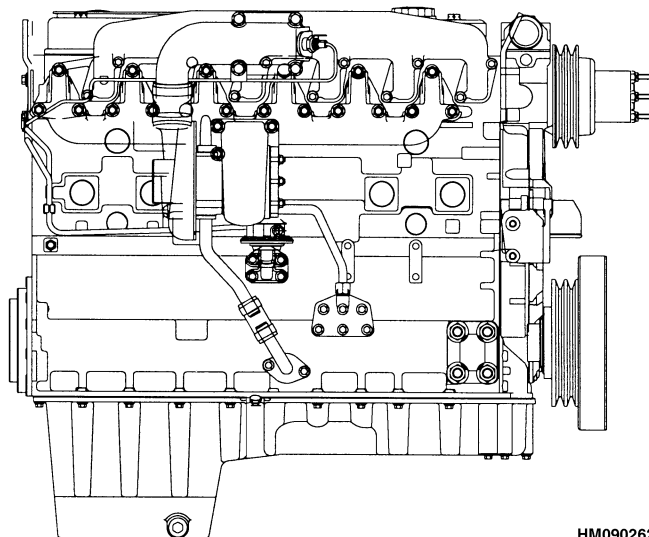


PERKINS TIER 2 DIESEL ENGINES

1100 (VK)

**H8.00-12.00XM (H170-280HD) [F007, G007];
H13.00-16.00XM (H300-360HD) [E019, F019];
H10.00-12.00XM-12EC (H360HD-EC) [E019, F019]**



HM090262

HYSTER

SAFETY PRECAUTIONS

MAINTENANCE AND REPAIR

- When lifting parts or assemblies, make sure all slings, chains, or cables are correctly fastened, and that the load being lifted is balanced. Make sure the crane, cables, and chains have the capacity to support the weight of the load.
- Do not lift heavy parts by hand, use a lifting mechanism.
- Wear safety glasses.
- DISCONNECT THE BATTERY CONNECTOR before doing any maintenance or repair on electric lift trucks. Disconnect the battery ground cable on internal combustion lift trucks.
- Always use correct blocks to prevent the unit from rolling or falling. See HOW TO PUT THE LIFT TRUCK ON BLOCKS in the **Operating Manual** or the **Periodic Maintenance** section.
- Keep the unit clean and the working area clean and orderly.
- Use the correct tools for the job.
- Keep the tools clean and in good condition.
- Always use **HYSTER APPROVED** parts when making repairs. Replacement parts must meet or exceed the specifications of the original equipment manufacturer.
- Make sure all nuts, bolts, snap rings, and other fastening devices are removed before using force to remove parts.
- Always fasten a DO NOT OPERATE tag to the controls of the unit when making repairs, or if the unit needs repairs.
- Be sure to follow the **WARNING** and **CAUTION** notes in the instructions.
- Gasoline, Liquid Petroleum Gas (LPG), Compressed Natural Gas (CNG), and Diesel fuel are flammable. Be sure to follow the necessary safety precautions when handling these fuels and when working on these fuel systems.
- Batteries generate flammable gas when they are being charged. Keep fire and sparks away from the area. Make sure the area is well ventilated.

NOTE: The following symbols and words indicate safety information in this manual:



WARNING

Indicates a condition that can cause immediate death or injury!



CAUTION

Indicates a condition that can cause property damage!

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This section is for the following models:

H8.00-12.00XM (H170-280HD) [F007, G007];

H13.00-16.00XM (H300-360HD) [E019, F019];

H10.00-12.00XM-12EC (H360HD-EC) [E019, F019]

General

This section has the description and repair instructions for the VK model of the Series 1100 Perkins diesel engine. All VK models are six-cylinder, turbocharged.

GENERAL SAFETY RULES



WARNING

Some seals used in this engine are made of synthetic materials called fluoroelastomers (a commercial name is Viton). These fluoroelastomers can decompose at temperatures greater than 316°C (600°F) or by burning and cause hydrofluoric acid to form on the surface of the seal or nearby equipment.

Do not touch gaskets, seals, or O-rings which appear charred or black and sticky after exposure to temperatures greater than 316°C (600°F) or burning. Contact with this acid can cause severe burns of the skin and eyes. Burns can be delayed several hours after contact.

Do the following procedures to prevent exposure to hydrofluoric acid:

- Wear disposable neoprene or PVC gloves and discard the gloves after use.
- Wash the area with 10 percent calcium hydroxide solution to neutralize any acid and then clean with water.

If burned seal by-product touches the skin or eyes:

- Immediately flush with water for a minimum of 15 minutes.
- Apply 2.5 percent calcium gluconate gel to affected area of skin.
- Get medical help immediately for suspected hydrogen fluoride or hydrofluoric acid burn.



WARNING

Disconnect the battery cables before doing any disassembly and repair of the engine or parts of the electrical system. Put a DO NOT OPERATE tag in the operator's area and on the battery connectors.

Long-term exposure to used engine oil can cause skin irritation or cancer. Wash with detergent and water.

Exhaust from internal combustion engines contains carbon monoxide and other harmful chemicals. Carbon monoxide is a colorless, odorless poison and can cause unconsciousness or death without warning. Long-term exposure to exhaust or chemicals in the exhaust can cause cancer, birth defects, and other reproductive harm. Avoid exposure to engine exhaust.

Do not use diesel engines indoors where soot can accumulate.

If engines are operated in confined spaces, maintain adequate ventilation or vent exhaust to the outside. Do not exceed applicable air contaminant limits.

Follow the inspection and maintenance schedule and procedures in this manual. Do not alter exhaust, ignition, or fuel systems.



CAUTION

Disposal of lubricants and fluids must meet local environmental regulations.

Disposal of batteries must meet local environmental regulations.

The diodes and resistors in the electrical system can be damaged if the following cautions are not followed:

- Do not disconnect the battery when the engine is running. The voltage surge can damage the diodes and resistors.
- Do not disconnect an electric wire before the engine is stopped and the switches are OFF.
- Do not cause a short circuit by connection of the electric wires to the wrong terminals. Make sure a correct identification is made of the wire before it is connected.
- Verify the battery is the correct voltage and polarity before it is connected.
- Do not check for current flow by making a spark because the electronic components can be damaged.

**CAUTION**

When setscrews or studs are fitted into holes which are tapped through the cylinder block, a suitable sealant must be used to prevent leakage.

Micro encapsulated anaerobic sealant (M.E.A.S.) fasteners have been introduced instead of jointing compounds or other sealants when the fasteners are fitted in through holes into oil or coolant passages. The identification of these fasteners, as supplied, is by a red, blue, or other color sealant around the fastener threads.

With M.E.A.S. sealed studs, the sealed end must be fitted into the cylinder head/cylinder block, etc. Ensure that the threaded holes have a 1.59 mm (0.0626 in.), 45° chamfer so that the M.E.A.S. sealant is not removed. If the fasteners have to be removed and fitted again, the threads must be cleaned and a suitable sealant used.

Observe the previous **WARNINGS** and **CAUTIONS** before repairing any equipment.

Description

The cylinder head is cast iron and has one inlet valve and one exhaust valve for each cylinder. The valve seats and the valve guides are replaceable. The fuel injectors are in the cylinder head. The overhead valve assembly is actuated by a camshaft inside of the engine block. A gear train, turned by the crankshaft, turns the camshaft, coolant pump, injection pump, and a power-takeoff (PTO) which is available for additional equipment. The hydraulic pump for the steering function or a compressor is normally turned by the PTO. The fuel pump is actuated by the camshaft. See Figure 1.

The crankshaft has seven main bearings. The main bearing in the center of the crankshaft is the thrust bearing and has thrust washers on both sides of the bearing.

The cylinder block is cast iron and has cylinder liners that can be replaced during overhaul.

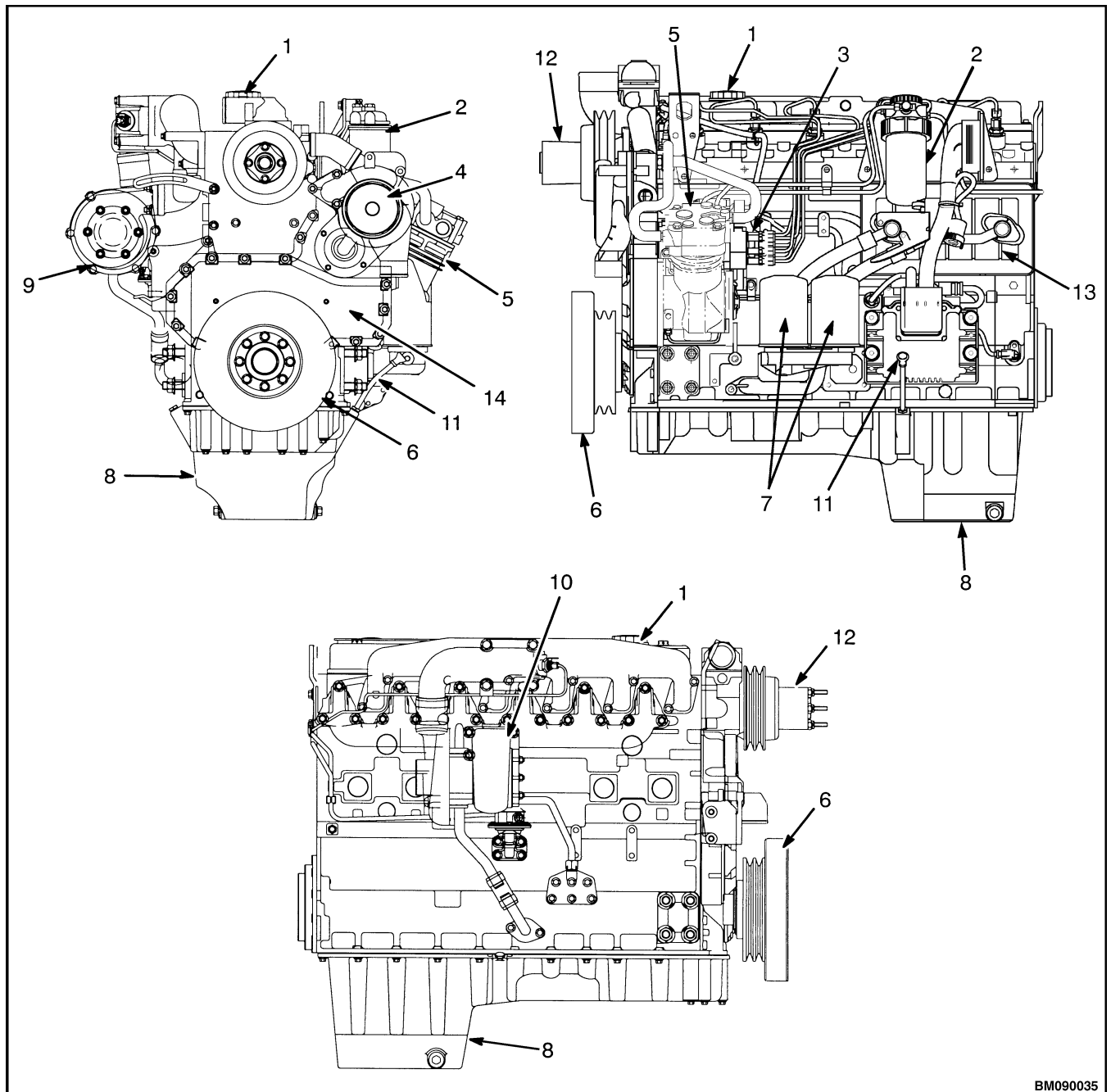
A Fastram™ combustion chamber in the top of each piston is designed to give an efficient mix of fuel and

air. Each piston has three piston rings (two compression rings and an oil control ring). The top compression ring has a special insert for the groove, to reduce wear. Axial location of the fully floating piston pin is by circlips. The piston pin is off-center to reduce the noise level. A jet for cooling oil to the bottom of the piston is installed.

The cooling fan and the alternator are turned by a drive belt. The cooling fan is not connected to the coolant pump. The coolant pump is turned by the gear for the fuel injection pump in the timing gear case.

The timing, speed adjustment, and quantity of fuel sent to the fuel injectors is controlled electronically by the Electronic Control Module (ECM).

A Bosch VP30 series fuel injection pump is used on all 1100 VK engines. Special tools are needed to repair an injection pump, and they are normally sent to an authorized repair station if repairs are necessary.



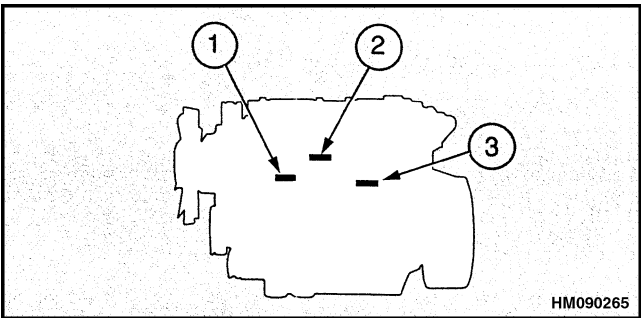
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- | | |
|----------------------------|--------------------------|
| 1. FILL CAP FOR ENGINE OIL | 8. OIL SUMP |
| 2. FUEL FILTER | 9. ALTERNATOR |
| 3. FUEL INJECTION PUMP | 10. TURBOCHARGER |
| 4. COOLANT PUMP | 11. DIPSTICK, ENGINE OIL |
| 5. AIR COMPRESSOR | 12. FAN DRIVE |
| 6. VIBRATION DAMPER | 13. OIL COOLER |
| 7. OIL FILTERS | 14. TIMING CASE |

Figure 1. Engine

ENGINE SERIAL NUMBER CODES

The engine number is on a label on the left side of the engine block. See Figure 2.



1. PART NUMBERS
FOR FUEL
INJECTION PUMP
2. ENGINE SERIAL
NUMBER
3. EMISSIONS LABEL

Figure 2. Serial Number Locations

A typical serial number has the following code:

VK	U	090001	H
1	2	3	4

where:

- 1 = Type of engine: VK = 1100
- 2 = Country of manufacture (U = manufactured in the United Kingdom)
- 3 = Serial number
- 4 = Year of manufacture. The letter indicates the year of manufacture. The letters I, O, Q, R, and Z are not used.

If parts or service are required for your engine, the complete engine number must be given to your dealer.

ENGINE DATA

The specifications and tolerance details for engine repair are in a chart at the end of this section.

1100 (VK)

- Power rating at 2300
rpm..... 129.5 kW (173.7 bhp)
- Number of cylinders..... 6
- Firing order 1-5-3-6-2-4
- Bore and stroke 100 × 127 mm
(3.937 × 5.000 in.)
- Displacement..... 6.00 liter (366 in.³)
- Compression ratio 17.25:1
- Minimum oil pressure
(at maximum speed
and normal operating
temperature)
- Governor speed (no
load) 280 kPa (41 psi)

See the **Periodic Maintenance** section for your model of lift truck.

Idle Speed 725 to 775 rpm

Thermostat

- Begin to open 80 to 84°C (176 to 183°F)
- Fully open..... 96°C (205°F)

Valve clearance (hot or cold)

- Inlet 0.20 mm (0.008 in.)
- Exhaust 0.45 mm (0.018 in.)

Engine Removal and Installation

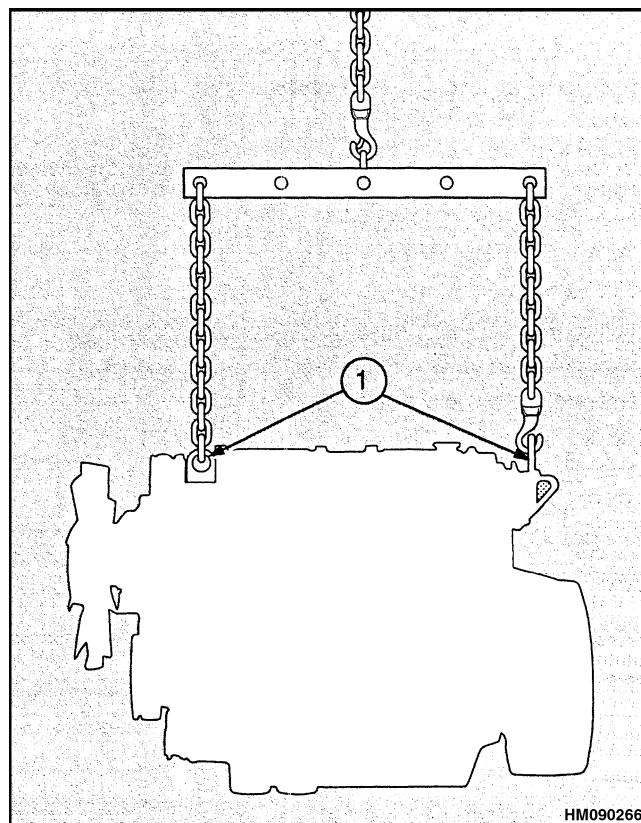
See the **Frame** section for the procedure for removing the engine and transmission. See the **Transmission** section for the procedure to separate the transmission from the engine.

There can be a variation in the maximum weight of the engine depending upon the components that are attached to it. The following minimum lifting capacity is needed for an engine without coolant, lubricants, or transmission:

1100 (VK) engines 600 kg (1323 lb)

Always use a lifting device that provides a vertical lift above the engine lift brackets as shown in Figure 3. **Never** use a single bracket to lift an engine.

Verify the engine brackets are correctly fastened to the engine. Verify that the valve cover and other components are not damaged by the lifting device. Use a lifting device to lift and move the heavy components of the engine: cylinder block, cylinder head, flywheel housing, flywheel, and crankshaft.



1. ENGINE LIFT BRACKETS

Figure 3. Lifting an Engine

Cylinder Head Assembly Repair

VALVE COVER

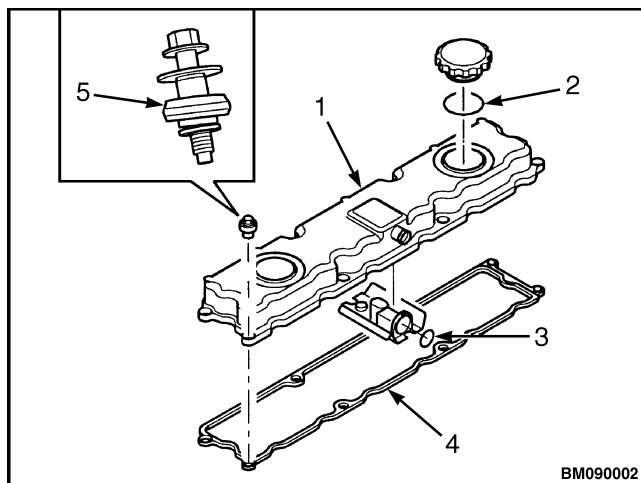


Figure 4. Valve Cover

Legend for Figure 4

1. VALVE COVER
2. OIL FILLER CAP SEAL
3. OIL SEPARATOR ASSEMBLY SEAL
4. VALVE COVER GASKET
5. CAPSCREW ASSEMBLY

Remove

1. Disconnect the breather pipe.
2. Remove the capscrews and sealing washers from the valve cover. See Figure 4.
3. Lift the valve cover and gasket from the cylinder head. The valve cover gasket fits between the valve cover and the induction manifold.

Install

1. Check the condition of the valve cover gasket, bolts, and seal washers. Replace components as necessary. Verify that the surfaces are clean.
2. Install the valve cover and gasket on the cylinder head. See Figure 4.
3. Install the valve cover bolts. Torque to 9 N•m (80 lbf in) in sequence shown in Figure 5.

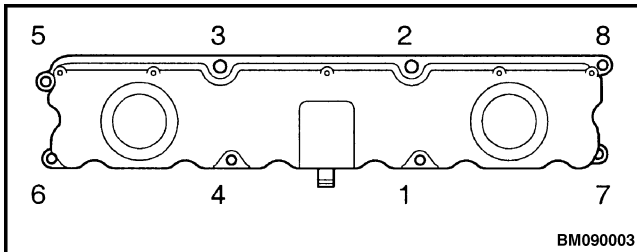


Figure 5. Valve Cover Torque Sequence

4. Connect the breather pipe.

ROCKER ARM ASSEMBLY

Remove

1. Remove the valve cover.
2. Loosen the nuts evenly that fasten the brackets for the rocker arm shafts to the cylinder head. Loosen the brackets at each end of the cylinder head first and loosen the brackets in sequence towards the center. Remove the nuts and washers when the pressure is removed from the rocker arms. Lift the rocker arm assembly from the cylinder head.
3. Remove the rubber seal from the oil supply connection or the hole for the oil supply in the cylinder head. See Figure 6.

Disassemble

1. Remove the clips from both ends of the rocker arm shaft. Verify that the ends of the rocker arm shaft are not damaged. Loosen the location screw for the oil supply connection.
2. Make a note of the position of each component on the rocker arm shaft so that they can be assembled correctly. Remove the components from the rocker arm shaft.

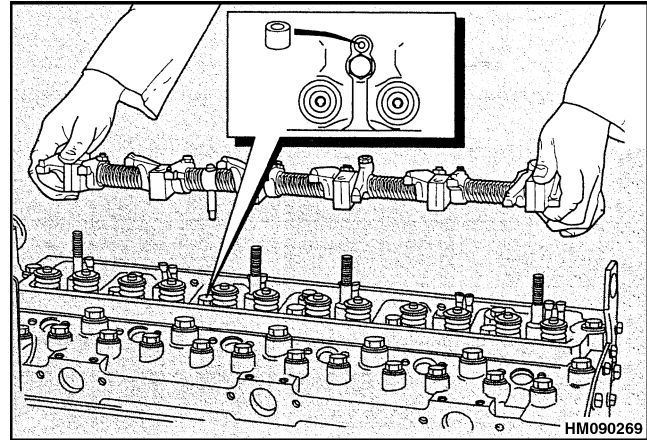


Figure 6. Rubber Seal Location

Inspect

Clean and inspect all the components for wear and damage. Check the clearance of the rocker arms on the rocker arm shaft. If the clearance is greater than 0.09 mm (0.0035 in.), install a new rocker arm, or install a new rocker arm shaft if it is worn.

Assemble

1. Verify that the lubrication holes in the rocker arms and the rocker arm shaft are open and clean.
2. Lubricate the components with clean engine oil as they are assembled on the rocker arm shaft. Verify the components are assembled in the correct order. See Figure 7. Verify that the location screw for the oil supply connection is fitted correctly in the rocker arm shaft and torqued to 4 N•m (35 lbf in). Install the clips at the ends of the rocker arm shaft.

Install

1. Verify that the rocker arm assembly is clean and dry.
2. Install a new rubber seal in the hole for the oil supply in the cylinder head. See Figure 6.
3. Check that the push rods fit correctly in the sockets for the tappets. Install the rocker arm assembly over the four studs, insert the oil supply connection into the oil supply hole in the cylinder head.

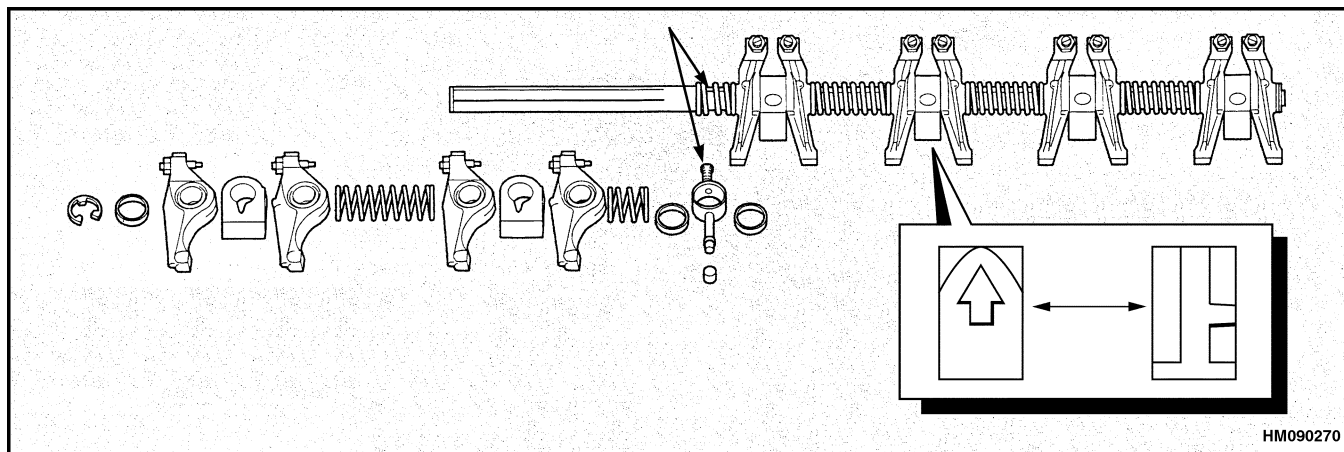


Figure 7. Rocker Arm Assembly



CAUTION

Loosen any tappet adjustment screws that may tighten during the following procedure.

4. Verify that the alignment of the rocker arms and the push rods is correct. Install the nuts and washers on the studs that hold the brackets for the rocker arm shafts to the cylinder head. Tighten the nuts evenly. Begin tightening the nuts at the center of the rocker arm shaft and tighten in sequence towards the ends of the shaft. The final torque on the nuts is 75 N•m (55 lbf ft).
5. Check and adjust valve tip clearances. See Valve Clearance Adjustments.

VALVE CLEARANCE ADJUSTMENTS

The valve clearance is measured between the top of the valve stem and the rocker arm as shown in Figure 8.

Valve clearance (hot or cold)

Inlet	0.20 mm (0.008 in.)
Exhaust	0.45 mm (0.018 in.)

Number one cylinder is at the front of the engine. The inlet valve is the first valve in the sequence. See Figure 9.

1. Turn the crankshaft in the normal direction of rotation until the inlet valve of number six cylinder has just opened and the exhaust valve of the same cylinder has not fully closed. Check the clearances of the valves of number one cylinder and adjust them as necessary.

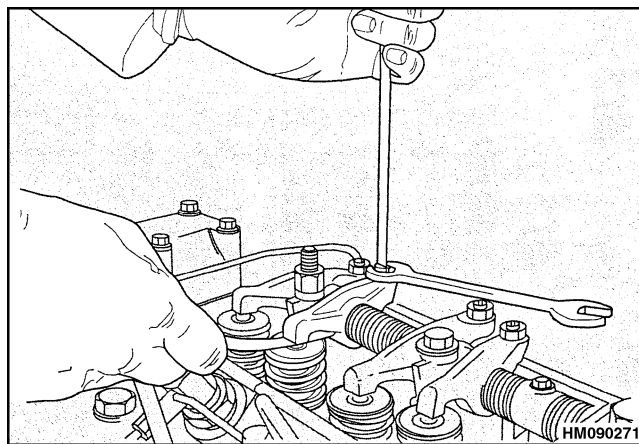


Figure 8. Valve Clearance Adjustment

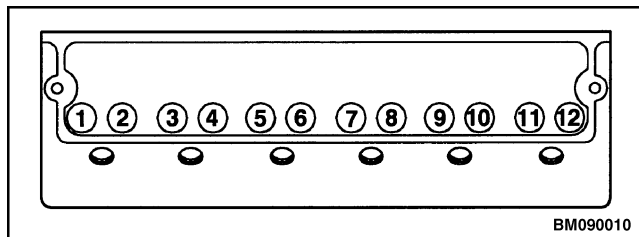


Figure 9. Valve Positions

NOTE: The torque for the locking nut is 27 N•m (21 lbf ft).

2. Turn the crankshaft in the normal direction of rotation until the inlet valve of number two cylinder has just opened and the exhaust valve of the same cylinder has not fully closed. Check the valve clearances on number five cylinder and adjust them as necessary.

3. Turn the crankshaft in the normal direction of rotation until the inlet valve of number four cylinder has just opened and the exhaust valve of the same cylinder has not fully closed. Check the valve clearances on number three cylinder and adjust them as necessary.
4. Turn the crankshaft in the normal direction of rotation until the inlet valve of number one cylinder has just opened and the exhaust valve of the same cylinder has not fully closed. Check the valve clearances on number six cylinder and adjust them as necessary.
5. Turn the crankshaft in the normal direction of rotation until the inlet valve of number five cylinder has just opened and the exhaust valve of the same cylinder has not fully closed. Check the valve clearances on number two cylinder and adjust them as necessary.
6. Turn the crankshaft in the normal direction of rotation until the inlet valve of number three cylinder has just opened and the exhaust valve of the same cylinder has not fully closed. Check the valve clearances on number four cylinder and adjust them as necessary.

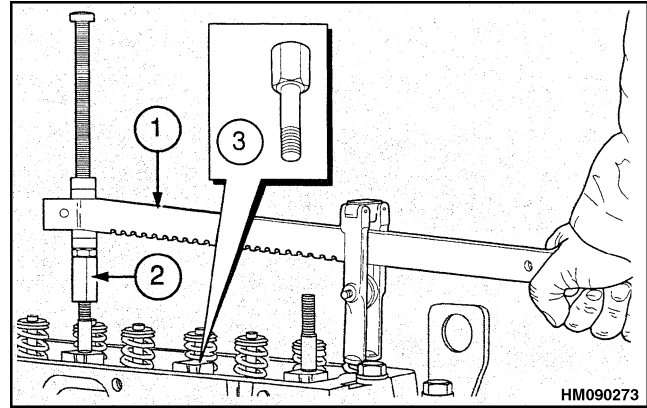
NOTE: After valve adjustments, lubricate the rocker assembly with clean engine oil.

VALVE SPRINGS

NOTE: This procedure is normally for changing the valve springs of a single cylinder while the cylinder head is still installed on the engine. If the valves and springs must be removed from the cylinder head for repairs, see the procedures under Valves and Valve Springs, later in this section.

Special Tools: Valve spring compressor
Stud adapter
Setscrew adapter

1. Remove the valve cover.
2. Turn the crankshaft in the normal direction of rotation until the piston for the cylinder is at top dead center (TDC). The inlet valve will just open and the exhaust valve will not be fully closed when the cylinder is at TDC.
3. Remove the rocker arm assembly.
4. Install the spring compressor and the adapter. See Figure 10.



- | | |
|----------------------------|---------------------|
| 1. VALVE SPRING COMPRESSOR | 3. SETSCREW ADAPTER |
| 2. STUD ADAPTER | |

Figure 10. Valve Spring Compressor

5. Compress the valve springs and remove the retainers. Verify the valve springs are compressed parallel to the valve stems, or the valve stems can be damaged.

NOTE: Do not turn the crankshaft while the valve springs are removed.

6. Release the valve spring compressor and remove the retainer cap and valve springs.

NOTE: The outer diameter of the exhaust valve guide is 1 mm (0.039 in.) larger than the inlet valve guide. To prevent leakage past the inlet valve stem it is important that the larger exhaust valve seal is not fitted into the inlet guide. The seals are color coded.

7. Install new valve stem seals on the valve guides. Verify that the brown seal is installed on the exhaust valve and the green seal on the inlet valves.
8. Install the new valve springs. The springs can be fitted with either end toward the cylinder head.
9. Install the retainer cap.
10. Use the valve spring compressor to compress the valve springs and install the retainers. Remove the valve spring compressor.
11. Install the rocker arm assembly.
12. Check the valve clearances. See Valve Clearance Adjustments.
13. Install the valve cover.

NOTE: Valve springs can be changed in two cylinders at a time.

When the piston in cylinder one is at TDC, the piston in cylinder six is also at TDC. When the piston in cylinder two is at TDC, the piston in cylinder five is also at TDC. When the piston in cylinder three is at TDC, the piston in cylinder four is also at TDC.

If the rocker arm assembly was removed before TDC was found, install the valve spring compressor and compress the valve springs to open the valve. Turn the crankshaft by hand in the normal direction until the piston touches the valve. Continue to turn the crankshaft and, at the same time, release the pressure on the valve spring compressor until the piston is at TDC. See Figure 11.

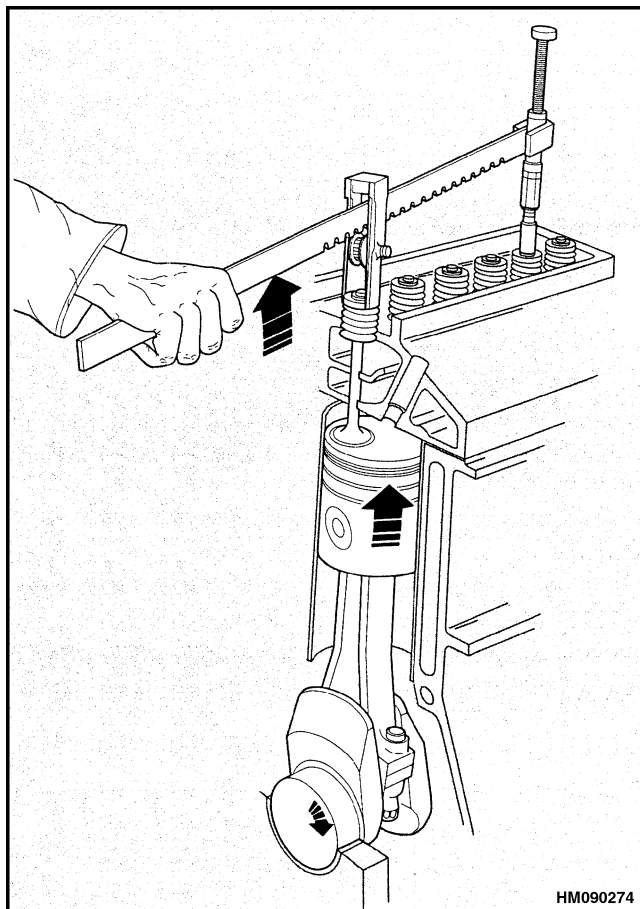


Figure 11. Find TDC With Valve Spring Compressor

CYLINDER HEAD ASSEMBLY

Remove

1. If the engine is still in the lift truck, do the following procedures:
 - a. Disconnect the battery terminals.
 - b. Drain the cooling system.
 - c. Disconnect the sender unit for the coolant temperature gauge.
2. If equipped, remove closed circuit breather unit.
3. Remove the Machine Interface Connector (MIC) connection from the mounting bracket if the mounting bracket is attached to the cylinder head.
4. Remove the air intake hose.
5. Remove the fuel line between the cold start aid in the induction manifold and the fuel filter. Disconnect the electrical connection and electrical connectors from sensors.
6. Disconnect all connections to the turbocharger and remove turbocharger. See Turbocharger, Remove.
7. Remove the induction manifold capscrews.
8. Remove the induction manifold and gasket from the cylinder head. Discard the gasket.
9. Remove exhaust manifold fasteners and the exhaust manifold.
10. Remove the low pressure fuel lines between the fuel injection pump and the fuel filter. Remove the fuel filter bracket and the fuel filters.
11. Remove the high pressure fuel lines. Use a separate wrench to prevent movement of the outlets of the fuel injection pump when the fuel lines are disconnected. Put plugs in the open ports of the fuel injection pump.
12. Remove the fuel injectors from the cylinder head. Keep the fuel injectors clean and prevent damage to the nozzles.
13. If an air compressor is installed, remove the coolant pipe between the cylinder head and the compressor. Remove the coolant pipe between the bypass connection and the compressor.

14. Loosen the hose clamp and remove the coolant bypass hose from the cylinder head. Remove the capscrews and remove the coolant bypass connection and the hose.
15. Disconnect the coolant temperature sender.
16. Remove the valve cover. See Valve Cover, Remove.
17. Remove the rocker arm assembly. See Rocker Arm Assembly, Remove.
18. Remove the push rods.
19. Loosen the capscrews for the cylinder head evenly in a reverse sequence from the sequence shown in Figure 12.

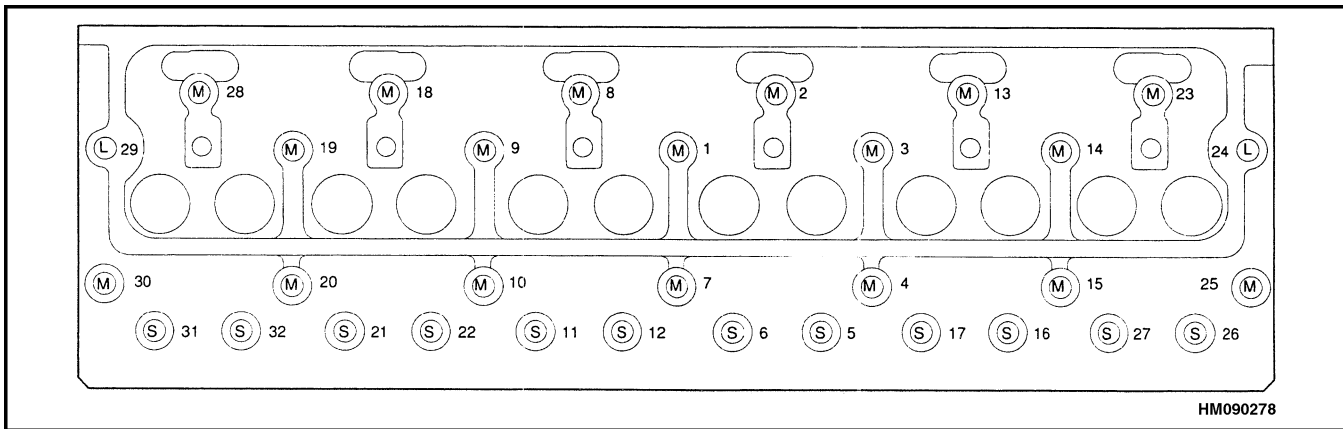


Figure 12. Cylinder Head Tightening Sequence

20. Lift the cylinder head from the engine block. Do not use a pry bar between the cylinder head and the engine block, that can cause damage to the gasket surfaces. See Figure 13.

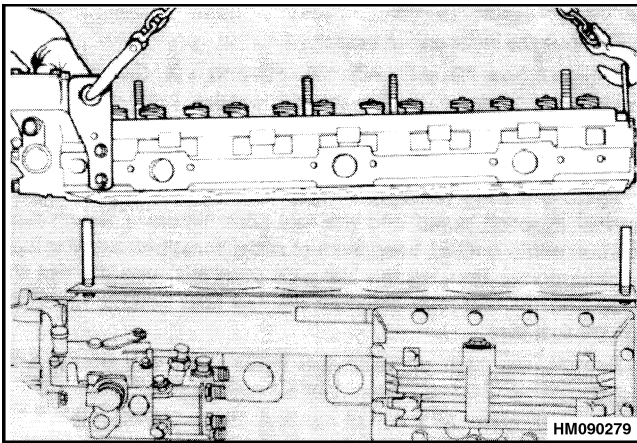
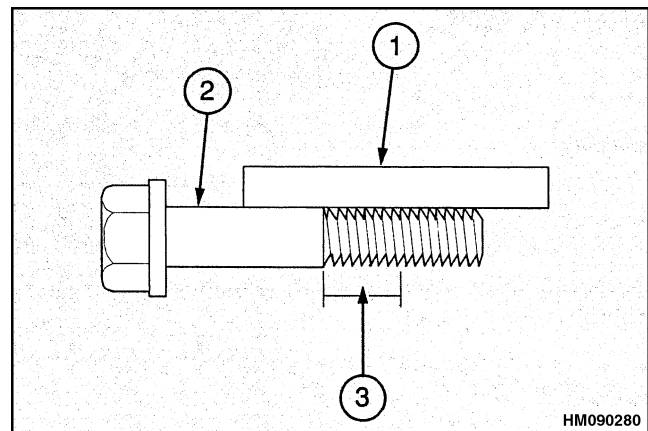


Figure 13. Cylinder Head Removal

21. Inspect the capscrews for the cylinder head with a straightedge. See Figure 14. Check that the capscrews are straight and do not have distortion. If there is a reduction in the diameter of the

thread that has not been in engagement with the cylinder block, the capscrew must be discarded.



1. STRAIGHTEDGE
2. CAPSCREW MUST BE STRAIGHT AND WITHOUT DISTORTION
3. THREADS MUST BE IN GOOD CONDITION AND NOT HAVE A REDUCED DIAMETER

Figure 14. Capscrews Inspection

Install

Special Tools: Angle gauge to tighten the capscrews for the cylinder head

1. Verify the surfaces of the cylinder head and the top of the engine block are clean. Verify that there is no dirt or objects in the cylinders.
2. Install the gasket for the cylinder head as shown in Figure 15. Verify the TOP FRONT is in the correct position. Do not use any gasket sealant on any of the surfaces.
3. Use two 1/2 UNF studs in positions 25 and 30. See Figure 16. Lower the cylinder head into position on the engine block. See Figure 17.

