly 5/16–18 locknuts.
6. Disconnect the air spring supply hose from the air spring.
7. Remove the four 5/16–18 locknuts that attach the isolator assembly to the top of the track assemblies. Remove the upper seat assembly.
8. Remove the four 5/16–18 locknuts that attach the track assemblies to the top of the seat support. Remove the track assemblies.
9. With the holes in the belt bar, belt bar spacers and seat track stop aligned with the holes in the seat support, install the new track assemblies on the seat support. Install and tighten the four 5/16–18 locknuts 15 lbf·ft (20 N·m).
10. Move the upper half of the track assemblies as needed to align their studs with the holes in the isolator assembly. Place the upper seat assembly on the track assemblies. Install and tighten the four 5/16–18 locknuts 15 lbf·ft (20 N·m).
11. Attach the air spring supply hose to the air spring.
12. Move the fore/aft adjustment lever to the right and slide the upper seat assembly forward and rearward while making sure that the air hose moves without restriction. Return the seat cushion to its original position.
13. Attach the air valve air supply hose.
14. Start the engine and allow the air reservoirs to fill. Test the seat for proper operation.
15. Install the suspension shroud (if equipped) on the seat base.
16. Remove the chocks from the rear tires.

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Specifications

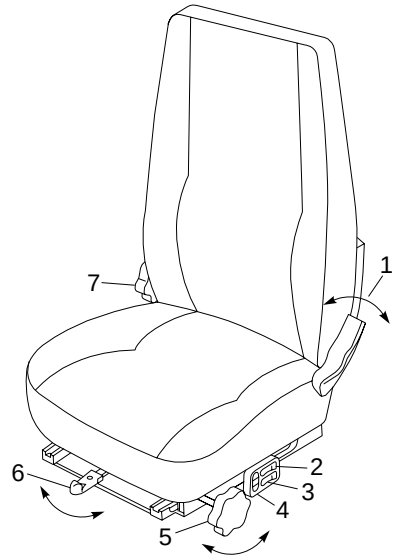
Fastener Torques	
Description	**Torque lbf·ft (N·m)**
Seat Base-to-Cab Deck Socket-Head Bolts	25 to 29 (34 to 39)
Seat Belt/Tether Belt-to-Belt Bar Capscrews	40 (54)
Shock Absorber-to-Bracket Locknuts	25 (34)
Track Assembly-to-Isolator Assembly Locknuts	15 (20)
Track Assembly-to-Upper Seat Frame Locknuts	15 (20)
Seat Support-to-Lower Seat Frame Locknuts	10 (15)

Table 1, Fastener Torques

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General Information

The Bostrom Talladega 915 air suspension seat offers weight-height adjustment, lumbar adjustment, fore/aft isolation and seat position adjustment. See **Fig. 1**.



1. Back Angle Adjustment
2. Upper Air Lumbar Adjustment
3. Lower Air Lumbar Adjustment
4. Weight and Height Adjustment
5. Seat Cushion Tilt Adjustment
6. Fore/Aft Isolation and Seat Position Adjustment
7. Lumbar Adjustment Knob

Fig. 1, Bostrom Talladega 915 Seat

For complete operating instructions, see Chapter 5 in the *Acterra Driver's Manual*.

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Removal

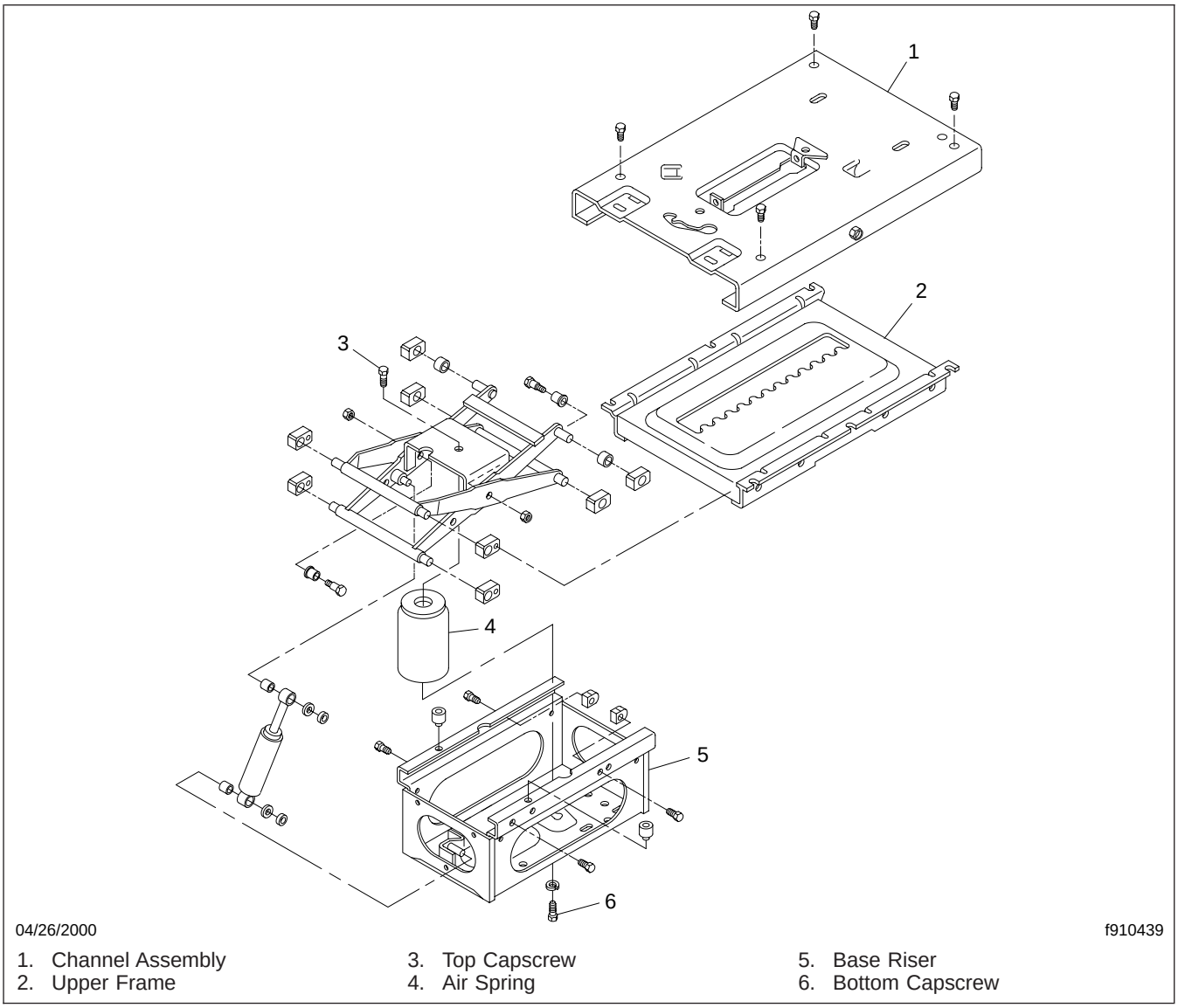
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the suspension shroud (if equipped) from the seat base.
3. Push on the top of the seat ride height rocker switch until the seat is adjusted to its maximum height.
4. Cut a wooden block to the length required to support the seat at its maximum height and place the block between the seat base and the upper frame.
5. Drain the vehicle air reservoirs. Push on the bottom of the seat ride height rocker switch until all air is exhausted from the air spring.
6. Disconnect the air valve air supply hose.
7. Unscrew the capscrews that attach the seat belt straps and tether straps.
8. Remove the capscrews and washers that attach the seat to the cab deck. Remove the seat from the cab.

Installation

1. Place the seat on the cab deck. Insert the capscrews through the washers and the seat base. Tighten the capscrews 25 to 29 lbf·ft (34 to 39 N·m).
2. Attach the brackets of the seat belt straps and tether straps. Tighten the capscrews 40 lbf·ft (54 N·m).
3. Attach the air valve air supply hose.
4. Start the engine and allow the air reservoirs to fill. Push on the top of the seat ride height rocker switch until the seat is adjusted to its maximum height. Remove the wooden block that supports the seat suspension.
5. Install the suspension shroud (if equipped) on the seat base.
6. Remove the chocks from the rear tires.

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Removal (See Fig. 1)



1. Channel Assembly
2. Upper Frame
3. Top Capscrew
4. Air Spring
5. Base Riser
6. Bottom Capscrew

Fig. 1, Bostrom Talladega 915 Seat Air Spring

NOTE: The seat, the seat/back assembly, and the channel assembly do not need to be removed. Move the channel assembly to the rearmost position to provide access to the air spring.