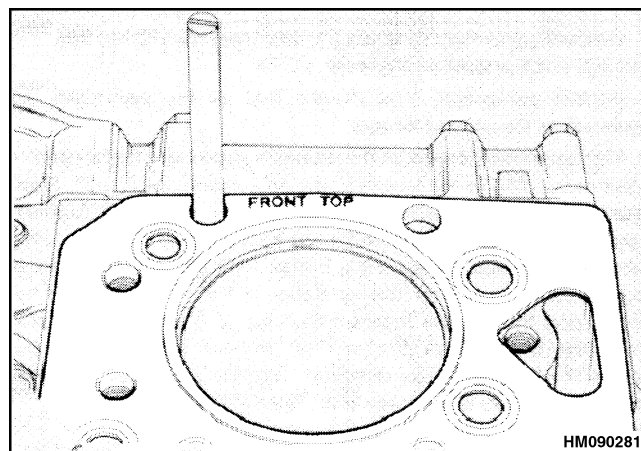


Figure 15. Head Gasket Position

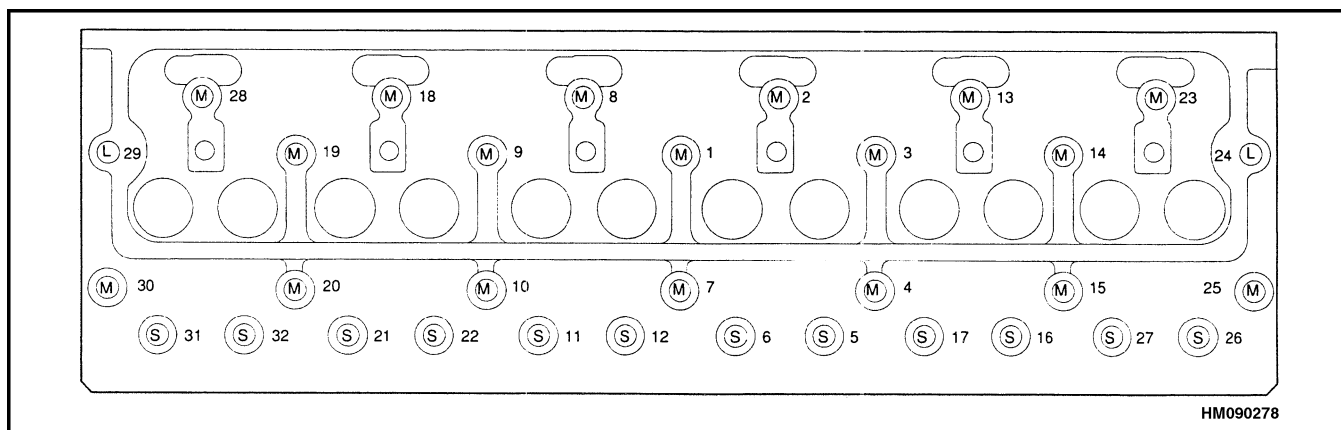


Figure 16. Cylinder Head Tightening Sequence

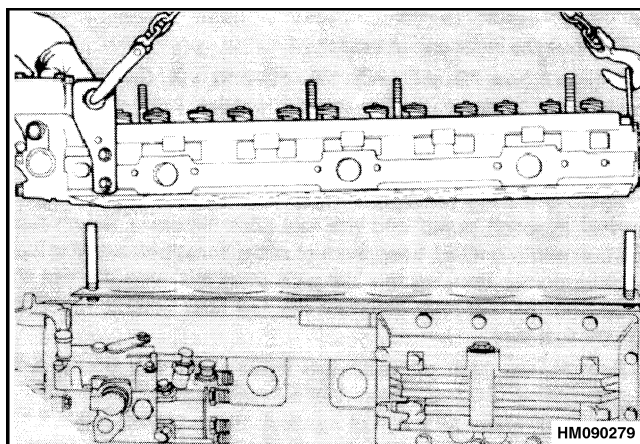


Figure 17. Cylinder Head Installation



CAUTION

There are three lengths of capscrews. S = short, M = medium, L = long. Figure 16 shows their positions in the engine. Verify that the capscrews are installed in the correct positions.

4. Lubricate the capscrews with a thin coat of oil and install them into their holes in the cylinder head. When the cylinder head and gasket are held in position, remove the two studs and install the two capscrews in those positions.
5. Evenly tighten the capscrews in the sequence shown in Figure 16. The final torque on the capscrews is 110 N•m (81 lbf ft).

6. Verify all of the capscrews are tightened to the correct torque described in Step 5. The capscrews must be further tightened in the sequence shown in Figure 16 according to the following procedure:
 - a. The short capscrews (S) must be tightened an additional 150° (2.5 flats).
 - b. The medium capscrews (M) must be tightened an additional 180° (3.0 flats).
 - c. The long capscrews (L) must be tightened an additional 210° (3.5 flats).

NOTE: A special tool shown in Figure 18 can be used for this procedure to measure the tightening angles. If an angle gauge is not available, make a mark in a line with one of the corners of the capscrew. See Figure 19. Make another mark at the correct angle (counterclockwise) on the edge of the flange of the cylinder head for each capscrew and according to the length of each capscrew. Tighten each capscrew in the correct sequence until the two marks are aligned.

7. Install the push rods in the engine. Verify that the end of each push rod fits correctly in the tappet socket.

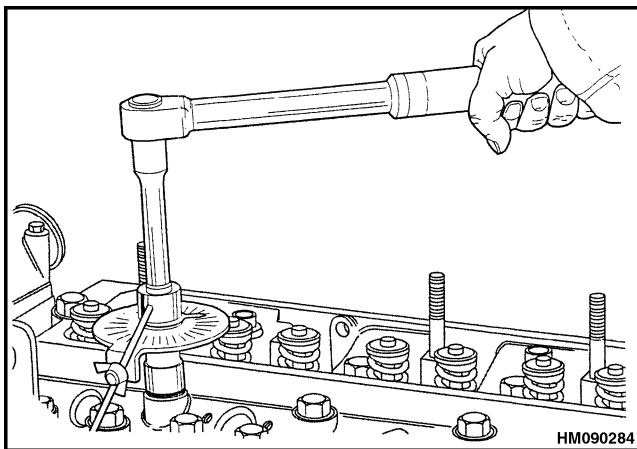


Figure 18. Angle Gauge

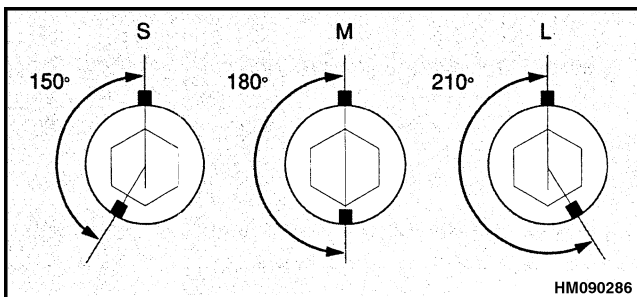


Figure 19. Tighten Cylinder Head Capscrews

8. Install the rocker arm assembly per Rocker Arm Assembly, Install.
9. Adjust the valve clearances per Valve Clearance Adjustments.
10. Install the fuel injectors per Fuel Injectors, Install.
11. Install the high pressure fuel lines between the fuel injection pump and the fuel injectors. Use a separate wrench to prevent movement of the outlets of the fuel injection pump when the fuel lines are connected. Tighten the connection nuts to $27.5 \text{ N}\cdot\text{m}$ (20 lbf ft).
12. Install the fuel filter and bracket. Install the low-pressure fuel lines between the fuel filter and the fuel injection pump.
13. If equipped, reinstall the MIC to the MIC mounting bracket.
14. Install the coolant bypass connection. Tighten the capscrews and the hose clamp.
15. If an air compressor is installed on the engine, install the coolant pipe between the cylinder head and the compressor. Install the pipe between the coolant bypass and the compressor.

NOTE: Do not use sealant compound on gaskets of the manifold.

16. Verify the exhaust manifold gaskets and gasket surfaces are clean and not damaged.
17. Place the temporary studs in the cylinder head.
 - a. For two-piece exhaust manifolds, place temporary studs in positions 4, 8, 11, and 15 of the cylinder head. See Figure 20.

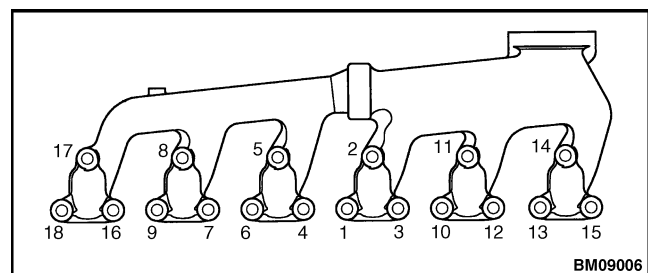


Figure 20. Two-Piece Exhaust Manifold Tightening Sequence

- b. For three-piece exhaust manifolds, place temporary studs in positions 2, 5, 14, and 17 of the cylinder head. See Figure 21.

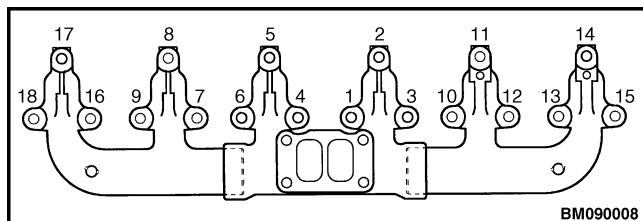


Figure 21. Three-Piece Exhaust Manifold Tightening Sequence

18. Place the exhaust manifold gaskets in position over the studs. Verify the gaskets are in the correct position.
19. Reassemble the sections of the exhaust manifold and place in position over the temporary studs.
20. Insert the capscrews into all positions that do not have temporary studs and torque to 12.5 N•m (9 lbf ft).
21. Remove temporary studs and insert remaining capscrews and torque to 12.5 N•m (9 lbf ft).
22. Torque the capscrews again in sequence to 12.5 N•m (9 lbf ft). See Figure 20 and Figure 21.



CAUTION

Before the inlet manifold capscrews are installed again, any loose M.E.A.S in the cylinder head holes must be removed to allow the manifold to be fully tightened.

Do not scratch or damage the flange faces of the inlet manifold.

NOTE: The capscrews that retain the manifold to the cylinder head have M.E.A.S applied to the threads. If the capscrews are removed and installed again, the threads must be cleaned and POWERPART thread-lock sealant used.

23. Place a new induction manifold gasket into position on the cylinder head.
24. Place the induction manifold in position on the cylinder head.

25. Install the induction manifold capscrews and torque in sequence to 22 N•m (16 lbf ft). See Figure 22.

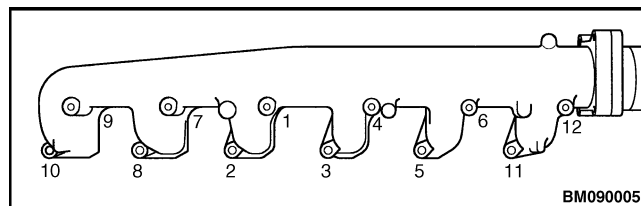


Figure 22. Induction Manifold Tightening Sequence

26. Install the fuel line between the fuel filter and the cold start aid. If the engine is in the lift truck, install the electrical connection to the cold start aid.
27. Install the air intake hose.
28. Install the turbocharger. See Turbocharger, Install.
29. Install the closed circuit breather assembly if previously removed.
30. Install the fuel lines between the fuel filter and the fuel injection pump.
31. If the engine is still in the lift truck, do the following procedures:
 - a. Connect the sender unit for the coolant temperature gauge.
 - b. Connect the hoses for the coolant system. Fill the cooling system.
 - c. Connect the battery terminals.
 - d. If the engine is ready to operate, remove the air from the fuel system. See the procedure described in Fuel System Air Removal.
32. When the engine can be started, run it at low speed. Check that oil flows from the holes in the rocker arms. If the oil flow is correct, install the valve cover. See Valve Cover, Install.

NOTE: It is not necessary to tighten the cylinder head capscrews again with the engine hot or after a limited period of service.

VALVES AND VALVE SPRINGS

Special Tools: Valve spring compressor
Stud adapter
Setscrew adapter

Remove

1. Remove the cylinder head. See Cylinder Head Assembly, Remove.
2. Clean the bottom face of the cylinder head and check the depth of the heads of the valves below the face of the cylinder head. See Figure 23.

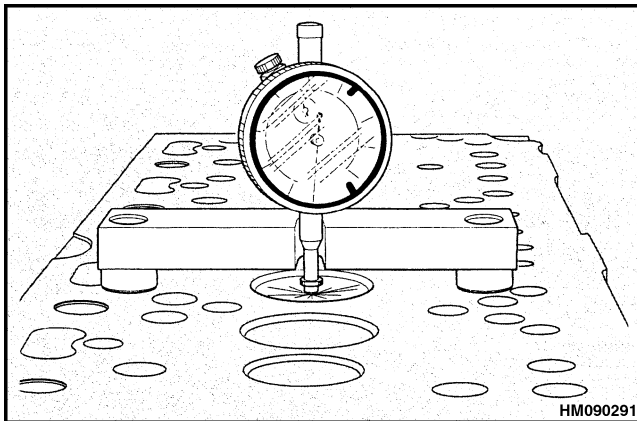
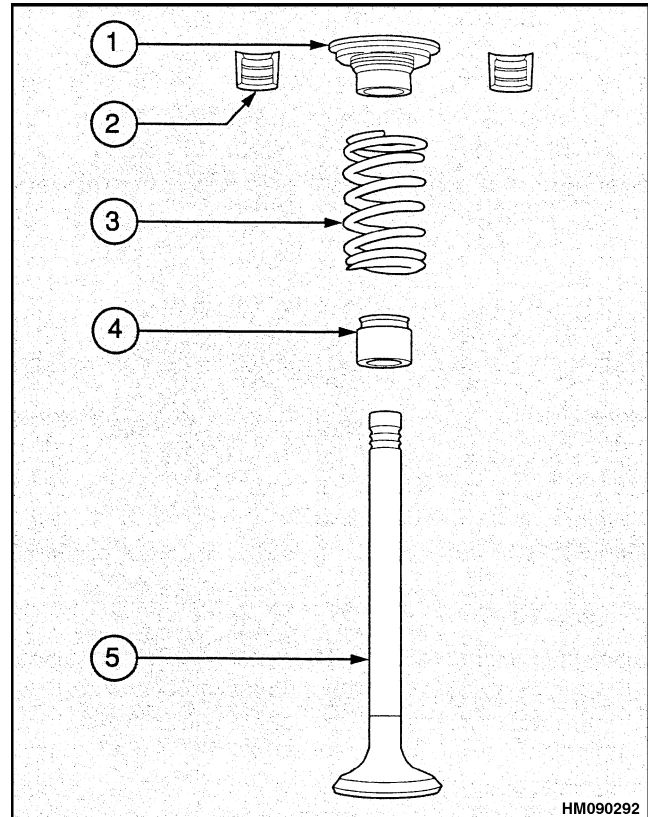


Figure 23. Valves Depth Check

3. Check the depth of the valves below the face of the cylinder head before the valve springs are removed. Put the dial indicator and fixture or other measuring tool on the face of the cylinder head and set the gauge to zero. Carefully put the dial indicator over the head of each valve and make a note of the measurement. The maximum service depth is shown in the Engine Specifications. If a valve is below the depth limit, remove the valve and install a new valve in that position. If the valve depth is still below the limit, the valve seat must be replaced. See New Valve Seats, Install.
4. If the valves will be used again, make a mark on each valve head so that they can be installed again in the same positions.
5. Use the valve spring compressor and the correct adapter to compress the valve springs and remove the retainers. Verify the valve springs are compressed parallel to the valve stems, or the valve stems can be damaged. See Figure 24.



- | | |
|---------------|--------------------|
| 1. CAP | 4. VALVE STEM SEAL |
| 2. COLLET (2) | 5. VALVE |
| 3. SPRING | |

Figure 24. Valve Components

6. Release the valve stem compressor. Remove the valve spring cap, valve springs, and seal.
7. Repeat Step 5 and Step 6 to remove the other valves.

Inspect

1. Check the valves for cracks. Check the stems of the valves for wear and the correct clearance in their valve guides. See Valve Guides.
2. Check that the seat faces of the valves are not badly burned. Seat faces of valves that are damaged, but can be repaired, must be checked for valve depth when they are installed. See Figure 23. When new valves are installed, the valve depth must be checked.
3. Check that the load on the valve springs is correct at their installed length. See Engine Specifications.

4. Install new valve springs during a complete overhaul of the engine.

Install

1. Lubricate the valve stems with engine oil when they are installed in their valve guides.



CAUTION

The outer diameter of the exhaust valve guide is 1 mm (0.039 in.) larger than the inlet valve guide. To prevent leakage past the inlet valve stem it is important that the larger valve seal is not installed into the inlet guide. The seals are color coded.

2. Install new seals on the valve guides. Verify that the brown seal is installed on the exhaust valves and the green seal is installed on the inlet valves.
3. Install the inner and outer valve springs on the seat washer. The springs can be installed with either end to the cylinder head.
4. Use the valve spring compressor and the correct adapter to compress the valve springs. Install the retainers. Verify the valve springs are compressed parallel to the valve stems or the valve stems can be damaged.
5. Repeat the installation procedure for each valve.

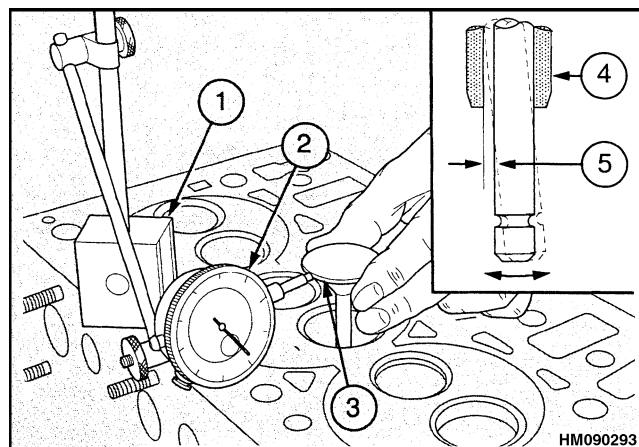
VALVE GUIDES

Inspect

1. Check the valve guides for wear. The maximum clearance between the valve stem and the bore of the guide is 0.100 mm (0.004 in.) for inlet valves and 0.121 mm (0.005 in.) for exhaust valves. If the clearance is greater than the limit when a new valve is installed, the valve guide must be replaced.
2. The following procedure is for checking the valve guides (see Figure 25):
 - a. Put a new valve into the valve guide.
 - b. Install a dial indicator on the cylinder head.
 - c. Lift the head of the valve approximately 15 mm (0.6 in.) above its seat. Move the

valve head away from the plunger of the dial indicator and set the dial indicator to zero.

- d. Move the valve toward the dial indicator and make a note of the movement. If the reading is equal to or greater than the maximum clearance, a new valve guide must be installed.



- | | |
|-------------------|----------------------|
| 1. MAGNETIC BASE | 4. VALVE GUIDE |
| 2. DIAL INDICATOR | 5. MAXIMUM CLEARANCE |
| 3. VALVE HEAD | |

Figure 25. Valve Guides Check

NOTE: The partially finished valve guides are reamed and the valve seats are cut in one operation with a special tool. This is done to ensure the concentricity of the valve seat to the valve guide and provide a good seal between the guide and its seat. New valves and valve seat inserts must be installed each time a new valve guide is used.

Remove

Install the tool for removal and replacement and the adapter on the valve guide. Pull the valve guide from the cylinder head. See Figure 26.

Install

1. Verify the bore in the cylinder head is clean.
2. Lubricate the outer surface of the new valve guide with engine oil.

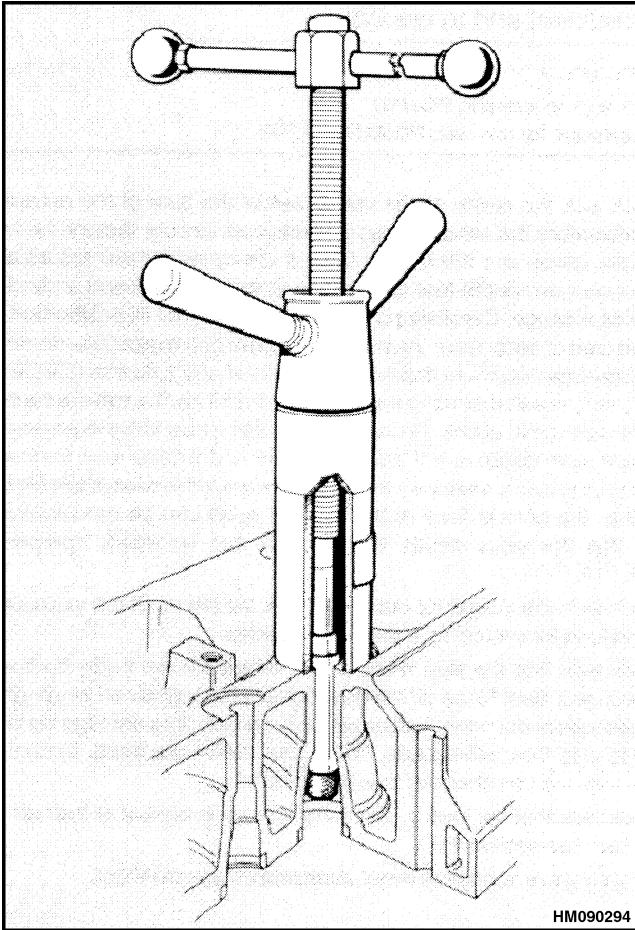


Figure 26. Valve Guide Removal

3. Install the valve guide on the special tool. See Figure 27. Use the special tool to pull the valve guide into the cylinder head. When the valve guide is correctly installed, the valve guide will extend 14.85 to 15.15 mm (0.585 to 0.596 in.) above the seat of the valve spring.

CYLINDER HEAD AND VALVE SEATS

Inspect

The cylinder head must be removed and the valves must be removed from the cylinder head before the valve seats can be inspected and repaired. Carefully clean the cylinder head.

1. Check the cylinder head for cracks. Carefully check the areas around the valve seats and around the holes for the fuel injectors.

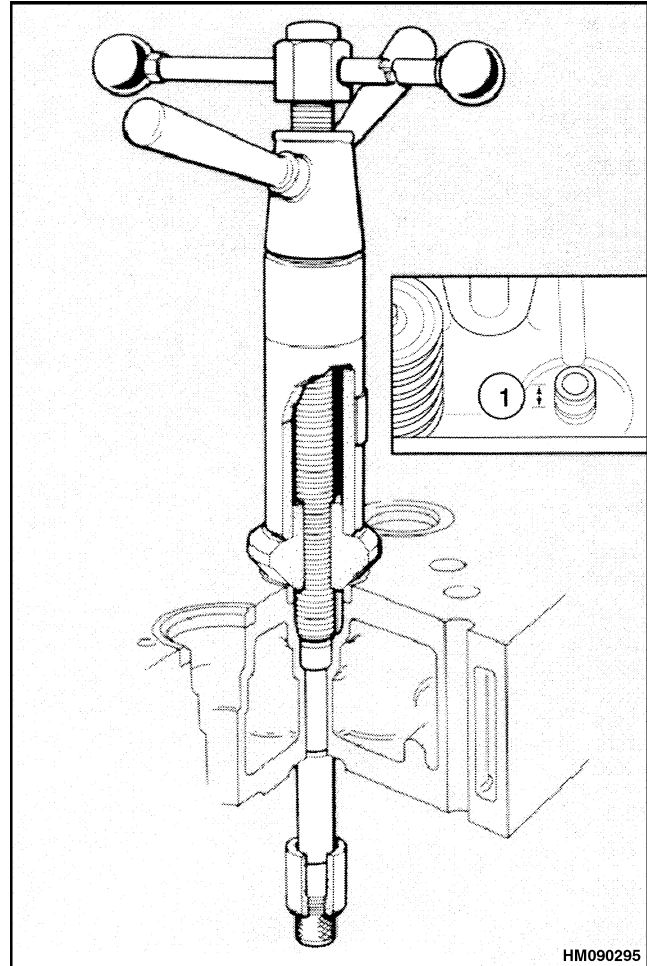


Figure 27. Valve Guide Installation

1. 14.85 to 15.15 mm (0.585 to 0.596 in.) ABOVE SEAT OF VALVE SPRING
2. Use a straightedge and spacer gauges to check the cylinder head for distortion across and along its face that joins the engine block. See Engine Specifications. If the distortion is more than the specifications, the face can be machined. Remove only the minimum metal so that the thickness of the cylinder head will not be less than 102.79 mm (4.047 in.) after the cylinder head has been machined.

NOTE: After the cylinder head has been machined, the valve seats must be checked for the correct depth. See Valves and Valve Springs, Inspect. If the depth of the valve seats must be increased, use the minimum limit to allow for later wear.

3. Check the valve seats for wear and damage. Before any work is done on the valve seats, verify

the valve guides are good. See Valve Guides, Inspect for inspection and replacement.

4. Damaged valve seats can be repaired with a cutter tool. See Figure 28. If the valve seat cannot be repaired so that the valve depth is within the specifications, the valve seat must be replaced.

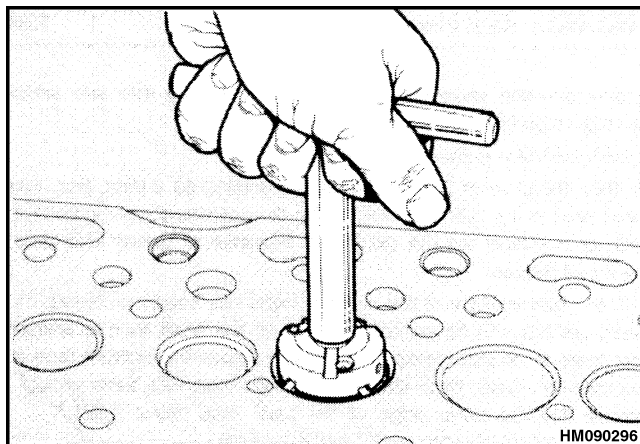


Figure 28. Valve Seats Cutter

Repair

Special Tools: Cutter for inlet valve seats
 Cutter for exhaust valve seats
 Valve guides reamer

1. Install the correct cutter into the valve seat that is to be repaired. Carefully turn the cutter in a clockwise direction. Remove only the minimum metal to repair the valve seat. Keep the valve seat as narrow as possible.
2. When the valve seat has been cut, remove the cutter and pilot. Clean the port area and remove any particles.

3. Check the valve depth. See Valves and Valve Springs, Inspect. If the valve seat is badly damaged or worn, replace the valve seat as described in the following paragraphs.

New Valve Seats, Install

1. Remove the valve guide. Clean the bore and install a new valve guide. See Valve Guides for inspection and replacement.
2. Use the bore of the new valve guide as a pilot and use a milling machine to remove the old valve seat. See the Engine Specifications. Clean the particles from the port and the area where the new valve seat will be installed.
3. If the bottom face of the cylinder head has been machined, the back face of the new valve seat must be machined so that it will not extend above the surface of the cylinder head. If the back face of the valve seat is machined, verify that the dimensions of the outer edge of the back face are within the Engine Specifications.
4. Use the bore of the valve guide as a pilot. Use a press to install the valve seat into the cylinder head. Verify the valve seat is fully inserted into the cylinder head.
5. Use a cutter to cut the valve seat at the correct angle. Check the valve depth as shown in Figure 23. Verify that the dimensions are within the Engine Specifications.

Piston and Connecting Rod Assemblies Repair

The connecting rods are forged from steel. The piston height is controlled by the length of the connecting rod. Each piston and connecting rod is matched to a cylinder during assembly to verify the piston height is correct for combustion efficiency to meet emission standards.

The manufacturer uses six length grades of connecting rods during assembly to give the correct piston height. These six length grades are made by machining the small-end bushing a small amount off-center.

Connecting rods for service replacement are available in two length grades.

The combustion chamber is machined into the top of the piston. See Figure 29. The pistons have two compression rings and an oil control ring. The groove for the top compression ring has a hard metal insert to reduce wear in the groove. The piston skirt has a layer of graphite to reduce wear.

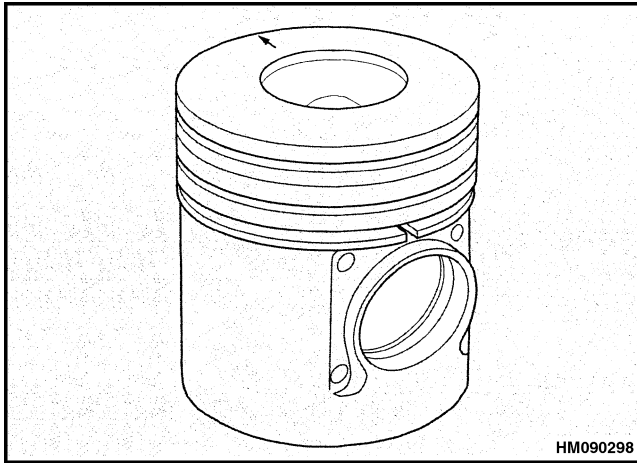
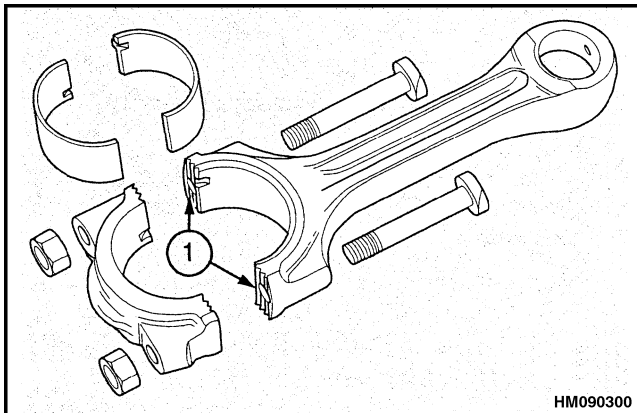


Figure 29. Piston

ROD BEARINGS

The engine has grooves (serrations) that are machined in the joint faces of the connecting rod and bearing cap to keep alignment between the two parts. The bearing cap is fastened to the connecting rod with two nuts and special bolts. See Figure 30.

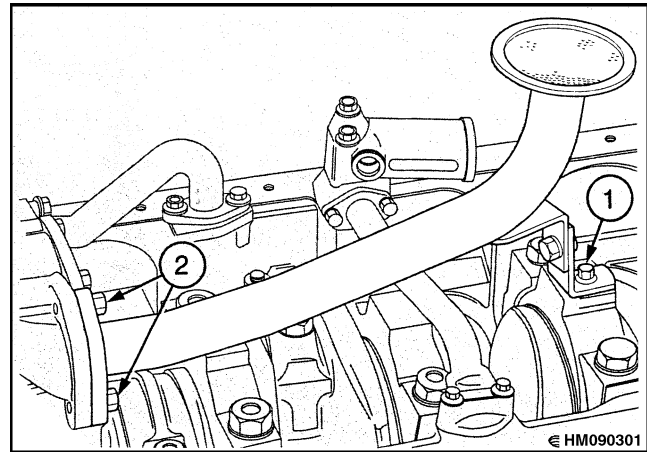


1. SERRATIONS

Figure 30. Connecting Rod Assembly With Serrations

Remove

1. Drain the engine oil from the sump. Remove the oil sump. See Oil Sump, Remove.
2. Remove the suction pipe and oil strainer. See Figure 31. Remove the capscrew that holds the bracket to the main bearing cap. Remove the two capscrews from the flange of the suction pipe and remove the suction pipe and screen. Clean the faces of both flanges.



1. SUPPORT BRACKET, MAIN BEARING CAP
2. CAPSCREWS, FLANGE, SUCTION PIPE

Figure 31. Sump Screen Removal

3. Turn the crankshaft until the connecting rod to be removed is at the lowest position on the crankshaft.



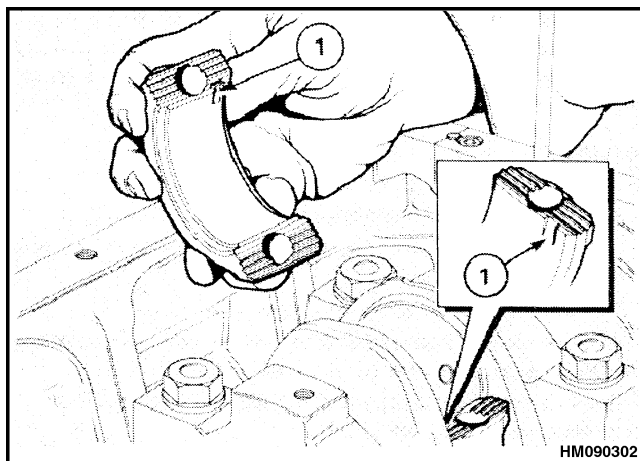
CAUTION

Do not permit the connecting rods to hit the cooling jets for the pistons. If a cooling jet is hit, the alignment must be checked and the cooling jet replaced if necessary.

4. Remove the nuts and remove the bearing cap.
5. Remove the lower bearing half from the bearing cap. Keep the bearing half with its cap.
6. Carefully push the connecting rod up the cylinder bore just enough to permit access to the upper bearing half. Remove the upper bearing half from the connecting rod. Keep the bearing halves together.

Install

1. Clean the bearing surfaces of the connecting rod and the crankshaft. Clean the bearing halves and lubricate them with clean engine oil.
2. Install the upper bearing half into the connecting rod. Verify that the location tab is installed correctly into its position in the connecting rod. See Figure 32.



1. POSITION OF LOCATION TAB IN BEARING HALF AND CONNECTING ROD

Figure 32. Rod Bearings Position

3. Install the bearing cap on the connecting rod. Verify that the assembly number on the bearing cap is the same as the assembly number on the connecting rod. Verify that the two assembly numbers are on the same side of the connecting rod as shown in Figure 33.

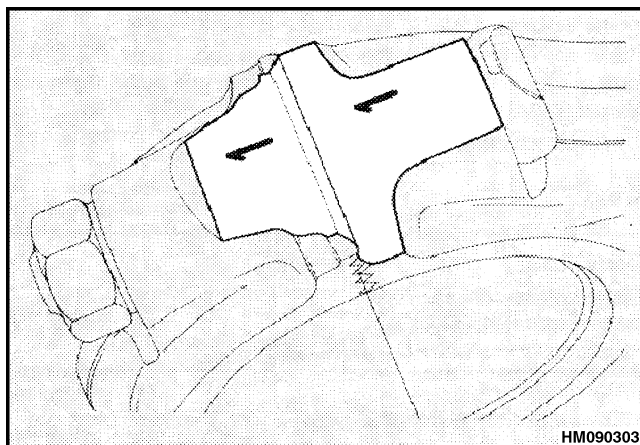


Figure 33. Bearing Cap Position, Connecting Rod

NOTE: New nuts must be installed with the bolts that secure the cap.

4. Install and tighten the nuts evenly to a torque of 125 N•m (92 lbf ft). Verify that the crankshaft turns freely.
5. Loosely assemble the bracket of the suction pipe to the main bearing cap. Install a new gasket and fasten the flanges of the suction line to the oil

pump. Verify that the suction pipe is aligned correctly and then tighten the capscrew that holds the bracket to the main bearing cap.

6. Install the oil sump. See Oil Sump, Install.

PISTON AND CONNECTING ROD ASSEMBLY

Service Note

If a piston must be replaced, verify that the piston has the same length grade. An H or an L is stamped into the top of the piston. See Figure 34. A production piston does not have an H or an L mark. The piston height must be checked after installation. See the procedure described in Install.

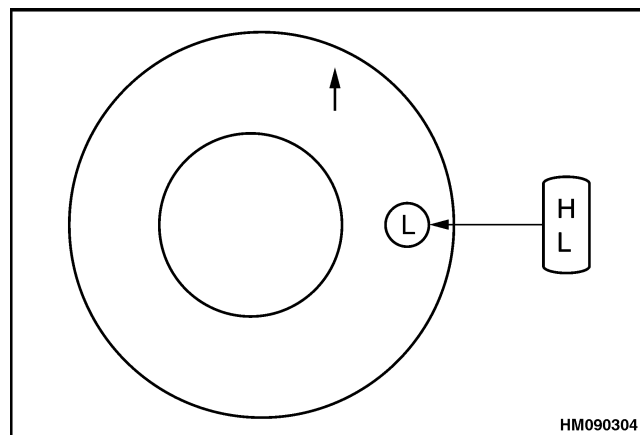


Figure 34. Piston Grade Mark

Remove

1. If the engine is still in the lift truck, drain the engine oil and the coolant.
2. Remove the cylinder head assembly as described in Cylinder Head Assembly, Remove. Remove the carbon from the tops of the bores of the cylinder liners.
3. Remove the oil sump. See Oil Sump, Remove.
4. Remove the suction line and oil strainer. See Figure 31. Remove the capscrew that holds the bracket to the main bearing cap. Remove the two capscrews from the flange of the suction line and remove the suction line and screen. Clean the faces of both flanges.
5. Remove the bearing cap and rod bearings as described under Rod Bearings, Remove. Mark the

bearing caps and rod bearings so that they can be installed again in their original positions.



CAUTION

Do not permit the connecting rods to hit the cooling jets for the pistons. If a cooling jet is hit, the alignment must be checked and the cooling jet replaced if necessary.

6. Push the piston and connecting rod out of the top of the cylinder liner.
7. Inspect the bearing surfaces on the crankshaft for damage.

Install

Special Tools: Piston installation tool (piston ring compressor)
 Piston height tool
 Dial indicator gauge

1. Verify all of the parts are clean. Lubricate the parts with engine oil as they are installed.
2. Turn the crankshaft until the position for the connecting rod to be installed is at the lowest position on the crankshaft.
3. Install the upper bearing half into the connecting rod. Verify that the location tab is installed correctly into its position in the connecting rod. See Figure 32.
4. Put the piston installation tool at the top of the cylinder. See Figure 35. The tool has a bore with a taper to compress the piston rings when the piston and connecting rod assembly is installed. Verify the smaller end of the taper is toward the cylinder block.
5. Put the open gaps in the three piston rings so that the gaps are 120° apart. Put the connecting rod through the piston installation tool and permit the piston to enter the tool. The piston and connecting rod must be turned so that the connecting rod does not hit the cooling jet for the piston.
6. When the connecting rod has passed the cooling jet during installation, the arrow or FRONT mark on the piston must be turned toward the front of the engine. See Figure 36.

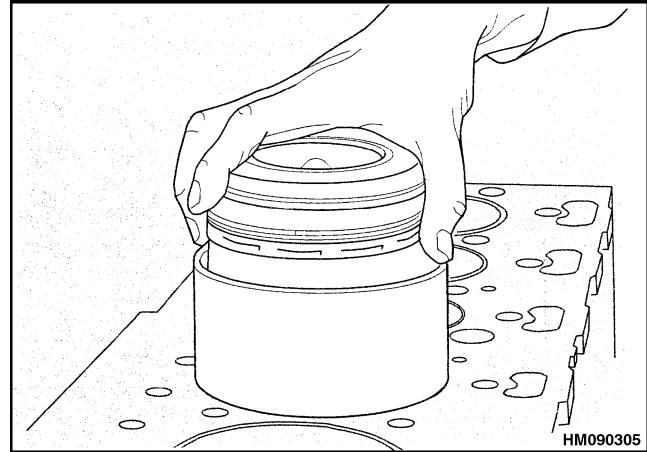


Figure 35. Piston Installation Tool

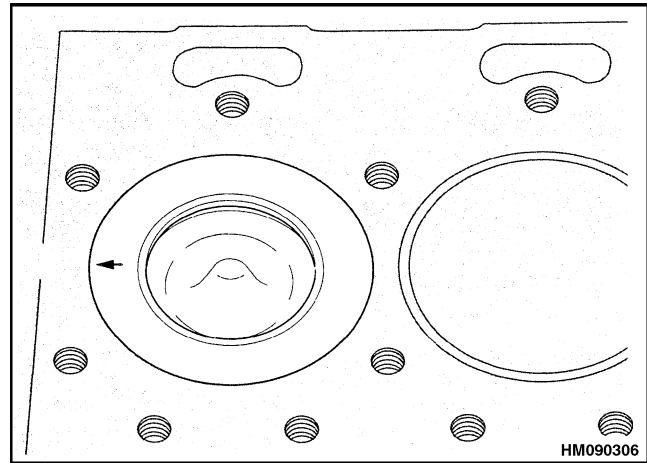


Figure 36. Piston in Bore Position

7. Lubricate the lower half of the rod bearing and install it into the bearing cap.
8. Install the bearing cap on the connecting rod. Verify that the assembly number on the bearing cap is the same as the number on the connecting rod. Verify that the two assembly numbers are on the same side of the connecting rod as shown in Figure 33.

NOTE: New nuts must be installed with the bolts that secure the cap.

9. Install and tighten the nuts evenly to a torque of 125 N•m (92 lbf ft). Verify that the crankshaft turns freely.
10. Measure the height of the piston above the top of the engine block with a dial indicator gauge. The crankshaft must be turned so that the piston is at TDC in the engine block. Put the dial indicator on the top of the engine block and measure the

height of the piston above the face of the engine block. See Figure 37.

The correct height of the piston above the engine block is 0.36 to 0.50 mm (0.014 to 0.020 in.). **The tops of the pistons must not be changed or machined.**

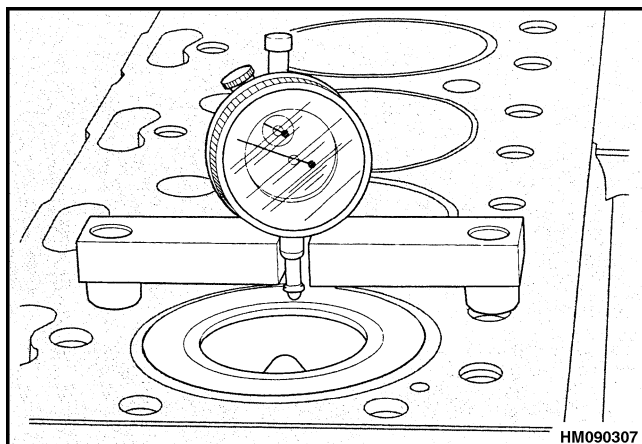


Figure 37. Piston Height Above Engine Block Measurement

11. Loosely assemble the bracket of the suction pipe to the main bearing cap. Install a new gasket and fasten the flanges of the suction pipe to the oil pump. Verify that the suction pipe is aligned correctly and tighten the capscrew that holds the bracket to the main bearing cap.
12. Install the oil sump. See Oil Sump, Install.
13. Install the cylinder head. See Cylinder Head Assembly, Install.

PISTON RINGS

Remove

1. Check that the piston rings can move freely in their grooves and are not broken.
2. Remove the piston rings with a ring expander. Increase the diameter of the piston rings only enough to remove them without damaging the piston.

Inspect

1. Check the piston for wear and damage.

2. Clean the carbon from the top of the cylinder liners. Fit the piston rings in the top part of the cylinder liner and measure the clearance at the ends of the ring. See Figure 38. The spring must be installed in the oil control ring when its end clearance is measured. The clearance measurements for the piston rings are shown in the Engine Specifications.

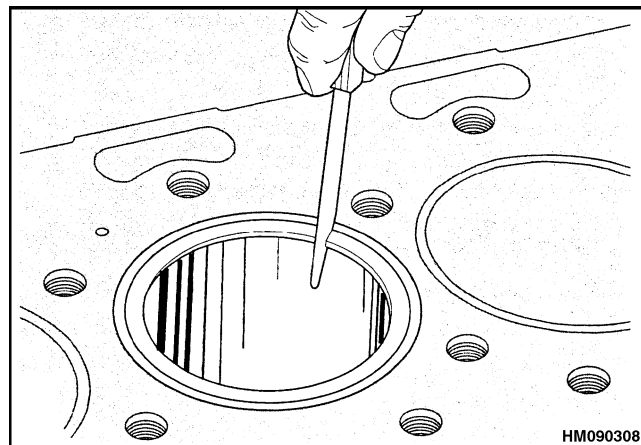


Figure 38. Piston Ring End Clearance Check

3. Install new piston rings on the piston and check the clearance in the grooves with a spacer gauge. See Figure 39. If the clearance between the piston rings and the piston are greater than the specifications, the piston must be replaced. See the Engine Specifications. The clearance in the top groove of the pistons for these engines cannot be checked because it has a taper.

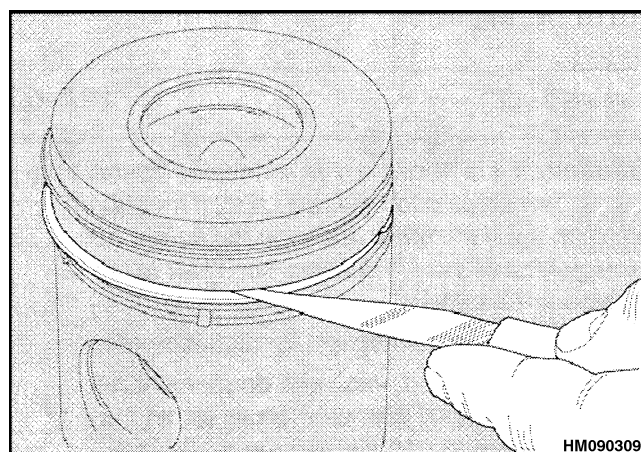


Figure 39. Piston Ring Clearance Check

Install

Install the piston rings with a ring expander. Increase the diameter of the piston rings only enough to install them without damaging the piston.

1. Install the spring for the oil control ring in the bottom groove of the piston. See Figure 40. Install the latch pin inside both ends of the spring. See Figure 41. Install the oil control ring over the spring so that the end space in the oil control ring is 180° to the latch pin.

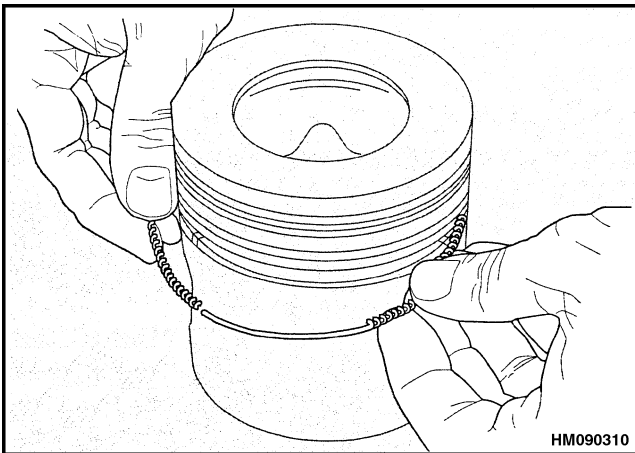
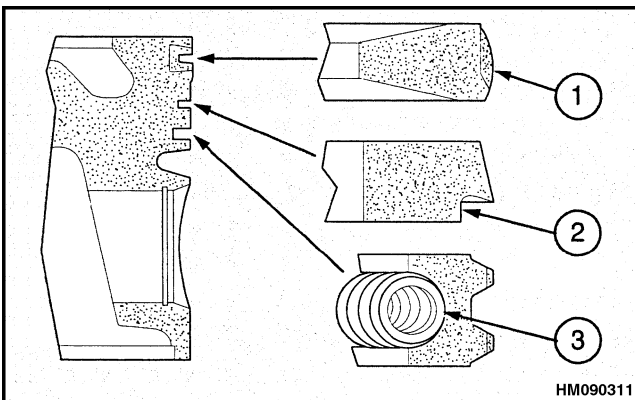


Figure 40. Spring Installation for Oil Control Ring



- | | |
|----------------|--------------------------------|
| 1. TOP RING | 3. OIL CONTROL RING AND SPRING |
| 2. SECOND RING | |

Figure 41. Piston Rings Installation



CAUTION

Verify that the word **TOP** or the manufacturer's symbol is toward the top of the piston. New piston rings have a red identification mark which must be on the left of the clearance space at the ends of the ring when the

ring is installed on the piston and the piston is upright.

2. Install the cast iron ring with the taper into the second groove of the piston. Verify that the word **TOP** or the manufacturer's symbol is toward the top of the piston. New piston rings have a green identification mark which must be on the left of the clearance at the ends of the ring when the ring is installed on the piston and the piston is upright.
3. Install the tapered (top ring) with the **TOP** toward the top of the piston.
4. Check that the open gaps of the piston rings are spaced 120° apart before installing the piston.

PISTON AND CONNECTING ROD

Disassemble

1. Remove the piston rings as described in Piston Rings, Remove.
2. Make a mark on the piston to indicate the cylinder number as shown on the connecting rod. Make the mark on the same side of the piston as the number on the connecting rod. See Figure 42.
3. Remove the snap rings that hold the piston pin in the piston. Push the piston pin from the piston with your thumb. If the piston pin is tight, heat the piston and connecting rod to 40 to 50°C (104 to 122°F) to make removal of the piston pin easier.

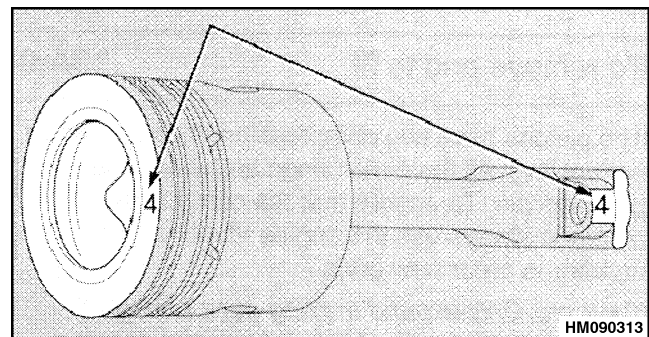
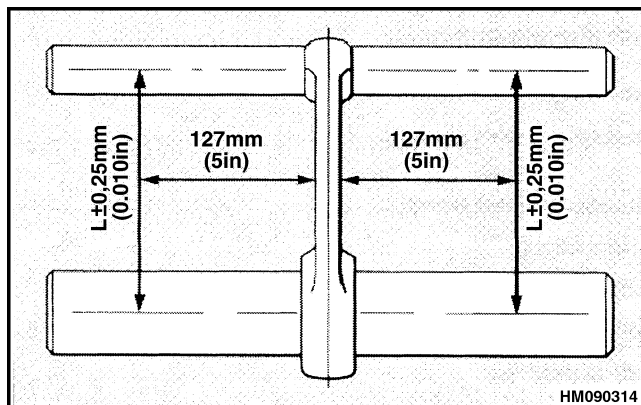


Figure 42. Marking Piston

Inspect

1. Clean and inspect all the components for wear and damage. Check the alignment of the connecting rod with a test mandrel. See Figure 43.



NOTE: THE LARGE AND SMALL BORES IN THE CONNECTING ROD MUST BE SQUARE AND PARALLEL WITH EACH OTHER WITHIN THE LIMITS OF ± 0.25 mm (0.010 in.). THE MEASUREMENT IS MADE AT 127 mm (5.0 in.) ON EACH SIDE OF THE AXIS OF THE CONNECTING ROD. IF THE BUSHING IS INSTALLED IN THE SMALL END OF THE CONNECTING ROD, THE LIMITS ARE REDUCED TO ± 0.06 mm (0.0025 in.).

Figure 43. Connecting Rod Alignment Check

2. Check the clearance of the bushing in the connecting rod with the piston pin. If the clearance is greater than 0.044 mm (0.0017 in.) or is damaged, install a new bushing.

NOTE: Connecting rod kits are available with a new small-end bushing installed and finished to the correct grade. Refer to How to Select Correct Replacements to identify the correct rod grade.

A partially finished small-end bushing, which can be installed in the original connecting rod and machined to obtain correct length grade, is also available.

3. If the bushing in the connecting rod is worn, use a press to remove the bushing.
4. Clean the parent bore of the connecting rod and remove any sharp edges.



CAUTION

Do not use a reamer to machine the partially finished bushing. Special equipment and trained personnel are needed.

5. Use a press to install a partially machined bushing in the connecting rod. Verify that the lubrication hole in the bushing is aligned with the lubrication hole in the connecting rod.

NOTE: The small end is wedge shaped. After the small end bushing has been installed, machine the bushing to the shape of the small end and remove any sharp edges.

6. Machine the partially finished bushing to obtain the correct connecting rod grade.



CAUTION

Do not use a letter stamp to mark the connecting rod.

7. Check that the grade letter on the connecting rod is correct. If necessary, delete the letter and etch a new letter on the side of the rod.

How to Select Correct Replacements



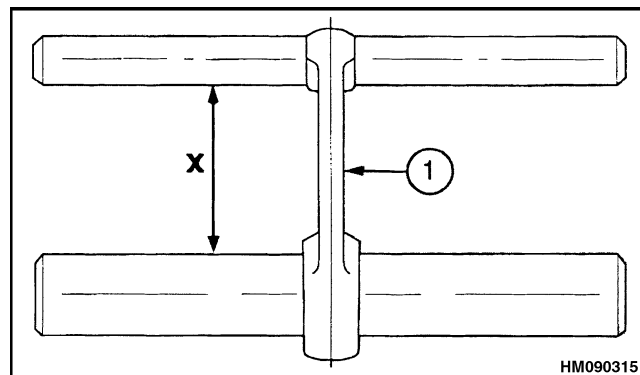
CAUTION

It is important that the piston does not contact the cylinder head. Ensure that the piston height above the cylinder block is correct.

Check that the connecting rods are fitted in the correct cylinder. Record the position of the connecting rod and its relevant cylinder when it is removed from the engine.

To check that the piston height above the cylinder block is correct, the engine may have up to six length grades (F to L) of connecting rods fitted.

Identification of the length grade is by a letter or color which is marked on the side of each connecting rod. See Figure 44. The letter F is the longest grade of connecting rod and letter L is the shortest grade. The difference between grades is 0.046 mm (0.0018 in.).



1. CONNECTING ROD

Figure 44. Rod Bearings Position

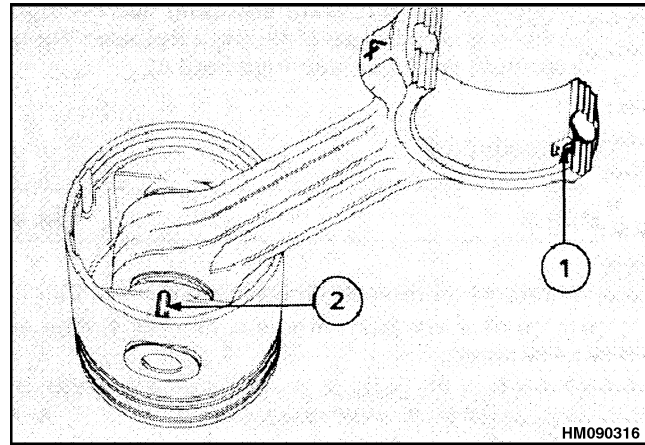
If the grade letter or color on the side of the connecting rod cannot be seen, the length can be checked by the measurement of the dimension (x) shown in Figure 44. Before the length of the connecting rod is measured, check that the bores of the big end and the small end are square and parallel. See Figure 43. The length is checked with the big end bearing removed and the original small end bush fitted. The dimensions for each grade are listed in the table that follows.

Length Letter	Color Code	Length
F	Red	165.728 to 165.761 mm
H	White	165.637 to 165.670 mm
J	Green	165.591 to 165.624 mm
K	Purple	165.545 to 165.578 mm
L	Blue	165.499 to 165.532 mm

Install

1. Verify that the parts are clean. Lubricate the parts with engine oil as they are assembled.
2. Install a new snap ring into one of the grooves to hold the piston pin.
3. Turn the piston for access to install the connecting rod. Install the connecting rod in position in the piston. If the original piston is to be installed again, verify that the mark on the piston is aligned with the mark on the connecting rod as shown in Figure 42. Verify that the piston and connecting rod are installed in the same cylinder again.
4. If a new piston or connecting rod is being installed, verify that index slot in the connecting rod for the rod bearing is on the same side of the

piston as the Iboss for the piston pin. See Figure 45.



1. INDEX SLOT FOR BEARING
2. IBOSS FOR PISTON PIN

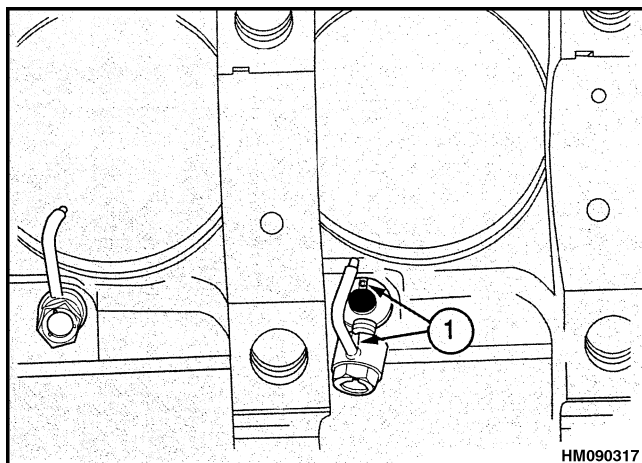
Figure 45. Piston and Connecting Rod Orientation

5. Install the piston pin to fasten the connecting rod to the piston. If the piston pin is tight, heat the piston to 40 to 50°C (104 to 122°F) to make installation of the piston pin easier.
6. Install the other snap ring to hold the piston pin in the piston.
7. Install the piston rings as described in Piston Rings, Install.

PISTON COOLING JETS

Remove

Release the valve assembly and remove the piston cooling jet. The crankshaft has been removed in Figure 46 to show the piston cooling jet.

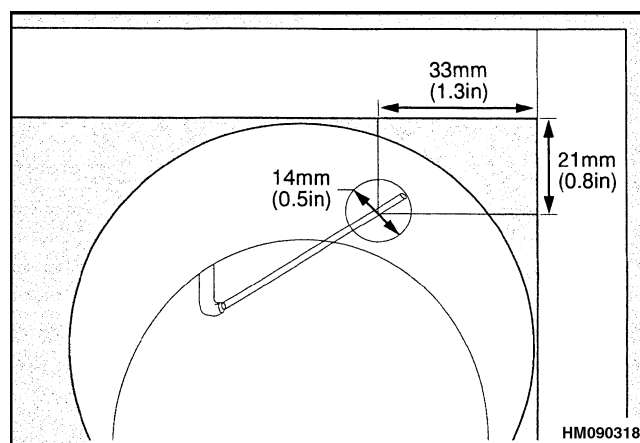


1. ALIGNMENT DOWEL

Figure 46. Piston Cooling Jet**Install**

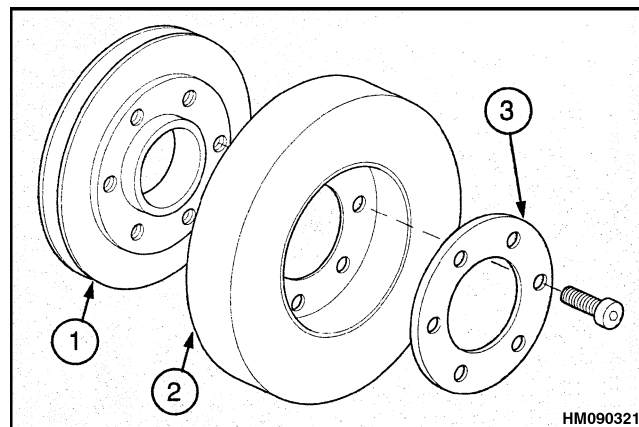
1. Check that the ball assembly moves freely against the spring pressure in the valve assembly and that the jet tube is not damaged. Replace any damaged or worn parts.
2. Install the cooling jet. Verify that the assembly is installed correctly on the alignment dowel in the cylinder block. Tighten the valve assembly to 27 N•m (21 lbf ft).

3. Check the alignment of the cooling jet. Insert a 1.70 mm (0.067 in.) rod into the nozzle of the cooling jet. The length of the rod must extend out of the top of the cylinder. If a rod of the correct diameter is not available, grind one end of a thicker rod to the 1.70 mm (0.067 in.) diameter for a length of 16.00 mm (0.630 in.) so that it will fit into the nozzle of the cooling jet. See Figure 47 for checking the alignment of the cooling jet.

**Figure 47. Piston Cooling Jet Alignment****Crankshaft Assembly Repair****GENERAL**

The crankshaft is forged from chrome-molybdenum steel. The center main bearing is the thrust bearing that controls the axial movement of the crankshaft. The thrust bearing has thrust washers on both sides of the bearing. The main bearings are an alloy of tin and aluminum. The center main bearing is a lead and bronze alloy. The main bearing caps are made of cast iron or spheroidal graphite (SG) iron. The front and rear oil seals are lip seals with an additional dust seal outside of the main lip and oil return grooves on the face of the main lip.

The location of the front pulley is by a key in the crankshaft nose and the pulley is held in position by a tapered rings arrangement. See Figure 48.



1. CRANKSHAFT PULLEY
2. VISCOUS DAMPER
3. TAPERED RING

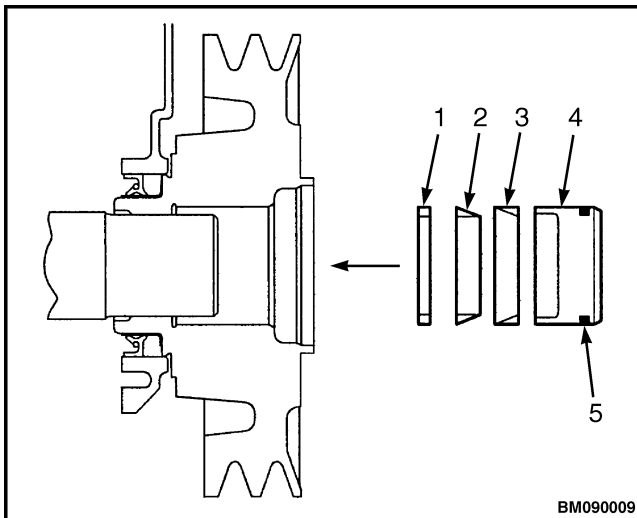
Figure 48. Crankshaft Pulley Arrangement

These engines have a viscous damper which is fastened to the front or rear face of the pulley. See Figure 48. All dampers are designed for the suppression of torsional vibrations in the engine crankshaft.

CRANKSHAFT PULLEY

Remove

1. Remove the drive belts.
2. Remove the three capscrews which hold the pulley to the crankshaft. See Figure 49. Remove the thrust block. If the crankshaft pulley will not slide from the crankshaft, DO NOT use a puller to remove the pulley. Hold a wood block against the inner hub of the pulley and lightly hit the wood block with a hammer. See Figure 50. This action will loosen the inner ring and outer ring so that the pulley can be removed from the crankshaft as shown in Figure 49.



- | | |
|----------------|-----------------|
| 1. SPACER RING | 4. THRUST BLOCK |
| 2. INNER RING | 5. O-RING |
| 3. OUTER RING | |

Figure 49. Crankshaft Pulley Arrangement

Inspect

1. Check the area around the holes for the damper fasteners, for cracks or wear. Replace the pulley if cracks or wear are found.
2. The viscous damper must be renewed if there is impact damage to the outer casing or if there is leakage of the viscous fluid from the cover plate.

See Figure 48. Check the area around the holes for the damper fasteners for damage.

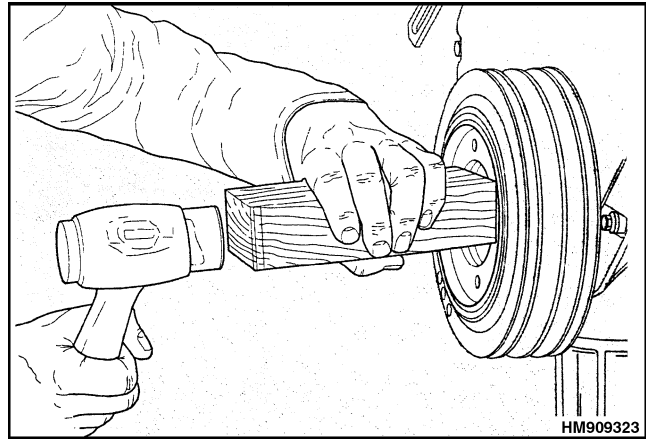


Figure 50. Crankshaft Pulley Installation

Install

1. Install the damper in position on the face of the pulley. For rear-mounted dampers, tighten the M10 Allen screws to 65 N•m (48 lbf ft) and the M8 Allen screws to 35 N•m (26 lbf ft). For front-mounted dampers, tighten the M12 bolts to 78 N•m (58 lbf ft).
2. Clean the end of the crankshaft and the parts of the crankshaft pulley. Do not use a degreasing solution. See Figure 49. Do not make any changes to the inner ring or the outer ring.
3. Put the crankshaft pulley on the crankshaft so that the key is engaged. Push the pulley onto the crankshaft.

NOTE: If the rings are not installed correctly, the crankshaft pulley will be very difficult to remove again.

4. Install the spacer ring, inner ring, and the outer ring in the correct order.
5. Lightly lubricate the O-ring and the thrust faces of the capscrews with engine oil. Put the thrust block and the capscrews in position.
6. Gradually and evenly tighten the capscrews to push the crankshaft pulley on the crankshaft. Tighten the capscrews to 115 N•m (85 lbf ft).
7. Install the drive belts. See Drive Belts.

REAR OIL SEAL

Special Tools: Seal alignment tool
Oil seal replacement tool

Remove

1. Remove the drive components from the rear of the engine.
2. Remove the flywheel and housing. See Flywheel, Remove.
3. Remove the capscrews and remove the seal housing and seal assembly. Clean the parts.
4. Inspect the oil seal for wear and damage. If there is any question about the condition of the oil seal, replace the oil seal.
5. Check that the oil seal area and outer circumference of the crankshaft flange are not worn or damaged.
6. Press the oil seal from the housing. Discard the oil seal.

Install



CAUTION

To prevent contamination, do not open the new rear oil seal assembly until required for use.

1. Verify that the crankshaft flange, rear of the cylinder block, and bridge piece are clean and dry.



CAUTION

Do not use lubricant on the crankshaft flange or the rear oil seal, as the seal is prewaxed.

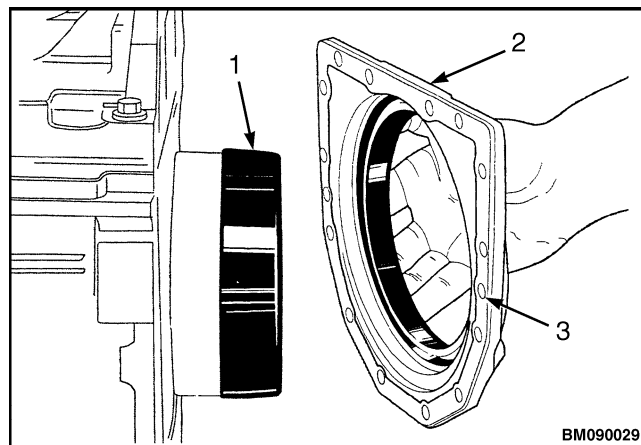
2. Open the new rear oil seal assembly and verify that the seal guide is aligned within the rear oil seal.



CAUTION

The seal guide must be in place when the rear oil seal is installed on the crankshaft flange to prevent damage to the seal.

3. Install the new gasket on the seal housing. Put the oil seal and housing on the seal guide. Carefully push the oil seal assembly into position on the crankshaft flange. See Figure 51.



1. SEAL GUIDE
2. OIL SEAL AND HOUSING
3. GASKET

Figure 51. Oil Seal Installation

4. Remove the seal guide and rotate the rear oil seal to align the holes of the rear oil seal assembly with the holes in the cylinder block and the cylinder block bridge piece.
 5. Install the capscrews but do not tighten.
- NOTE:** The seal alignment tool is not available at this time. The tool must be manufactured locally. It must be made from material EN32 and outer surfaces knurled. Verify that all sharp edges are removed. See Figure 52.
6. Put the seal alignment tool on the crankshaft flange and over the rear oil seal housing. Align the rear oil seal with the crankshaft flange.
 7. Torque capscrews (1 and 2) to 22 N•m (16 lbf ft). See Figure 53.
 8. Remove the seal alignment tool. Torque remaining capscrews in sequence to 22 N•m (16 lbf ft).
 9. Install flywheel and housing. See Flywheel, Install.
 10. Install rear drive components.

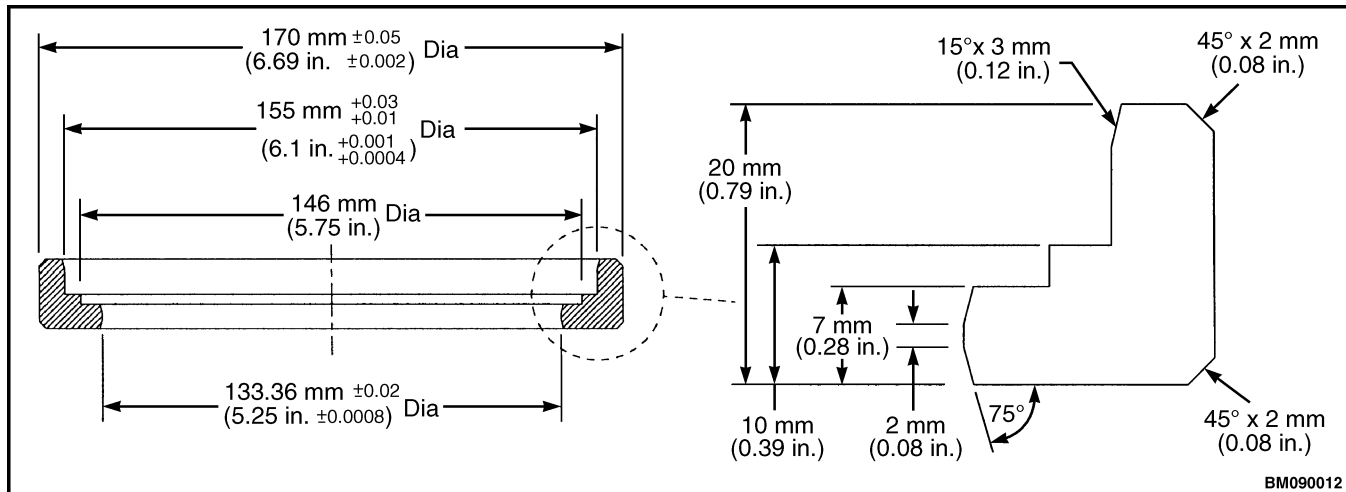


Figure 52. Seal Alignment Tool

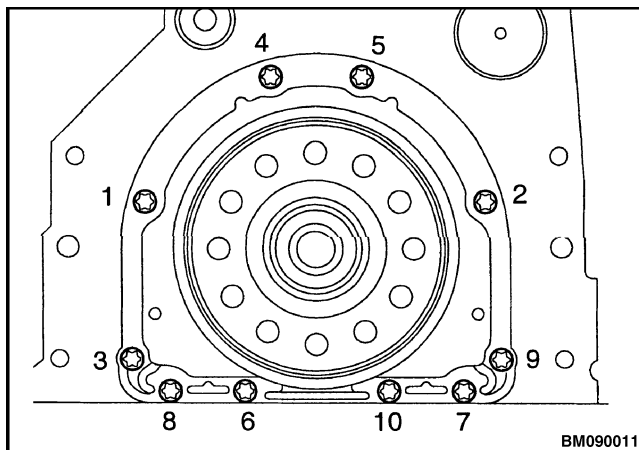


Figure 53. Oil Seal Housing Torque Sequence

MAIN BEARINGS

NOTE: The following procedure is for replacement of the main bearings without removing the crankshaft from the engine.

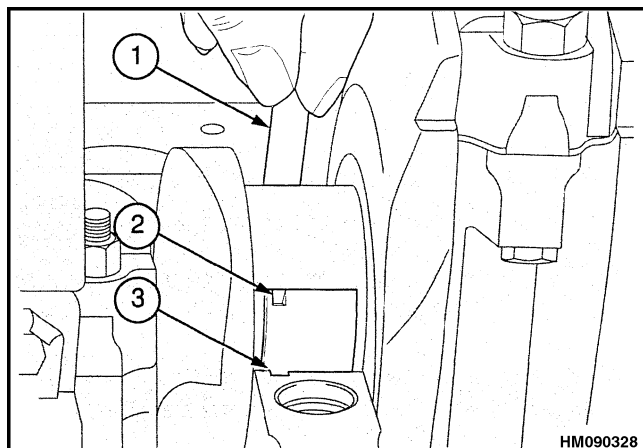
If the rear main bearing must be replaced, the flywheel, flywheel housing, rear oil seal housing, and bridge piece must be removed.

The front main bearing can be difficult to replace when the timing case is on the engine. The oil pump is installed on the front bearing cap. A special

wrench can be required to apply the correct torque to the capscrews for removal and installation. If a wrench is not available to install the capscrews on the main bearing cap, the timing case must be removed. The oil pump will be removed with the cap for the front main bearing. The suction pipe, oil strainer, delivery pipe, and relief valve must be removed.

Remove

1. Drain the engine oil and remove the oil sump.
2. Remove the necessary components for access to the bearing cap for the bearing that must be replaced.
3. Remove the capscrews and remove the bearing cap. Remove the lower half of the bearing from the bearing cap.
4. Use a thin flexible tool to push on the side of the upper bearing half that is opposite from the location tab. Push on the bearing half so that it begins to rotate out of the engine block. Carefully rotate crankshaft so that bearing will rotate out of the engine block.
5. Check that the bearing journal on the crankshaft is clean and in good condition. See Figure 54.



- | | |
|----------------------------|-------------------|
| 1. BEARING
REMOVAL TOOL | 2. LOCATION SLOTS |
| | 3. BEARING GROOVE |

Figure 54. Main Bearing Removal

Inspect

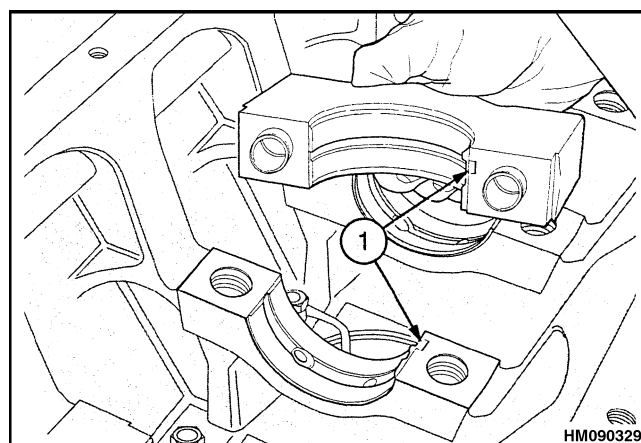
Inspect the bearings for wear and other damage. If a bearing is worn or damaged, replace both halves of the shell bearings and check the condition of the other bearings.

Install

NOTE: Only the upper half of the bearing has lubrication holes and it must be installed into the engine block.

1. Lubricate the upper bearing half with engine oil. Install the plain end of the bearing between the crankshaft journal and the side of the bearing housing that has the location slot. Carefully slide the bearing half into the bearing housing until the location tab fits into the location slot.
2. Lubricate the lower bearing half with engine oil and install it into the bearing cap. Verify the location tab is installed correctly into the location slot.
3. Verify that the location thimbles are installed in either the bearing cap or the bearing housing of the engine block. Verify that the orientation of the location slots for the bearing halves is correct as shown in Figure 55. Install the bearing cap.

4. Verify the capscrews are in good condition. Install the capscrews into the bearing cap. Tighten the capscrews gradually and evenly. Tighten the capscrews to a final torque of 265 N•m (195 lbf ft).
5. Verify that the crankshaft rotates freely. If the thrust washers have been removed and installed again, the axial movement of the crankshaft must be checked. See Thrust Washers.
6. Install the components that were removed for access to the main bearing.
7. Install the oil sump.



1. LOCATION SLOTS FOR MAIN BEARING HALVES

Figure 55. Main Bearing Cap Orientation

THRUST WASHERS

Crankshaft Axial Movement, Check

The axial movement of the crankshaft is controlled by two half thrust washers, one installed on each side of the center main bearing. See Figure 56. The axial clearance can be checked with a spacer gauge inserted between the crankshaft and the thrust washer. See Figure 57. A dial indicator can be used to check the axial movement from the end of the crankshaft as shown in Figure 58. The normal axial movement is 0.05 to 0.38 mm (0.002 to 0.015 in.). The maximum axial movement permitted is 0.51 mm (0.020 in.).

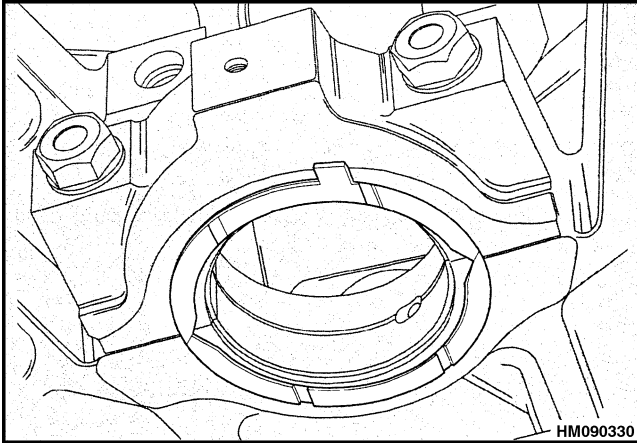


Figure 56. Thrust Washers

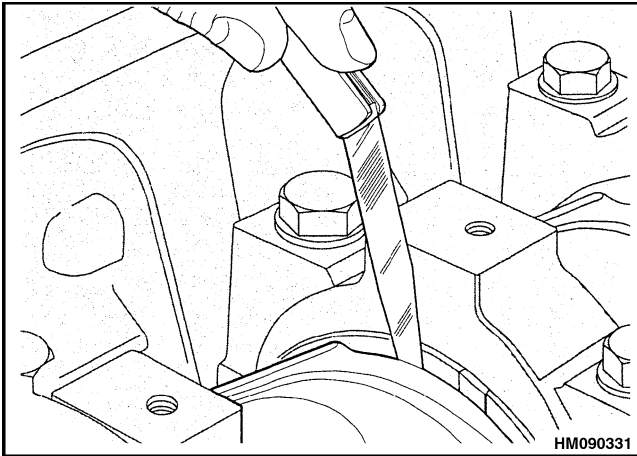


Figure 57. Axial Clearance Measurement With Spacer Gauge

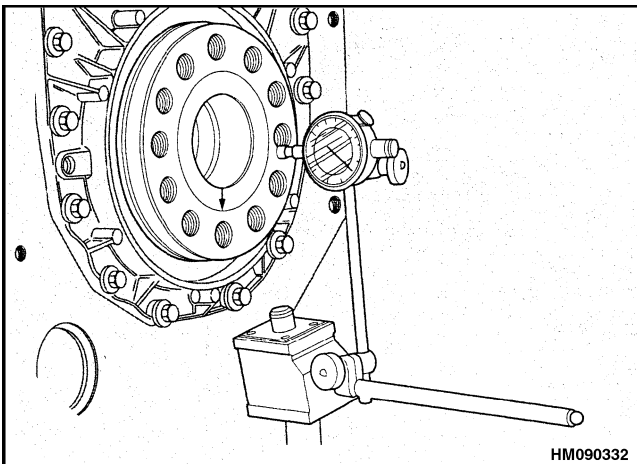


Figure 58. Axial Movement Measurement With Dial Indicator

If the axial movement is greater than the specifications, oversize thrust washers can be installed on one side or both sides of the main bearing. The oversize thrust washers are 0.019 mm (0.00075 in.) larger than the standard thrust washers.

Remove

1. Drain the engine oil from the sump. Remove the oil sump. See Oil Sump, Remove.
2. Remove the suction pipe and oil strainer. See Figure 31. Remove the capscrew that holds the bracket to the main bearing cap. Remove the two capscrews from the flange of the suction pipe and remove the suction pipe and screen. Clean the faces of both flanges.
3. Remove the capscrews for the center main bearing cap. Remove the bearing cap, lower bearing half, and the lower halves of the thrust washers.
4. Use a thin flexible tool to push the upper halves of the thrust washers from their positions next to the main bearing housing. See Figure 59. Use a small pry bar as necessary to move the crankshaft to loosen a tight thrust washer.

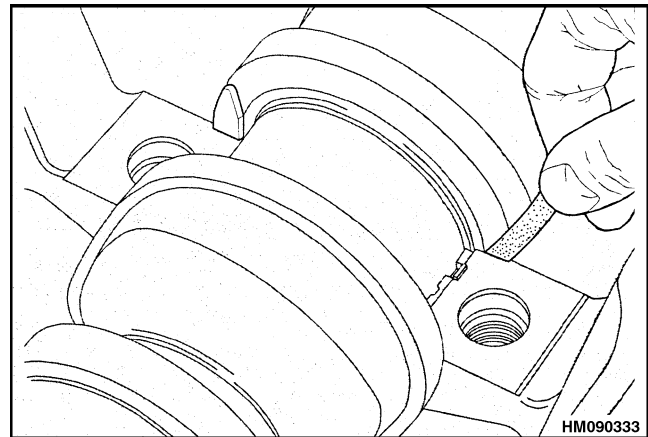


Figure 59. Thrust Washer Upper Half Removal

Install

1. Lubricate the thrust washers with engine oil. Slide the upper halves of the thrust washers into their positions in the engine block. Verify that the sides of the thrust washers with the grooves are against the crankshaft.
2. Install the lower halves of the thrust washers into the main bearing cap. Verify that the location tabs are in their correct positions.

3. Verify that the location thimbles are installed in either the bearing cap or the bearing housing of the engine block. Verify that the orientation of the location slots for the bearing halves is correct as shown in Figure 55. Lubricate the bearing and thrust washers with engine oil. Install the bearing cap.
4. Inspect the capscrews and reuse if in good condition. Install the capscrews into the bearing cap. Tighten the capscrews gradually and evenly. Tighten the capscrews to a final torque of 265 N•m (195 lbf ft).
5. Verify that the crankshaft rotates freely. Check the axial movement of the crankshaft to verify that it is within the specifications.
6. Loosely assemble the bracket of the suction line to the main bearing cap. Install a new gasket and fasten the flanges of the suction line to the oil pump. Verify that the suction line is aligned correctly and tighten the capscrew that holds the bracket to the main bearing cap.
7. Install the oil sump. See Oil Sump, Install.

CRANKSHAFT

Remove

1. Remove the engine from the lift truck. See the **Frame** section. See the **Transmission** section for separating the engine from the transmission.
2. Remove the oil sump. See Oil Sump, Remove.
3. Remove the fan, drive belts, fan drive pulley and housing, and coolant pump.
4. Remove the crankshaft pulley. See Crankshaft Pulley.
5. Remove the alternator and its mount bracket.
6. Remove the timing case cover. See Timing Case Cover, Remove.
7. Remove the fuel injection pump. See Fuel Injection Pump, Remove.
8. Remove the timing gears and the timing case. See Timing Case and Timing Gears Repair.
9. Remove the flywheel and the flywheel housing. See Flywheel, Remove.
10. Remove the rear oil seal housing. See Rear Oil Seal, Remove.
11. If the engine is not already in a position with the crankshaft facing up, turn the engine to that position. Remove the suction pipe and oil strainer. See Figure 31. Remove the capscrew that holds the bracket to the main bearing cap. Remove the two capscrews from the flange of the suction pipe and remove the suction pipe and screen. Clean the faces of both flanges. Remove the oil pump, delivery tube, and relief valve. See Oil Pump and Relief Valve.
12. Remove the bridge piece over the rear main bearing. Make a note if there is a round rubber seal at each end of the bridge piece where it joins the crankcase. Some engines have rubber seals and other engines have sealant.
13. Remove the bearing caps and lower bearing halves from the connecting rods. Make an arrangement so that the parts for each connecting rod will be assembled again in their original positions. Carefully push the pistons into their bores a small amount so that the connecting rods are separated from the crankshaft.



CAUTION

Verify the cooling jets for the pistons are not damaged or moved out of alignment. If a cooling jet is hit, the alignment must be checked and the cooling jet replaced if necessary.

14. Verify that each main bearing cap is are marked with their position number. Remove the main bearing caps, lower bearing halves, and the upper and lower thrust washers. Keep all the parts in an arrangement so that the parts can be installed in their original positions.
15. Lift the crankshaft from the cylinder block. Remove the upper bearing halves and put each of them with its lower bearing half.

Inspect

Check the crankshaft for wear and other damage. The maximum wear and out-of-round on the bearing journals is 0.04 mm (0.0016 in.). See Table 20.

The bearing journals on standard crankshafts can be ground to the following diameters smaller than the original size:

- 0.25 mm (0.010 in.)
- 0.51 mm (0.020 in.)
- 0.76 mm (0.030 in.)

Special bearings are available for these sizes.

The crankshaft must be replaced if the surface must be ground more than 0.76 mm (0.030 in.).

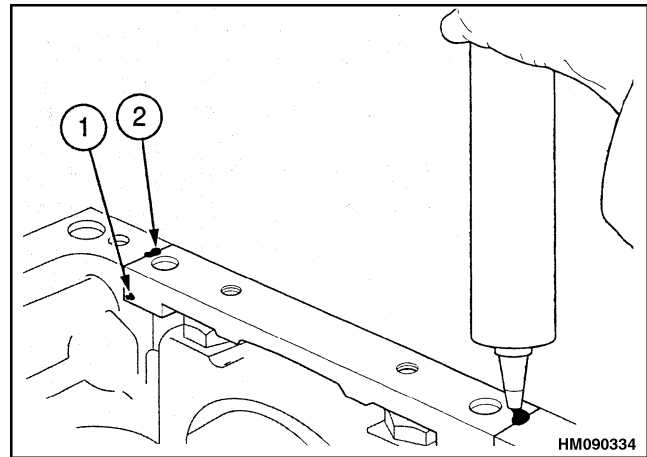
The area on the crankshaft flange for the rear oil seal can be machined to remove wear marks. See the Engine Specifications. The minimum diameter of this area is 133.27 mm (5.247 in.).