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Fill the air spring so that the seat is at maximum height.
3. Remove the suspension cover from the seat base, if equipped.

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Air Spring Removal and Installation

4. Block the suspension up with a spacer placed between the base riser and the upper frame
5. Release the air pressure from the air spring so that the seat is supported by the spacer.
6. Disconnect the air line from the air spring by pushing in the collar of the fitting while pulling the air line out of the fitting.
7. Remove the top capscrew, and loosen the bottom capscrew through the rear opening in the base riser. Remove the air spring from the suspension.

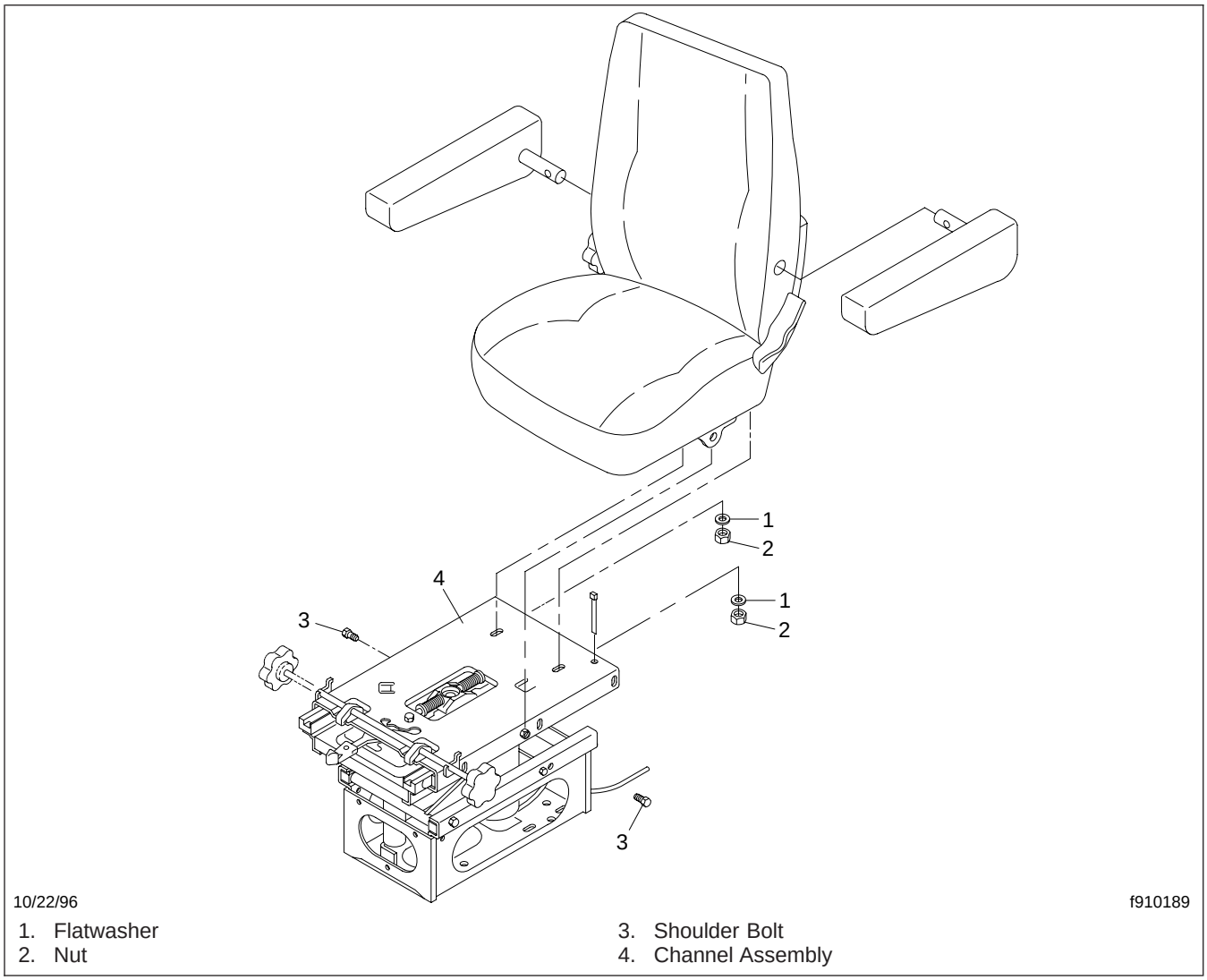
Installation (See Fig. 1)

1. Assemble the bottom capscrew to the new air spring. Install the air spring by fitting the bottom capscrew into the key hole opening in the bottom of the base riser. Position the air spring so the fitting at the bottom of the air spring is toward the back of the seat.
2. Tighten the bottom capscrew 9 to 11 lbf·ft (12 to 15 N·m).
3. Install the top capscrew and torque 15 to 19 lbf·ft (20 to 26 N·m).
4. Connect the air line to the fitting in the air spring by pushing the tube into the fitting.
5. Fill the air spring and remove the spacer block.
6. Install the suspension cover on the seat base, if equipped.
7. Remove the chocks from the rear tires.

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Seat/Back Assembly Removal and Installation

Removal (See Fig. 1)



1. Flatwasher
2. Nut
3. Shoulder Bolt
4. Channel Assembly

Fig. 1, Bostrom Talladega 915 Seat

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Adjust the seat/back assembly to the most rearward position and remove the two nuts and flatwashers from the underside of the channel assembly.
3. Remove the two shoulder bolts from the channel assembly.
4. Disconnect the air lines to the lumbar supports.
5. Remove the seat/back assembly.

Installation (See Fig. 1)

1. Place the seat/back assembly onto the channel assembly.
2. Connect the air lines to the lumbar supports.

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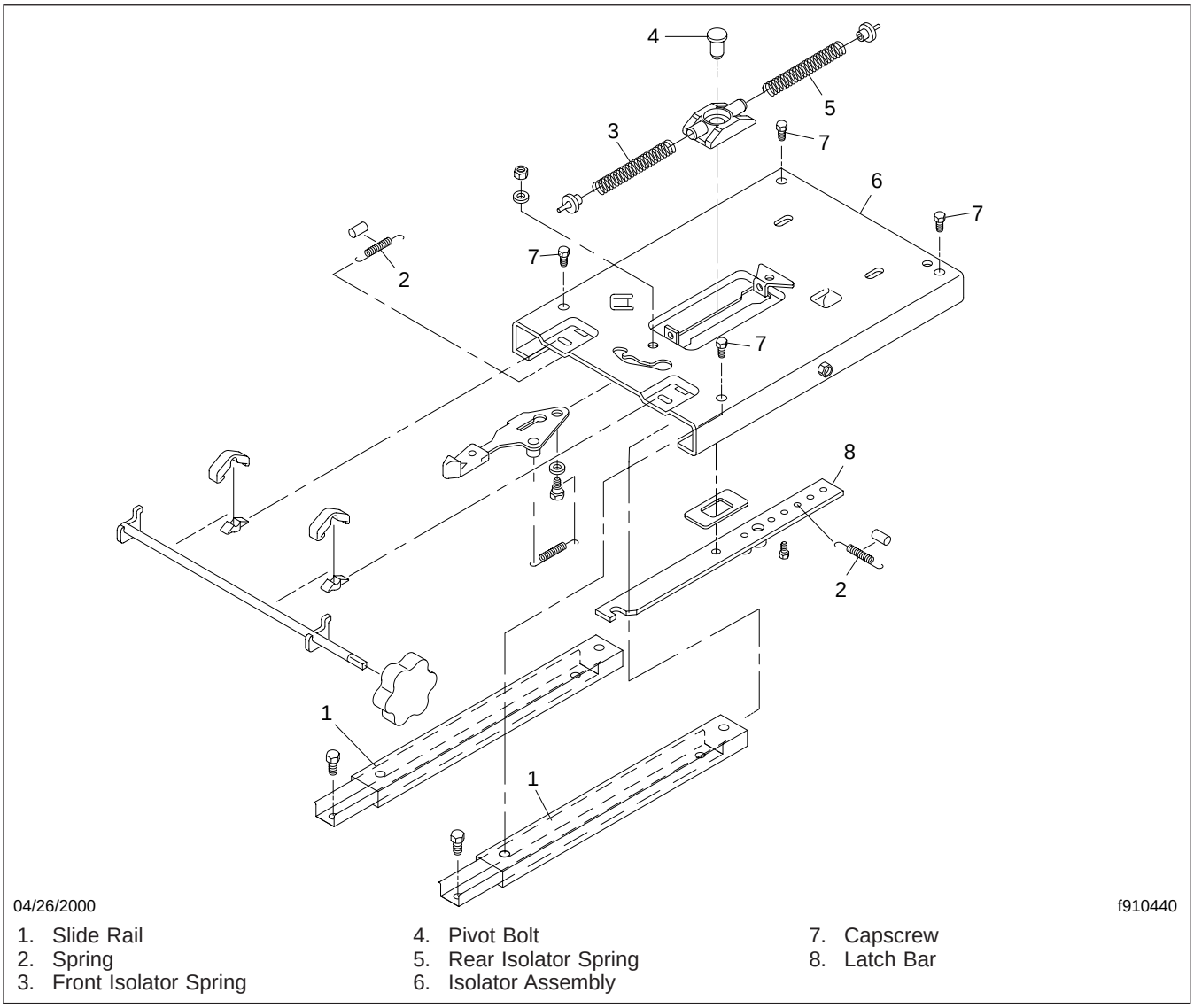
Seat/Back Assembly Removal and Installation

3. Install the two shoulder bolts in the channel assembly.
4. Install the two nuts and flatwashers in the underside of the channel assembly.
5. Remove the chocks from the rear tires.

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Fore/Aft Isolator Assembly Removal and Installation

Removal (See Fig. 1)



1. Slide Rail
2. Spring
3. Front Isolator Spring
4. Pivot Bolt
5. Rear Isolator Spring
6. Isolator Assembly
7. Capscrew
8. Latch Bar

Fig. 1, Isolator Assembly

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the seat assembly. For instructions, see **Subject 100**.
3. Remove the seat/back assembly. For instructions, see **Subject 120**.
4. With the isolator assembly set in its unlocked position, or in the "isolation position," push the isolator assembly rearward and remove the rear isolator spring. Pull the isolator assembly forward and remove the front isolator spring.
5. Remove the four capscrews that attach the isolator assembly to the slide rails.

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Fore/Aft Isolator Assembly Removal and Installation

6. Disconnect the springs from the latch bar.
7. Remove the pivot bolt, slide the latch bar out and remove the isolator assembly.

Installation (See Fig. 1)

1. Place the isolator assembly onto the upper frame, slide the latch bar in and install the pivot bolt. Torque the bolt 26 to 34 lbf·ft (36 to 46 N·m).
2. Connect the springs to the latch bar.
3. Install the four capscrews that attach the isolator assembly to the slide rails.
4. With the isolator assembly in the isolation position, pull the assembly forward and install the front isolator spring. Push the assembly rearward and install the rear isolator spring.
5. Install the seat/back assembly. For instructions, see **Subject 120**.
6. Install the seat assembly. For instructions, see **Subject 100**.
7. Remove the chocks from the tires.

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Removal (See Fig. 1)

NOTE: The seat/back assembly does not need to be removed.

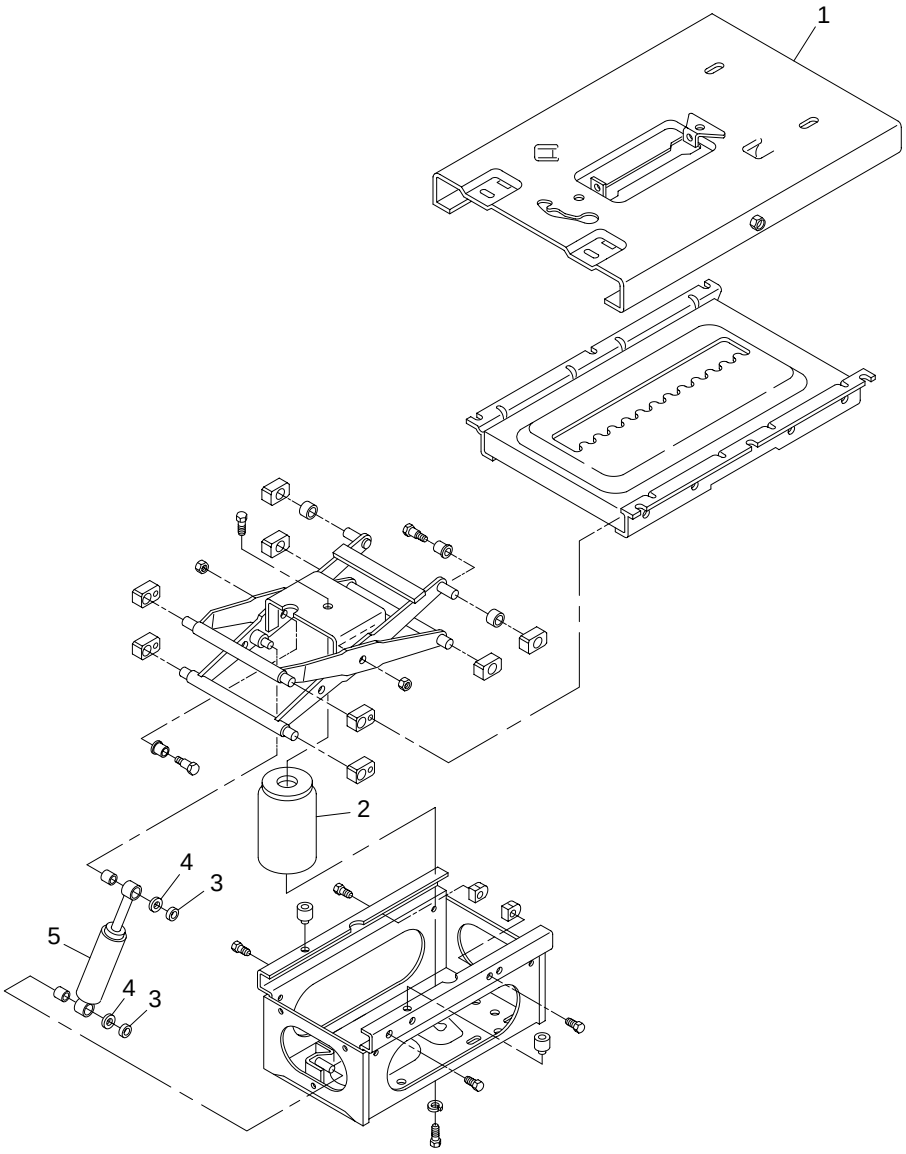
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the suspension shroud (if equipped) from the seat base.
3. Move the isolator assembly to the rearmost position to provide access to the damper assembly.
4. Fill the air spring so that the seat is at maximum height.
5. Use pliers or a screwdriver to twist off the push-on fasteners. The push-on fasteners are not reusable.
6. Remove the damper.

Installation (See Fig. 1)

1. Install the new damper with the flanges of the bearings to the outside of the suspension.
2. Install the thrustwashers and the new push-on fasteners until they seat. A 1/2-inch box-end wrench works well to push the fasteners on.
3. Install the suspension shroud (if equipped) on the seat base.
4. Remove the chocks from the rear tires.

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Damper Removal and Installation



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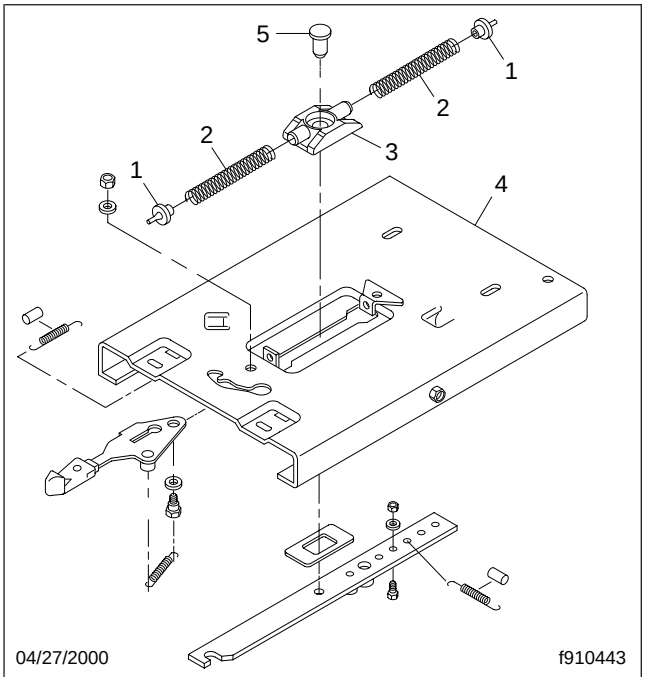
1. Channel Assembly
2. Air Spring
3. Push-On Fastener
4. Thrust Washer
5. Damper

Fig. 1, Isolator Assembly

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Isolator Bumper Removal and Installation

Removal (See Fig. 1)



1. Isolator Bumper
2. Isolator Spring
3. Pivot Block
4. Isolator Assembly
5. Pivot Bolt

Fig. 1, Isolator Assembly

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the seat/back assembly using the instructions in **Subject 120**.
3. Remove the two isolator springs by pushing the isolator assembly rearward to remove the rear spring and pulling the isolator assembly forward to remove the front spring.
4. Remove the isolator bumpers.