Install

1. Verify that all of the oil passages are clean.
2. Verify all of the bearings and bearing caps are clean. Install the upper bearing halves into their positions in the connecting rods and the housings for the main bearings. Verify that the position tags of the bearings fit into their position slots. Lubricate the bearings with engine oil.
3. Install the crankshaft in position on the main bearings.
4. Lubricate the thrust washers with engine oil. Slide the upper halves of the thrust washers into their positions in the engine block. Verify that the sides of the thrust washers with the grooves are against the crankshaft.
5. Install the lower halves of the thrust washers into the main bearing cap. Verify that the location tags are in their correct positions.
6. Verify that the location thimbles are installed in either the bearing cap or the bearing housing of the engine block. Verify that the orientation of the location slots for the bearing halves is correct, as shown in Figure 55. Lubricate the bearing and thrust washers with engine oil. Install the bearing cap.
7. Verify the main bearing caps are installed according to their position numbers shown on the cap. The serial numbers on the main bearing caps will also be in alignment. The serial number on the main bearing caps must be the same

as the number on the bottom face of the engine block. (The third and fifth bearing caps are not marked with a serial number.)

8. Inspect the capscrews and reuse if in good condition. Install the capscrews into the main bearing cap. Tighten the capscrews gradually and evenly. Tighten the capscrews to a final torque of 265 N•m (195 lbf ft). Repeat this step for all five main bearings.
9. When the bridge piece is put into position, inject liquid gasket sealant (Loctite® 5900) into the upper groove at each end of the bridge piece. See Figure 60. Inject the sealant until the upper groove is full and the sealant leaves the lower groove at the front and rear of the bridge piece. Verify all of the grooves are completely full of sealant.



1. LOWER GROOVE 2. UPPER GROOVE

Figure 60. Bridge Piece and Sealant

10. Use a straightedge to verify the bridge piece is aligned with the rear face of the engine block. See Figure 61. Tighten the capscrews to 16 N•m (12 lbf ft).
11. Install the connecting rods to the crankshaft. See Rod Bearings, Install. Install the upper bearing half into the connecting rod. Verify that the location tab is installed correctly into its position in the connecting rod. See Figure 32. Verify that the assembly number on the bearing cap is the same as the number on the connecting rod. Verify that the two assembly numbers are on the same side of the connecting rod as shown in Figure 33.

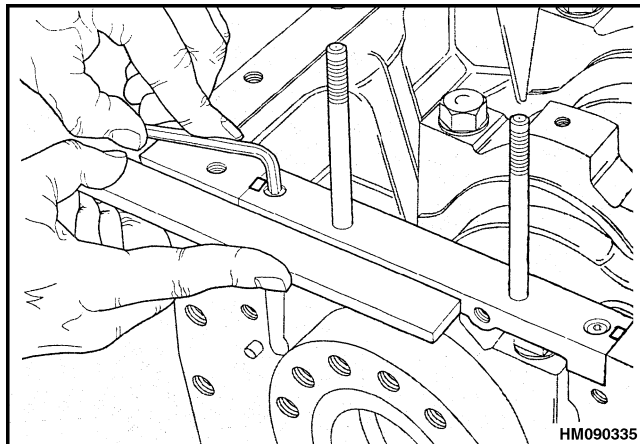


Figure 61. Bridge Piece Alignment

12. Install and tighten the nuts evenly to a torque of 125 N•m (92 lbf ft). Verify that the crankshaft turns freely.
13. Install the oil pump, delivery pipe, and relief valve. Loosely assemble the bracket of the suction pipe to the main bearing cap. Install a new gasket and fasten the flanges of the suction line to the oil pump. Verify that the suction pipe is aligned correctly and tighten the capscrew that holds the bracket to the main bearing cap.
14. Install the rear oil seal housing. See Rear Oil Seal, Remove.
15. Install the flywheel and the flywheel housing. See Flywheel, Install.
16. Install the timing gears and the timing case. See Timing Case and Timing Gears Repair.
17. Install the fuel injection pump. See Fuel Injection Pump, Install.
18. Install the timing case cover. See Timing Case Cover, Install.
19. Install the alternator and its mount bracket.
20. Install the crankshaft pulley. See Crankshaft Pulley.
21. Install the coolant pump, fan drive pulley and fan housing, drive belts, and the fan.
22. Install the oil sump. See Oil Sump, Install.
23. Install the engine into the lift truck. See the **Frame** section and the **Transmission** section for the lift truck.

FLYWHEEL

The steel flywheel has a hardened steel starter ring. The starter ring has 126 teeth.

Remove

1. Remove two opposite capscrews from the flywheel and temporarily install two studs to help control the flywheel when the other capscrews are removed.
2. Remove the other capscrews that fasten the flywheel to the crankshaft. Remove the flywheel.
3. Check the flywheel and ring gear for damage.

Ring Gear, Replace



WARNING

Wear eye protection for this operation to prevent eye injury from metal chips. You will be using a hammer and chisel to break the ring gear.

1. Before the ring gear is removed, check the position of the chamfer on the teeth.
2. Use a hammer and chisel to break the ring gear. Make sure that you do not damage the flywheel.
3. The ring gear must be heated before it can be installed on the flywheel. Use an oven that has a temperature control. Verify that the ring gear is not heated to more than 250°C (482°F).
4. Verify that the chamfer on the ring gear teeth is in the correct direction. Install the ring gear on the flywheel.

Install

1. Verify the surfaces of the crankshaft and flywheel are clean so that the two parts will fit together correctly.
2. Install the flywheel over the guide studs. Install four capscrews. Remove the two studs and install the remainder of the capscrews. Tighten the capscrews in a cross pattern to 107 N•m (78 lbf ft).
3. Check the flywheel runout with a dial test indicator. See Figure 62. This must be less than 0.30 mm (0.012 in.) total indicator reading.

4. Check the alignment of the flywheel face. See Figure 63. The error in alignment must not be more than 0.003 mm (0.0001 in.) total indicator reading for every 25 mm (1.0 in.) of the flywheel radius from the crankshaft axis to the indicator plunger. During this check, keep the crankshaft pressed toward the front to remove the effect of crankshaft end-float.

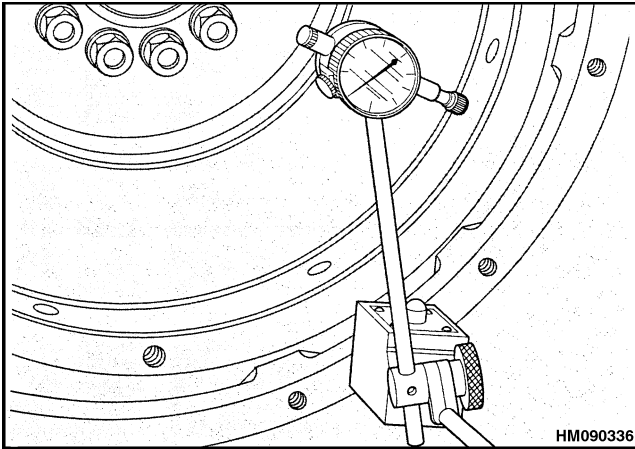


Figure 62. Flywheel Run-Out Check

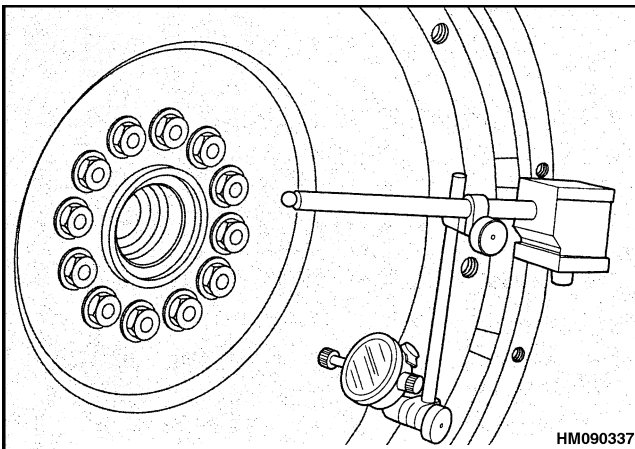


Figure 63. Flywheel Face Alignment

FLYWHEEL HOUSING

Remove



WARNING

The flywheel housing is heavy. Use lift equipment or get help to assist with the lift operation before removal of the flywheel housing fasteners.

1. Remove the starter.
2. Remove the flywheel. See Flywheel, Remove.
3. Release the housing setscrews and with a soft face hammer, carefully hit the housing to remove it from the dowels.

Install

1. Ensure that the rear face of the cylinder block and the faces of the housing are clean and free from damage. Ensure that the location dowels are fitted correctly. If a felt seal is installed to the rear flange of the sump, replace the seal.
2. Fit the housing onto the dowels and lightly tighten the setscrews.
3. Check the housing concentricity with a dial test indicator. See Figure 64. The runout limit is given in the data and dimensions. If any adjustment is necessary, it must be made on the housing, and the concentricity checked again.

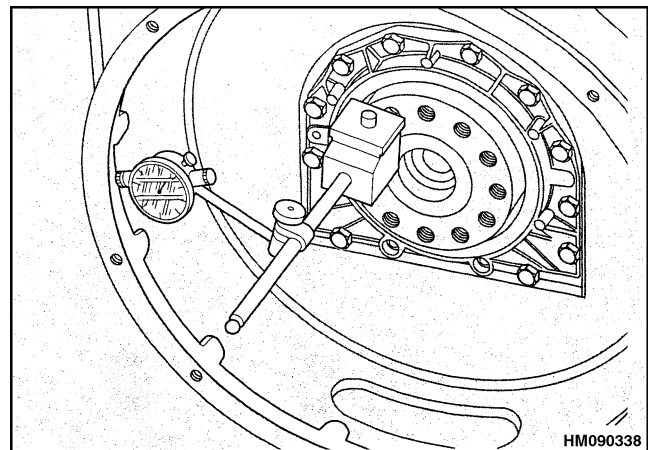


Figure 64. Flywheel Housing Concentricity Check

4. Tighten the setscrews to the torque recommended in the Special Torque Specifications.
5. Check the housing alignment. See Figure 65. The maximum tolerance is given in the data and dimensions. Any necessary adjustment must be made on the housing and not on the cylinder block.
6. Install the flywheel and the starter motor.

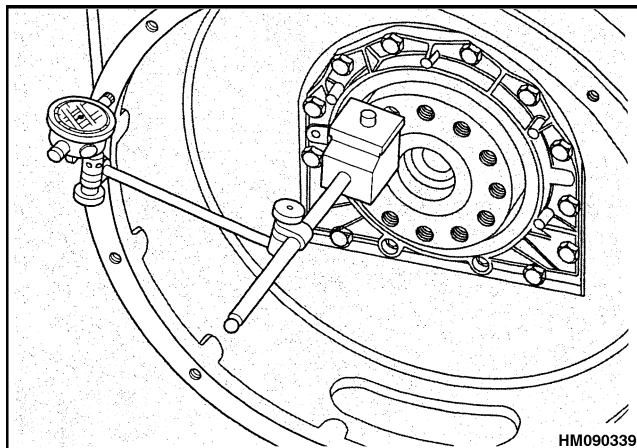


Figure 65. Flywheel Housing Alignment Check

Timing Case and Timing Gears Repair

GENERAL

The timing case can be either cast aluminum or cast iron. The timing gears are steel.

The gear train includes the crankshaft gear, idler gear, gear for the fuel injection pump, camshaft gear, and PTO gear. The timing case cover is aluminum and has the front oil seal for the crankshaft. The timing case cover has a noise shield on its front surface.

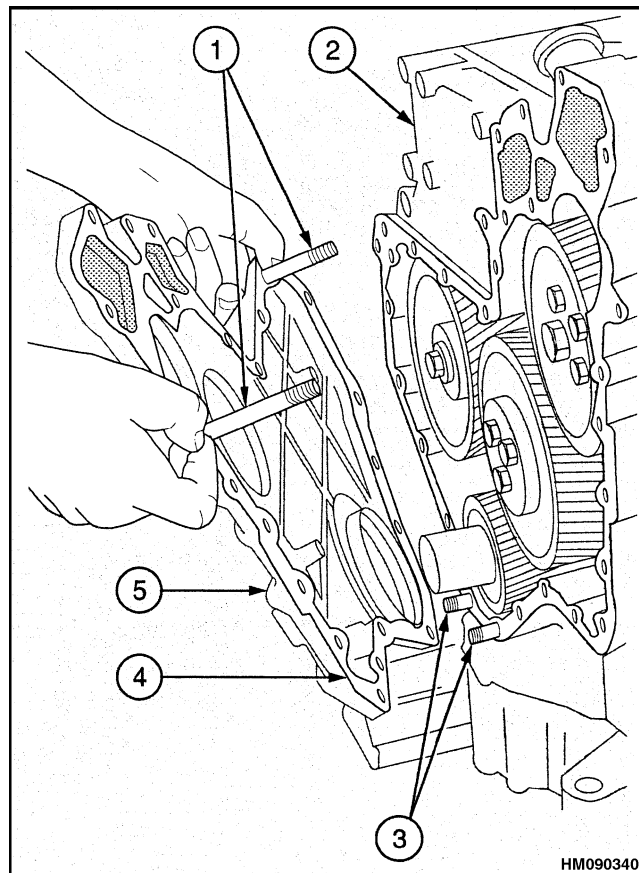
See Description for additional information on timing gears and engine timing.

The camshaft is made from cast iron. The lobes on the camshaft for the fuel pump are hardened.

TIMING CASE COVER

Remove

1. Drain the coolant. Remove the fan. See Figure 66.
2. Remove the drive belts and alternator.
3. Remove the crankshaft pulley. See Crankshaft Pulley.
4. Remove the fan drive pulley if additional clearance is needed.
5. Remove the coolant pump. See Coolant Pump, Remove.



- | | |
|-------------------|----------------------|
| 1. CAPSCREW | 4. GASKET |
| 2. CYLINDER BLOCK | 5. TIMING CASE COVER |
| 3. STUD | |

Figure 66. Timing Case Cover

6. Remove the capscrews and nuts that hold the timing case cover to the timing case. Remove the timing case cover and the sound shield.

Install

Special Tools: Alignment tool, front oil seal

1. Use a new gasket and install the timing case cover on the timing case. See Figure 66. Use two capscrews to hold the timing case cover in position. Install the special tool on the crankshaft. Use the special washer and the capscrews for the crankshaft pulley to hold the alignment tool in position. The purpose of the special tool is to verify that the front oil seal evenly fits the circumference of the seal surface of the crankshaft pulley. See Figure 67.

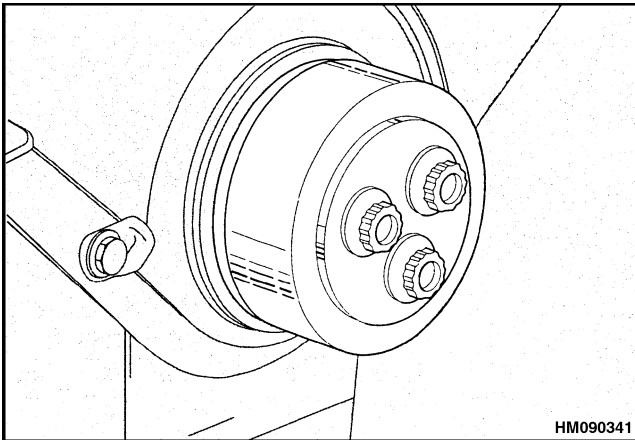


Figure 67. Front Oil Seal Alignment Tool



CAUTION

The correct alignment of the timing case cover is important and must be done carefully. The front oil seal can leak and the gears for the coolant pump can fail if the alignment is not correct.

2. When the timing case cover is aligned with the crankshaft, install the capscrews and nuts in the timing case cover. Tighten the capscrews and nuts to 22 N•m (16 lbf ft). Remove the alignment tool.
3. Install the coolant pump. See Coolant Pump, Install.
4. Install crankshaft pulley. See Crankshaft Pulley.
5. Install the fan drive pulley if it was removed.

6. Install the alternator and drive belts and adjust the tension. See Drive Belts.
7. Install the fan. Fill the cooling system.

FRONT OIL SEAL

Remove

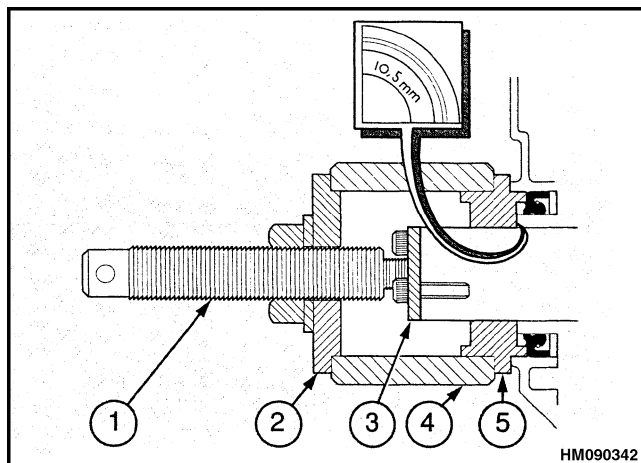
1. Remove the fan and drive belts.
2. Remove the crankshaft pulley.
3. Use a pry bar to remove the front oil seal from the timing gear cover. Put the pry bar behind the main lip of the front oil seal. Verify that the edge of the housing for the oil seal is not damaged during removal.

Install

Special Tools: Installation tool for front oil seal
Pressure plate
Fastener plate
Sleeve
Seal adapter

NOTE: The front oil seal is normally installed to a depth of 10.20 to 10.70 mm (0.402 to 0.421 in.) from the front face of the oil seal housing to the flat front face of the oil seal. If the crankshaft pulley is worn at this location, a wear sleeve can be installed. See Figure 69.

1. Clean the oil seal housing. Inspect the oil seal for damage. Do not install a front oil seal that has a scratch or any damage on the lip of the seal.
2. Lubricate the outer circumference of the oil seal with engine oil and install the front oil seal into the oil seal housing. Verify that the lip of the seal is toward the inside of the cover for the timing gear case and the front oil seal is parallel to the bore of the oil seal housing.
3. Put the replacement tool for the front oil seal on the crankshaft as shown in Figure 68. Use the fastener plate to fasten the installation tool to the crankshaft. Install the seal adapter so the 10.5 mm mark is toward the front oil seal. Put the sleeve and the pressure plate into position and fasten it to the stud of the fastener plate as shown in Figure 68.



- | | |
|--|-------------------|
| 1. REPLACEMENT
TOOL FOR FRONT
OIL SEAL | 3. FASTENER PLATE |
| 2. PRESSURE PLATE | 4. SLEEVE |
| | 5. SEAL ADAPTER |

Figure 68. Front Oil Seal Installation

4. Install a rod through the hole in the end of the tool so the tool will not turn. Turn the nut on the pressure plate with a wrench and the front oil seal will be pushed into the housing. Push the seal into the correct depth. Remove the installation tool.
5. Lubricate the seal area of the crankshaft pulley with engine oil. Install the crankshaft pulley. See Crankshaft Pulley.
6. Install the drive belts and adjust the belt tension.
7. Install the fan.

CRANKSHAFT PULLEY WEAR SLEEVE

Install

To renew a worn crankshaft pulley, a wear sleeve is fitted over the spigot. See Figure 69.

1. Remove the crankshaft pulley. See Crankshaft Pulley, Remove.

NOTE: Full instructions and a special tool to install the wear sleeve are in each service kit.

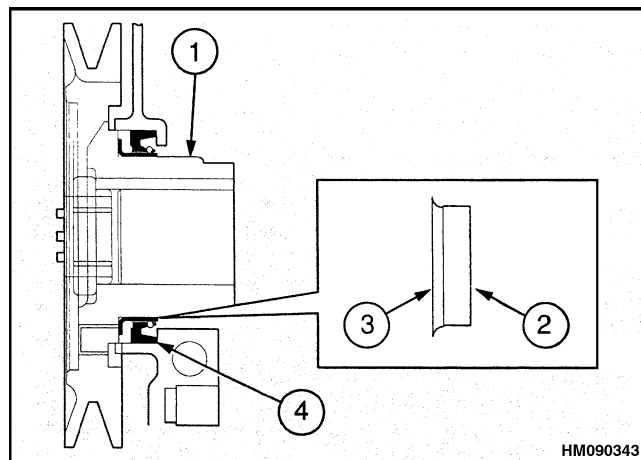
2. Install the wear sleeve in accordance with the manufacturer's instructions.

It is not necessary to remove the flange of the wear sleeve after it has been fitted.

A new front oil seal must be used when a wear sleeve is fitted.

The dimension to press the new oil seal into the timing case, with or without a wear sleeve fitted, is 9.3 mm (0.366 in.), from the front face of the timing case.

3. Install the crankshaft pulley. See Crankshaft Pulley, Install.



- | | |
|----------------|-------------|
| 1. SPIGOT | 3. FLANGE |
| 2. WEAR SLEEVE | 4. OIL SEAL |

Figure 69. Crankshaft Pulley Wear Sleeve

IDLER GEAR AND HUB

Remove

1. Remove the timing case cover. See Timing Case Cover, Remove.
2. Turn the crankshaft until the marked teeth of the crankshaft gear, the camshaft gear, and the gear for the fuel injection pump are aligned as shown in Figure 70. The marked teeth on the idler gear will not necessarily be aligned with the marked teeth of the other three gears because of the different speed of rotation of the idler gear.

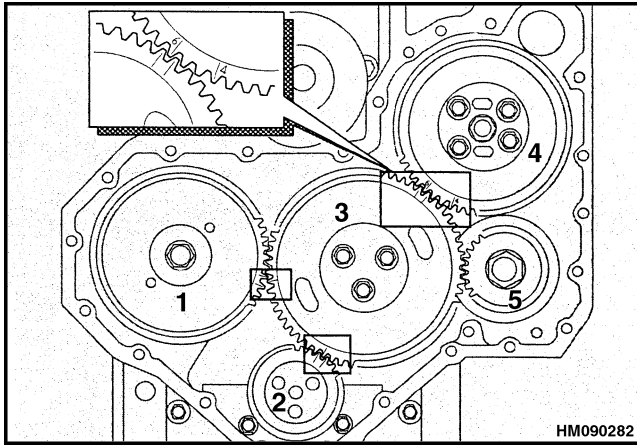


CAUTION

Verify that the crankshaft is not turned while the idler gear is removed. A piston can hit and damage a valve. The valve timing and the fuel injection pump timing will be lost if the crankshaft is turned.

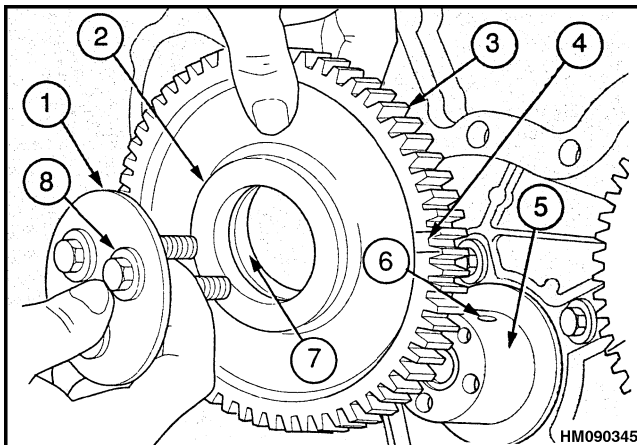
3. Remove the three capscrews, the plate of the idler gear, and the idler gear. See Figure 71.

Make a note of the position of the oil hole. The gear for the fuel injection pump will turn a small amount in the counterclockwise direction as the teeth become disengaged from the idler gear.



- | | |
|--------------------|---------------------------------|
| 1. CAMSHAFT GEAR | 4. GEAR FOR FUEL INJECTION PUMP |
| 2. CRANKSHAFT GEAR | 5. PTO GEAR |
| 3. IDLER GEAR | |

Figure 70. Timing Marks Alignment



- | | |
|------------------|-----------------------|
| 1. PLATE | 6. OIL HOLE |
| 2. THRUST WASHER | 7. REAR THRUST WASHER |
| 3. IDLER GEAR | 8. CAPSCREW |
| 4. TIMING MARKS | |
| 5. HUB | |

Figure 71. Idler Gear Components

- Inspect the idler gear and bushings for wear and damage. The idler gear and bushings are available as an assembly or as separate parts.
- If the bushings must be replaced, use a puller to remove them from the idler gear. If a puller is not available, grind one of the faces from the

bushings and use a press to remove them from the idler gear. Use a press to install new bushings. The bores and faces of the bushings will need machining to correctly fit the hub. See the Engine Specifications for the measurements.

Install

- Use the three capscrews for the idler gear to verify that the hub for the idler gear is in the correct position, with the lubrication hole at the top.
- Lubricate the bushings in the idler gear with engine oil. Align the timing marks on the idler gear with the marks on the crankshaft gear and the camshaft gear. Turn the gear for the fuel injection pump clockwise as necessary to align the timing marks when the teeth of the idler gear engage the other gears. Verify all of the alignment marks are aligned as shown in Figure 70.
- Install the plate for the idler gear and the three capscrews. Tighten the capscrews to 44 N•m (32 lbf ft).
- Check the clearance between the bushings of the idler gear and the plate of the idler gear. The correct clearance is 0.10 to 0.20 mm (0.004 to 0.008 in.). A maximum service limit is 0.38 mm (0.015 in.). See Figure 72.

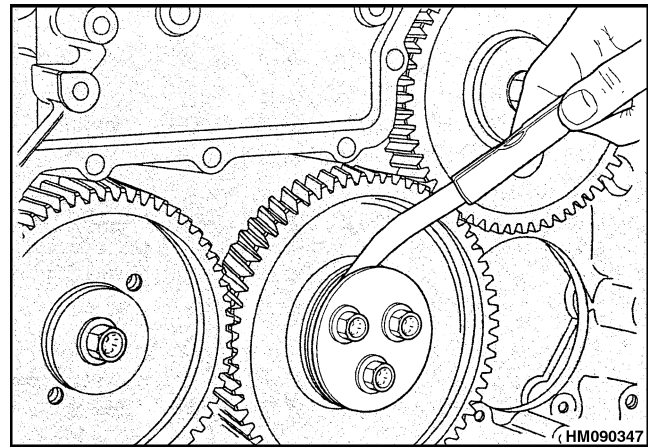


Figure 72. Idler Gear Hub Clearance Check

- Check the timing gear clearances as shown in Figure 75. The minimum clearances for all gears is 0.08 mm (0.003 in.).
- Install the timing case cover, coolant pump, crankshaft pulley, fan drive pulley, drive belts, and fan. See Timing Case Cover, Install.

AIR COMPRESSOR DRIVE, BENDIX

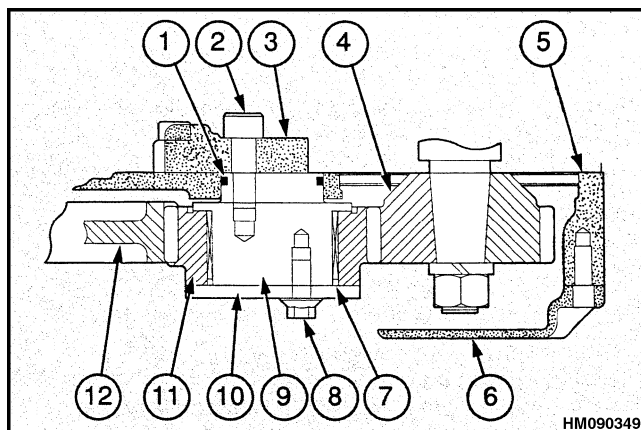
Disassemble



CAUTION

Do not turn the engine crankshaft or the crankshaft for the air compressor. If either crankshaft is moved, the air compressor must be timed to the engine.

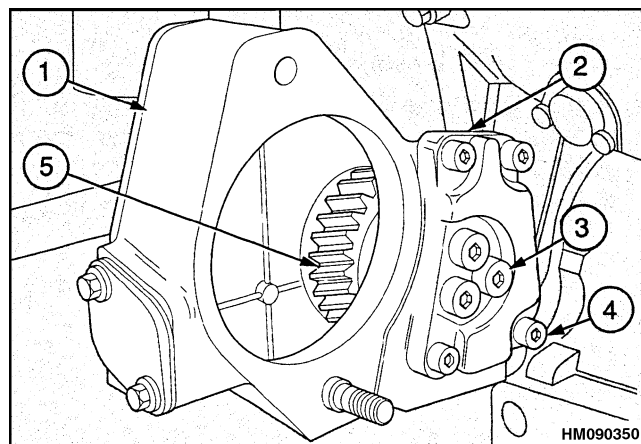
1. Set the number one piston to TDC as described in the Engine Timing section.
2. Remove the timing case cover as described in Timing Case Cover, Remove.
3. Remove the three capscrews shown. See Figure 73. Remove the cover plate. Remove the idler gear and the needle bearings from the idler hub.



- | | |
|-------------------------------|-----------------------|
| 1. O-RING | 7. NEEDLE BEARING |
| 2. CAPSCREW | 8. CAPSCREW (3) |
| 3. BRACKET | 9. IDLER HUB |
| 4. DRIVE GEAR, AIR COMPRESSOR | 10. COVER PLATE |
| 5. TIMING CASE | 11. IDLER GEAR |
| 6. COVER, TIMING CASE | 12. ENGINE IDLER GEAR |

Figure 73. Bendix Compressor Drive

4. Remove the three capscrews which fasten the idler hub to the bracket. Remove the idler gear hub. See Figure 74.
5. Remove and discard the O-ring. See Figure 73.
6. Inspect the parts for wear or damage.



- | | |
|-----------------------|------------------|
| 1. TIMING CASE | 3. CAPSCREWS (3) |
| 2. BRACKET, IDLER HUB | 4. CAPSCREWS (4) |
| | 5. IDLER GEAR |

Figure 74. Bendix Compressor Drive

Assemble

1. Install the O-ring. See Figure 73.
2. Check that the four capscrews (4) which fasten the idler hub bracket to the timing case are tightened to 35 N•m (26 lbf ft). See Figure 74.
3. Install the hub into the timing case. See Figure 73 and Figure 74. Install the three capscrews and tighten them to 60 N•m (44 lbf ft). Install the needle bearing assembly on the hub.
4. Lubricate the bore of the idler gear with clean engine oil and install the idler gear on the needle bearings. See Figure 73. Install the cover plate and tighten three capscrews to 22 N•m (16 lbf ft).
5. Check the clearance between the bushings of the idler gear and the plate of the idler gear. The correct clearance is 0.10 to 0.20 mm (0.004 to 0.008 in.). A maximum service limit is 0.38 mm (0.015 in.). See Figure 72.
6. Check the timing gear clearances as shown in Figure 75. The minimum clearance is 0.08 mm (0.003 in.).
7. Install the timing case cover as described in Timing Case Cover, Install.

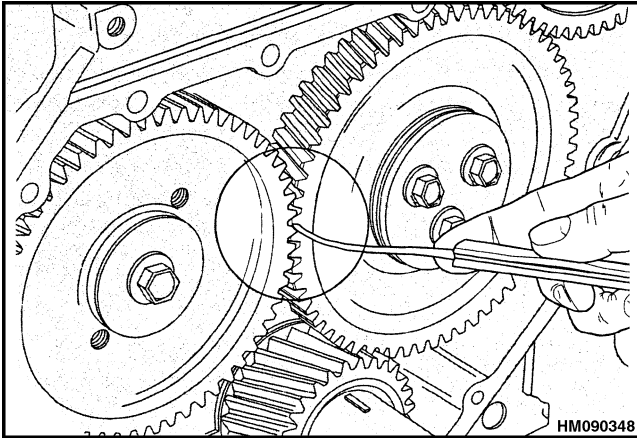
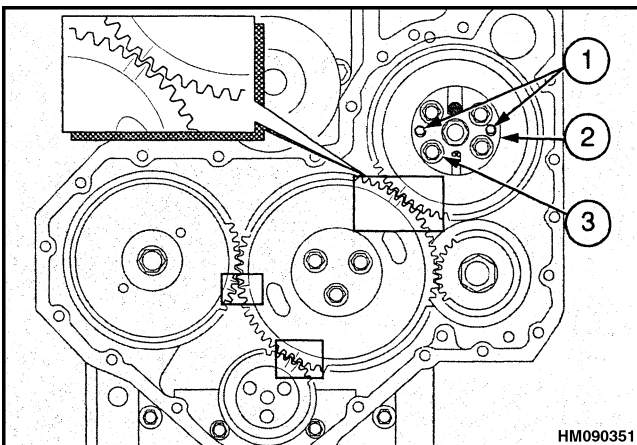


Figure 75. Timing Gear Clearances Check

FUEL INJECTION PUMP GEAR

The fuel injection pump has a timing plate fastened to the front face of the gear for the fuel injection pump. See Figure 76. This timing plate is installed by the manufacturer after the fuel injection timing has been accurately set to TDC, number one cylinder on the compression stroke. The timing plate is fastened by two M5 special capscrews.



- | | |
|-------------------------|------------------|
| 1. M5 SPECIAL CAPSCREWS | 2. TIMING PLATE |
| | 3. CAPSCREWS (4) |

Figure 76. Fuel Injection Pump Gear Removal

Remove



CAUTION

Do not loosen the two M5 special capscrews. If this timing plate is moved, the fuel injection pump must be timed again.

Do not loosen or remove the large nut from the shaft of the fuel injection pump. The hub is permanently fastened to the shaft. If the hub is removed, special equipment and special training is required to correctly install the hub again.

Special Tools: Bosch fuel injection pump timing pin

1. Remove the timing case cover. See Timing Case Cover, Remove.



CAUTION

Verify the shaft of the fuel injection pump is not locked.

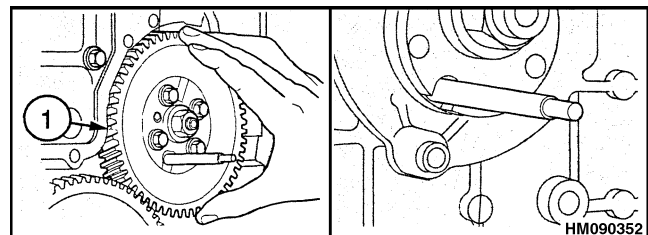
2. Set the number one piston to TDC on the compression stroke. Turn the crankshaft until the marked teeth of the crankshaft gear, the camshaft gear, and the gear for the fuel injection pump are aligned as shown in Figure 76. The marked teeth on the idler gear will not necessarily be aligned with the marked teeth of the other three gears because of the different speed of rotation of the idler gear.



CAUTION

DO NOT turn the crankshaft while removing the camshaft gear. A piston can hit and damage a valve.

3. Install the timing pin until the small end of the pin is pushed fully into the hole in the body of the fuel injection pump. See Figure 77.
4. Remove the four capscrews from the fuel pump gear and remove the gear from the hub.
5. Inspect the gear for wear and damage, and replace if necessary.



1. TIMING PIN

Figure 77. Fuel Injection Pump Gear Removal

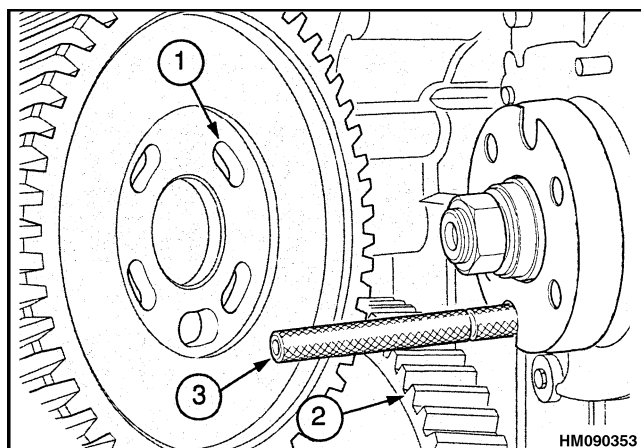
Install



CAUTION

Verify the shaft of the fuel injection pump is not locked.

1. The gear for the fuel injection pump can only be installed in one position. The letters C and M are toward the front of the engine. Verify the number one piston is set to TDC on the compression stroke.
2. If the timing pin was removed during service, install it in the hole in the body of the fuel injection pump. See Figure 78. Leave the timing pin in position so that the gear for the fuel injection pump can be installed.



- | | |
|------------------------------------|---------------|
| 1. GEAR FOR FUEL
INJECTION PUMP | 2. IDLER GEAR |
| | 3. TIMING PIN |

Figure 78. Fuel Injection Pump Gear Installation

3. Install the gear for the fuel injection pump over the timing pin so that it engages correctly with the idler gear.

NOTE: If a new gear is installed, install the original timing plate onto the front face of the new gear. Install the two M5 special capscrews loosely and install the gear on the hub. If the gear and timing plate are installed correctly, the four threaded holes in the hub can be seen through the slots in the gear.

4. Install the four capscrews loosely in the centers of the slots of the gear.

NOTE: If a new gear is installed, carefully rotate the gear counterclockwise to remove any clearance between the gear and the idler gear. See Figure 77. Do not rotate the crankshaft or it will be necessary to set TDC again.

5. Tighten the four capscrews to 28 N•m (21 lbf ft). Remove the timing pin from the fuel injection pump.
6. If a new gear has been installed, check the clearance as shown in Figure 75.
7. Install the timing case cover, coolant pump, crankshaft pulley, fan drive pulley, drive belts, and fan. See Timing Case Cover, Install.

CAMSHAFT GEAR

Remove

Special Tools: Gear puller with adapters

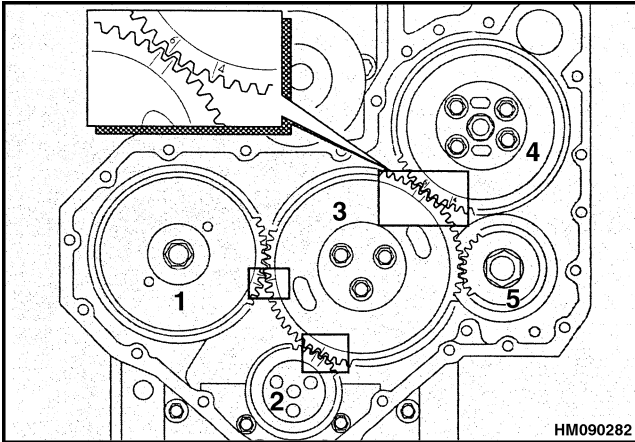
1. Remove the timing case cover. See Timing Case Cover, Remove.
2. Turn the crankshaft until the marked teeth of the crankshaft gear, the camshaft gear, and the gear for the fuel injection pump are aligned as shown in Figure 79. The marked teeth on the idler gear will not necessarily be aligned with the marked teeth of the other three gears because of the different speed of rotation of the idler gear.



CAUTION

Verify that the crankshaft is not turned while the camshaft gear is removed. A piston can hit and damage a valve.

3. Remove the capscrew and washer. Use a puller and adapter to pull the gear from the camshaft. Make sure that the woodruff key in the camshaft is not lost. Inspect the camshaft gear for wear and damage. See Figure 80.



- | | |
|--------------------|---------------------------------|
| 1. CAMSHAFT GEAR | 4. GEAR FOR FUEL INJECTION PUMP |
| 2. CRANKSHAFT GEAR | 5. PTO GEAR |
| 3. IDLER GEAR | |

Figure 79. Timing Marks Alignment

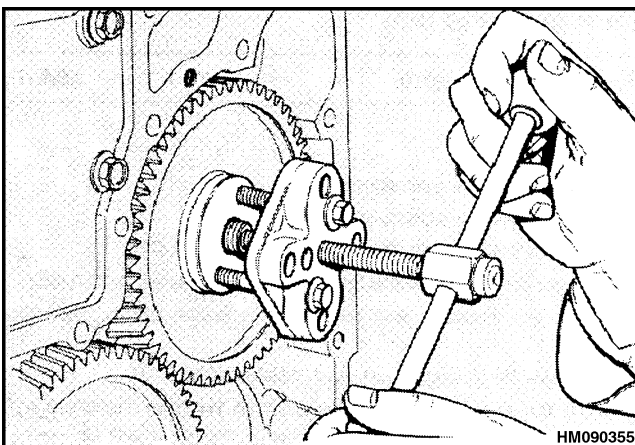


Figure 80. Camshaft Gear Removal

Install

CAUTION

If the crankshaft or the camshaft must be turned to permit the alignment of the marks on the timing gears, a piston can hit and damage a valve. The rocker arm assembly must be loosened so that the valves are closed when the crankshaft or the camshaft is turned.

1. Verify that the woodruff key is installed correctly in the end of the camshaft.
2. Remove the idler gear. See Idler Gear and Hub, Remove.

3. Install the camshaft gear on the shaft with the marked teeth toward the front and the keyway correctly aligned. Use a soft hammer to push the gear onto the camshaft. Verify that the timing marks are aligned correctly as the gear teeth are engaged. See Figure 79.
4. Install the idler gear with the marked teeth correctly aligned. See Idler Gear and Hub, Install. If the camshaft has to be turned and a valve hits a piston, disengage the rocker assembly.
5. Install the capscrew and washer and tighten the capscrew to press the gear into position. Tighten the capscrew to 95 N•m (74 lbf ft).
6. If new gears have been installed, check the timing gear clearances as shown in Figure 75. The minimum clearances for all gears is 0.08 mm (0.003 in.).
7. Install the timing case cover, coolant pump, crankshaft pulley, fan drive pulley, drive belts, and fan. See Timing Case Cover, Install.

CRANKSHAFT GEAR

Remove

1. Remove the timing case cover. See Timing Case Cover, Remove.
2. Turn the crankshaft until the marked teeth of the crankshaft gear, the camshaft gear, and the gear for the fuel injection pump are aligned as shown in Figure 79. The marked teeth on the idler gear will not necessarily be aligned with the marked teeth of the other three gears because of the different speed of rotation of the idler gear.

CAUTION

Verify that the crankshaft is not turned while the idler gear or the crankshaft gear is removed. A piston can hit and damage a valve.

3. Remove the idler gear. See Idler Gear and Hub, Remove.
4. The crankshaft gear is pressed onto the crankshaft. Sometimes a puller will remove the crankcase gear. Sometimes the gear fits so tightly on the crankshaft that the crankshaft must be removed from the engine so that the gear can be removed.

Install

1. Put the crankshaft gear in a pan of hot oil. Verify that the temperature can be controlled. **DO NOT** heat the crankshaft gear more than 200°C (392°F). Use boiling water if a container of hot oil and a temperature control is not available. **DO NOT** use an open flame to heat the gear.
2. Align the gear with the key on the crankshaft and with the timing marks on the gear away from the engine. Push the gear onto the crankshaft.
3. Install the idler gear. See Idler Gear and Hub, Install.
4. Check the timing gear clearances as shown in Figure 75. The minimum clearances for all gears is 0.08 mm (0.003 in.).
5. Install the timing case cover, coolant pump, crankshaft pulley, fan drive pulley, drive belts, and fan. See Timing Case Cover, Install.

TIMING CASE

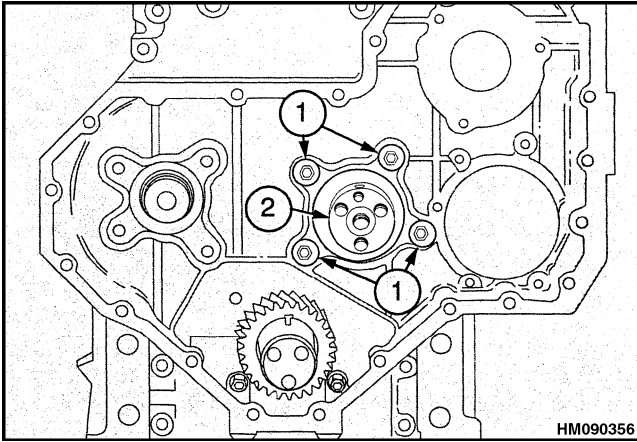
Remove

1. Remove the fan.
2. Remove the drive belts.
3. Remove the crankshaft pulley. See Crankshaft Pulley.
4. Remove the fan drive assembly. See Fan and Fan Drive, Remove.
5. Drain the coolant and remove the coolant pump. See Coolant Pump, Remove.
6. Remove the alternator and its mount bracket and the front support plate.
7. Remove the air compressor. See Air Compressor, Repair.
8. Remove the timing case cover. See Timing Case Cover, Remove.
9. Turn the crankshaft until the marked teeth of the crankshaft gear, the camshaft gear, and the gear for the fuel injection pump are aligned as shown in Figure 79. The marked teeth on the idler gear will not necessarily be aligned with the marked teeth of the other three gears because of the different speed of rotation of the idler gear.

10. Remove the fuel injection pump. See Fuel Injection Pump, Remove.
11. Remove the idler gear and the camshaft gear. See Idler Gear and Hub, Remove and Camshaft Gear, Remove.
12. Remove the capscrews that hold the timing case to the engine block. Remove the capscrews that hold the oil sump to the timing gear case.
13. Remove the timing gear case, gasket, and hub for the idler gear. Do not permit the hub to fall and become damaged.

Install

1. Inspect the oil sump gasket for damage. If the gasket is damaged, remove the oil sump and install **after** the timing case has been installed. A damaged section of the gasket can be cut and a new section can be installed in its place, but the work must be carefully done to prevent oil leaks.
2. If the oil sump has been removed, install the hub for the idler gear on the front of the engine block. Use the three capscrews for the idler gear to hold the hub in position. Verify that the oil hole in the hub is toward the top of the engine.
3. Verify that the thrust washer for the camshaft is in the correct position.
4. Install a new gasket for the timing case to the engine block. Cut the bottom ends of the gasket to correctly fit the space. Use gasket compound at the bottom ends of the gasket.
5. Put the timing case into position on the engine block. If the oil sump was not removed, install the hub for the idler gear. Use the four capscrews for the idler gear to hold the hub in position. Verify that the oil hole in the hub is toward the top of the engine. Install the four capscrews that hold the hub of the idler gear to the engine block. See Figure 81.
6. Install the alternator and its front support plate in position and install the remainder of the capscrews into the timing case. If the front support plate has been separated from the alternator bracket, verify that the support plate is even with the machined face of the engine block where the alternator bracket is installed. Tighten the capscrews to 22 N•m (16 lbf ft).



1. CAPSCREWS FOR HUB 2. HUB FOR IDLER GEAR

Figure 81. Idler Gear Hub Installation

NOTE: If a new timing case is being installed, remove the two studs from the timing case and clean the threads that fit into the timing case. Apply liquid sealant to the threads of the studs and install them into the new timing case.

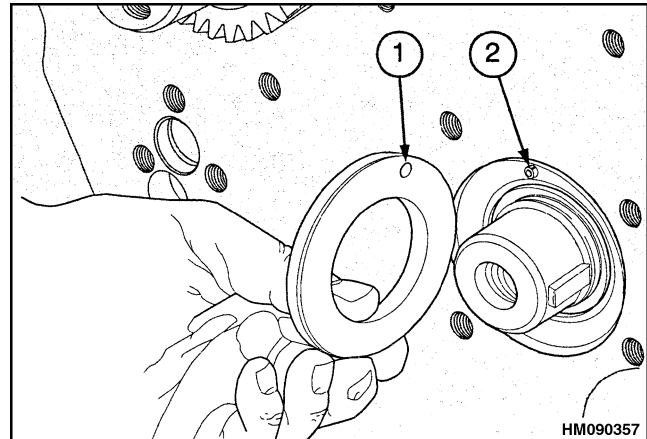
7. Install the camshaft gear. Install the capscrew and washer and tighten the capscrew to press the gear into position. Tighten the capscrew to 95 N•m (70 lbf ft).
8. Lubricate the bushings in the idler gear with engine oil. Align the timing marks on the idler gear with the marks on the crankshaft gear and the cam shaft gear. Remove the three capscrews from the hub for the idler gear and install the idler gear. Verify that the timing marks are aligned as shown in Figure 79.
9. Install the fuel injection pump. See Fuel Injection Pump, Install.
10. If new gears have been installed, check the timing gear clearances as shown in Figure 75. The minimum clearances for all gears is 0.08 mm (0.003 in.).
11. If the oil sump was removed, install it. Verify that any joints in the gaskets are fitted to prevent oil leaks.
12. Install the timing case cover, coolant pump, crankshaft pulley, fan drive, alternator, drive belts, and fan. See Timing Case Cover, Install.

CAMSHAFT AND TAPPETS

Remove

NOTE: The removal and installation of the camshaft and tappets require disassembly of many components of the engine. The engine is normally removed from the lift truck for this operation. See the **Frame** section for procedures to remove the engine. See the **Transmission** section for procedures to separate the engine from the transmission.

1. Drain the engine oil and coolant.
2. Remove the timing case. See Timing Case, Remove.
3. Remove the valve cover, rocker arm assembly, and push rods. See Rocker Arm Assembly, Remove.
4. Remove the fuel pump.
5. Turn the engine so that the oil sump is up, and remove the oil sump.
6. Remove the thrust washer for the camshaft. See Figure 82.



1. THRUST WASHER, CAMSHAFT 2. POSITION DOWEL

Figure 82. Camshaft Thrust Washer

7. Carefully remove the camshaft. See Figure 83.
8. Remove the tappets.

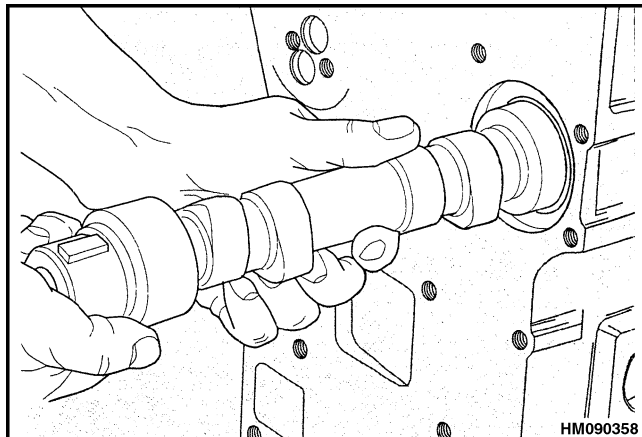


Figure 83. Camshaft Removal and Installation

9. Inspect the camshaft and the tappets for wear and damage. See the Engine Specifications for the measurements. Replace any worn or damaged parts.

Install

1. Verify all of the parts are clean. Lubricate the parts with engine oil as they are assembled.
2. Install the tappets in their positions.
3. Carefully install the camshaft. See Figure 83.
4. Install the thrust washer for the camshaft. Verify the thrust washer fits correctly on the dowel. See Figure 82.

5. Use a new gasket and install the timing case. See Timing Case, Install.
6. Check the axial clearance of the camshaft. A dial indicator can be used to check the axial movement from the end of the camshaft. The normal axial movement is 0.10 to 0.41 mm (0.004 to 0.016 in.). The maximum axial movement permitted is 0.53 mm (0.021 in.).
7. Turn the camshaft until the cam for the fuel pump is at the minimum lift position. Install the fuel pump.
8. Turn the engine to the upright position. Turn the crankshaft until the key slot in the crankshaft is towards the top. Install the timing gears. See Crankshaft Gear, Install.
9. Install the fuel injection pump.
10. Install the push rods and the rocker arm assembly. See Rocker Arm Assembly, Install.
11. Adjust the valve clearances. See Valve Clearance Adjustments.
12. Install the oil pump.
13. Install the timing case cover. See Timing Case Cover, Install. Install the oil sump.
14. Install the engine. When the engine can be operated, remove the air from the fuel system before operation.

Cylinder Block Assembly Repair

DESCRIPTION

The cylinder block is made of cast iron. The engines have removable cylinder liners pressed into the cylinder block. A bushing is installed in the front of the cylinder block for the front journal of the camshaft. The other camshaft journals do not have bushings and run directly in the cylinder block.

CYLINDER BLOCK

Disassemble

1. Remove the engine from the lift truck. See the **Frame** section for procedures to remove the engine. See the **Transmission** section for procedures to separate the engine from the transmission.

2. Drain all engine fluids.
3. Remove the Electronic Control Module (ECM). See Electronic Control Module (ECM), Remove.
4. Remove the Voltage Load and Protection Module (VLPM). See Voltage Load and Protection Module (VLPM), Remove.
5. Remove the engine speed and timing sensor. See Engine Speed and Timing Sensor, Remove.
6. Remove the fan, drive belts, fan drive, and coolant pump.
7. Remove the engine air compressor.

8. Remove the crankshaft pulley. See Crankshaft Pulley.
9. Remove the alternator and its mount bracket.
10. Remove the timing case cover. See Timing Case Cover, Remove.
11. Remove the fuel injection pump. See Fuel Injection Pump, Remove.
12. Remove the fuel injectors, fuel lines, fuel filter, and fuel pump. See Fuel System Repair.
13. Remove the oil cooler. See Oil Cooler, Remove.
14. Remove the turbocharger. See Turbocharger, Remove.
15. Remove the starter motor. See Starter Motor, Remove.
16. Remove the timing gears and the timing case. See Timing Case and Timing Gears Repair.
17. Remove the oil filter and oil sump. See Oil Sump, Remove.
18. Remove the cylinder head assembly. See Cylinder Head Assembly, Remove.
19. Remove the flywheel and flywheel housing. See Flywheel, Remove.
20. Remove the rear oil seal housing. See Rear Oil Seal, Remove.
21. If the engine is not already in a position with the crankshaft facing up, turn the engine to that position. Remove the suction line and oil strainer. See Figure 106. Remove the capscrew that holds the bracket to the main bearing cap. Remove the two capscrews from the flange of the suction line and remove the suction line and screen. Clean the faces of both flanges. Remove the oil pump, delivery pipe, and relief valve. See Oil Pump, Remove and Relief Valve.
22. Remove the bridge piece over the main bearing.
23. Remove the bearing caps and lower bearing halves from the connecting rods. Make an arrangement so that the parts for each connecting rod will be assembled again in their original positions. Carefully push the pistons into their bores a small amount so that the connecting rods are separated from the crankshaft.
24. Verify that the main bearing caps are marked with their position number. Remove the main bearing caps, lower bearing halves, and the upper and lower thrust washers. Keep all the parts in an arrangement so that the parts can be installed in their original positions.
25. Lift the crankshaft from the cylinder block. Remove the upper bearing halves and put each with its lower bearing half.
26. Carefully remove the pistons and connecting rod assemblies from the engine.
27. Remove the camshaft and tappets. See Camshaft and Tappets, Remove.
28. Remove the cooling jets for the pistons.
29. Remove the Closed Circuit Breather System (CCB) drain valve. See CCB Assembly, Remove.

Inspect

1. Verify all of the oil and coolant passages in the engine block are clean.
2. Check the engine block for cracks and damage.

NOTE: The top face of the cylinder block cannot be machined because the cylinder liners and pistons will not fit. See Table 28.

3. Check the front bushing for the camshaft for wear. If a new bushing must be installed, use a puller to remove the old bushing. Verify the oil hole for the new bushing is away from the engine when it is installed. Verify the oil hole is aligned with the passage in the cylinder block when it is installed. Use a press to install a new bushing and align it in position in the cylinder block.

Assemble

1. Verify all the parts are clean.
2. Remove the screw plugs from the cylinder block and clean the threads. Apply a sealant to the



CAUTION

Verify the cooling jets for the pistons are not damaged or moved out of alignment. If a cooling jet is hit, the alignment must be checked and the cooling jet replaced if necessary.

threads of the plugs and install them in the cylinder block.

3. Install the cooling jets for the pistons. See Piston Cooling Jets, Install.
4. Install the pistons and connecting rods.
5. Install the crankshaft and rear oil seal assembly. See Crankshaft Assembly Repair.
6. Install the flywheel and flywheel housing. See Flywheel.
7. Install the tappets and camshaft. See Camshaft and Tappets.
8. Install the relief valve, oil pump, suction line, and oil strainer.
9. Install the timing case and timing gears. See Timing Case and Timing Gears Repair.
10. Install the cylinder head assembly. See Cylinder Head Assembly, Install.
11. Install the starter motor.
12. Install the fuel pump.
13. Install the turbocharger. See Turbocharger, Install.
14. Install the oil filter assembly and the oil sump. See Oil Sump, Install.
15. Install the oil cooler. See Oil Cooler, Install.
16. Install the fuel injectors, fuel lines, fuel filter, and fuel injection pump. See Fuel System Repair.
17. Install the coolant pump, fan drive pulley, and fan. See Cooling System Repair.
18. Install the alternator and mount brackets.
19. Install the drive belts and adjust the tension. See Drive Belts.
20. Install the Closed Circuit Breather System (CCB) drain valve. See CCB Assembly, Install.

21. Install the Voltage Load Protection Module (VLPM). See Voltage Load and Protection Module (VLPM), Install.

22. Install the Electronic Control Module (ECM). See Electronic Control Module (ECM), Install.

23. Install the engine speed and timing sensor. See Engine Speed and Timing Sensor, Install.

24. Install the engine to the lift truck.

25. Remove the air from the fuel system before operating the engine. See Fuel System Air Removal.

CYLINDER LINER

Inspect

For the best performance during the life of the engine, it is important that worn or damaged cylinder liners are replaced. If a change of liner becomes necessary, transition fit liners and partially finished liners are available.

The condition of a cylinder liner is decided by:

- The amount and location of any polished areas.
- Wear.
- Damage to the liner wall.

NOTE: It will not be necessary to replace the liners if:

- The honed finish can still be clearly seen.
- The engine performance and oil consumption are acceptable.

Cylinder Liner Condition, Check

1. Inspect the liner surface for cracks and deep scratches.
2. Check the liner wall for areas where the honed finish has been polished away. See Figure 84 and Figure 85. Check especially the area around the top of the liner bore just below the carbon ring. In this area, thrust from the top piston ring is at its maximum.

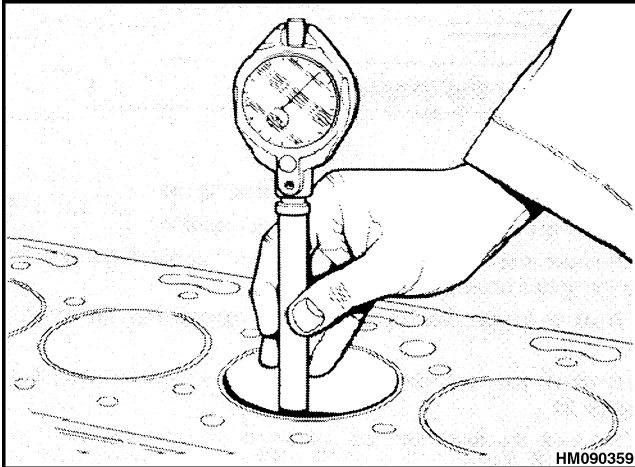


Figure 84. Cylinder Liner Wear Check

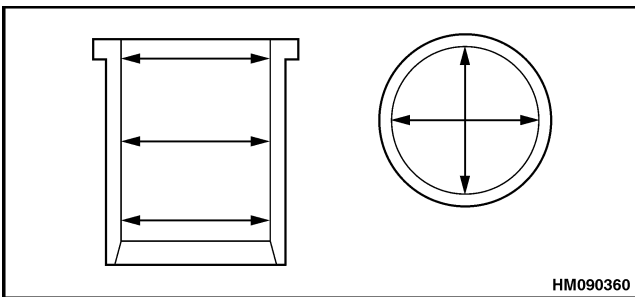


Figure 85. Where to Measure Cylinder Liner for Wear Check



CAUTION

Do not use "Flex-hone" to repair cylinder liners.

Damaged or worn liners must be replaced.

New piston rings must be fitted when the cylinder liner is replaced.

An engine can have high oil consumption with very little wear of the liner bores, if the surfaces of the liners are glazed.

Specialist training and equipment is needed to machine the finish of a partially finished liner.

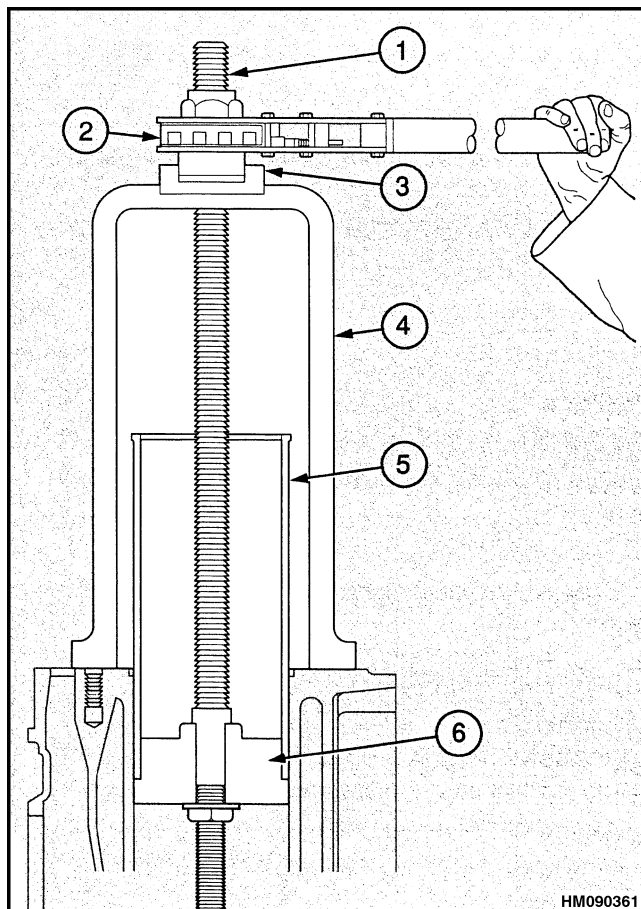
3. Partially finished cylinder liners must be bored and then diamond honed, silicon carbide base honed, and silicon carbide plateau honed to the finished size to conform to the dimensions in the Engine Data section. Specialist training and equipment is needed to machine a partially finished liner. For further information contact your nearest Perkins Distributor.

Remove

Special Tools: Removal and installation tool and adapters for cylinder liners
Piston height tool
Dial indicator gage

NOTE: If several cylinder liners must be removed, or a cylinder liner is very tight, a recommendation is to remove the crankshaft and use a press to remove the cylinder liners. The removal and installation tool can also be used to remove and install a cylinder liner if a press is not available or the crankshaft must stay in the engine. This procedure can be difficult.

1. Disassemble the engine as necessary. The piston, connecting rod, and piston cooling jet must be removed from the engine for each cylinder liner that must be removed.
2. Turn the crankshaft to give access to the cylinder liner and protect the bearing journal.
3. Install the removal and installation tool over the center of the cylinder liner as shown in Figure 86. Verify that the base of the tool is not on top of the flange of the next cylinder liner.
4. Verify that the lugs on the top of the removal adapter engage flats on the threaded rod. Install the nut and washer on the threaded rod and tighten the nut against the removal adapter. Turn the handle to remove the cylinder liner from the cylinder block. Use lubricating oil on the moving parts to reduce the friction.



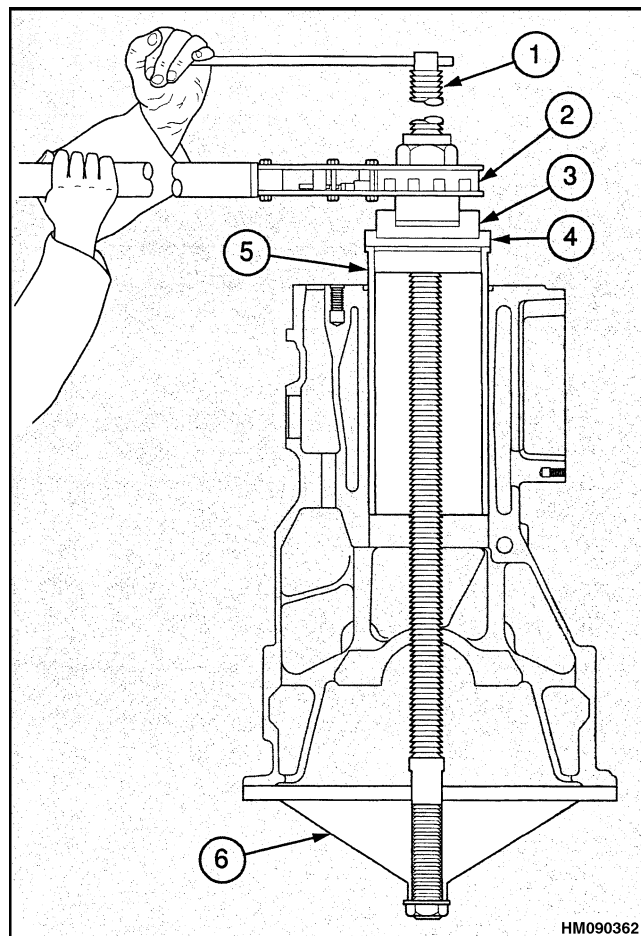
- | | |
|--------------------------|--------------------|
| 1. THREADED ROD | 5. CYLINDER LINER |
| 2. HANDLE | 6. REMOVAL ADAPTER |
| 3. BEARING | |
| 4. SHELL REMOVAL ADAPTER | |

Figure 86. Cylinder Liner Removal

Service Liner, Install

A service liner is a transition fit of ± 0.03 mm (± 0.001 in.) of the parent bore. Some replacement cylinder liners are easier to install than others because of the manufacturing tolerances. A cylinder liner installation tool can be used to install a tight cylinder liner. See Figure 87. A press can also be used to install a tight cylinder liner. **DO NOT use a hammer to install a cylinder liner.**

1. Verify the parts are clean. Lubricate the bore in the cylinder block with engine oil. **DO NOT lubricate** the upper 50 mm (2 in.) of the bore in the cylinder block. Sealant will be applied to this area.



- | | |
|-------------------------|-------------------------------|
| 1. THREADED ROD | 5. CYLINDER LINER |
| 2. HANDLE | 6. BASE, INSTALLATION ADAPTER |
| 3. BEARING | |
| 4. INSTALLATION ADAPTER | |

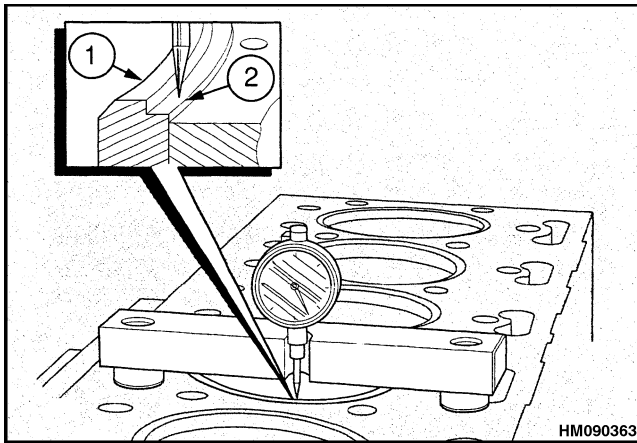
Figure 87. Cylinder Liner Installation

2. Install the cylinder liner in the bore in the cylinder block. Verify the cylinder liner is vertical and aligned with the bore in the cylinder block. Use the cylinder installation tool as shown in Figure 87 to press the cylinder liner into the cylinder block to within 50 mm (2 in.) of the final position.
3. Apply Loctite® 602 to the upper 25 mm (1 in.) of the outer surface of the cylinder liner. Apply Loctite® 602 to the flange and the cylinder block where the flange of the cylinder liner will fit into the cylinder block.
4. Press the cylinder liner into its final position in the cylinder block. Remove the tool and clean the Loctite® from the cylinder block.

- Wait 15 minutes before the dimensions in the bore of the cylinder liner are checked. The Loctite® will reach full strength after six hours.

The inside diameter of a service liner, when fitted, should be 100.00 to 100.06 mm (3.937 to 3.939 in.).

- Use the piston height tool and dial indicator gauge to check that the cylinder liner is in the correct position. See Figure 88. The flange of the cylinder liner must be between 0.10 mm (0.004 in.) above to 0.10 mm (0.004 in.) below the top surface of the cylinder block.



- FLAME RING
- FLANGE

Figure 88. Cylinder Liner Check

- Install new piston rings on the piston. See Piston Rings, Install.
- Install the piston and connecting rod assembly. See Piston and Connecting Rod Assembly, Install.
- Install the cooling jets for the pistons. See Piston Cooling Jets, Install.
- Install the cylinder head assembly. See Cylinder Head Assembly, Install.
- Install the oil sump. See Oil Sump, Install.

NOTE: Special training and equipment are often needed to correctly machine the finish on the inner surface of a cylinder liner. Contact a Perkins distributor for additional information.

NOTE: If a new cylinder liner has been installed, the following recommendations are for the next five hours of engine operation:

- Do not operate the engine at full load.
- Do not operate the engine at high speed.
- Do not permit the engine to operate at idle speed for long periods.

Partially Finished Liner, Install

The partially finished liner is an interference fit in the parent bore. A special tool will be necessary to fit the liners. See Figure 87. If a liner is a very tight fit, it may be necessary to use a hydraulic press.



CAUTION

Do not hit a liner with a hammer.

- Thoroughly clean the parent bore of the cylinder block.
- Inspect the parent bore for damage and corrosion. Damaged cylinder blocks should be discarded.
- Thoroughly clean the outer surface of the liner with an approved degreasing fluid.
- Apply a small amount of engine oil around the top of the parent bore to assist the entry of the liner.
- Install the cylinder liner into the parent bore; verify that the liner is vertical. Use the cylinder installation tool as shown in Figure 87 to press the cylinder liner into the fully fitted position in the cylinder block.
- Use the piston height tool and dial indicator gauge to check that the cylinder liner is in the correct position. See Figure 88. The flange of the cylinder liner must be between 0.10 mm (0.004 in.) above to 0.10 mm (0.004 in.) below the top surface of the cylinder block.



CAUTION

Specialist training and equipment is needed to machine the finish of a partially finished liner.

- Install new piston rings on the piston. See Piston Rings, Install.
- Install the piston and connecting rod assembly. See Piston and Connecting Rod Assembly, Install.
- Install the cooling jets for the pistons. See Piston Cooling Jets, Install.

10. Install the cylinder head assembly. See Cylinder Head Assembly, Install.

11. Install the oil sump. See Oil Sump, Install.

NOTE: Special training and equipment are often needed to correctly machine the finish on the inner surface of a cylinder liner. Contact a Perkins distributor for additional information.

NOTE: If a new cylinder liner has been installed, the following recommendations are for the next five hours of engine operation:

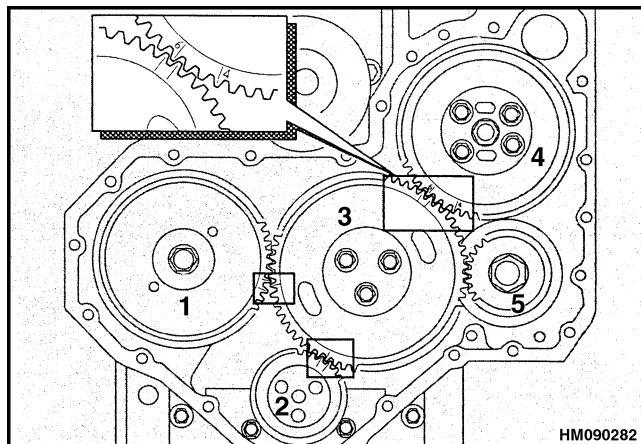
- Do not operate the engine at full load.
- Do not operate the engine at high speed.
- Do not permit the engine to operate at idle speed for long periods.

Engine Timing

DESCRIPTION

The correct timing is important for this engine to meet current emission standards. The correct timing of the fuel injection pump operates 4° after top dead center (TDC) on the compression stroke.

The timing gears are stamped with timing marks to verify they are installed correctly. See Figure 89. The marked teeth of the crankshaft, the camshaft, and the fuel pump gears will each be engaged with the idler gear, as shown in Figure 89. When the number one piston is at TDC on the compression stroke. The marks on the idler gear will not necessarily be aligned in this position because of the different speeds at which the gears rotate. The marks on the idler gear can be used to verify the marked teeth of the other three gears are correctly aligned when the components of the timing system are being assembled.



- | | |
|--------------------|---------------------------------|
| 1. CAMSHAFT GEAR | 4. GEAR FOR FUEL INJECTION PUMP |
| 2. CRANKSHAFT GEAR | 5. PTO GEAR |
| 3. IDLER GEAR | |

Figure 89. Timing Marks Alignment

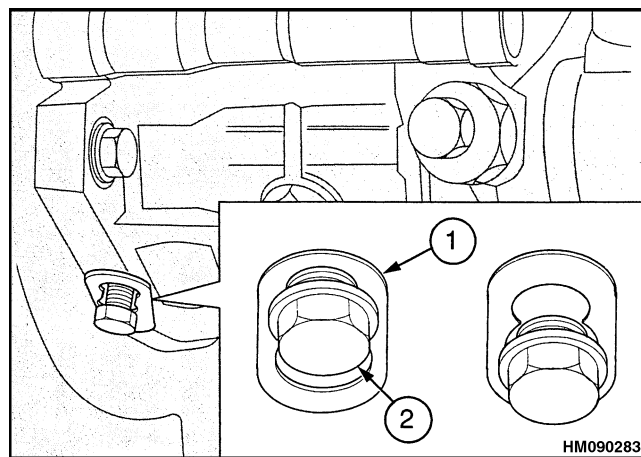
The fuel injection pump is timed at TDC on the compression stroke of number one cylinder. There is no timing mark on the rear of the timing case.



CAUTION

A replacement fuel injection pump can have the pump shaft locked in position. See Figure 90. The drive shaft of the pump must not be turned unless the spacer is in position under the lock screw.

The fuel injection pumps have a hub which is **mounted permanently** onto the drive shaft. See Figure 91.

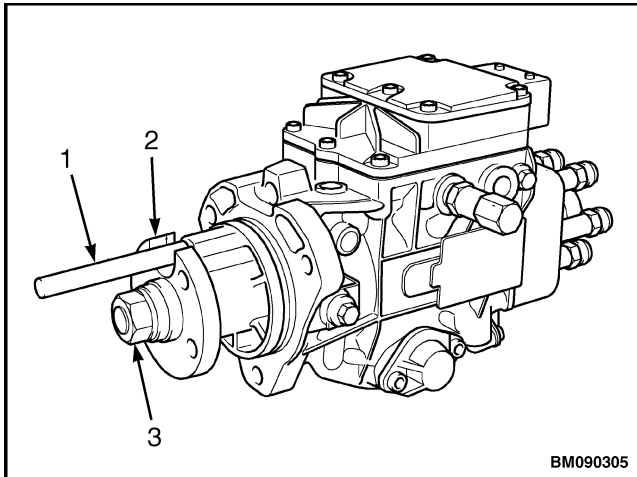


- | | |
|-----------|---------------|
| 1. SPACER | 2. LOCK SCREW |
|-----------|---------------|

Figure 90. Lock Screw

NOTE: If a timing pin is not available, an 8 mm drill bit can be used.

The manufacturer fits the hub to the pump to ensure very accurate timing. Engines that have this arrangement have the drive gear fastened to the hub instead of to the shaft of the pump. A pin is used to accurately time the pumps. See Figure 91.



1. TIMING PIN 3. NUT
2. HUB

Figure 91. Injection Pump Timing Pin



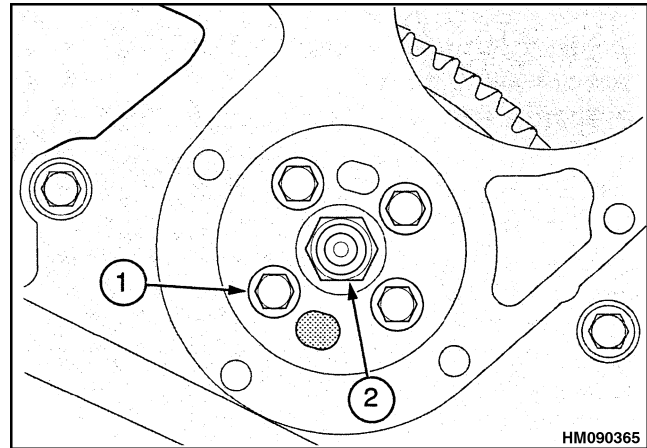
CAUTION

Do not release the nut (Figure 91) from the fuel injection pump. See Figure 92. The nut is shown in position when the fuel pump is installed on the engine. The fuel pump hub is installed to the shaft in the factory to verify that the fuel pump is in the correct position for timing. If the nut is removed and the hub moves, the hub will need to be accurately installed to the pump by use of specialist equipment before the pump can be installed on the engine.

The fuel pump gear is fastened to the hub of the fuel pump by four setscrews. The setscrews pass through slots in the gear, which allows for adjustment of the backlash.

NOTE: Four tamper-proof fasteners retain the fuel pump gear. Special tools are needed to remove these fasteners. Refer to your Perkins distributor.

To remove the fuel injection pump from the engine it is only necessary to remove the four capscrews which secure the fuel pump gear to the hub. See Figure 92.



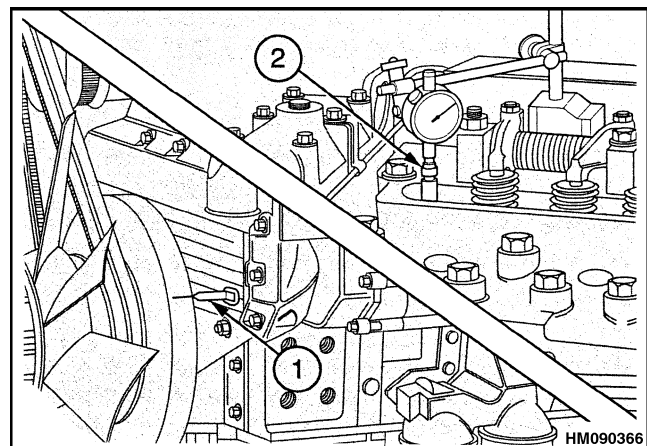
1. CAPSCREWS (4) 2. NUT

Figure 92. Injection Pump Hub

How to Set Number One Piston to TDC on Compression Stroke

Special tools: Valve spring compressor
 Stud adapter
 Setscrew adapter

1. Fasten a temporary pointer to the timing case cover with its tip near to the outer edge of the crankshaft pulley or damper. See Figure 93.



1. TEMPORARY POINTER 2. DIAL TEST INDICATOR

Figure 93. Procedure to Find TDC

2. Remove the gland nuts that retain the fuel injectors. Remove the fuel injectors.
3. Remove the rocker cover.
4. Rotate the crankshaft clockwise from the front until the push rod for the inlet valve in the rear cylinder just begins to push on the rocker arm.
5. Remove the spring clip and the spacer from the front of the rocker shaft. Release the capscrews of the front two pedestals of the rocker shaft and remove the front rocker lever. Tighten the capscrews of the rocker shaft pedestals.
6. Remove the valve springs from the front valve with the valve spring compressor and the adapter, for pedestal studs, or with the adapter, for pedestal capscrews.



CAUTION

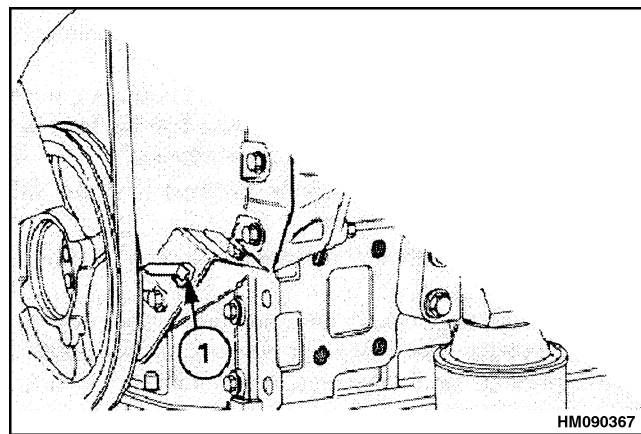
Fit a suitable collar near the top of the valve to hold the valve if the crankshaft is rotated too far.

7. Allow the valve to be held by the top of the piston.
8. Fasten a dial test indicator with its plunger in contact with the top of the valve stem and with a reading shown on the gage. See Figure 93. Rotate slowly the crankshaft clockwise from the front until the clockwise movement of the dial gage pointer just stops. Make a mark on the crankshaft pulley or damper to align with the temporary pointer. Continue to rotate the crankshaft in the same direction until the gauge pointer just begins to move in a counterclockwise direction. Make another mark on the pulley or damper to align with the pointer. Mark the center point between the two marks on the pulley or damper and remove the other two marks.
9. Rotate the crankshaft approximately 45° counterclockwise from the front and then clockwise until the mark on the pulley or damper is aligned with the pointer. Number one piston is now at TDC on the compression stroke.
10. Install the fuel injector and gland nuts. Torque nuts to 40 N•m (30 lbf ft).

How to Set Number One Piston to TDC on Compression Stroke (Alternate Procedure)

This alternate procedure can be used if the above procedure cannot be used.

1. Fasten a temporary pointer to the timing case cover so that its tip is near the outer edge of the crankshaft pulley as shown. See Figure 94.



1. TEMPORARY POINTER

Figure 94. Alternate Procedure to Find TDC

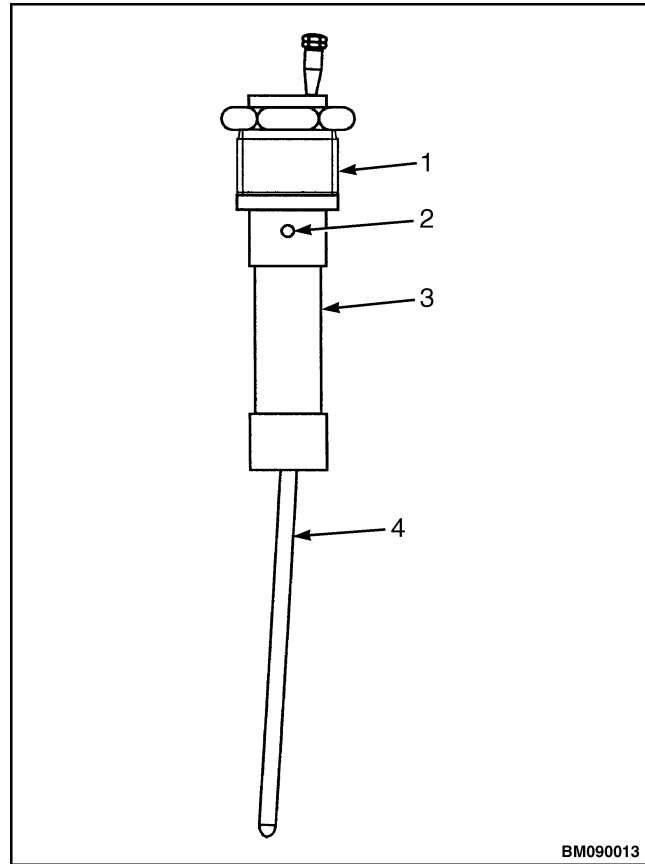
2. Remove the gland nuts on the fuel injectors. Remove the fuel injectors.
3. Remove the valve cover.
4. Rotate the crankshaft in a clockwise direction from the front until the push rod for the inlet valve in the rear cylinder just begins to push on the rocker arm.
5. Rotate the crankshaft a further 1/8 turn clockwise. Use a small lever between the rocker arm and the spring cap of number one inlet valve. Open the inlet valve enough to install a 5.0 mm (0.2 in.) spacer between the end of the valve stem and the rocker arm.
6. Slowly rotate the crankshaft counterclockwise until the piston touches the open valve. Carefully make a mark on the pulley that is aligned with the tip of the temporary pointer.

7. Rotate the crankshaft clockwise one or two degrees and remove the spacer between the valve stem and the rocker arm. Rotate the crankshaft 1/4 turn counterclockwise. Install the spacer again between the valve stem and the rocker arm.
8. Slowly rotate the crankshaft clockwise until the piston touches the open valve. Make a second mark on the pulley that is aligned with the temporary pointer.
9. Mark the center point between the two marks on the crankshaft pulley and remove the other two marks. Rotate the crankshaft 1/8 turn counterclockwise and remove the spacer between the valve stem and the rocker arm.
10. Rotate the crankshaft clockwise until the mark on the crankshaft pulley is aligned with the temporary pointer. Number one piston is now at TDC on the compression stroke.

How to Set Number One Piston to 4° After TDC on Compression Stroke

Special tools: Piston displacement tool

1. Remove the fuel injector of the number one piston and set the number one piston to TDC on compression stroke. Do not reinstall the fuel injector at this time. See How to Set Number One Piston to TDC on Compression Stroke.
 2. Remove the gland nut and fuel injector from the number two piston. Verify that the fuel injector bore and seat are clean.
- NOTE:** Normally the piston displacement tool is used with the number two cylinder but can also be used with the number 5 cylinder if required.
3. Align the displacement tool pin with the fuel injector alignment slot in the cylinder head. Insert the main body of the displacement tool into the fuel injector bore. See Figure 95 and Figure 96.
 4. Place the gland nut on the displacement tool body. Tighten the gland nut to lock the displacement tool in position.
 5. Lubricate the displacement tool probe with clean engine oil.