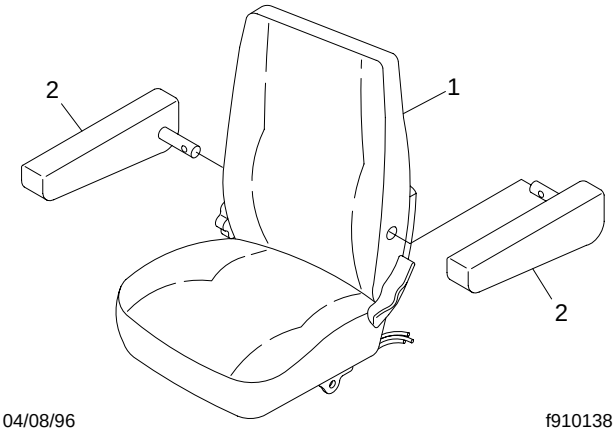
Installation (See Fig. 1)

1. If the pivot block was removed, install the pivot block with the pivot bolt. Torque the bolt 26 to 34 lbf·ft (36 to 46 N·m).
2. Install the isolator bumpers.
3. Install the two isolator springs by pulling the isolator assembly forward to install the front spring and pushing the isolator assembly rearward to install the rear spring.
4. Install the seat/back assembly using the instructions in **Subject 120**.
5. Remove the chocks from the tires.

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Back Cover/Pad Assembly Removal and Installation

Removal (See Fig. 1)



1. Upper Seat Assembly
2. Armrest

Fig. 1, Upper Seat Assembly (armrests removed)

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the seat/back assembly from the suspension, using the instructions in **Subject 120**. Remove the armrests, if equipped.
3. Remove the back cover and pad from the seat frame assembly. Note the location of the fasteners on the existing back cover.

Installation (See Fig. 1)

1. Place a new pad over the back frame. If the seat has lumbar adjustment, make a cut in the edge of the pad to fit around the handle.
2. Place the cover (inside out) over the top of the back pad. Pull down the cover until the three tie-down tabs are even with the three slots in the pad. Pull the tie down tabs through the slots in the pad and run a short wire through all three tabs. Continue to pull the cover down completely over the pad. Tuck the front flap of the back cover between the seat cushion and the bottom of the back pad and lock the J-welt together.

NOTE: If the seat is a high back, there will be two sets of tie down tabs (six total with two wires) to be pulled through the back pad and wired.

3. Attach the upper seat assembly to the suspension using the instructions in **Subject 120**. Install the armrests, if equipped.
4. Remove the chocks from the tires.

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Suspension Rebuild Bearing/Slide Block Removal and Installation

Removal (See Fig. 1)

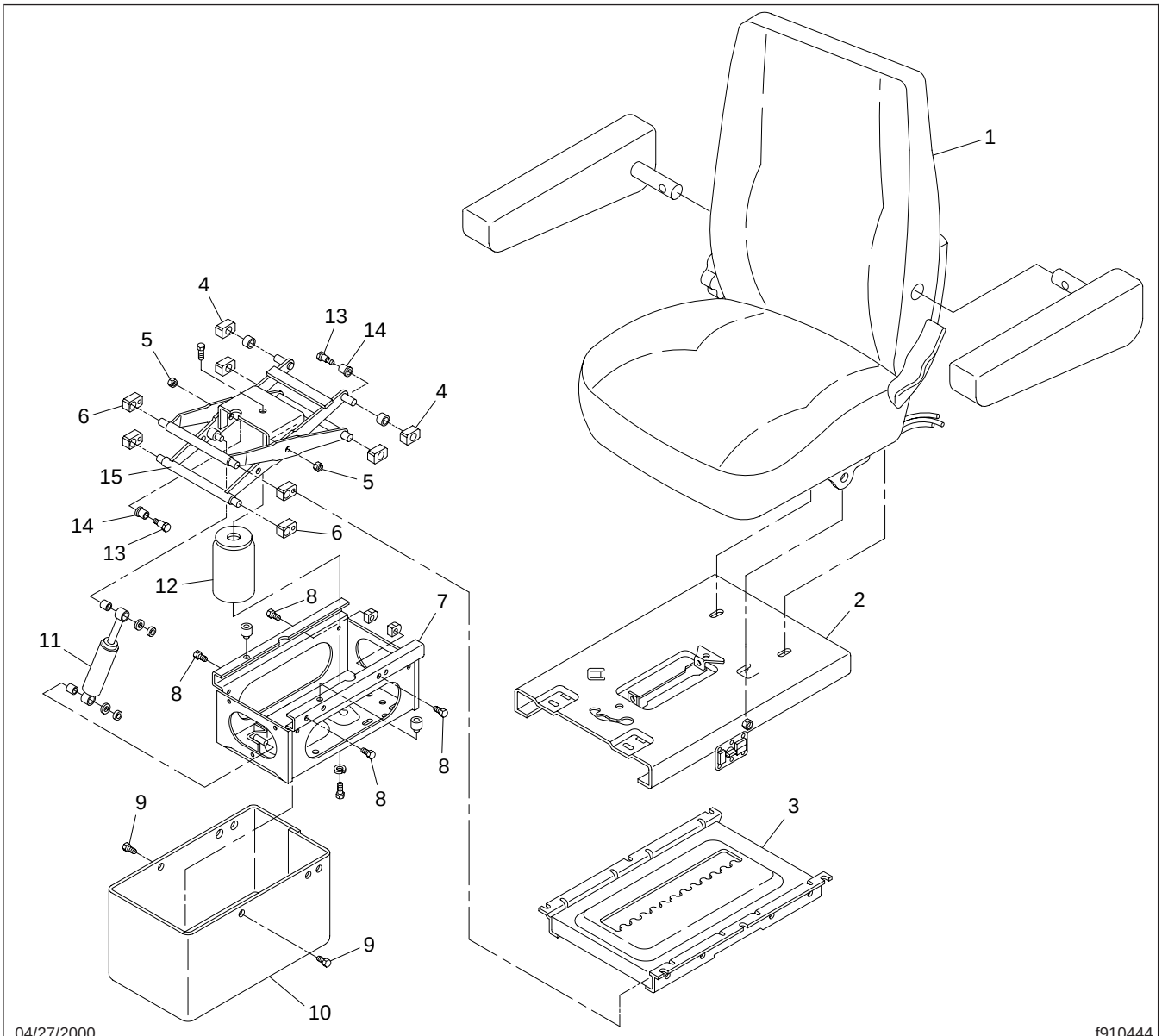
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires.
2. Remove the seat from the vehicle using the instructions in **Subject 100**.
3. Remove the seat/back assembly using the instructions in **Subject 120**.
4. Remove the isolator assembly using the instructions in **Subject 130**.
5. Remove the capscrews and the seat belt bracket.
6. Remove the capscrews from the upper bearing blocks.
7. Remove the upper frame assembly by sliding it forward off the bearing blocks and the slide blocks.
8. Remove the air spring using the instructions in **Subject 110**. Mark the air lines for reassembly.
9. Remove the damper using the instructions in **Subject 140**.
10. Remove the capscrews from the lower bearing blocks and slide the lever assemblies forward until the bearing blocks are removed from the channel on the base riser. Slide the lever assemblies rearward to remove the slide blocks from the channel.
11. Remove the shoulder bolts and nuts from the pivots of the lever assemblies and inspect the bolts. If the bolts are worn, replace them.

Installation (See Fig. 1)

1. Replace the bearings at the pivots on the lever assembly by pushing out the old bearings and pressing in the new bearings. The flange of the bearings should be on the outside of the lever assembly.
2. Install the shoulder bolts and nuts into the pivots of the lever assemblies. Torque the bolts 18 to 22 lbf·ft (24 to 30 N·m).
3. Install new bearing blocks, spacers and slide blocks on the levers with the beveled surfaces outward. Slide the levers with blocks into the channel on the base riser. Torque the capscrews 27 to 33 lbf·ft (37 to 45 N·m).
4. Slide the upper frame assembly over the blocks. Line up the capscrews with the bearing blocks and torque the capscrews 27 to 33 lbf·ft (37 to 45 N·m).
5. Manually move the suspension up and down to make sure there are no clearance problems.
6. Block the suspension up with a spacer block placed between the base riser and the upper frame. Install the air spring using the instructions in **Subject 110**.
7. Install the damper using the instructions in **Subject 140**.
8. Install the seat belt bracket and capscrews.
9. Install the isolator assembly using the instructions in **Subject 130**.
10. Install the seat/back assembly using the instructions in **Subject 120**.
11. Install the seat in the vehicle using the instructions in **Subject 100**.
12. Remove the chocks from the tires.