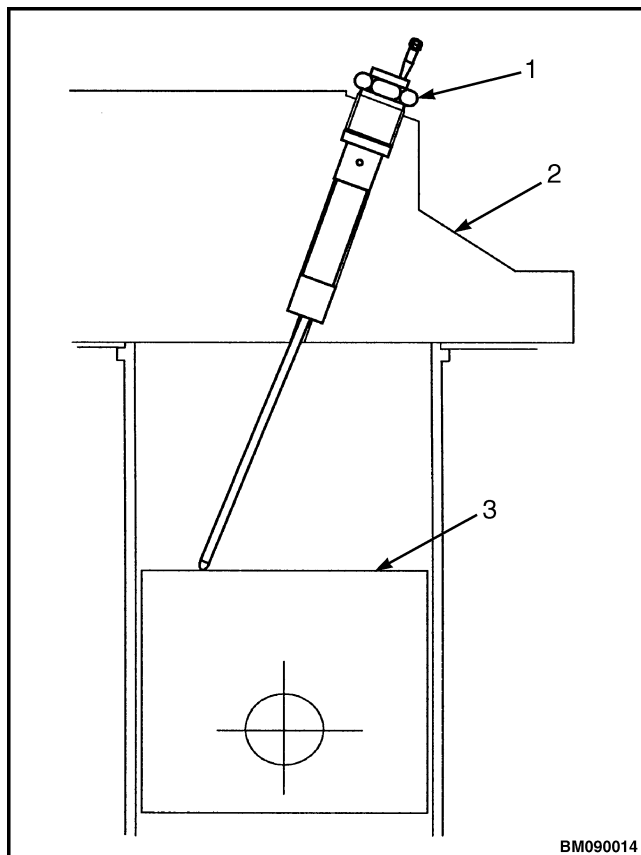


BM090013

1. GLAND NUT
2. PIN
3. MAIN BODY
4. PISTON DISPLACEMENT PROBE

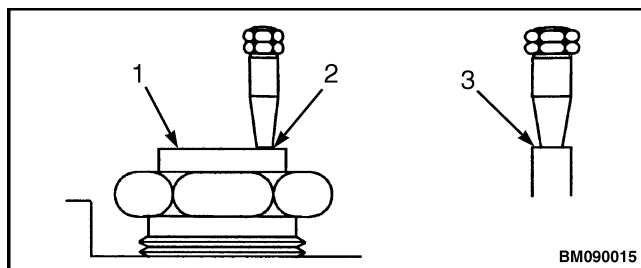
Figure 95. Displacement Tool

6. Insert the displacement tool probe into the main body of the displacement tool and lower it onto the top of the piston.
7. Slowly rotate the crankshaft clockwise from the front until the machined face of the probe aligns with the top face of the main body Pos. 1 at Pos. 2. See Figure 97.
8. Remove the displacement tool probe and main body from the cylinder head.
9. Install the fuel injectors.



1. DISPLACEMENT TOOL
2. CYLINDER HEAD
3. PISTON

Figure 96. Insertion of Displacement Tool in Cylinder Head



1. TOP FACE OF MAIN BODY, POS. 1
2. TOP FACE OF MAIN BODY, POS. 2
3. MACHINED FACE OF PROBE

Figure 97. Displacement Tool Probe Alignment

Valve Timing, Check

1. Remove the valve cover.

2. Set the piston of number one cylinder to TDC on the compression stroke.
3. Fasten a temporary pointer to the timing case so that its tip is near the outer edge of the crankshaft pulley. See Figure 94.
4. Rotate the crankshaft clockwise from the front until the inlet valve of the rear cylinder is fully open.
5. Set the valve tip clearance of number one cylinder inlet valve to 1.5 mm (0.059 in.) and the exhaust valve to 1.32 mm (0.052 in.).
6. Rotate the crankshaft clockwise from the front until the push rod of number one cylinder inlet valve just tightens. In this position, check if the mark on the crankshaft pulley or damper is within $\pm 2.5^\circ$ of the temporary pointer. Use the formula below to find the measurement that is equal to 2.5° on the pulley or damper.

$$\frac{C \times P}{360}$$

C = circumference of pulley or damper

P = 2.5 degrees

7. If the timing is more than 2.5° out of position, the timing gears are probably not in correct mesh.

NOTE: One tooth on the camshaft gear is equivalent to 19 mm (0.75 in.) at the circumference of a pulley of 203 mm (8 in.) diameter. If a large damper is fitted, one tooth on the camshaft gear is equivalent to 29 mm (1.14 in.) at the circumference of a damper of 310 mm (12.2 in.) diameter, or 30 mm (1.18 in.) at the circumference of a damper of 327 mm (12.9 in.) diameter.

8. Rotate the crankshaft clockwise from the front until the inlet valve of the rear cylinder is fully open. Set the valve tip clearance of the inlet valve of number one cylinder to 0.20 mm (0.008 in.) and the exhaust valve to 0.45 mm (0.018 in.).
9. Install the rocker cover.
10. Remove the temporary pointer from the timing case and the timing mark from the pulley or damper.

Fuel Injection Pump Timing, Check

Special tools: Timing pin, Bosch fuel injection pumps



CAUTION

Do not remove the nut which retains the hub to the shaft of the fuel injection pump. The hub is fitted permanently to the shaft. If the hub is moved, it will be necessary for a fuel injection pump specialist to correctly position the hub on the shaft with special test equipment available to Perkins distributors.

1. Set the piston of number one cylinder to 4° after TDC on the compression stroke operation. See How to Set Number One Piston to 4° After TDC on Compression Stroke.

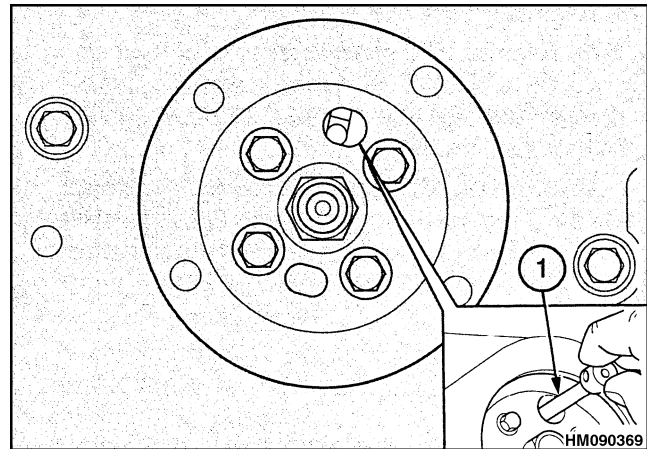
2. Remove the coolant pump.

NOTE: Four tamper-proof fasteners retain the fuel pump gear. Special tools and personnel with the correct training are necessary to remove these fasteners. Refer to your nearest Perkins distributor.

3. Insert the timing pin through the hole in the fuel pump gear and the slot of the hub. Push the pin fully into the hole in the body of the fuel pump. If the pin can be fully inserted, the pump timing is correct. There should be no resistance when the pin is inserted.

NOTE: The position for the timing pin for Bosch fuel injection pumps is shown in Figure 98.

4. Remove the timing pin.
5. If the timing pin cannot be pushed into the pump body, check that the engine is correctly set at 4° after TDC on the number one cylinder compression stroke. If the engine is set correctly, but the pin does not fit in the hole, the fuel pump must be removed and set by a specialist.
6. Fit the coolant pump.



1. TIMING PIN

Figure 98. Timing Gear for Bosch Fuel Injection Pump

Turbocharger

GENERAL

The turbocharger is installed between the induction and exhaust manifolds. Exhaust gases turn the turbocharger and cause it to supply air to the induction manifold at greater than atmospheric pressure. The bearings in the turbocharger are lubricated with engine oil from the main oil passage in the engine block. The oil passes through the bearing housing of the turbocharger and returns to the oil sump.

REMOVE

1. Clean the turbocharger. Remove the air cleaner hose at the compressor inlet.
2. Remove or disconnect the support bracket for the turbocharger. Remove the heat shield for the fuel pump if additional clearance is necessary.

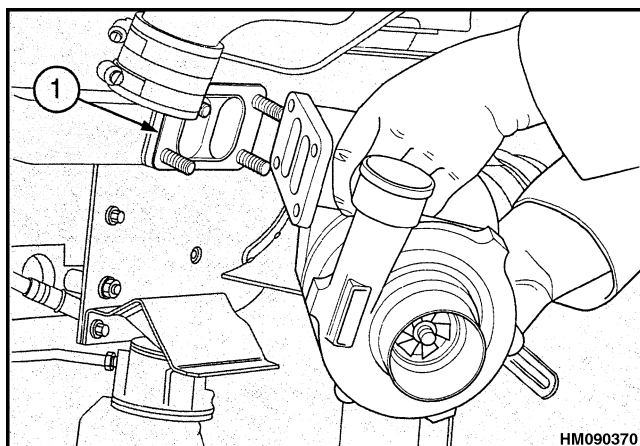
3. Remove the nuts and remove the exhaust elbow and its gasket from the turbocharger.
4. Release the hose clamps and push the hose from the compressor outlet up the elbow of the induction manifold.
5. Disconnect the oil supply line at the flange at the top of the bearing housing of the turbocharger. Remove the oil supply line and gasket.
6. Disconnect the oil drain line at the flange at the bottom of the bearing housing of the turbocharger. Remove the oil drain line and gasket. If necessary, release the hose clamps from the oil drain line and push the hose down.
7. Remove the nuts at the flange that holds the turbocharger to the exhaust manifold. Remove

the turbocharger from the exhaust manifold. Remove the gasket. Cover the open ports in the manifolds, the turbocharger, and the pipes to be sure that dirt, etc., will not enter.

8. Check the hoses, lines, and duct for cracks, wear, or damage.

INSTALL

1. Remove the covers from the pipes, manifolds, and turbocharger.
2. Check that the openings of the turbocharger and the manifolds are clean. Verify that the compressor shaft in the turbocharger rotates freely.
3. Install a new gasket where the turbocharger connects to the exhaust manifold. See Figure 99. If the original nuts are to be used, verify they are in good condition. Use a compound on the threads to prevent seizure of the nuts to the studs.



1. GASKET

Figure 99. Turbocharger Installation

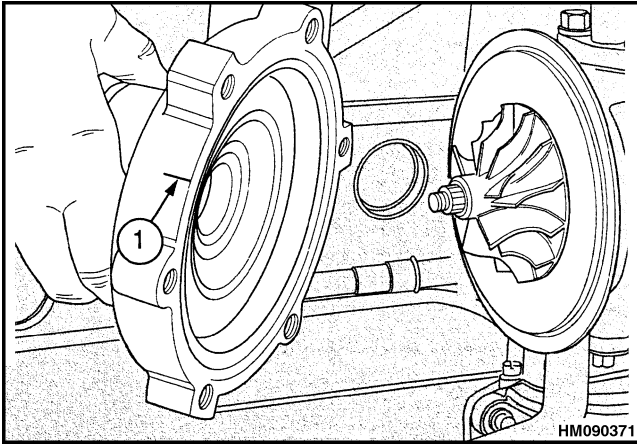
4. Install the turbocharger. Tighten the nuts to 44 N•m (32 lbf ft).
5. Lubricate the bearing housing of the turbocharger with clean engine oil. Use a new gasket and install the oil supply line.
6. Use a new gasket and install the oil drain line. Tighten the capscrews, but do not connect the hose.

7. Install the exhaust elbow on the turbocharger. If the original nuts are to be used, verify they are in good condition. Use a compound on the threads to prevent seizure of the nuts to the studs. New nuts have a coating on them to prevent seizure. Install a new gasket on the studs. Tighten the nuts to 22 N•m (16 lbf ft) (plated) or 25 N•m (18 lbf ft) (non-plated).
8. Install the support bracket for the turbocharger. Install the heat shield for the fuel pump if it was removed.
9. Slide the hose on the elbow for the induction manifold onto the outlet of the turbocharger. Install the hose clamps.
10. Verify that there is no restriction in the duct from the air filter to the turbocharger. Install the duct on the turbocharger and tighten the fastener.
11. Check that the bearings in the turbocharger have an oil flow. Disconnect the electric stop control so that the engine cannot start. Use the starter motor to operate the engine until engine oil flows from the oil drain line from the turbocharger. Connect the hose to the oil drain line. Connect the electric stop control.

IMPELLER AND COMPRESSOR HOUSING, CLEAN

NOTE: The compressor housing can sometimes be removed for cleaning without removing the turbocharger first. The compressor housing is held by a circlip, and access to the circlip (large snap ring) is not always possible.

1. Clean the turbocharger. Remove the duct from the air filter where it connects to the inlet of the turbocharger.
2. Release the hose clamps and push the hose from the compressor outlet up the elbow of the induction manifold.
3. Make a reference mark on the compressor housing and the bearing housing as shown in Figure 100.



1. REFERENCE MARK

Figure 100. Compressor Housing Removal

4. Remove the capscrews and remove the lock plates. Carefully remove the compressor housing from the turbocharger as shown in Figure 100. If the compressor housing is a tight fit, use a soft hammer.



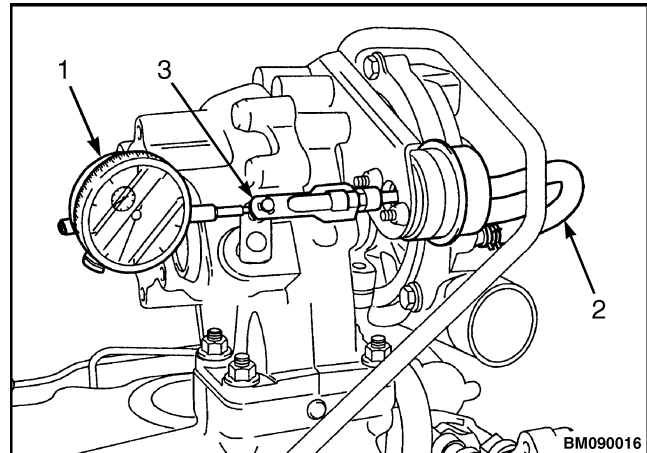
CAUTION

Be careful that the blades of the impeller are not damaged. If the impeller is damaged, the turbocharger must be replaced or repaired by a special repair service.

5. Put the compressor housing in a container with a solvent that is not caustic. When the dirt has loosened, use a hard brush or a soft scraper to clean the compressor housing. Use compressed air at low pressure to dry the compressor housing.
6. Clean the impeller with a soft brush.
7. Carefully push the impeller toward the bearing housing and turn the impeller with your hand. Check that the impeller turns freely and there is no noise that can indicate wear or damage. If there is a fault, the turbocharger must be replaced or repaired by a special repair service.
8. Install the compressor housing on the turbocharger. Verify the reference marks are aligned. Install the lock plate and capscrews, and torque the capscrews to 11 N•m (9 lbf ft).
9. Install the ducts on the inlet and outlet of the compressor housing and tighten the clamps.

WASTE-GATE VALVE CHECK

1. Remove the actuator hose at the actuator and connect an air line with adjustable pressure and an accurate gauge to the actuator. See Figure 101.



1. DIAL INDICATOR GAUGE
2. ACTUATOR HOSE
3. ACTUATOR ROD END

Figure 101. Turbocharger Waste-Gate Valve Check

2. Connect a dial indicator gauge to the turbocharger with the indicator gauge plunger in contact with the end of the actuator rod to measure the axial movement of the rod.



CAUTION

Do not apply more than 205 kPa (30 psi) of air pressure to the actuator. Higher pressures may cause damage to the actuator.

3. Slowly apply air pressure to the actuator. Verify the pressure needed to move the rod 1 mm (0.039 in.) within limits. See Engine Specifications, Turbocharger.
4. Release pressure and verify that the dial on the indicator gauge returns to zero.
5. Repeat the test several times to verify that the readings are accurate. It may be necessary to lightly hit the turbine housing with a soft hammer during testing.
6. If the air pressure is correct, release the pressure and remove the test equipment. Reconnect the actuator hose to the actuator.

7. If the air pressure and the waste-gate operation are not correct, contact your nearest Perkins approved dealer.

CLOSED CIRCUIT BREATHER SYSTEM (CCB)

CCB Assembly, Remove



CAUTION

Do not operate the engine if the breather valve or intake hose is disconnected, damaged, or restricted. Damage to the engine could occur.

1. Remove the breather hose and drain hose. See Figure 102.

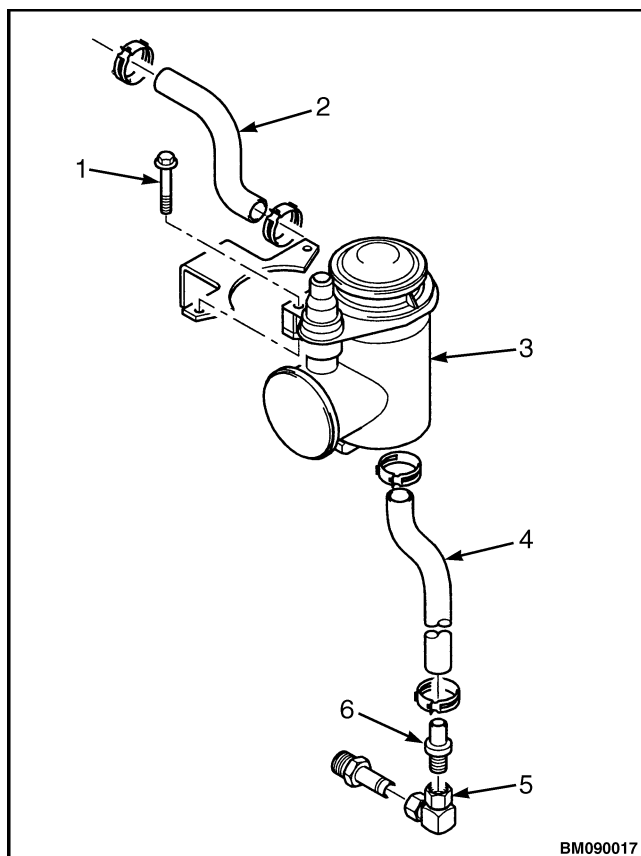


Figure 102. Closed Circuit Breather System (CCB)

Legend for Figure 102

1. M6 CAPSCREW
2. BREATHER HOSE
3. ASSEMBLY HOUSING
4. DRAIN HOSE
5. COMPRESSION ELBOW NUT
6. DRAIN VALVE

2. Remove the two M6 capscrews and remove the closed circuit breather assembly from the mounting brackets.

Closed Circuit Drain Valve, Remove

1. Remove the drain hose. See Figure 102.
2. Remove the compression elbow nut.
3. Remove the drain valve from the compression elbow.

CCB Assembly, Install

1. Place the closed circuit breather assembly in the mounting bracket.
2. Install the two M6 capscrews and torque to 9 N•m (7 lbf ft).
3. Check the breather hose and drain hose for damage. Replace if necessary.
4. Install the breather hose and drain hose.

Closed Circuit Drain Valve, Install

1. Apply non-permanent Loctite® to the threads of the drain valve and install in the compression elbow. Tighten the nut finger tight; then, with a suitable tool, tighten the nut an additional 1-1/4 turns.
2. Check the drain hose for damage. Replace if necessary.
3. Install the drain hose.

Lubrication System Repair

GENERAL

The oil pump is turned by a gear on the crankshaft through an idler gear. Engine oil from the sump passes through a strainer and pipe to the suction side of the pump. A relief valve on the outlet of the oil pump controls the maximum oil pressure in the lubrication system. The engine oil flows from the oil pump through the oil filter to the oil cooler.

Engine oil from the main oil passage flows to the main bearings of the crankshaft and through the passages in the crankshaft to the rod bearings. The pistons and cylinder bores are lubricated by splash and oil mist.

Engine oil also flows from the main bearings to the journals of the camshaft. Some engine oil goes through the center camshaft bearing to the rocker arm assembly.

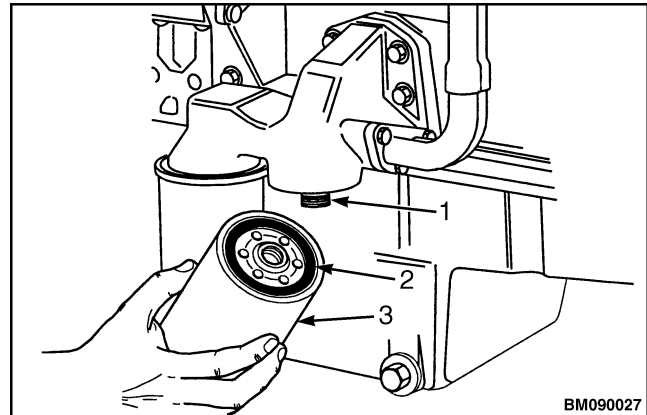
The hub of the idler gear has an oil passage to the main oil passage and the timing gears are splash lubricated.

An outlet from the main oil passage supplies oil to the bearings of the turbocharger. The engine flows through the bearings of the turbocharger and returns to the oil sump. All engines have a cooling jet connected to the main oil passage for each cylinder. The cooling jets spray engine oil on the bottoms of the pistons for additional cooling.

OIL FILTER, REPLACE

NOTE: There are two oil filters and both must be changed at the same time.

1. Change the oil filter when the engine oil is changed. Put a drain pan under the filter. Remove the filter cartridge. Verify the adapter stays in the filter head as shown in Figure 103. Discard the filter cartridge.
2. Clean the filter head.
3. Add some clean engine oil to the new filter cartridge. Apply clean engine oil to the gasket.
4. Install the new filter cartridge and tighten by hand only.
5. When new oil has been added and the engine can be operated, start the engine. Check the area around the filter for leaks.



1. ADAPTER
2. GASKET
3. FILTER

Figure 103. Oil Filter

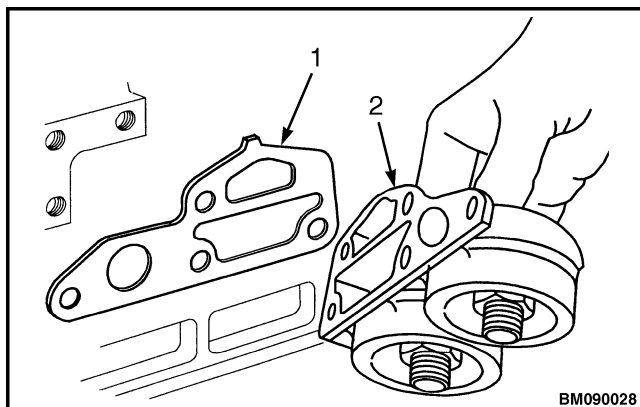
OIL FILTER HEAD

Remove

1. Put a drain pan under the filter head.
2. Remove the filter cartridges.
3. Remove the turbocharger oil feed line from the union on the oil filter head.
4. Remove the capscrews from the filter head and remove the filter head from the cylinder block. See Figure 104.
5. Discard the gasket.

Install

1. Clean the cylinder block face and the face of the filter head.
2. Fit a new gasket to the filter head.
3. Place the oil filter head assembly in position on the adapter plate. Apply Loctite® to the first three threads of the capscrews. Install the capscrews and tighten.
4. Install the turbocharger oil feed line.
5. Install a new oil filter.



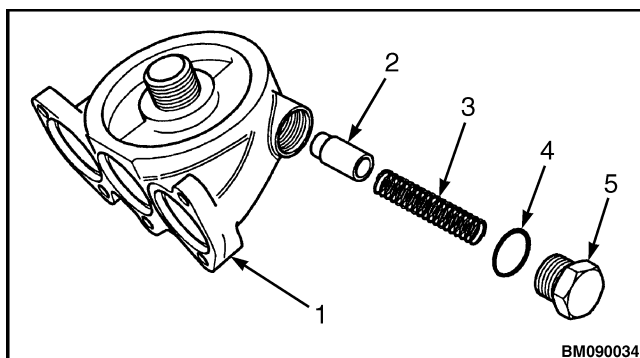
1. GASKET
2. FILTER HEAD

Figure 104. Oil Filter Head Assembly

OIL FILTER HEAD BYPASS VALVE

Remove and Install

1. Remove the threaded plug. See Figure 105.



1. OIL FILTER HEAD ASSEMBLY
2. BYPASS VALVE
3. SPRING
4. O-RING
5. THREADED PLUG

Figure 105. Oil Filter Head Bypass Valve

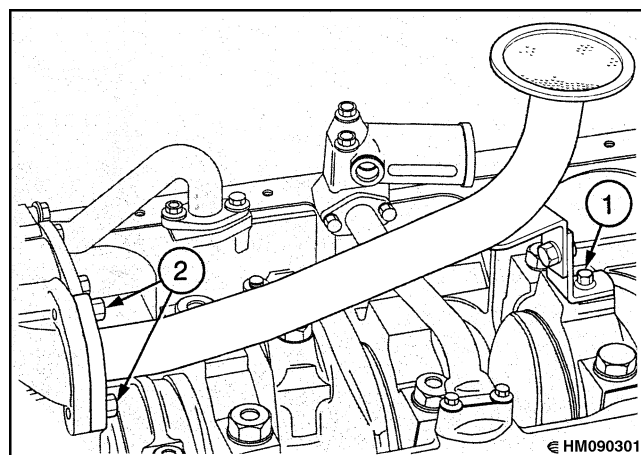
2. Remove the spring and bypass valve from the oil filter head assembly.
3. Clean the components and check for wear or damage. Replace as necessary.
4. Lubricate the valve with clean engine oil and install in the oil filter head assembly.
5. Install the spring.

6. Check the O-ring on the threaded plug for wear or damage. Replace if necessary. The O-ring must be clean and dry when installed.
7. Install the threaded plug and torque to 60 N•m (44 lbf ft).

OIL SUMP

Remove

1. Drain the engine oil. Remove the capscrews and the two nuts that fasten the oil sump to the engine block. Lower the oil sump. Remove the gasket.
2. Clean the oil sump with mineral oil solvent.
3. If the suction line and oil strainer must be removed, see Figure 106. Remove the capscrew that holds the bracket to the main bearing cap. Remove the two capscrews from the flange of the suction line and remove the suction line and screen. Clean the faces of both flanges.



1. SUPPORT BRACKET, MAIN BEARING CAP
2. CAPSCREWS, FLANGE, SUCTION PIPE

Figure 106. Oil Sump Screen Removal

Install

1. If the oil strainer and suction line were removed, loosely assemble the bracket of the suction line to the main bearing cap. Install a new gasket and fasten the flanges of the suction line to the oil pump. Verify that the suction line is aligned correctly and tighten the capscrew that holds the bracket to the main bearing cap.

2. Use a new gasket and install the oil sump. Use capscrews on each side of the oil sump to align and hold the gasket in position during assembly. Install the remainder of the capscrews and the two nuts. Tighten all of the fasteners to 22 N•m (16 lbf ft).
3. Install the drain plug in the oil sump. Use a new O-ring and tighten to 34 N•m (25 lbf ft).

OIL PUMP

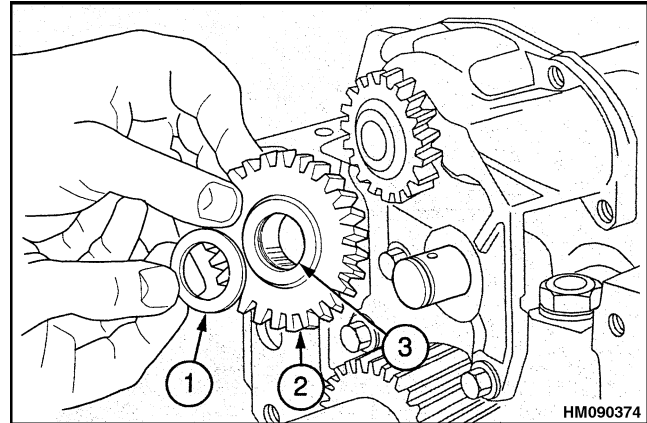
Remove

1. Drain the engine oil and remove the oil sump. Remove the oil strainer and suction line. See Oil Sump, Remove.
2. Remove the relief valve and connection line.
3. The oil pump is fastened to the number one main bearing cap. Access to the capscrews on the main bearing can be difficult when the timing case is on the engine. A special wrench can be required to apply the correct torque to the capscrews for removal and installation. If a wrench is not available to install the capscrews on the main bearing cap, the timing case must be removed. See Timing Case, Remove.
4. Remove the snap ring that holds the idler gear to the oil pump. Remove the washer and the idler gear. See Figure 107.
5. Remove the capscrews and the oil pump. See Figure 108.

Inspect

If the oil pump is worn so that the performance is decreased, the oil pump must be replaced.

1. Remove the capscrews and the cover of the oil pump.
2. Remove the outer rotor and clean all the parts. Check for damage and wear.



1. WASHER
2. IDLER GEAR
3. BUSHING

Figure 107. Idler Gear, Oil Pump Removal

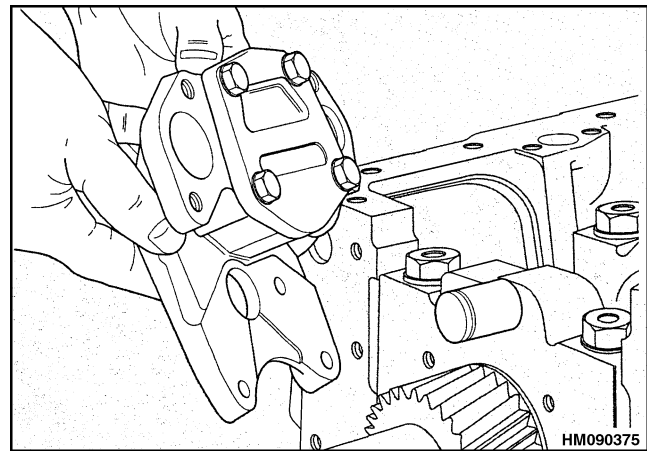


Figure 108. Oil Pump Removal

3. Install the outer rotor and check the clearances. See Figure 109. See Engine Specifications for the wear tolerances.
4. Check the clearances of the inner rotor. See Figure 110. See Engine Specifications for the wear tolerances.
5. Check end clearance and axial movement of the rotor. Use a spacer gauge and a straightedge. See Figure 111. See the Engine Specifications for the wear tolerances.

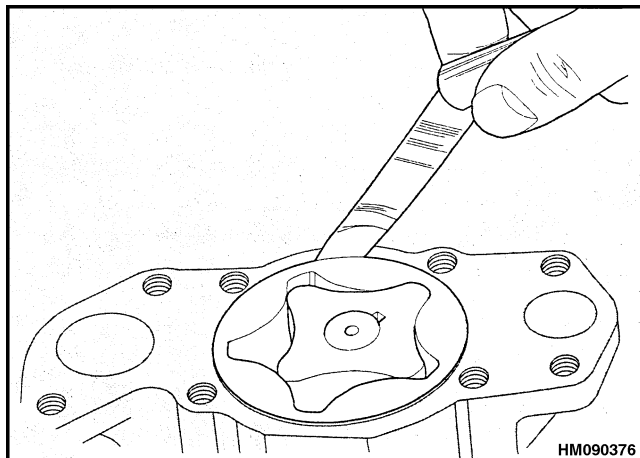


Figure 109. Outer Rotor Clearance Check

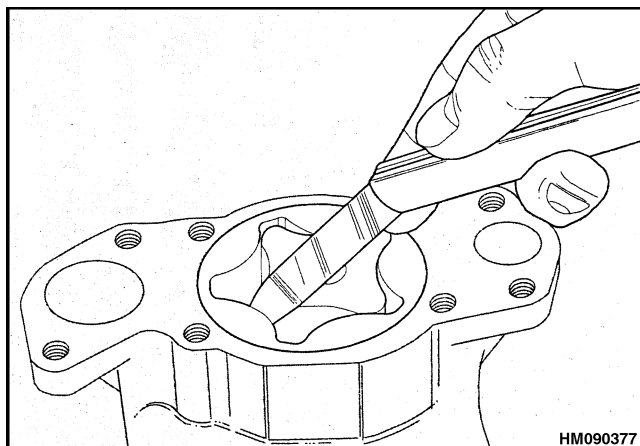


Figure 110. Inner Rotor Clearances Check

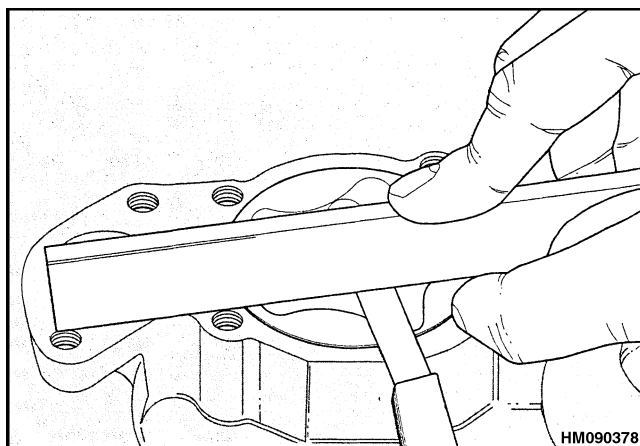


Figure 111. Rotor End Clearances Check

6. When the parts are clean and inspected, install the cover to the oil pump. Tighten the capscrews to 28 N•m (21 lbf ft).

Install

1. Lubricate the internal parts of the oil pump with engine oil before installation. Install the oil pump on the main bearing cap and tighten the capscrews to 22 N•m (16 lbf ft).
2. Verify the idler gear and bushing are in good condition. The bushing is available as a separate part. Install the idler gear, washer, and snap ring. See Figure 107. Check the gear clearance. See Figure 112. The minimum clearance is 0.062 mm (0.0024 in.) between the oil pump gear and the idler gear.

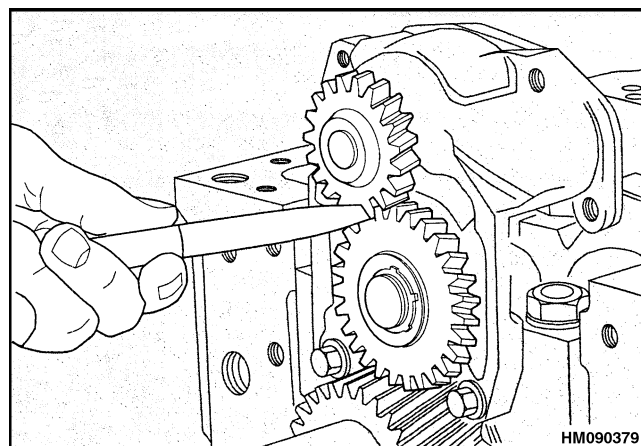


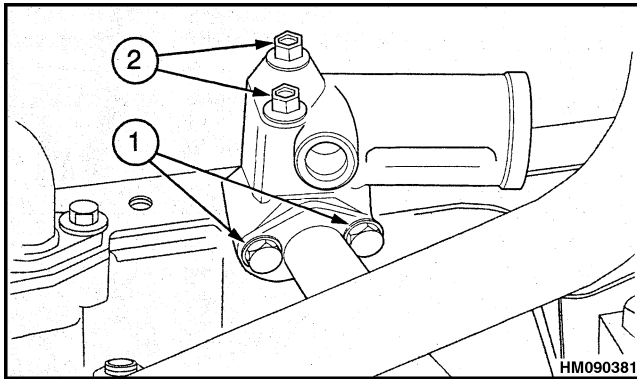
Figure 112. Clearances Check Between Oil Pump Gear and Idler Gear

3. If the main bearing cap was removed, lubricate the bearing with engine oil and install the bearing cap. Tighten the capscrews to 265 N•m (195 lbf ft). Check the gear clearance. See Figure 112. The minimum clearance is 0.095 mm (0.0037 in.) between the crankshaft gear and the idler gear.
4. If the timing case was removed, install the timing case. See Timing Case and Timing Gears Repair.
5. Install the relief valve and the connection line. See Relief Valve, Remove.
6. Install the oil sump. See Oil Sump, Install.

RELIEF VALVE

Remove

1. Drain the engine oil. Remove the oil sump. See Oil Sump, Remove.
2. Remove the capscrews that fasten the cross flow pipe to the relief valve. See Figure 113. Remove the flange. Remove the two capscrews that fasten the relief valve to the cylinder block and remove the relief valve.



1. CAPSCREW (2) 2. CAPSCREW (2)

Figure 113. Relief Valve Removal

Disassemble



CAUTION

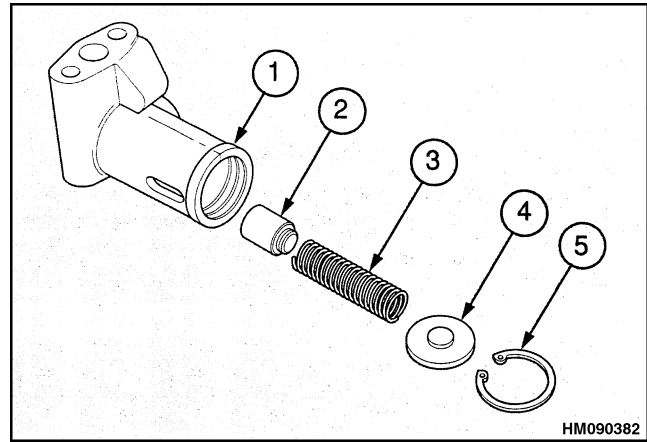
The relief valve has a compressed spring. Do not permit the spring to be released so that it causes an injury.

NOTE: The relief valve can be disassembled without removing it from the engine.

Apply pressure against the end plate of the spring assembly. See Figure 114. Remove the snap ring. Carefully release the end plate and release the pressure on the compressed spring. Remove the end plate, spring, and plunger.

Inspect

1. Clean the parts. Check the parts for wear and damage. Check the load necessary to compress the spring to its fitted length. See Engine Specifications.
2. Check that the seat of the plunger is not damaged and that the plunger moves easily in its bore.



- | | |
|-----------------------|--------------|
| 1. BODY, RELIEF VALVE | 3. SPRING |
| 2. PLUNGER | 4. END PLATE |
| | 5. SNAP RING |

Figure 114. Relief Valve Assembly

Assemble

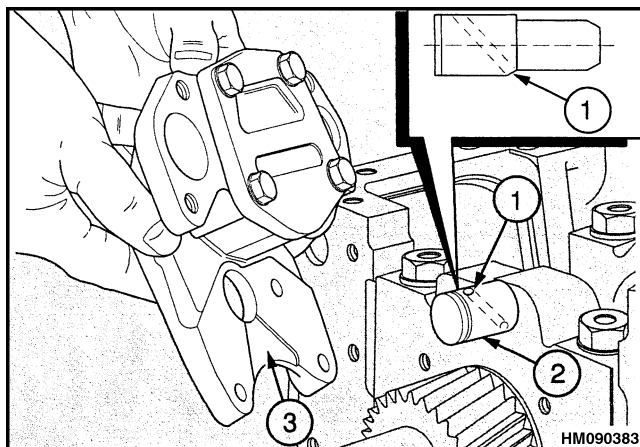
Lubricate the parts with engine oil during assembly. Install the plunger in the bore as shown in Figure 114. Install the spring and end cap. Compress the spring and end cap into the bore so that the snap ring can be installed. Install the snap ring.

Install

1. Verify the faces of the cross flow pipe and the relief valve are clean. Install the relief valve and new gasket to the cylinder block. Install the four capscrews and tighten the flange capscrews and then the valve capscrews to 22 N•m (16 lbf ft).
2. Install the oil sump. See Oil Sump, Install.

IDLER GEAR SHAFT, REPLACE

The shaft for the idler gear in the oil pump is installed in the front main bearing cap. See Figure 115. If this idler gear shaft must be replaced, use the procedures in the following paragraphs. The idler gear shaft has an oil passage for lubrication of the bushing for the idler gear. Engine oil from the front main bearing passes through a channel in the body of the oil pump and then through the oil passage to the idler gear.

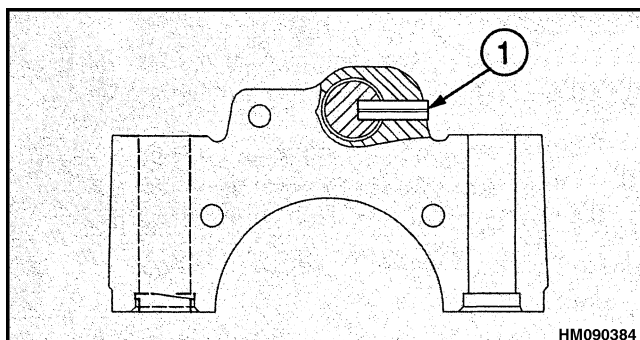


1. OIL PASSAGE
2. IDLER GEAR SHAFT
3. CHANNEL IN OIL PUMP

Figure 115. Idler Gear Shaft

Remove

The idler gear shaft is fastened in the front main bearing cap with a roll pin. See Figure 116. This roll pin is hardened metal. If the following procedure does not remove the roll pin, see Remove (Alternative).



1. ROLL PIN

Figure 116. Idler Gear Shaft Roll Pin

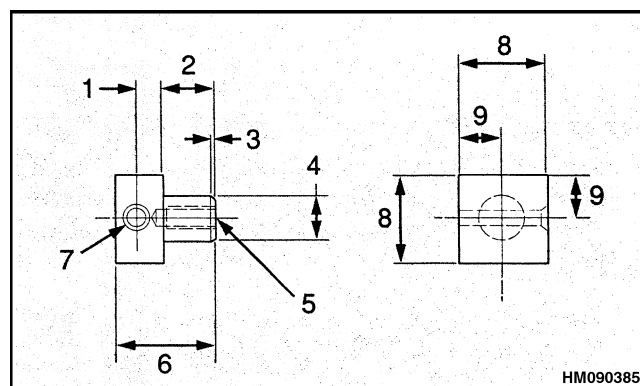
- Carefully use an M5 × 0.8 mm taper tap to put a chamfer in the end of the roll pin.
- Carefully use an M5 × 0.8 mm plug tap to cut a minimum three threads in the end of the roll pin. If the tap breaks, see Remove (Alternative).
- Obtain the following parts to make a puller:
 - M5 × 0.8 mm capscrew that has a minimum thread length of 15 mm.
 - M5 × 0.8 mm nut.

- Spacer with a 15.88 mm or 19.05 mm outside diameter and a minimum internal diameter of 8.73 mm. The length of the spacer must be 9.5 mm.

- Install the nut fully on the capscrew. Hold the spacer on the capscrew and engage the threads of the roll pin with the capscrew.
- Center the spacer over the roll pin and tighten the nut against the spacer. Continue to tighten the nut to pull the roll pin from the front main bearing cap.
- Press the idler gear shaft from the front main bearing cap.