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Suspension Rebuild Bearing/Slide Block Removal and Installation



1. Seat/Back Assembly
2. Isolator Assembly
3. Upper Frame
4. Slide Block
5. Nut
6. Bearing Block
7. Base Riser
8. Capscrew
9. Fastener
10. Suspension Cover
11. Damper
12. Air Spring
13. Shoulder Bolt
14. Bearing
15. Slide Lever Assembly

Fig. 1, Bostrom Talladega 915 Seat

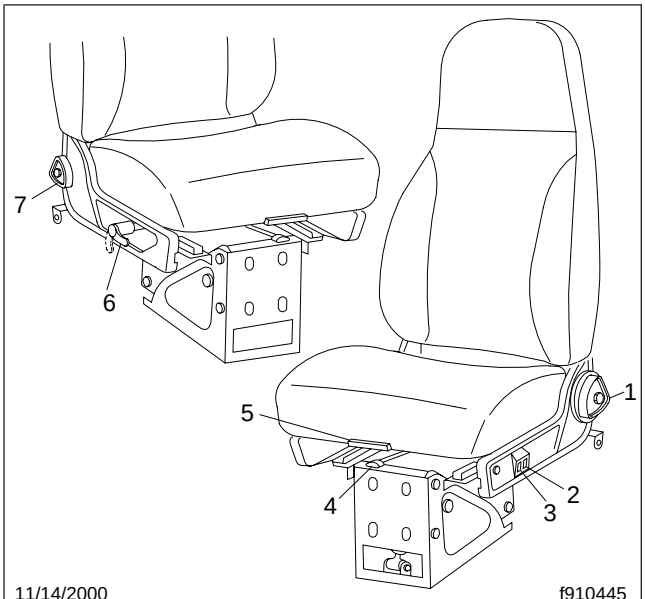
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General Information

The National 2000 Series air suspension seat features height adjustment, fore and aft seat adjustment, back cushion tilt, lumbar support, bottom cushion front height adjustment, and an isolator. See **Fig. 1**. The air suspension adjustment features receive air pressure from the vehicle air system. Pressure in the air suspension is controlled by the switches attached to the seat frame.

For operating instructions on the seat adjustments, refer to Chapter 5 in the *Acterra Driver's Manual*.

See **Fig. 2** for an assembly drawing of the seat.

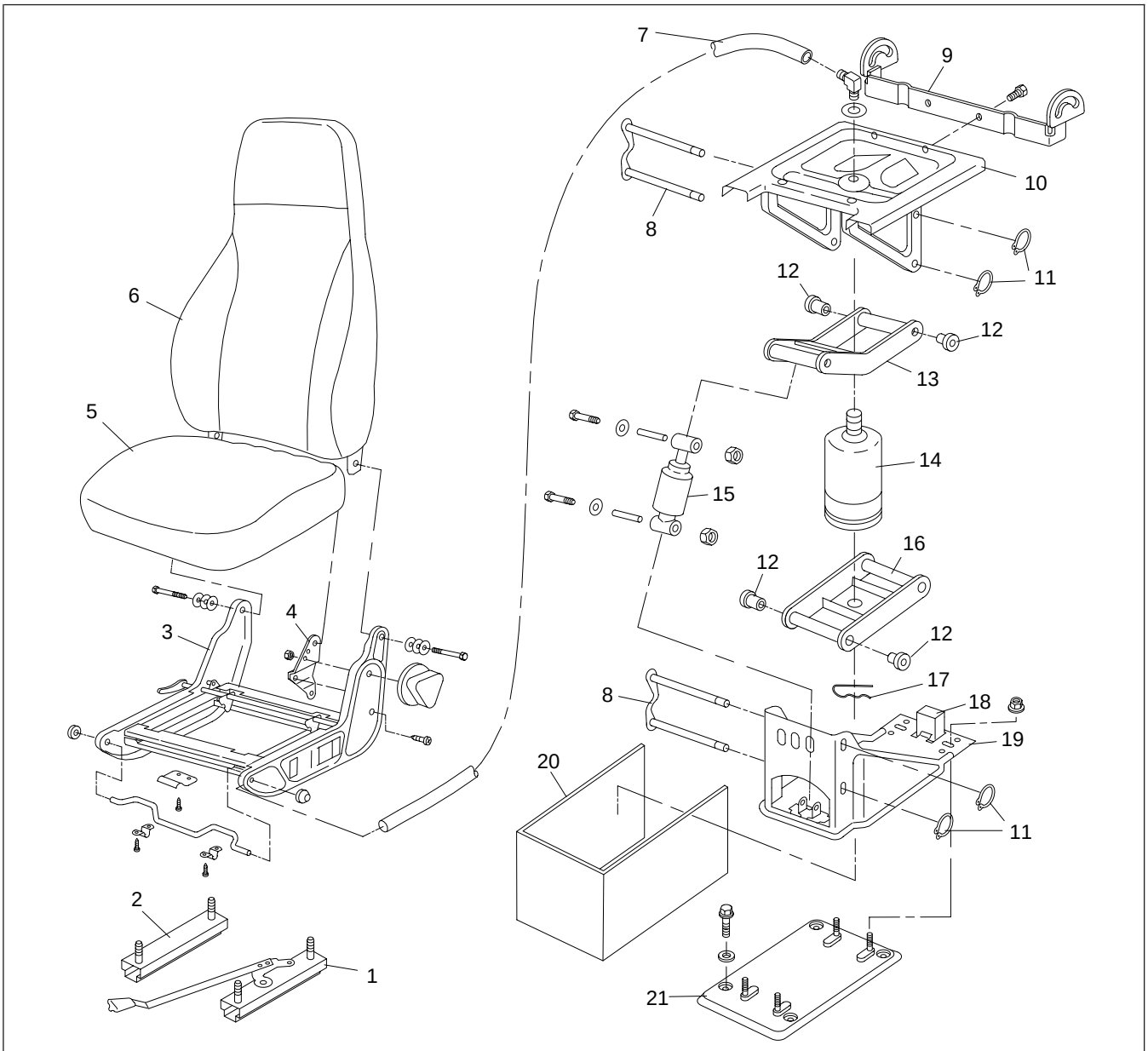


1. Back Cushion Tilt Knob
2. Lumbar Support Switch
3. Height Adjustment Switch
4. Fore and Aft Seat Adjustment Lever
5. Bottom Cushion Front Height Adjustment Handle
6. Isolator Handle
7. Rear Cushion Adjustment Knob

Fig. 1, National 2000 Series Seat

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General Information



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1. Locking Track
2. Slave Track
3. Lower Frame Assembly
4. Recline Limit Bracket
5. Seat Cushion
6. Seat Back
7. Air Hose
8. Shaft Assembly
9. Belt Bar
10. Upper Base Assembly
11. Snap Ring
12. Bushing
13. Upper Arm Assembly
14. Air Spring Kit
15. Shock Kit
16. Lower Arm Assembly
17. Clip
18. Bumper Stop
19. Lower Base Assembly
20. Shroud
21. Mounting Plate

Fig. 2, National 2000 Series Seat Assembly

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Removal

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Press the height adjustment switch until the seat is at the maximum height.
3. If the seat is equipped with a seat suspension shroud, remove the shroud.
4. Cut a wooden block to the length required to support the seat at the maximum height, and place the block between the seat base and the rear crosstube of the lower arm.
5. Drain the air system air reservoirs. Then press the height adjustment switch until all the air is exhausted from the air suspension.
6. Disconnect the air hose from the quick-connect union behind the seat.
7. Using an 11/16-inch wrench or a T50 Torx® wrench, remove the capscrew that attaches the seat belt and tether belt to the bracket.
8. Remove the nuts and washers that attach the seat to the cab floor. Remove the seat from the cab.

Installation

1. Place the seat on the cab floor. Install the nuts and washers on the studs. Tighten the nuts 23 to 29 lbf·ft (31 to 39 N·m).
2. Using the capscrew, attach the seat belt and tether belt to the seat. Tighten the capscrew 40 lbf·ft (54 N·m).
3. Attach the air hose by pressing the pneumatic tubing into the quick-connect union behind the seat.
4. Start the engine and allow the air reservoirs to fill. Press the height adjustment switch until the seat is at the maximum height, then remove the wooden block that supports the seat suspension.
5. If the seat is equipped with a seat suspension shroud, install the shroud.
6. Remove the chocks from the tires.

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General Information

Sterling Truck Corporation currently applies DuPont® single-stage Imron® 5000 or two-stage (base coat and clear coat) Imron 6000 high-solids polyurethane enamel on the vehicle cab at the factory.

Black Imron 5000 is used on the vehicle chassis. The chassis includes the frame, spoke spider, running gear, and any components attached to the frame. Aluminum fuel tanks are not painted.

To meet the federal air quality regulations imposed by the EPA and local jurisdictions, these products contain lower levels of volatile organic compounds (VOCs) than earlier types (916Y, Centari®, and Imron), and are formulated free of lead and chrome.

The procedures in this section are for use with DuPont products. Unless otherwise noted, all products are manufactured by E. I. du Pont de Nemours and Company, Inc. Obtain approval from a Sterling Regional Office for use of topcoats produced by other manufacturers.

Color-Matching

The recommended aftermarket paints for color-matching factory-applied paint are as follows:

- Cab—use Imron 5000 or Imron 6000
- Chassis—use only Imron 5000

To ensure proper gloss, durability, and color-matching of the enamel, use only Imron 5000 on panels that were previously painted with Imron 5000, and use only Imron 6000 on panels painted with Imron 6000.

To determine the correct paint number for color-matching any original finish on a vehicle, see the paint specification on the vehicle specification decal. See the vehicle driver's manual for the location of this decal.

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General Guidelines

This section provides instructions for preparing large panels or the entire cab for topcoating with DuPont® products. For spot repairs or touch-ups, see **Subject 120**.

Before topcoating, the surface must be thoroughly cleaned and sanded. Any bare areas must also be conditioned and primed.

1. Preparation materials specified for one type of surface should not be used for any other type of surface.
2. Limit intermediate coatings, such as primers, to the brand and type specified by the finish-coat manufacturer.

⚠ CAUTION

Only experienced, qualified persons using proper equipment should attempt repainting or touch-up painting. Incorrect application of chemicals or paint could damage the surface or impair the finish.

Preparation for Prime Coat

Use the cleaners and conditioners specified in each step to prepare the surface for priming. See **Specifications, 400** for a summary of the products used in this procedure.

⚠ WARNING

Do not use solvent-based cleaners on large areas of plastic or fiberglass, such as the hood or air fairing. Wiping down these large areas may cause a buildup of static electricity. The resulting spark could cause a flash fire, which could result in personal injury or property damage.

CAB AND HOOD PREPARATION

1. Wash and dry the entire vehicle with a mild detergent.

⚠ WARNING

Solvents are flammable. Keep them away from heat, sparks, and open flame. Keep the container closed. Use only with adequate ventilation. Avoid breathing the vapor, or headache, nausea, and impaired reaction time and coordination may result.

2. Wipe all surfaces to be painted with a clean cloth soaked with solvent or cleaner. Remove all traces of wax, polish, grease, and silicones.
   - Metal—use DuPont Prep-Sol 3919 S.
   - Plastic—use DuPont Plastic Prep 2319 S.
   - Fiberglass—use DuPont Prep-N-Solv.

   2.1 Work on small areas at a time, wetting the surface liberally.

   2.2 Quickly wipe the surface with a clean cloth before the solvent or cleaner has a chance to dry. Change cloths frequently.
3. Feather the edge of all repaired areas, chipped surfaces, and scratches.

   3.1 Cut down the edges of broken spots with No. 220 sandpaper.

   3.2 Feather the edges by hand, using a sanding block with No. 400 sandpaper.
4. Sand the entire area to be painted. Using a sanding block and No. 400 sandpaper, remove the gloss to improve adhesion of the primer.
5. Using a clean cloth soaked with cleaner, remove any sanding dust.
   - Metal or plastic—use DuPont 3939 S lacquer and enamel cleaner.
   - Fiberglass—use a solution of one part water and one part isopropyl alcohol (IPA).
6. Treat bare metal and rusted areas.
   - Steel—use DuPont 5717 S metal conditioner.
   - Aluminum—use DuPont 225 S aluminum cleaner.

   6.1 Mix one part of the cleaner with two parts of water in a plastic bucket.

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Preparing for Topcoating

6.2 Apply the cleaner with a cloth or sponge. If corrosion is present, work the surface with a stiff plastic brush or 3M Scotch-Brite® pad. Do not use any pads containing iron.

6.3 While the metal is still wet, wipe thoroughly with a clean, dry cloth. Allow the surface to dry before applying a conversion coating.

7. Apply a conversion coating to all bare metal.
   - Steel—use DuPont 5718 S metal conversion coating.
   - Zinc casings or galvanized surfaces (iron or steel)—use DuPont 5718 S metal conversion coating.
   - Aluminum—use DuPont 226 S aluminum conversion coating.

   7.1 Pour the conversion coating into a plastic container (do not dilute). Using a 3M Scotch-Brite or similar non-iron abrasive pad, apply the conversion coating to the metal surface. Work only as much area as can be coated and rinsed before the solution dries.

   7.2 Leave the coating on the surface for two to five minutes. Rinse off the solution with cold water, or mop with a sponge or cloth rinsed frequently in clean water.

   If the metal surface dries before rinsing, reapply the conversion coating, then repeat the previous substep.

   7.3 Wipe the surface dry with a clean cloth, or air dry.

8. With paper and tape, mask all areas that are not to be painted.

AIR FAIRING KIT PREPARATION

Before installing a new air fairing, prepare the surface for topcoating.

1. Wash the air fairing with a mild detergent. Dry with a clean, absorbent, lint-free cloth or paper towels.
2. Using a clean cloth soaked with DuPont Prep-N-Solv®, wipe the entire surface to remove any trace of grease or oil.
3. Scuff-sand the air fairing with No. 320 grit sandpaper.
4. Wipe the air fairing with a clean cloth soaked in a solution of one part water and one part isopropyl alcohol. Allow 10 to 15 minutes for the air fairing to dry.
5. With tape and paper, mask all areas that are not to be painted.

Prime Coat

Prime all bare and feathered areas before topcoating. The specified primers can be used on any surface.

1. Clean all cracks and surfaces with dry compressed air.
2. Using a tack cloth, wipe all surfaces to be painted.

⚠ WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying primer, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

3. Prime all bare metal and feathered areas with DuPont primer.
   - Steel and aluminum—use Corlar 824 S epoxy primer.
   - Fiberglass—use Corlar 825 S epoxy primer.

   3.1 Stir the primer thoroughly.

   3.2 Mix two parts Corlar epoxy primer with one part DuPont 826 S activator.

   3.3 Reduce three parts of this mixture with one part DuPont 3602 S lacquer thinner (viscosity reading is 18 to 22 seconds in a No. 2 Zahn cup). Stir thoroughly.

   3.4 Wait 1 to 2 hours from time of mixing before using. This provides time for complete chemical induction.

   3.5 Set the air pressure at the spray gun at 45 psi (310 kPa). For pressure feed sys-

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tems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.

3.6 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

3.7 Spray one full wet coat to give a dry film thickness of 0.7 to 1.0 mil (18 to 25 µm).

3.8 Clean the equipment immediately after use with DuPont 3602 S lacquer thinner.

3.9 Air dry 2 hours or force dry 20 minutes.

4. Wet sand the primer with No. 400 grit or finer sandpaper. Feather the edge into the surrounding area.

5. Dry the surface. Using a clean cloth soaked with cleaner, remove any sanding dust.
   - Metal or plastic—use DuPont 3939 S lacquer and enamel cleaner.
   - Fiberglass—use solution of 1 part water and 1 part isopropyl alcohol (IPA).

NOTE: See **Subject 110** for topcoating instructions.

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General Guidelines

This section provides instructions for applying a topcoat of DuPont® enamel to full panels or the entire cab. For spot repairs or touch-ups, see **Subject 120**.

⚠ CAUTION

Only experienced, qualified persons using proper equipment should attempt repainting or touch-up painting. Incorrect application of chemicals or paint could damage the surface or impair the finish.

Do not mix additives with the finish coats unless they are specified by the finish-coat manufacturer. See **Specifications, 400** for a summary of the products used in this procedure.

Before applying any topcoat:

1. Prepare the surface for topcoating. See **Subject 100** for instructions.
2. Clean all cracks and surfaces with dry compressed air.
3. Using a tack cloth, wipe all surfaces to be painted.

After topcoating, remove the masking as follows:

- After normal air drying—remove all masking when the surface is reasonably dry.
- After forced drying—remove the masking immediately after the finish has been baked.
- After two-toning—remove the masking used for the first coat as soon as it has set up, usually in about 35 to 40 minutes. Follow the same procedure for the second color.

Imron 5000 Topcoating

Imron 5000 is a single-stage, low VOC, high-solids polyurethane enamel. It provides a durable, high-gloss surface with good chemical resistance. It requires the addition of an activator.