Remove (Alternative)

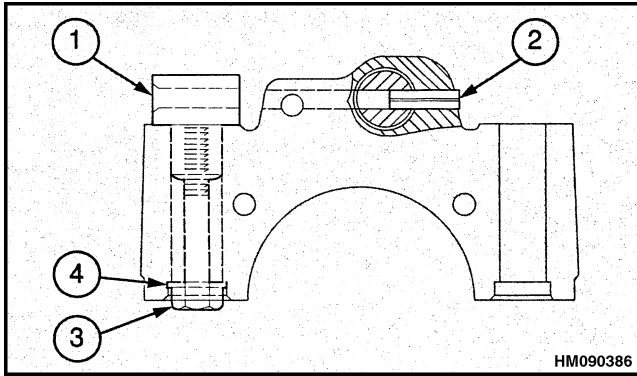
- Make a drill guide to the dimensions shown in Figure 117.



- 8.3 mm (0.327 in.)
- 20.0 mm (0.787 in.)
- 1.0 mm (0.039 in.)
- 16.1 to 16.4 mm (0.634 to 0.646 in.)
- 6.9 × 22 mm (0.272 × 0.866 in.) DIAMETER HOLE FOR 5/16-24 UNF × 18 MM THREAD
- 36.0 mm (1.42 in.)
- 6.5 to 6.6 mm (0.256 to 0.260 in.) DIAMETER HOLE, COUNTERSUNK 9.0 MM × 900 INCLUDED
- 31.75 mm (1.250 in.)
- 15.9 mm (0.626 in.)

Figure 117. Drill Guide Dimensions

- Install the drill guide on the front main bearing cap as shown in Figure 118. Verify that the countersink in the guide faces away from the roll pin. Verify the edge of the drill guide is aligned with the front edge of the bearing cap.



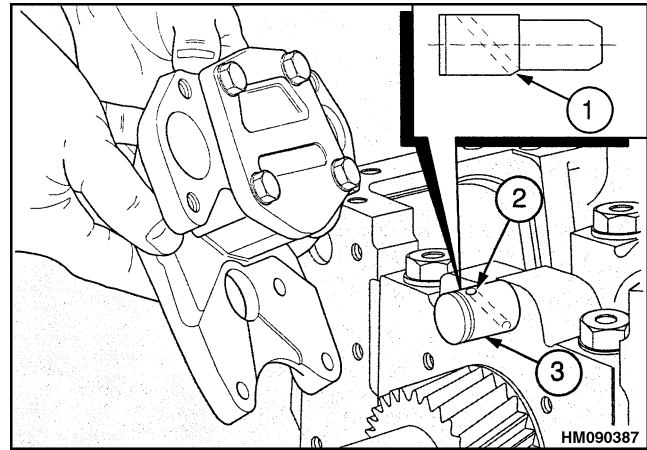
1. DRILL GUIDE
2. ROLL PIN
3. 5/16 UNF CAPSCREW
4. FLAT WASHER

Figure 118. Drill Guide Installation

3. Drill a 6.35 mm (0.25 in.) diameter hole in the bearing cap. Drill the hole 47.0 mm (1.85 in.) into the bearing cap.
4. Use a punch to drive the roll pin from its position.
5. Press the idler gear shaft from the front main bearing cap.

Install

1. Verify the hole in the main bearing cap for the idler gear shaft is clean and any rough edges are removed.
2. Use a press to install the idler gear shaft into the main bearing cap. Verify that the oil passage in the idler gear shaft is correctly oriented. See Figure 119. Apply Loctite® 603 to the chamfer of the idler gear shaft where it joins the main bearing cap.
3. Verify the idler gear shaft is pressed fully into the main bearing cap. Use the original hole for the roll pin as a drill guide. Drill a 6.35 mm (0.25 in.) diameter hole into the idler gear shaft 9.5 mm (0.37 in.) deep.
4. Install a new roll pin into the main bearing cap and the idler gear shaft.



1. CHAMFER
2. OIL PASSAGE
3. IDLER GEAR SHAFT

Figure 119. Idler Gear Shaft Installation

Install (Alternative)

Some engines do not have a roll pin installed to fasten the idler gear shaft in position. If the idler gear shaft must be replaced, a roll pin must be installed to hold the new idler gear shaft in position. This procedure describes how to install a new roll pin.

1. Verify the hole in the main bearing cap for the idler gear shaft is clean and any rough edges are removed.
2. Use a press to install the idler gear shaft into the main bearing cap. Verify that the oil passage in the idler gear shaft is correctly oriented. See Figure 119. Apply Loctite® 603 to the chamfer of the idler gear shaft where it joins the main bearing cap.
3. Make a drill guide as described in Remove (Alternative).
4. Install the drill guide on the front bearing cap as shown in Figure 120.
5. Use the drill guide and drill a 6.35 mm (0.25 in.) diameter hole into the idler gear shaft 25.4 mm (1.00 in.) deep. Remove the drill and the drill guide.
6. Install a roll pin into the bearing cap and the idler gear shaft.

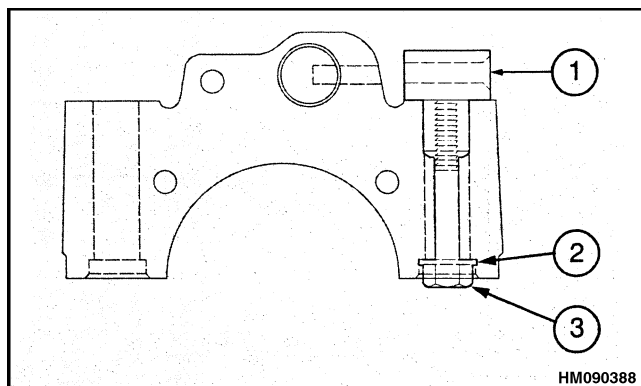


Figure 120. Idler Gear Shaft Roll Pin

Legend for Figure 120

- | | |
|----------------|----------------------|
| 1. DRILL GUIDE | 3. 5/16 UNF CAPSCREW |
| 2. FLAT WASHER | |

Fuel System Repair

DESCRIPTION



CAUTION

There are no adjustments that can be carried out on the fuel injection pump. The fuel injection equipment must only be checked by personnel who have had the authorized training.



CAUTION

If a fuel injection pump is returned for repair, or under warranty, all of the fuel ports must be closed with a plastic blanking cap to prevent the entry of water and dirt into the pump. If these blanking caps are not fitted then the warranty may be affected.



CAUTION

Do not release the nut on the shaft of the fuel injection pump. See Figure 121. If this nut is removed, the fuel injection pump must be returned to an authorized service center. Setting the correct timing requires special equipment. A replacement fuel injection pump can have the pump shaft locked in position. See Figure 125. The drive shaft of the pump must not be turned unless the spacer is in position under the lock screw. Before the crankshaft is turned or the pump is installed, put the spacer into position under the locking screw to verify that the pump drive shaft is released.

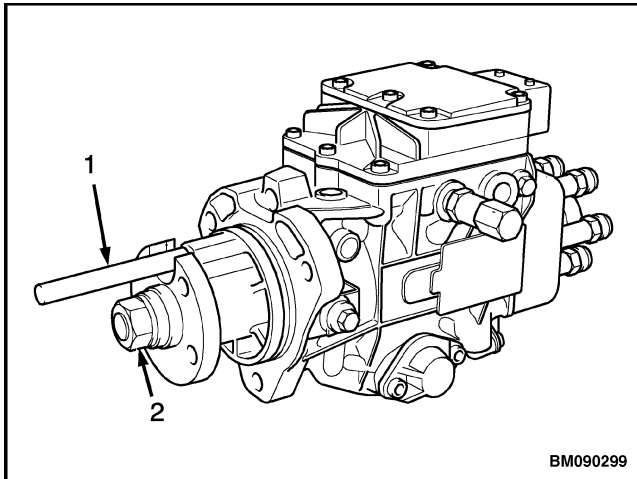
NOTE: Special tools and training are needed to repair the Bosch VP30 fuel injection pumps. They are normally sent to an authorized repair station if repairs are necessary. Fuel injectors also require special equipment and training for repair. Most users have a special repair service do this work.

A Bosch VP30 series fuel injection pump is used on these engines. The pump timing and the speed adjustment cannot be changed. An Electronic Control Module (ECM) controls the pump timing, the speed adjustment, and the amount of fuel supplied. A lock screw holds the shaft of the pump from turning when it is not installed on the engine. See Figure 125. **This lock screw must be released when the fuel injection pump is installed on the engine.**

The manufacturer fits the hub to the pump to ensure very accurate timing. These engines have the drive gear fastened to the hub instead of to the shaft of the pump.

The mounting flange has holes instead of slots to prevent incorrect adjustments to the engine timing by rotation of the fuel injection pump.

Accurate timing of the pump to the engine is by a pin used to align the fuel injection pump gear and the hub with a hole in the body of the fuel injection pump. See Figure 121. The gear is passed over the pin and fastened to the hub with four flanged setscrews and hardened washers.



1. TIMING PIN
2. NUT

Figure 121. Bosch Fuel Injection Pump

An O-ring is fitted into a groove in the pump flange. This O-ring is fitted, instead of a gasket, between the pump flange and the timing case. See Figure 125.

The maximum no-load speed is shown on the emissions data plate fitted to the right side of the cylinder block.

The fuel injectors, which are of the valve covered orifice (VCO) type, have nozzles with five holes. The fuel injectors inject fuel in a very fine spray into the combustion chamber in the top of each piston. Each fuel injector is fastened to the cylinder head by a gland nut.

The fuel injectors receive fuel under high pressure from the fuel injection pump. The fuel injectors are

set in the factory and they are not serviceable, but they must be checked in accordance with the preventive maintenance schedules in the **Periodic Maintenance** section for your lift truck. The operation pressure of a fuel injector cannot be changed.

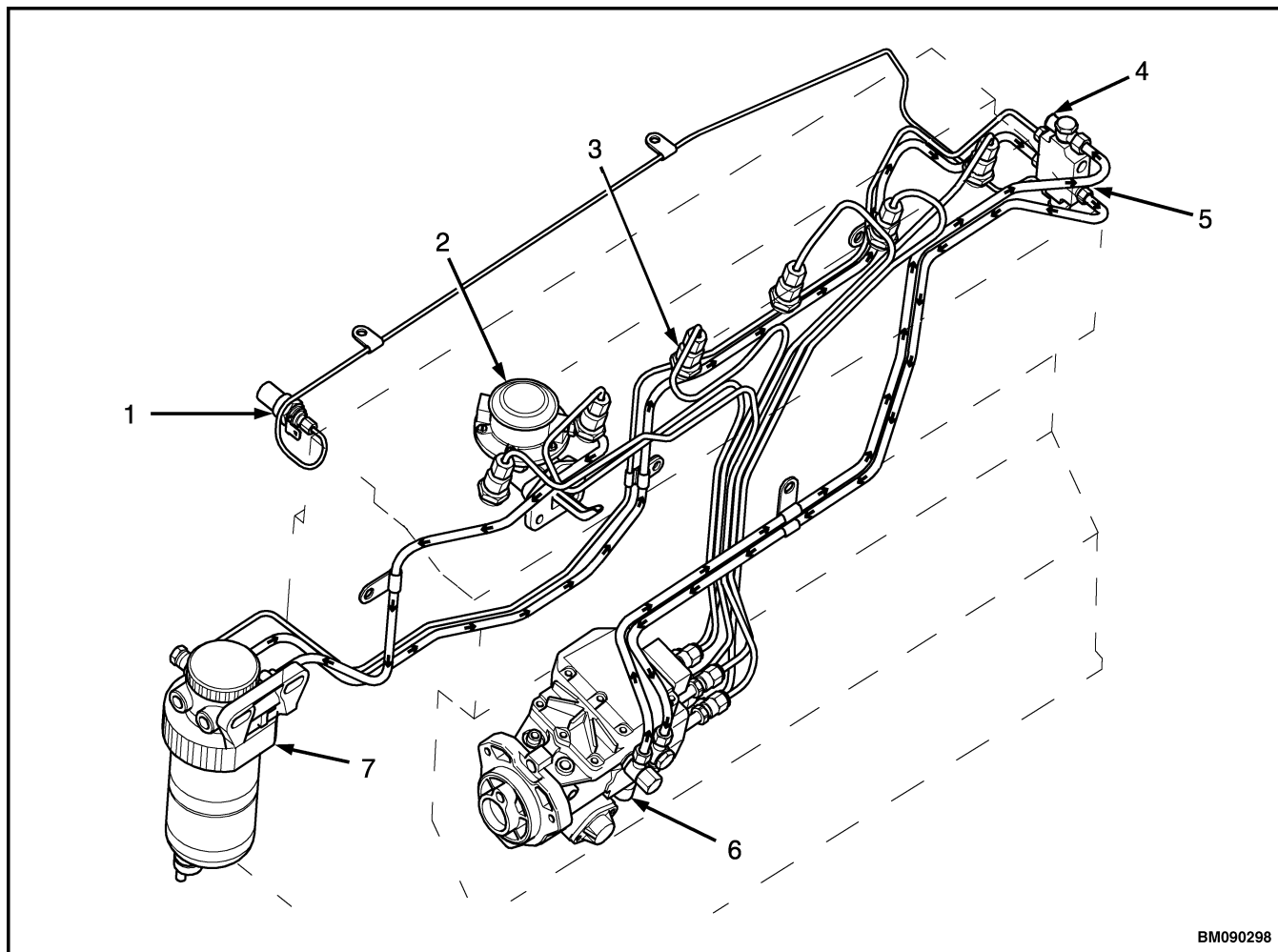
Fuel from the tank passes to the diaphragm type lift pump, which is driven by an eccentric on the camshaft. Fuel leaves the fuel lift pump under pressure and passes through a full flow filter to the fuel injection pump. See Figure 122.

A vent in the fuel injection pump permits an engine to start if there is a small amount of air in the fuel system. If the fuel system has a large amount of air, the air must be removed as described in Fuel System Air Removal. The fuel in the injection pump also lubricates and cools the pump.

The fuel injection pump increases the fuel pressure and injects high-pressure fuel at the correct time and sequence through the fuel lines to the fuel injectors.

The cold start aid is operated electrically. Fuel is supplied to it by a fuel line from a connection in the filter head.

NOTE: Good operation of the fuel injection system requires clean fuel. No dirt can be permitted in the system. Always clean carefully around a connection before it is disconnected. Install covers on open ports during maintenance. When the fuel system is opened for maintenance, the air must be removed from the fuel system before the engine is operated.



BM090298

1. COLD START AID
2. FUEL LIFT PUMP
3. FUEL INJECTOR
4. FUEL LINE CONNECTION

5. CONNECTOR BLOCK
6. FUEL INJECTION PUMP
7. FUEL FILTER

Figure 122. Typical Fuel System

FUEL INJECTION PUMP

Remove

Special tools: Timing pin PD.246 for Bosch fuel injection pumps



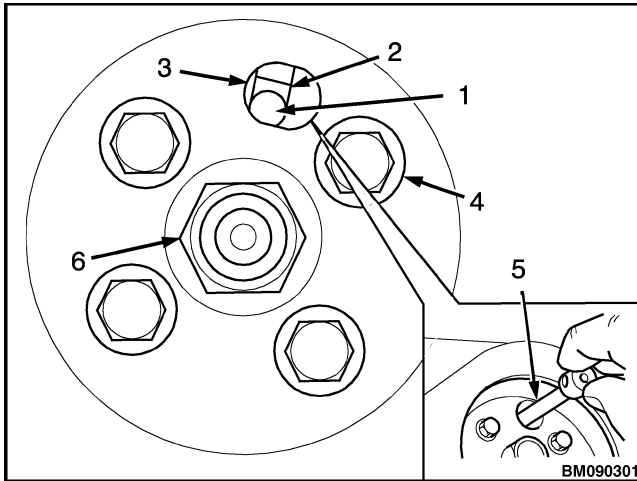
CAUTION

Do not release the nut on the shaft of the fuel injection pump. See Figure 123. If this nut is removed, the fuel injection pump must be returned to an authorized service center. Setting the correct timing requires special equipment. A replacement fuel injection pump can have the pump shaft locked in position. See

Figure 125. The drive shaft of the pump must not be turned unless the spacer is in position under the lock screw. Before the crankshaft is turned or the pump is installed, put the spacer into position under the locking screw to verify that the pump drive shaft is released.

1. Disconnect the battery.
2. Set the number one piston to 4° after TDC on the compression stroke. See How to Set Number One Piston to 4° After TDC on Compression Stroke.
3. Remove the coolant pump. See Coolant Pump, Remove.

4. Remove the CCB assembly if required. See CCB Assembly, Remove.
5. Insert the timing pin through the hole in the fuel injection pump gear and the slot of the hub. See Figure 123. Push the pin fully into the hole in the body of the fuel injection pump. If the pin can be fully inserted, then the pump timing is correct. There should be no resistance when the pin is inserted.



1. TIMING HOLE IN BODY OF FUEL INJECTION PUMP
2. TIMING SLOT IN HUB
3. HOLE IN THE FUEL INJECTION PUMP GEAR
4. CAPSCREW AND WASHER
5. TIMING PIN
6. NUT

Figure 123. Timing Components

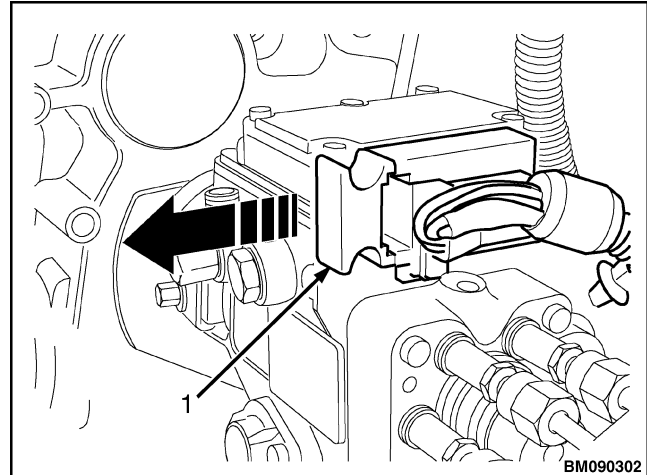
6. Disconnect all of the fuel lines from the fuel injection pump. Use a second wrench to prevent movement of the union nuts when the fuel lines are disconnected.



CAUTION

Do not damage the pins of the electrical connector.

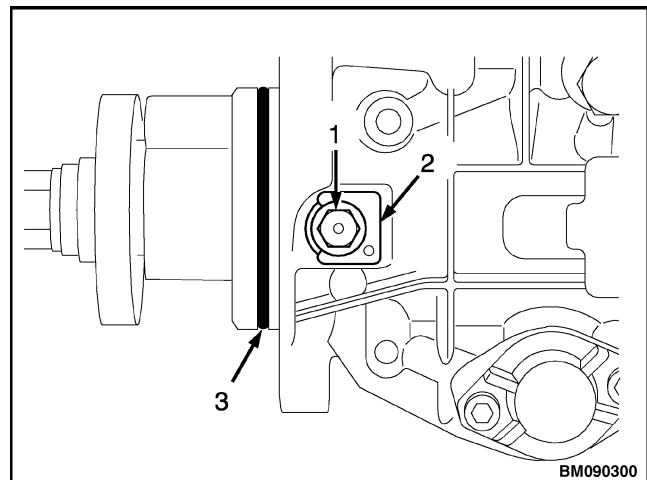
7. Disconnect the electrical connector. To disconnect the electrical connector, pull the locking mechanism from the connector. Carefully remove the connector from the fuel injection pump. See Figure 124.



1. LOCKING MECHANISM

Figure 124. Electrical Connector

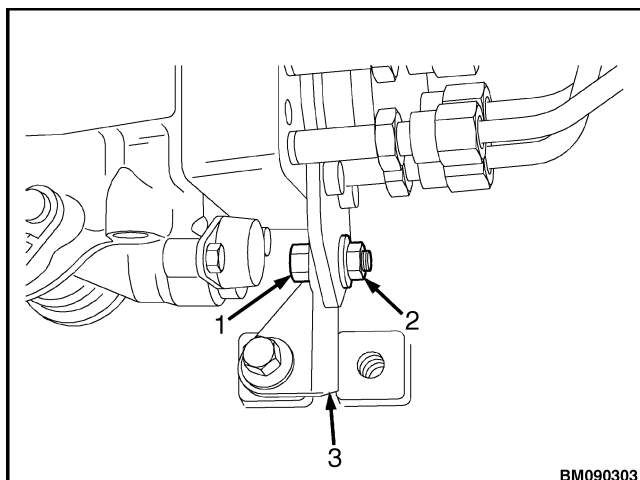
8. Remove the gear for the fuel injection pump as described in Fuel Injection Pump Gear.



1. LOCK SCREW
2. SPACER
3. O-RING

Figure 125. Lock Screw

9. Remove the cap screw and nut from the fuel injection pump bracket. See Figure 126.
10. Remove the nuts that fasten the flange of the fuel injection pump to the timing case.
11. Remove and discard O-ring. See Figure 125.



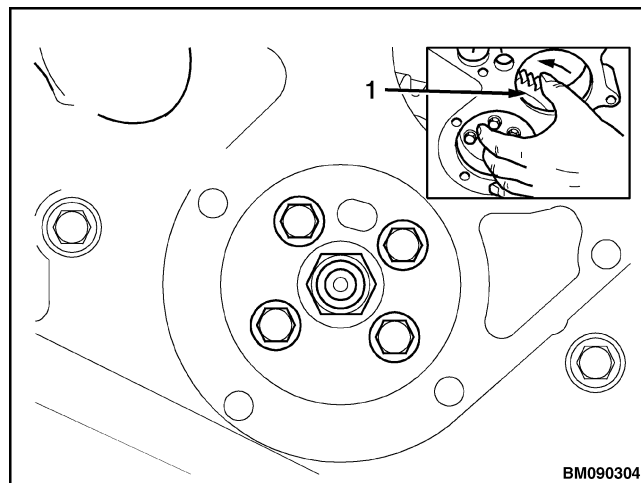
1. CAPSCREW
2. NUT
3. BRACKET

Figure 126. Fuel Injection Pump Bracket

Install

1. The engine must be set for the number one piston to 4° after TDC on the compression stroke. If the crankshaft needs to be rotated, the pump must be installed temporarily, or the loose gear could damage the timing case.
2. Install a new O-ring as shown in Figure 125. Lubricate the O-ring with a thin coat of engine oil.
3. Install the fuel injection pump on the three studs and install the nuts. Tighten the nuts to 28 N•m (21 lbf ft).
4. Install the cap screw and nut for the fuel injection pump bracket.
5. Install the fuel injection pump gear onto the hub of the fuel injection pump. See Figure 123. The fasteners for the fuel injection pump gear should be in the center of the slots to allow for the removal of the backlash. Tighten the cap screws finger tight.
6. Insert the timing pin through the hole of the fuel injection pump gear and the slot of the hub until it can be pushed fully into the hole in the body of the fuel injection pump. See Figure 123. If the timing pin cannot be pushed into the pump body, check that the engine is correctly set at TDC on the number one cylinder.

7. Carefully turn the gear for the fuel injection pump with your hand to remove the clearance between the gear and the idler gear. See Figure 127. Do not rotate the crankshaft or the shaft of the fuel injection pump. Tighten the cap screws for the gear for the fuel injection pump to 28 N•m (21 lbf ft).



1. REMOVE GEAR CLEARANCE WITH YOUR HAND

Figure 127. Gear for Fuel Injection Pump Installation

8. Remove the timing pin.
9. Connect the fuel lines. Use a second wrench to prevent movement of the union nuts when the fuel lines are connected. Do not tighten the union nuts greater than 22 N•m (16 lbf ft). If there is a leak, verify the fuel line is correctly aligned. A union nut that is too tight can cause a restriction in the fuel line.
10. Connect the electrical connection.
11. Install the coolant pump. See Coolant Pump, Install.
12. Install the CCB assembly. See CCB Assembly, Install.
13. Connect the battery.
14. Remove the air from the fuel system. See Fuel System Air Removal.

FUEL SYSTEM AIR REMOVAL

Small amounts of air will be removed from the fuel injection pump automatically when the engine is in operation if the fuel lines have been disconnected, the fuel filter has been replaced, or the engine has run out of fuel. Air must be removed from the fuel system.

WARNING

Avoid skin contact with high pressure fuel. If contact occurs, seek medical assistance immediately.

WARNING

Keep away from all moving parts when the engine is in operation. Some moving parts cannot be seen while the engine is running.

CAUTION

Damage to the fuel injection pump, starter motor, and battery can occur if the starter motor is used to remove air from an empty fuel system.

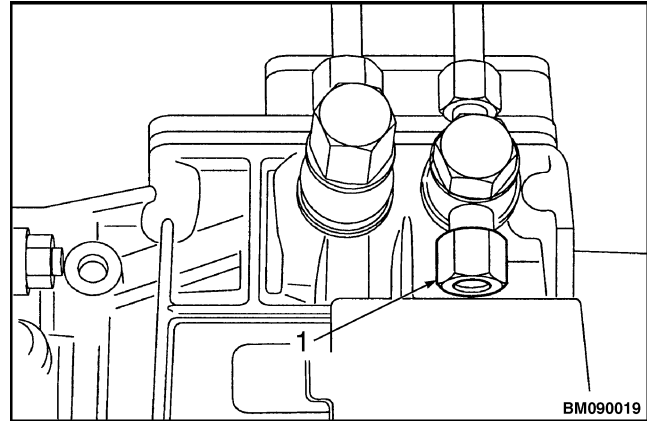
CAUTION

It is necessary to remove air from the fuel system if the fuel system is empty or the canister for the fuel filter has been replaced. Be sure to remove the air from the fuel injection pump.

1. If the fuel system or a component in the fuel system has been drained, use the following steps to remove air from the fuel system.
 - a. Loosen the vent nut on the fuel injection pump. See Figure 128.

NOTE: If the lobe on the camshaft has moved the internal lever of the fuel lift pump to the highest point of its lift, the priming lever will not operate. The crankshaft must be rotated one revolution to move the lobe on the camshaft.

- b. Operate the priming lever on the fuel lift pump until fuel, without air bubbles, comes from the loosened connection bolt. See Figure 129.



1. VENT NUT

Figure 128. Loosen Vent Nut

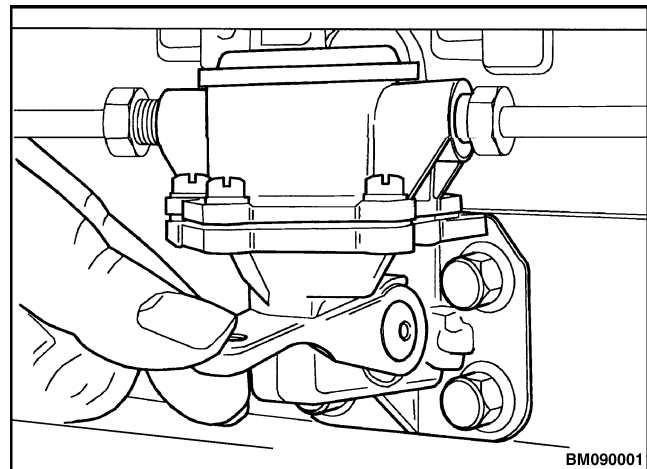
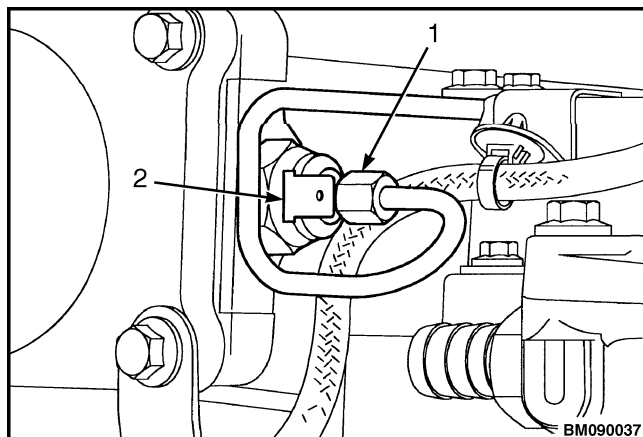


Figure 129. Priming Fuel System

CAUTION

Use a suitable wrench to prevent movement of the cold start aid when loosening the inlet connection.

- c. Loosen the connection on the inlet to the cold start aid. Operate the priming lever on the fuel lift pump until fuel, without air bubbles, comes from the loosened connection. Then tighten the connection. See Figure 130.



1. CONNECTION
2. COLD START AID

Figure 130. Loosen One Connection on Inlet to Cold Start Aid



WARNING

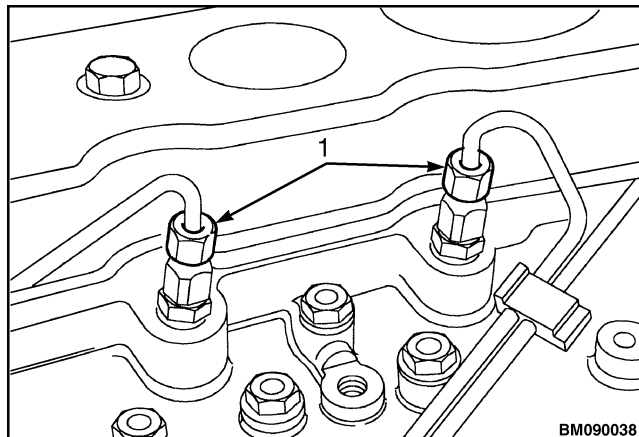
When operating the starter to remove air from the high pressure lines, the engine may start running.



CAUTION

Damage to the fuel injection pump, battery, and starter motor can occur if excessive use of the starter motor is used to remove air from the fuel system.

- d. Loosen the connections at all of the inlets to the fuel injectors. Operate the engine with the starter motor until fuel, without air bubbles, comes from the loosened connections. Then tighten the connection to 28 N•m (21 lbf ft). See Figure 131.



1. CONNECTION

Figure 131. Loosen All Connections on the Inlets to the Fuel Injectors



CAUTION

Operate the engine for a minimum of five minutes immediately after removing air from the fuel system. This will ensure that the pump is free of air and prevent any damage to the internal parts of the pump.

2. The engine is now ready to start. If there is still a small amount of air in the fuel system, the engine sometimes runs correctly for a short time and then stops. If a second attempt to start the engine causes the engine to run correctly for a short time and then stop, or if the engine runs roughly, check for air in the fuel system. Check for leaks in the low pressure (suction) part of the fuel system.
3. After the engine starts, operate the engine at idle speed for five minutes to verify all of the air is removed from the fuel system.

FUEL FILTER, REPLACE



CAUTION

Disposal of diesel fuel and filter must meet local environmental regulations.



CAUTION

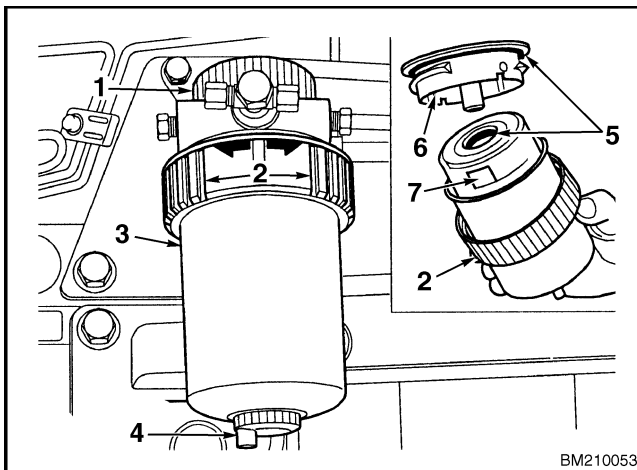
It is important that only the genuine Perkins parts are used. The use of a wrong canister or element can damage the fuel injection pump.

Do not allow dirt to enter the fuel system. Before a connection is disconnected, thoroughly clean the area around the connection. After a component has been disconnected, fit a suitable cover to all open connections.

1. Thoroughly clean the outside surfaces of the filter assembly.

NOTE: If the filter does not have a drain device, release the cap on top of the filter head. See Figure 132. Remove the nylon insert to lower the level of the fuel in the filter canister. This will prevent fuel spill when the gland ring is released.

2. Loosen the drain devices if a prefilter is fitted at the bottom of the canister or sediment bowl and allow the water or fuel to drain into a suitable container. See Figure 132.



- | | |
|-----------------|-----------|
| 1. CAP | 5. SEALS |
| 2. GLAND RING | 6. SPLINE |
| 3. FUEL FILTER | 7. GROOVE |
| 4. DRAIN DEVICE | |

Figure 132. Fuel Filter

3. Support the filter canister(s) and rotate the gland ring to the left. Remove the gland ring.
4. Remove the canister(s) from the filter head by a direct pull downward, and discard the old canister.
5. If a sediment bowl is installed, remove the bowl and thoroughly clean the cover of the bowl.
6. Check the two O-ring seals of the sediment bowl and fit the bowl for damage. Replace the O-ring seals if necessary.
7. Clean the threads of the sediment bowl, align the splines, and fit the bowl to the canister. Tighten by hand only.



CAUTION

It is important to ensure that the main and pre-filters are fitted in the correct positions.

8. Ensure the filter head is clean. Push the new canister(s) fully into the filter head.
9. Support the canister(s), fit the gland ring, and rotate it to the right to fasten the canister to the filter head.
10. If it was removed, fit the nylon insert, used to lower the level of the fuel, into the filter canister, and fasten the cap.
11. Remove the air from the fuel system. See Fuel System Air Removal.

FUEL INJECTORS

The engine will run rough if a fuel injector has a defect. To find which fuel injector has a defect, operate the engine at approximately 1000 rpm. Loosen and tighten the connection to the inlet of each fuel injector in a sequence. When the connection to the fuel injector with the malfunction is loosened, there will not be a change in the engine speed.

Remove



WARNING

Do not put your hands on fuel lines under pressure. Diesel fuel can be injected into your body by the hydraulic pressure.



CAUTION

Do not allow dirt to enter the fuel system. Before a connection is disconnected, thoroughly clean the area around the connection. After a component has been disconnected, cover all open connections.

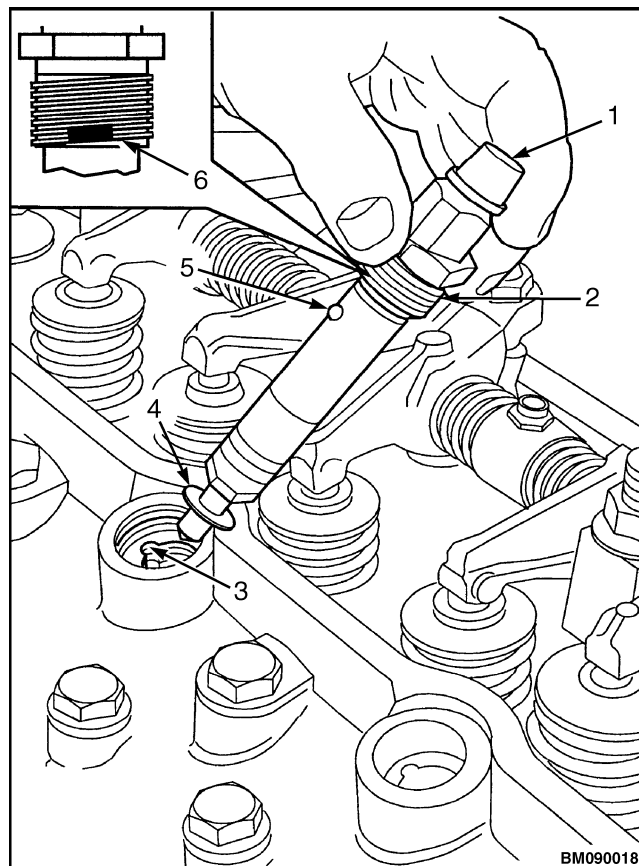
1. Disconnect the fuel return line from the fuel injector.
2. Disconnect the high pressure line at the inlet to the fuel injector. Disconnect the other end of the high pressure line from the fuel injection pump. Hold the outlet fitting from the fuel injection pump with a wrench so that it does not turn while the connection is loosened for the fuel line. Do not bend the fuel line. See Figure 133. Install a plastic cap to cover the inlet connection and the injector.
3. Loosen the nut and remove the fuel injector. See Figure 133. Remove the seat washer from the cylinder head.

Inspect

The inspection and repair of fuel injectors require special tools and training. A special repair service normally makes repairs on injectors. Fuel injectors that have a malfunction will cause black smoke in the exhaust, a decrease in engine power, and an increase in engine noise.

Install

1. Verify that the original seat washer was removed from the cylinder head, or the fuel injector will not fit correctly.
2. Verify the threads of the nut and the threads in the cylinder head are clean. See Figure 133.



- | | |
|----------------|------------------|
| 1. PLASTIC CAP | 5. LOCATION BALL |
| 2. NUT | 6. LOCK NUT |
| 3. GROOVE | THREADS |
| 4. SEAT WASHER | |

Figure 133. Fuel Injector



CAUTION

Always use a new seat washer and verify that the washer is of the correct type.

3. Install a new seat washer.



CAUTION

Do not allow any thread sealant below the threads of the nut.

4. Put a 2 mm (0.08 in.) bead of thread sealant onto the first two threads of the nut. The thread sealant is either Perkins POWERPART Atomizer Thread Sealant or Hylomar Advance Formulation, Part No. 21825474. The bead should extend approximately 6 mm (0.24 in.) around each of the threads. Verify there is no thread sealant on the body of the fuel injector.

5. Install the fuel injector into the cylinder head. Verify the location ball fits into the groove.

**CAUTION**

Do not move the nut after it has been tightened. The seal will be broken and there can be leaks past the seat of the fuel injector.

6. Tighten the nut smoothly to 40 N•m (30 lbf ft). As the nut is tightened, the fuel injector will rotate a small amount clockwise as the location ball moves in its slot. Remove any excess thread sealant.

**CAUTION**

Do not tighten the union nuts of the high pressure pipes more than the recommended torque tension. If there is a leakage from the union nut, verify that the pipe is correctly aligned with the fuel injector inlet. Do not tighten the fuel injector union nut more, as this can cause a restriction at the end of the pipe. This can affect the fuel delivery.

7. Remove the plastic cap and install the high pressure fuel line. Tighten the union nuts to 28 N•m (21 lbf ft).
8. If the fuel system is empty, remove the air from the fuel system. See Fuel System Air Removal.
9. When the engine can be operated, check for fuel leaks.

FUEL LIFT PUMP**Remove**

1. If a heat shield has been installed, remove the heat shield for the fuel lift pump. Disconnect the fuel lines to the fuel lift pump.
2. Remove the capscrews. Remove the fuel lift pump. If the lobe on the camshaft has moved the internal lever of the fuel lift pump to the highest point of its lift, the fuel lift pump can be difficult to remove. The crankshaft must be rotated one revolution to move the lobe on the camshaft.

Disassemble

1. Clean the outside surfaces of the fuel lift pump. Make a mark across the flanges of the two halves of the fuel lift pump to verify that they are assembled again in the same positions.

2. Remove the cover and the screen. See Figure 134. Remove the screws and separate the two halves of the fuel lift pump.

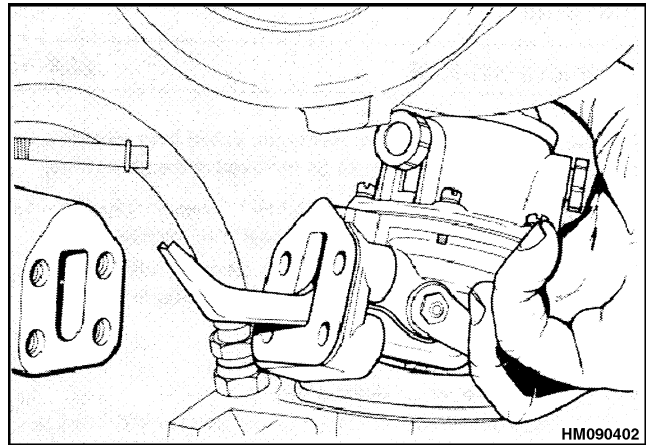


Figure 134. Fuel Lift Pump Removal and Installation

3. Turn the diaphragm assembly 90° to release the pull rod from the link arm, and remove the diaphragm assembly.
4. Remove the stem seal, the spring seat washer, and the spring from the pull rod. The diaphragm and pull rod assembly must be replaced as a unit.
5. The valves are held in their seats by punch marks in the metal. The metal must be made smooth so that valves can be removed.
6. Remove the link arm. Hold the rocker lever in a vise and hit the body of the fuel lift pump with a soft hammer to release the two retainers. Be careful that the joint face of the fuel lift pump body is not damaged. Remove the rocker lever, pin, link arm, and the return spring. Check the components for wear or damage.

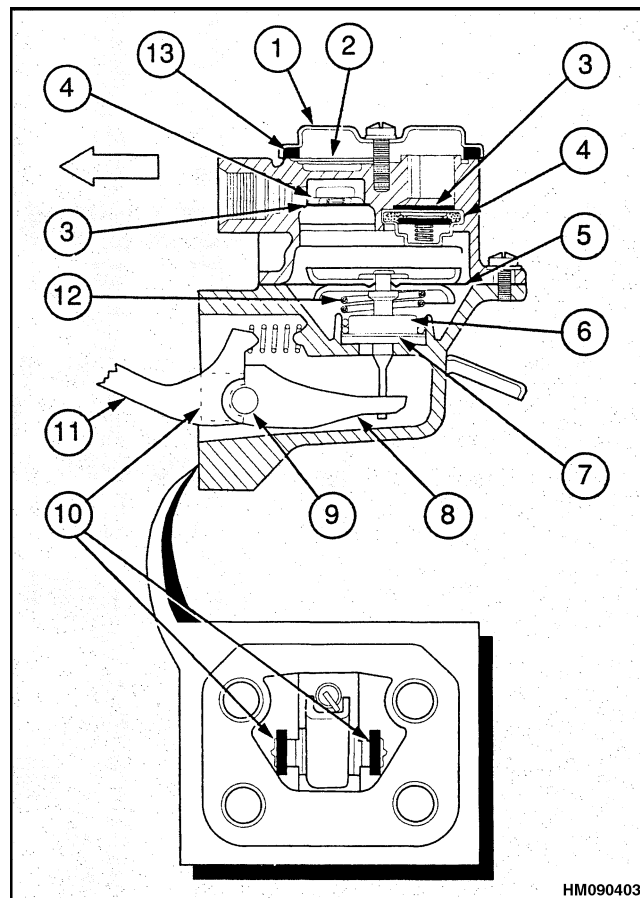
Assemble

1. Thoroughly clean the valve housings. Install new seat washers. See Figure 135. Push new valves into position. The valves are the same, but they are installed in opposite directions. Verify that the valves are installed in the correct position. When the valves are correctly installed, use a punch on the edge of the valve housings to hold the valves in position. Use the punch in six places around each valve to hold the valve in position.