⚠ WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator approved by NIOSH or MSHA (TC-19C), while spraying Imron 5000, and until the work area has been exhausted of all vapor and spray mist. Breathing paint vapor or spray mist can cause personal injury.

MIXING

1. Stir the Imron 5000 enamel thoroughly.
2. Mix three parts Imron 5000 enamel with one part of DuPont 193 S or 194 S activator. No further reduction is necessary for application.

NOTE: The pot life of the mixture is about 2 to 4 hours at 70°F (21°C), unless an accelerator is added.

3. If faster curing time is desired, add DuPont 389 S fast-dry accelerator. Add up to 2 ounces (60 mL) to 1 gallon (3.8 L) of mixed material.
4. Mix thoroughly and strain.

NOTE: The viscosity of the mixture is about 9 to 20 seconds in a No. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.

APPLICATION

1. Set the air pressure at the spray gun to 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.
2. Apply the topcoating.
   - 2.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.
   - 2.2 Using a cross-coat technique, spray one medium-wet coat in a north-to-south direction
   - 2.3 Allow 5 to 10 minutes drying time between each application. Do not sand.
   - 2.4 Apply a second medium-wet coat in an east-to-west direction.
   - 2.5 A third medium-wet coat may be needed for good coverage of some colors.
3. To air dry, allow 2 to 4 hours with accelerator 389 S, and 6 to 8 hours without the accelerator.

   To force dry, wait 15 minutes following the application of the final coat. Dry for 30 minutes at 140 to 180°F (60 to 82°C).

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4. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.
5. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

RECOATING OR DECORATING

Two-toning, striping, or lettering may be applied in 4 to 6 hours if DuPont 389 S accelerator is used. Wait 10 to 12 hours if no accelerator is used.

Decals may be applied in 12 to 16 hours if 389 S accelerator is used. Wait 24 hours if no accelerator is used.

For topcoats cured over 72 hours, scuff-sand with No. 400 grit sandpaper and wipe with a clean tack cloth before recoating, striping, lettering, or applying decals.

Imron 6000 Topcoating

Imron 6000 is a two-stage, high-solids polyurethane enamel. It provides good cover with one cross-coat of the base color followed by one coat of Imron 6000 clear coat. Both the base color and clear coat require the addition of an activator.

⚠ WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator approved by NIOSH or MSHA (TC-19C), while spraying Imron 6000, and until the work area has been exhausted of all vapor and spray mist. Breathing paint vapor or spray mist can cause personal injury.

MIXING

1. Stir the Imron 6000 base color thoroughly.
2. Mix three parts Imron 6000 base color with one part DuPont 193 S or 194 S activator. No further reduction is necessary for application.

NOTE: The pot life of the mixture is about 2 to 4 hours at 70°F (21°C), unless an accelerator is added.

3. If faster curing time is desired, add DuPont 389 S fast-dry accelerator. Add up to 2 ounces (60 mL) to 1 gallon (3.8 L) of mixed material.
4. Mix thoroughly and strain.

NOTE: For solids, the viscosity of the mixture is about 20 seconds in a DuPont M-222 (M-50) cup; for metallics, it is about 18 seconds.

APPLICATION

1. Set the air pressure at the spray gun to 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.
2. Apply the topcoating.
   - 2.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.
   - 2.2 Apply one cross-coat of the Imron 6000 base color.
   - 2.3 Flash 10 minutes minimum. Do not sand.
   - 2.4 Mix three parts DuPont 3440 S or 3480 S clear with one part DuPont 193 S or 194 S activator.
   - 2.5 Apply one coat of the activated DuPont 3440 S or 3480 S clear.
3. To air dry, allow two to four hours if DuPont 389 S accelerator is used, and six to eight hours if no accelerator is used.

   To force dry, wait 15 minutes following the application of the clear coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).
4. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.
5. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

RECOATING OR DECORATING

Two-toning, striping, and lettering may be applied in 4 to 6 hours if DuPont 389 S accelerator is used. Wait 10 to 12 hours if no accelerator is used.

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Decals may be applied in 12 to 16 hours if 389 S accelerator is used. Wait 24 hours if no accelerator is used.

For topcoats cured over 72 hours, scuff-sand with No. 400 grit sandpaper and wipe with a clean tack cloth before recoating, striping, lettering, or applying decals.

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General Guidelines

This section provides instructions for making spot repairs or touch-ups with DuPont® enamels. Buffing may correct minor imperfections; more serious repairs require surface preparation before a topcoating can be applied. For striping, lettering, or decal application after the repair is complete, see **Subject 110**.

1. Preparation materials specified for one type of surface should not be used for any other type of surface. See **Specifications, 400** for a summary of the materials used in this section.
2. Limit intermediate coatings, such as primers, to the brand and type specified by the finish-coat manufacturer.
3. Do not mix additives with the finish coats unless they are specified by the finish-coat manufacturer.

⚠ CAUTION

Only experienced, qualified persons using proper equipment should attempt repainting or touch-up painting. Incorrect application of chemicals or paint could damage the surface or impair the finish.

Buffing Minor Imperfections

1. Clean the area carefully with a mild detergent and rinse.
2. Remove imperfections using ultra-fine or micro-fine sandpaper (1500 or 2000 grit) and water. Rinse the area with clean water, then dry.
3. Buff the area.
   - 3.1 Use a clean foam pad at low speed (about 1600 rpm) with one of the following products:
     - DuPont 1500 S
     - Meguiar's No. 2
     - 3M Finesset Two 5928
   - 3.2 Using medium pressure, buff slowly in an overlapping pattern until the imperfection has been eliminated. Repeat as necessary.
   - 3.3 Rinse the area with clean water, then dry.
4. Polish the area.
   - 4.1 Apply one of the following products with a clean pad (3M Waffle Pad):
     - DuPont 3000 S
     - Meguiar's No. 9
     - 3M 5996
   - 4.2 Using medium pressure, work small areas using an even, overlapping pattern until the gloss is restored. As the polish dries and the gloss appears, ease the pressure on the polishing pad. Repeat as necessary.

Preparing for Topcoating

1. Wash the entire panel with mild detergent. Dry with a clean, lint-free cloth.

⚠ WARNING

Solvents are flammable. Keep them away from heat, sparks, and open flame. Keep the container closed. Use only with adequate ventilation. Avoid breathing the vapor or headache, nausea and impaired reaction time and coordination may result.

2. Clean the area to be repaired with DuPont 3939 S solvent and quickly wipe the surface with a clean, lint-free cloth before the solvent dries. Remove all traces of wax, polish, grease, and silicones.
3. Sand or grind all dents and scratches.
4. Wet sand and the area being repaired with No. 320 grit or finer sandpaper, or a 3M Scotch-Brite® or similar non-iron abrasive pad. Feather the edge.
5. Remove the sanding dust. Use the same solvent and wipe-on, wipe-off method used earlier to clean the area.
6. Mask all areas that will not be painted.
7. Clean all cracks and surfaces with dry compressed air.
8. Using a tack cloth, wipe all surfaces to be painted.

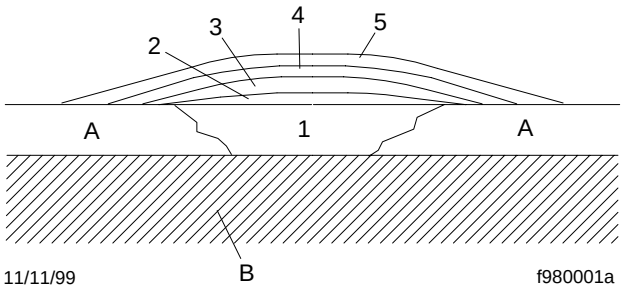
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Spot Repair

WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying primer, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

9. Prime all bare metal and feathered areas with DuPont primer. See **Fig. 1**.
   - Steel and aluminum — use Corlar 824 S epoxy primer.
   - Fiberglass — use Corlar 825 S epoxy primer.



NOTE: Scale exaggerated for clarity. The number of layers depends on the specific application.

A. Existing Paint
B. Panel Material (substrate)
1. Primer
2. First Color Topcoat
3. Second Color Topcoat
4. Third Color Topcoat
5. Clear Coat

Fig. 1, Spot Repair Cross-Section

9.1 Stir primer thoroughly.

9.2 Mix two parts Corlar epoxy primer with one part DuPont 826 S activator.

9.3 Reduce three parts of this mixture with one part DuPont 3602 S lacquer thinner (viscosity reading is 18 to 22 seconds in a No. 2 Zahn cup). Stir thoroughly.

9.4 Wait one to two hours from time of mixing before using. This provides time for complete chemical induction.

9.5 Set the air pressure at the spray gun to 45 psi (310 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.

9.6 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

9.7 Spray one wet coat to give a dry film thickness of 0.7 to 1.0 mil (18 to 25 µm).

9.8 Clean the equipment immediately after use with DuPont 3602 S lacquer thinner.

9.9 Air dry 2 to 4 hours or force dry 20 minutes.

10. Wet sand the primer with No. 400 grit or finer sandpaper. Feather the edge into the surrounding area.
11. If the original paint was Imron 6000, hand-rub the area around the spot repair with a medium grade compound to ensure a seamless finish.
12. Remove the sanding dust. Use the same solvent and wipe-on, wipe-off method used earlier to clean the area.
13. Wipe the repair area with a tack cloth.
14. If the finish is old, apply one coat of DuPont 222 S adhesion promoter over the entire repair area.

    14.1 Set the air pressure to 35 psi (240 kPa) at the spray gun.

    14.2 Flash for 5 to 10 minutes at 70°F (21°C) before topcoating.

Topcoating a Spot Repair

WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator approved by NIOSH or MSHA (TC-19C), while spraying topcoating, and until the work area has been exhausted of all vapor and spray mist. Breathing topcoating vapor or spray mist can cause personal injury.

Imron 5000 Topcoating

1. Mix the Imron 5000 polyurethane enamel.

   1.1 Stir the Imron 5000 enamel thoroughly.

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1.2 Mix three parts Imron 5000 base color with one part DuPont 193 S or 194 S activator. No further reduction is necessary for application.

1.3 Mix thoroughly and strain.

2. Set the air pressure at the spray gun at 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.

3. For metallic topcoats only, apply one coat of DuPont 500 S urethane clear.

3.1 Mix eight parts of 500 S urethane with one part 193 activator.

3.2 Reduce the activated 500 S urethane mixture 50 percent with 8685 S reducer.

3.3 Apply a medium-wet coat of the reduced 500 S urethane over the entire repair area, and well beyond where the color will be applied.

3.4 Flash 3 minutes before applying the Imron 5000 topcoat.

4. Apply the solid color or metallic topcoating.

4.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

4.2 Spray one medium-wet coat over the primed area.

4.3 Flash 5 to 10 minutes.

4.4 Apply a second medium-wet coat. Extend the spray area slightly to taper the edge and avoid a visible ring.

4.5 A third medium-wet coat may be needed for good coverage of some colors. Allow each coat to flash before applying the next coat.

NOTE: A mist coat of five parts of color to three parts of 8022 S is recommended when applying metallics. Hold the gun about 18 inches (45 cm) from the surface.

5. Blend the repair area into the OEM finish.

5.1 Lower the air pressure to 15 to 20 psi (100 to 140 kPa) at the spray gun.

5.2 Empty the spray cup and refill it with DuPont 8022 S reducer or a blend of 8022 S and 8093 S.

5.3 Carefully blend the edge of the repair with even coats to melt in the overspray.

5.4 Spray one or two medium coats of the reducer over the entire area.

5.5 If a haze appears around the edge after the reducer has dried, lightly rub the edge with DuPont 1500 S one-step polish.

6. To air dry, allow 2 to 4 hours if DuPont 389 S accelerator is used, and 6 to 8 hours if no accelerator is used.

To force dry, wait 15 minutes following the application of the final coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).

7. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.

8. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

Imron 6000 Topcoating

1. Mix the Imron 6000 polyurethane enamel.

1.1 Stir the Imron 6000 base color thoroughly.

1.2 Mix three parts Imron 6000 base color with one part DuPont 193 S or 194 S activator. No further reduction is necessary for application.

1.3 Mix thoroughly and strain.

2. Set the air pressure at the spray gun at 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.

3. Apply the topcoating.

3.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

3.2 Apply one cross-coat of the Imron 6000 base color over the primed area. No flash time is required before applying a clear coat.

3.3 Flash 10 minutes minimum. Do not sand.

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Spot Repair

3.4 Mix three parts DuPont 3440 S or 3480 S clear with one part DuPont 193 S or 194 S activator.

NOTE: For best results, apply the clear coat over the entire panel. If a blend of the repair area is attempted, apply the clear coat only over the repair area, overspraying the edge slightly.

3.5 Apply one coat of the activated DuPont 3440 S or 3480 S clear.

4. Blend the 3440 S or 3480 S clear into the surrounding topcoat.

   4.1 Set the air pressure to 25 psi (170 kPa) at the spray gun.

   4.2 Apply one coat of 3401 S blending clear over the repair area only to the overspray edge.

   4.3 Flash two minutes. Repeat if necessary.

5. To air dry, allow two to four hours if DuPont 389 S accelerator is used, and six to eight hours if no accelerator is used.

   To force dry, wait 15 minutes following the application of the final coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).

6. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.

7. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

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Equipment Application Parameters		
Parameter	**English Units**	**Metric Units**
Atomizing Air		
Primer	45 psi	310 kPa
Enamel	60–65 psi	410–450 kPa
Fluid Delivery	12–16 oz/min	350–470 mL/min
Booth Temperature	75°F	23°C
Spray Gun Distance	10–12 in	25–30 cm

Table 1, Equipment Application Parameters

DuPont Surface Preparation Materials				
Step	**Surface Preparation Materials**			
	Steel	**Aluminum**	**Plastic**	**Fiberglass**
Wash and Dry	Mild Detergent (Such As Dishwashing Detergent)			
Wipe with Cleaner	Prep-Sol 3919 S	Prep-Sol 3919 S	Plastic Prep 2319 S	Prep-N-Solv
Sand and Feather	220 Grit, then 400 Grit			320 Grit
Remove Sanding Dust	3939 S Lacquer and Enamel Cleaner			Mix: - 1 Part Water - 1 Part Isopropyl Alcohol
Treat Bare Metal	5717 S Metal Conditioner	225 S Aluminum Cleaner	—	—
Apply Conversion Coating to Bare Metal	5718 S Metal Conversion Coating	226 S Aluminum Conversion Coating	—	—
Apply Sealer Primer	Mix: - 2 Parts Corlar 824 S Primer with 1 Part DuPont 826 S Activator - Reduce 3 Parts of Mixture with 1 Part DuPont 3602 S Lacquer Thinner		Mix: - 2 Parts Corlar 825 S Primer with 1 Part DuPont 826 S Activator - Reduce 3 Parts of Mixture with 1 Part DuPont 3602 S Lacquer Thinner	

Table 2, DuPont Surface Preparation Materials

DuPont Topcoating Materials		
Step	**Topcoating Materials**	
	Imron 6000	**Imron 5000**
Mix Enamel	Mix: - 3 Parts Imron 6000 - 1 Part 193 S or 194 S Activator	Mix: - 3 Parts Imron 5000 - 1 Part 193 S or 194 S Activator
Add Accelerator (Optional)	389 S Accelerator (Up to 2 oz/gal of Activated Enamel)	

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Specifications

DuPont Topcoating Materials		
Step	**Topcoating Materials**	
	Imron 6000	**Imron 5000**
Mix Clear Coat	Mix: - 3 Parts 3440 S or 3480 S Clear - 1 Part 193 S or 194 S Activator	—
Pressure at Gun	60–65 psi (414–448 kPa)	60 psi (414 kPa)
Equipment Cleanup	3939 S Lacquer and Enamel Cleaner or 8685 S Reducer	

Table 3, DuPont Topcoating Materials

DuPont Spot Repair Materials		
Step	**Spot Repair Materials**	
	Imron 6000	**Imron 5000**
Cleaning	3939 S Lacquer and Enamel Cleaner	
Sanding	320 Grit or Finer	
Sealer Primer	Mix: - 2 Parts Corlar 824 S Primer with 1 Part DuPont 826 S Activator - Reduce 3 Parts of Mixture with 1 Part DuPont 3602 S Lacquer Thinner	
Compound	Medium Grade Compound	—
Adhesion Promoter	222 S Adhesion Promoter	
Topcoat	1 Coat Imron 6000: - 3 Parts Base Color - 1 Part 193 S or 194 S Activator	2 Coats Imron 5000: - 3 Parts Enamel - 1 Part 193 S or 194 S Activator
Topcoat Viscosity	Solids: 20 Sec; Metallics: 18 Sec (No. 2 Zahn Cup)	9–20 Sec (No. 3 Zahn Cup)
Clear Coat	Mix: - 3 Parts 3440 S or 3480 S Clear - 1 Part 193 S or 194 S Activator	—
Accelerator (Optional)	389 S Accelerator	
Blending Clear	1 Coat 3401 S Blending Clear	
Equipment Cleanup	3939 S Lacquer and Enamel Cleaner or 8685 S Reducer	

Table 4, DuPont Spot Repair Materials