2. Install the rocker lever, pin, and the link arm assembly into position in the body of the fuel lift pump. Install the return spring. Verify that the ends of the return spring are in their correct positions.
3. Use a small hammer and a drift or a punch to install the retainers in their grooves in the body of the fuel lift pump until they fasten the pin. Use a punch to close the ends of the grooves to fasten the retainers in position.
4. Install the diaphragm spring into its position under the diaphragm. Put the spring seat washer and the new stem seal into position on the pull rod. Verify that the small diameter at the top of the stem seal is on the round part of the pull rod.
5. Put the diaphragm assembly into position over the lower half of the body of the fuel lift pump. Align the blade of the pull rod with the slot in the link arm. Press down lightly on the diaphragm until the notch in the pull rod is in the slot in the link arm. Then turn the diaphragm 90° in either direction. This action will engage and retain the pull rod in the slot of the link arm.
6. Push the rocker arm towards the body of the fuel lift pump until the diaphragm is level with the flange half. Install the top half of the body in position. Align the reference marks. Keep the pressure on the rocker arm and install the lock-washers and screws. Tighten the screws evenly around the circumference of the fuel lift pump.
7. Install the screen and the cover. Verify that the rubber seal is fitted correctly and tighten the screw that holds the cover.

Install

1. The lobe on the camshaft must be in the minimum lift position before the fuel lift pump is installed. See Figure 134. Use a new gasket and install the fuel lift pump on the engine block. Apply Loctite® to the first three threads of the cap-screws. Install the cap-screws. Tighten the cap-screws to 22 N•m (16 lbf ft).
2. Connect the fuel lines to the fuel lift pump. Install the heat shield.
3. Loosen the fuel lift pump vent nut on top of the filter as shown in Figure 128.



- | | |
|--------------------|------------------|
| 1. COVER | 7. SPRING SEAT |
| 2. SCREEN | WASHER |
| 3. SEAT WASHER (2) | 8. LINK ARM |
| 4. VALVE (2) | 9. PIN |
| 5. DIAPHRAGM | 10. RETAINER (2) |
| ASSEMBLY | 11. ROCKER LEVER |
| 6. STEM SEAL | 12. DIAPHRAGM |
| | SPRING |

Figure 135. Fuel Lift Pump Disassembly

4. Operate the priming lever on the fuel lift pump until fuel, without air bubbles, comes from the loosened connection bolt. See Figure 129.
5. When the engine can be operated again, check for leaks.

Test

1. Disconnect the fuel line from the outlet of the fuel lift pump. Install a 0 to 70 kPa (0 to 10 psi) pressure gauge to the outlet of the fuel lift pump. Loosen the connection at the gauge, and operate the priming lever on the fuel lift pump to remove air from the fuel lift pump and the connection to the pressure gauge. Then tighten the connection.

2. Use the starter motor to operate the engine for 10 seconds. See the maximum pressure indicated on the pressure gauge. If the pressure is less than 42 to 70 kPa (6 to 10 psi), repair or replace the fuel lift pump. Also check the rate at which the pressure reduces to half of the maximum pressure. If the rate is less than 30 seconds to reduce to half of the maximum pressure, repair or replace the fuel lift pump.
3. Remove the pressure gauge from the fuel lift pump. Connect the fuel line to the outlet of the fuel lift pump again.
4. Loosen the fuel lift pump vent nut on top of the filter as shown in Figure 128. Operate the priming lever on the fuel lift pump until fuel, without air bubbles, comes from the loosened connection bolt.
5. When the engine can be operated again, check for leaks.

Cooling System Repair

GENERAL

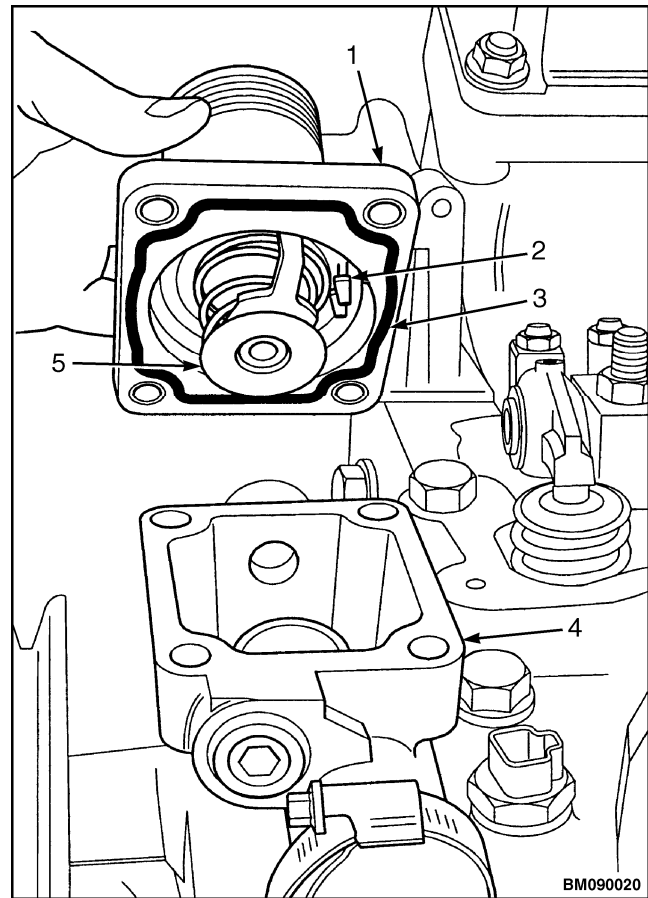
Coolant from the bottom of the radiator flows through the centrifugal coolant pump which is installed on the front of the timing case. The coolant pump is gear driven from the gear for the fuel injection pump. The coolant goes from the coolant pump through a passage in the timing case to the front of the engine block.

THERMOSTAT

Identification of the thermostat is by the nominal temperature which is stamped on the bypass valve of the thermostat.

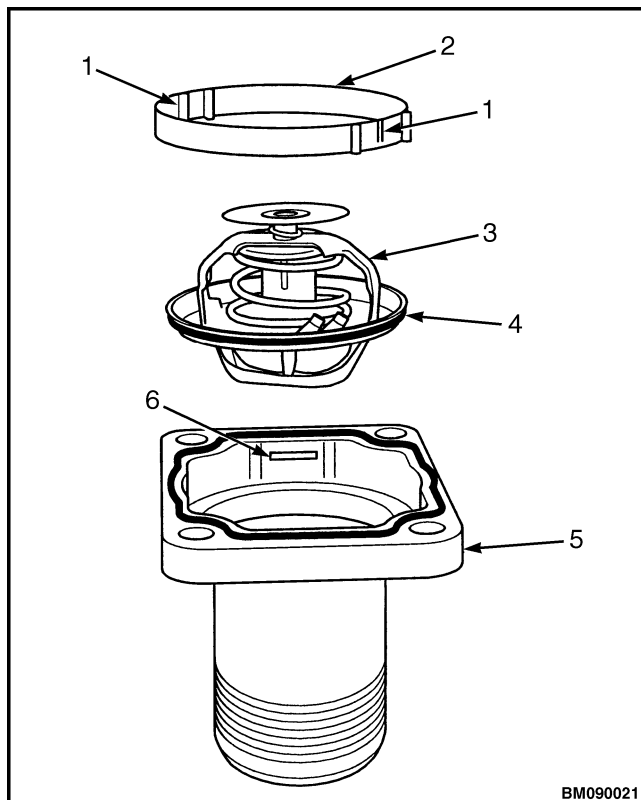
Remove

1. Drain the coolant level in the cooling system to below the thermostat position and disconnect the top hose from the coolant outlet connection.
2. Release the four capscrews and remove the thermostat housing from the lower body. Discard the gasket. See Figure 136.
3. Press the retainer clips inward, and lift the plastic collar from the thermostat housing. See Figure 137.
4. Remove the thermostat and O-ring assembly from the thermostat housing. Discard the O-ring.



1. THERMOSTAT HOUSING
2. JIGGLE PINS
3. GASKET
4. MOUNTING ASSEMBLY
5. THERMOSTAT

Figure 136. Thermostat Housing Assembly



1. RETAINER CLIP
2. COLLAR
3. THERMOSTAT
4. O-RING
5. THERMOSTAT HOUSING
6. GROOVE

Figure 137. Thermostat Assembly

Install

1. Clean the thermostat housing. Verify that the groove for the clip retainers and the seat for the O-ring are free of debris.
2. Verify that the gasket faces of the thermostat housing and the lower body are clean and that the jiggle pin in the thermostat is free to move.

3. Replace the O-ring and put the new thermostat in position in the housing.
4. Press the retainer clips inward, and push the plastic collar into the thermostat housing until the clip retainers engage the groove.
5. Install a new gasket (the gasket is installed dry). Fit and tighten the capscrews.
6. Connect the top hose and fill the cooling system.

Test

1. Hang the thermostat in a suitable container filled with coolant.



CAUTION

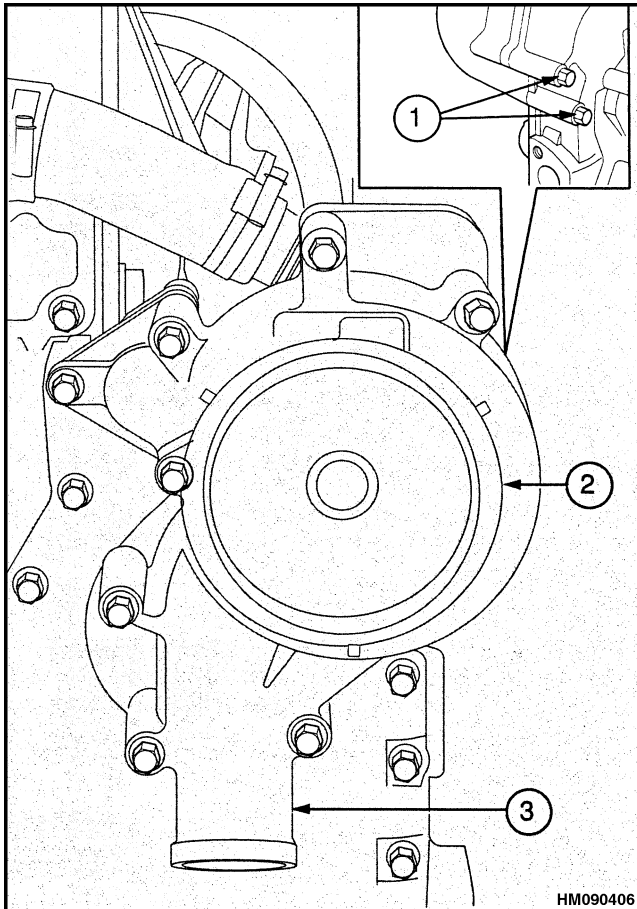
If the thermostat does not operate correctly, it must be replaced. Do not try to adjust the settings.

2. Heat the coolant gradually. Use a thermometer to check the temperature at which the valve starts to open and at which it is fully open. The correct temperatures are given in the data and dimensions.

COOLANT PUMP

Remove

1. Drain the cooling system and disconnect the hose at the inlet to the coolant pump.
2. Remove the two capscrews from the rear face of the timing case. See Figure 138.
3. Remove the eight capscrews which hold the coolant pump to the front cover of the timing case. Remove the coolant pump.
4. Remove and discard the gasket.



1. NUTS ON REAR FACE OF TIMING CASE
2. COOLANT PUMP COVER
3. INLET CONNECTION

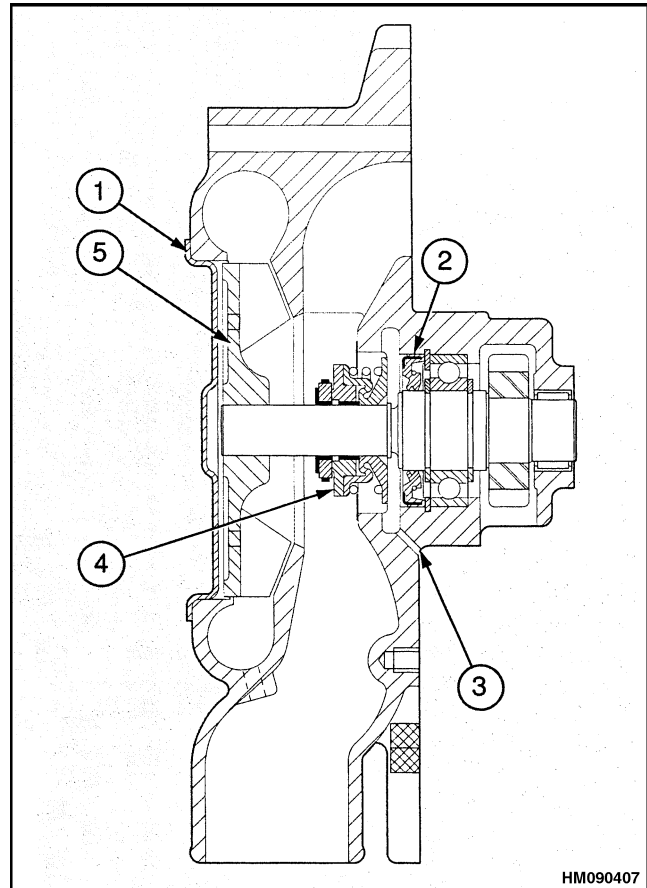
Figure 138. Coolant Pump Removal

Disassemble

The coolant pump must be repaired if coolant or engine oil leaks from the hole in the pump body. See Figure 139. This leak indicates that the coolant seal or the oil seal is worn or damaged.

Special tool: Seal replacement tool

1. Remove the two studs from the pump body.
2. Remove the cover. See Figure 140. There are three access spaces on the edge of the cover so that a pry bar can be used to remove the cover from the pump body. Work carefully so the cover does not have distortion.



1. COOLANT PUMP COVER
2. OIL SEAL
3. DRAIN HOLE
4. COOLANT SEAL
5. IMPELLER

Figure 139. Coolant Pump Seals

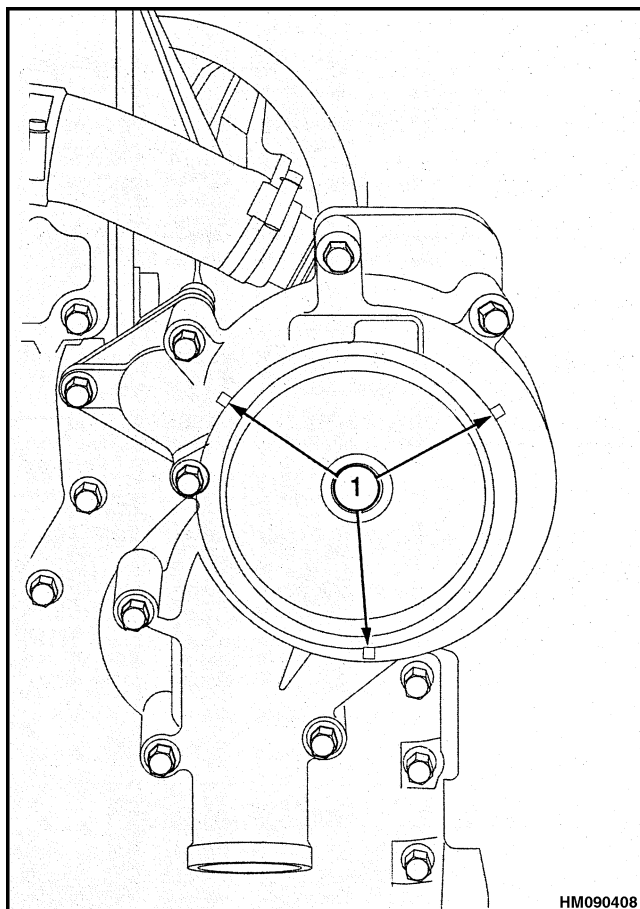
3. Remove the impeller from the shaft. Drill four 6.35 mm (0.25 in.) holes at equal distance round the end of the pump shaft. These holes will break the press fit between the impeller and the pump shaft so that the impeller can be removed.



CAUTION

Do not damage the seal face in the pump body for the coolant seal during removal of the seal.

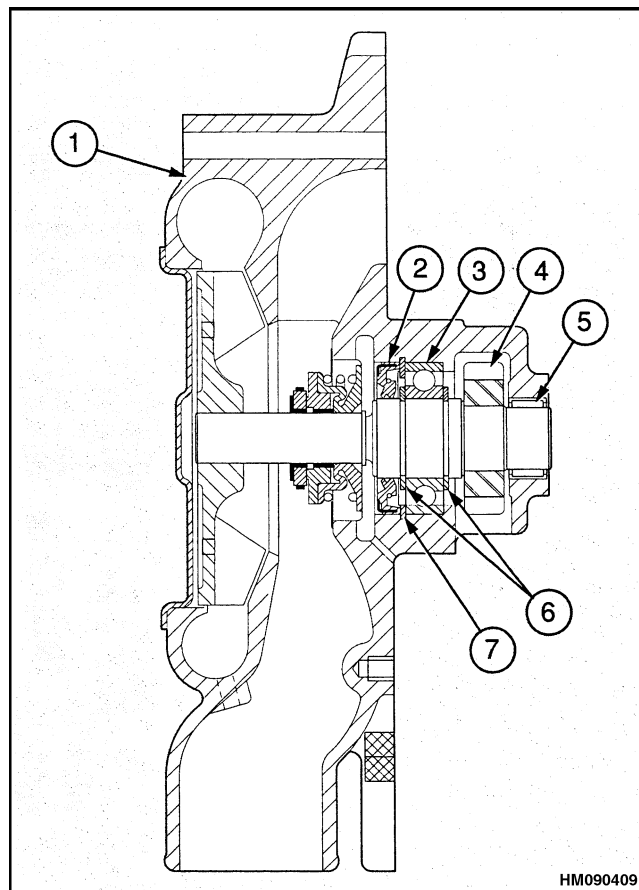
4. Remove the coolant seal. The carbon seal must be broken and then use an extractor to remove the center sleeve of the seal from the pump shaft.



1. ACCESS SPACE FOR PRY BAR

Figure 140. Coolant Pump Cover Removal

5. Remove the body of the seal. Drill three 3.175 mm (0.125 in.) holes through the top of the coolant seal 120 degrees apart. Install three 25.4 mm (1.00 in.) self-tapping screws in the holes. Insert a pry bar through the cooling inlet of the pump body and gradually and carefully apply the lever under the head of each self tapping screw. Carefully remove the coolant seal from the shaft. Discard the coolant seal.
6. Drill a 3.175 mm (0.125 in.) hole through the top of the oil seal. Install a 25.4 mm (1.00 in.) self-tapping screw in the hole. Insert a pry bar through the cooling inlet of the pump body and carefully apply the lever under the head of the self tapping screw. See Figure 141. Carefully slide the oil seal from the shaft. Discard the oil seal.



1. COOLANT PUMP BODY
2. OIL SEAL
3. BALL BEARING
4. PUMP GEAR
5. NEEDLE ROLLER BEARING
6. SNAP RING (2)
7. SNAP RING

Figure 141. Coolant Pump Seals Removal



CAUTION

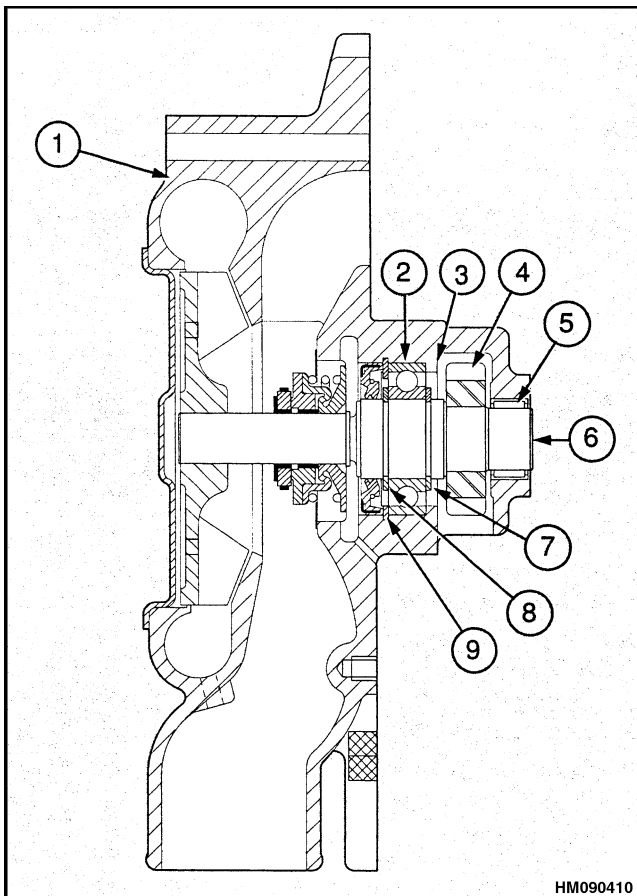
Do not damage the seal face in the pump body for the oil seal during removal of the seal.

7. Remove and discard the snap ring.
8. Put a support under the pump body so that it is not damaged. Use a press to push the shaft through the pump gear and the pump body until the shaft and the ball bearing assembly are released from the pump. Discard the ball bearing assembly, the pump shaft, and the two snap rings. Remove the pump gear.
9. Inspect the pump gear for wear and damage. Replace a worn or damaged pump gear.

10. Use a press to push the needle roller bearing from the pump body. Discard the bearing.

Assemble

1. Clean the pump body. Give special attention to the bore for the bearing and the bore for the water seal. Both of these bores and their chamfers must be clean and free of corrosion.
2. Install a new snap ring onto the shaft. See Figure 142.



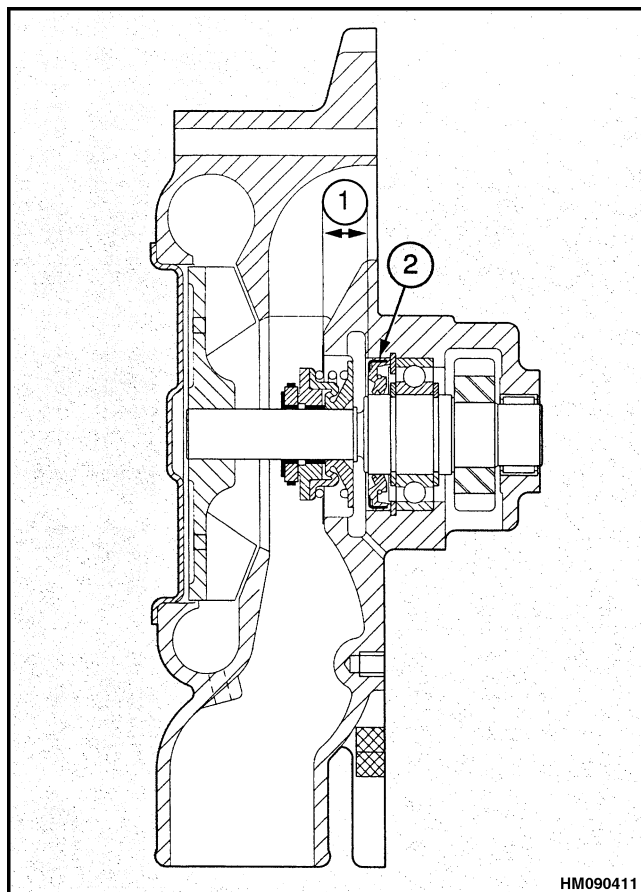
- | | |
|----------------------|--------------------------|
| 1. COOLANT PUMP BODY | 5. NEEDLE ROLLER BEARING |
| 2. BALL BEARING | 6. SHAFT |
| 3. HOUSING SURFACE | 7. SNAP RING |
| 4. PUMP GEAR | 8. SNAP RING |
| | 9. SNAP RING |

Figure 142. Coolant Pump Assembly

3. Apply a thin layer of Loctite® 638 to the outer surface of the needle roller bearing. Verify the

Loctite does not get into the bearing. Use a press to install the needle roller bearing into the pump body until the end of the bearing is even with the body or not more than 0.5 mm (0.020 in.) below the surface of the body.

4. Apply a thin layer of Loctite® 638 to the outer surface of the ball bearing. Verify the Loctite® does not get into the bearing. Use a spacer as a support for the pump gear. Verify the pump gear is against the housing surface. Use an adapter and a press to push the new ball bearing onto the shaft. Verify the adapter presses on both the inner and outer races of the ball bearing so it is not damaged as it is pressed into the housing. Verify the inner race touches the snap ring.
5. Remove the spacer that is a support for the shaft at the end with the pump gear. Continue to press the ball bearing into the housing. Then install the snap ring.
6. Install the new snap ring. Verify the bevel edge of the snap ring is toward the oil seal. This snap ring holds the shaft and bearing assembly in the pump body.
7. Put the pump gear into position in the pump body and use a press to push the shaft into the pump gear. If the original pump gear is used, use Loctite® 638 between the pump gear and the shaft. Verify the pump gear is against the shoulder of the shaft.
8. Lightly lubricate the oil seal with clean engine oil. See Figure 143. Install the tapered tool PD.247 onto the shaft with the tapered end toward the bearing. The purpose of the tapered tool is to verify the lip of the oil seal is correctly fitted when the oil seal is pressed into position. Push the oil seal over the tapered tool and into position in the pump body. The flat face of the oil seal is toward the impeller.
9. Press the oil seal into the oil seal space in the pump body. The tool shown in Figure 144 can be made to press the oil seal into position. The tool will also prevent axial distortion of the oil seal when it is pressed onto the shaft.



1. 14.5 mm (0.57 in.) DISTANCE BETWEEN OIL SEAL AND FLANGE FOR COOLANT SEAL
2. OIL SEAL

Figure 143. Coolant Pump Seals Oil Seal Installation

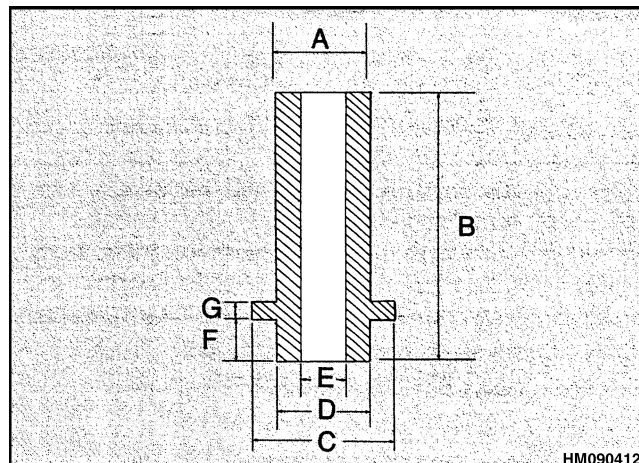
10. Use the tool to press the oil seal into the pump body until the seal is 14.5 mm (0.57 in.) from the end of the flange for the coolant seal. When the seal is in position, continue to apply force for approximately 10 seconds to verify the oil seal remains in position when the force is released.



CAUTION

Do not lubricate the coolant seal. It is important that the coolant seal is not contaminated with oil or grease. If the seal is held in the hand, only touch the edge of the outside flange. Verify the green sealant that is applied to the coolant seal just behind the flange is not damaged.

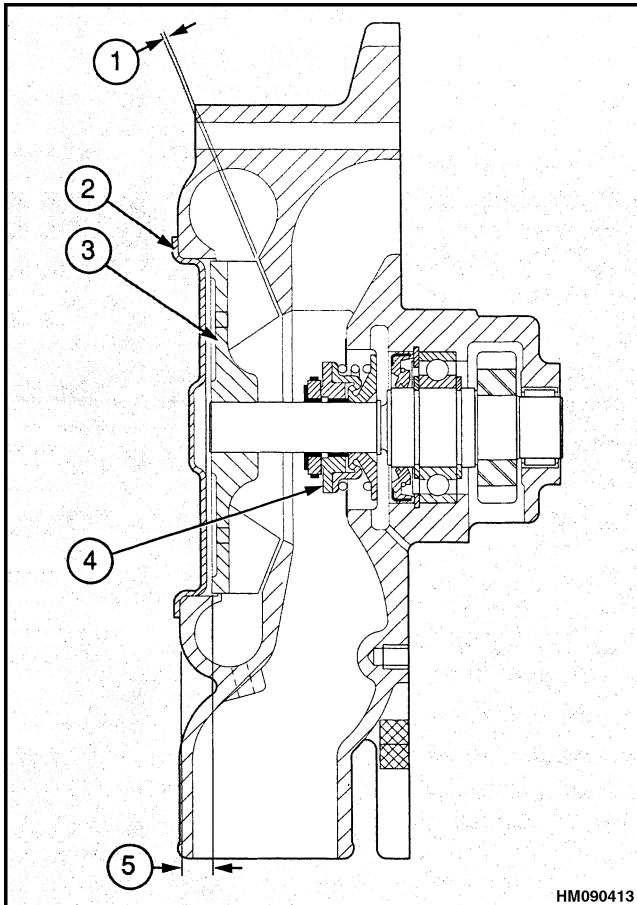
11. Push the coolant seal onto the shaft until it touches the counterbore for the coolant seal. See Figure 145. The widest part of the coolant seal is toward the oil seal. Verify the coolant seal is aligned with the counterbore and use a press and adapter to push the coolant seal into the counterbore. Verify the adapter only pushes on the outer flange of the coolant seal. Continue to apply force for approximately ten seconds to be sure the seal remains in position when the force is released.



- | | |
|-----------------------|-----------------------|
| A. 40.0 mm (1.57 in.) | E. 29.0 mm (1.14 in.) |
| B. 80.0 mm (3.15 in.) | F. 14.5 mm (0.57 in.) |
| C. 60.0 mm (2.36 in.) | G. 12.0 mm (0.47 in.) |
| D. 42.0 mm (1.65 in.) | |

Figure 144. Installation Tool for Oil Seal

12. A tool can be made to press the coolant seal into position. See Figure 146. The dimensions of this tool will verify the coolant seal is the correct length after installation. The tool will prevent axial distortion of the coolant seal when it is pressed onto the shaft.
13. Verify the end of the shaft with the drive gear has a support. Use a press and an adapter to press the impeller onto the shaft. The face of the impeller must be 10.35 to 10.48 mm (0.407 to 0.413 in.) recess distance from the front of the pump body. See Figure 145. Rotate the impeller after installation to verify it rotates freely.



1. IMPELLER CLEARANCE = 0.44 to 1.06 mm (0.017 to 0.042 in.)
2. COOLANT PUMP COVER
3. IMPELLER
4. COOLANT SEAL
5. RECESS DISTANCE FROM FRONT OF PUMP BODY TO IMPELLER

Figure 145. Coolant Pump Assembly

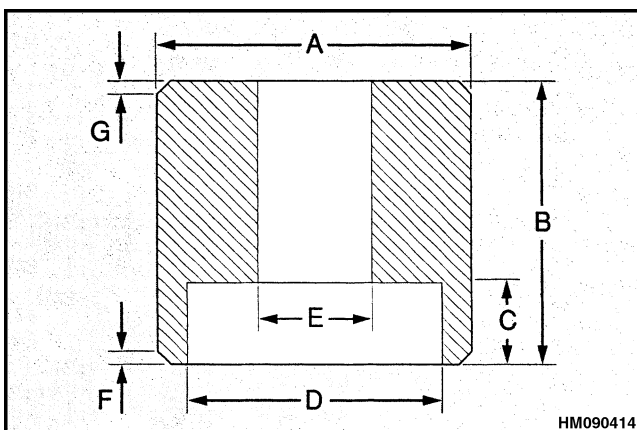


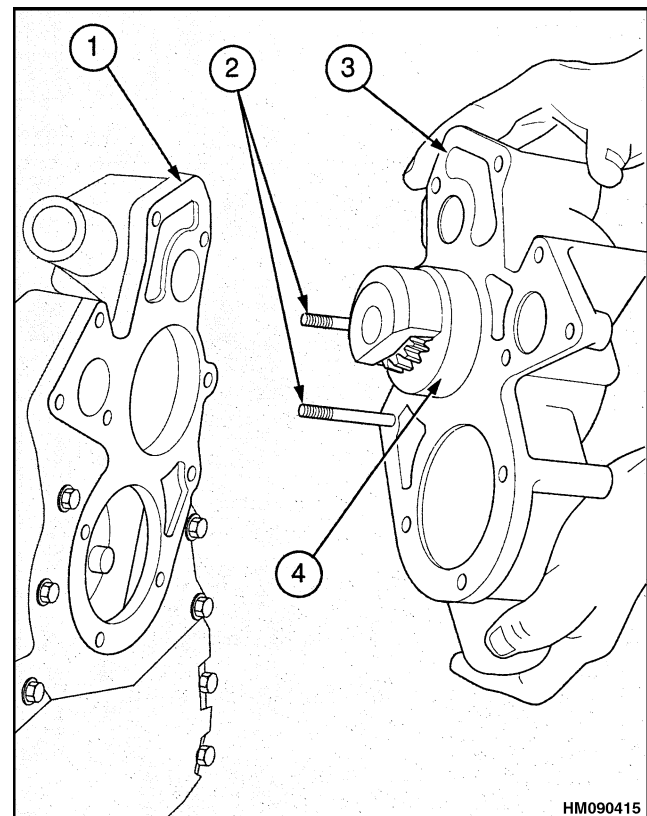
Figure 146. Installation Tool for Coolant Seal

Legend for Figure 146

- | | |
|-----------------------|-----------------------|
| A. 44.0 mm (1.73 in.) | F. 1.00 mm (0.04 in.) |
| B. 40.0 mm (1.57 in.) | AT 45 DEGREES |
| C. 12.2 mm (0.48 in.) | G. 2.00 mm (0.08 in.) |
| D. 35.8 mm (1.41 in.) | AT 45 DEGREES |
| E. 16.1 mm (0.63 in.) | |

14. Put a bead of Loctite® 290 on the contact surface of the pump cover (2). Verify the cover is aligned with the pump body and use a press to install the cover. Verify the pump cover is pressed evenly and fully onto the pump body.

15. Install the two studs into the pump body. See Figure 147.



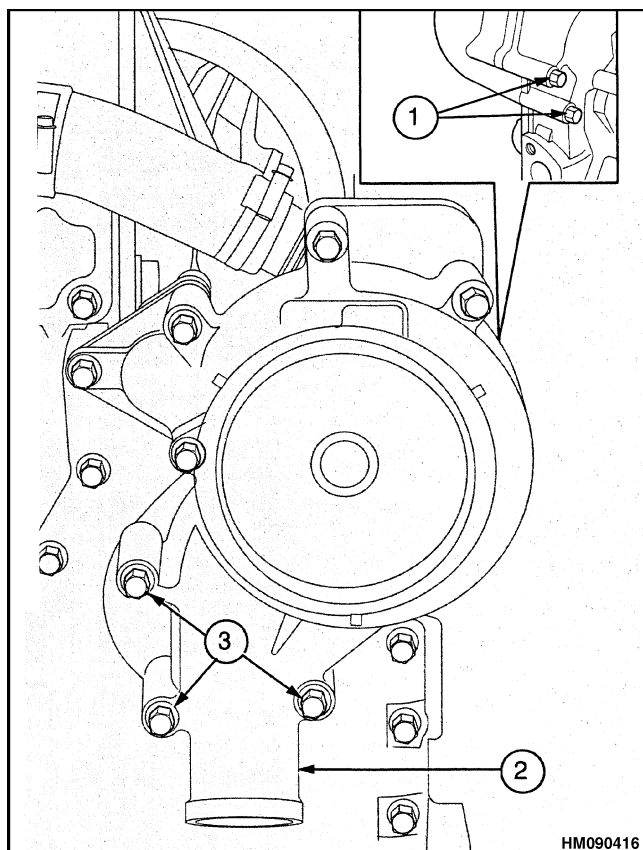
- | | |
|-------------------------|-----------------|
| 1. COVER OF TIMING CASE | 3. GASKET |
| 2. STUDS | 4. COOLANT PUMP |

Figure 147. Coolant Pump Connections

Install

1. Verify the gasket surfaces of the coolant pump and the timing case cover are clean. See Figure 147. Verify the surface at coolant pump is clean.

2. Verify the gear for the coolant pump is not worn or damaged. A worn or damaged gear must be replaced.
3. Install a new gasket on the pump body. Do not use sealant.
4. Verify the studs are correctly installed and tightened.
5. Install the coolant pump on the timing case cover. Verify the pump gear engages correctly the gear for the fuel injection pump.
6. Three of the capscrews have sealant applied when they are new. See Figure 148. If these capscrews are installed again, the old sealant must be cleaned and apply Loctite® 542 to the first three threads.



1. NUTS ON REAR FACE OF TIMING CASE
2. INLET CONNECTION
3. ADD SEALANT TO THREAD OF CAPSCREWS

Figure 148. Coolant Pump Installation

7. Install and tighten the two nuts on the studs at the back of the timing case.
8. Install the eight capscrews that fasten the coolant pump to the cover of the timing case.
9. Connect the coolant hose at inlet connection and fill the cooling system. When the engine can be operated, check for leaks.

FAN AND FAN DRIVE

Remove

1. Remove the capscrews and remove the fan.
2. Loosen the pivot fasteners for the alternator and the fastener for the adjustment bracket. Remove the drive belts.
3. Check the axial movement of the fan shaft. If the axial movement is greater than 0.25 mm (0.010 in.), the fan bearing assembly must be replaced.
4. Remove capscrews and remove the fan drive from the timing case cover.

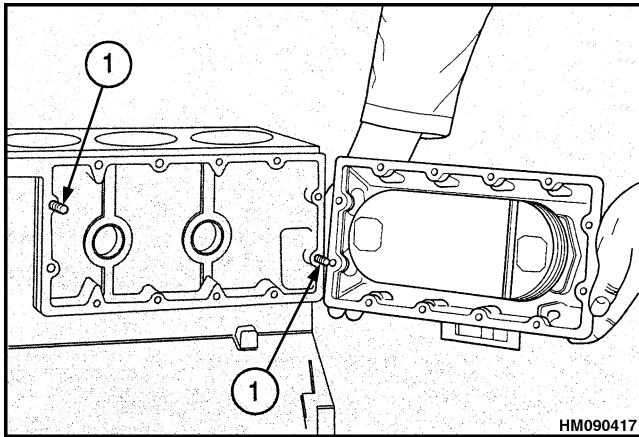
Install

1. Install the fan drive on the timing case cover and tighten the capscrews to 44 N•m (32 lbf ft).
2. Install the fan. Tighten the capscrews.
3. Install the drive belts and adjust the tension.

OIL COOLER

Remove

1. Drain the cooling system.
2. Disconnect the oil lines at the flange on the cover of the oil cooler.
3. Remove the capscrews and nuts from the cover of the oil cooler and remove the cover and element. See Figure 149.



1. STUDS

Figure 149. Oil Cooler and Element

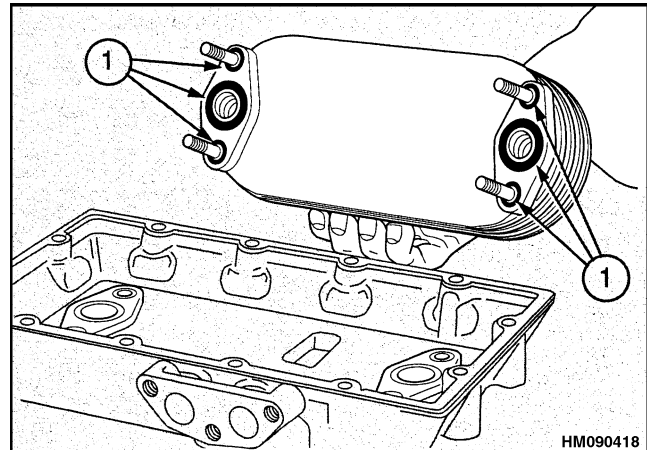
Disassemble and Assemble

1. Remove the capscrews and remove the cover.
2. Remove the nuts on the front of the cover and remove the cooler element from the cover.
3. Clean the cooler element and check for cracks. If a cleaning solution is used to clean the outside of the element, verify that the cleaning solution does not enter the element. Check that there are no restrictions for the oil flow through the element. If the internal part of the element must be cleaned, use a cleaning solution that will not damage copper. Flush the element to remove the cleaning solution and dry the element with compressed air at low pressure. Then flush the internal part of the element with clean engine oil.
4. Use new O-rings on the flanges and studs as shown in Figure 150.
5. Install the cooler element on the cover and tighten the nuts to 22 N•m (16 lbf ft).

Install

1. If the studs have been removed and will be used again, clean the threads on the studs and on the engine block. Use liquid sealant on the threads before they are installed in the engine block.

2. Use a new gasket and install the oil cooler assembly to the engine block. Tighten the capscrews and nuts in sequence to 22 N•m (16 lbf ft). See Figure 151.
3. Use a new gasket and connect the oil lines to the flange on the cover and tighten the screws.
4. Fill the coolant system.
5. When the engine can be operated again, check for leaks.



1. O-RINGS

Figure 150. Cooler Element Joints

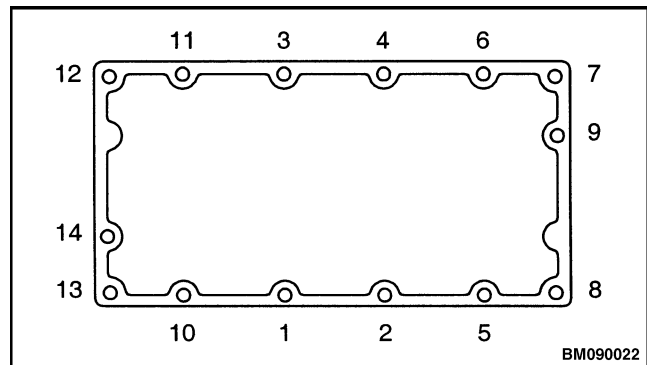


Figure 151. Oil Cooler Tightening Sequence

Electrical Equipment Repair

DRIVE BELTS

Check the drive belts for wear and damage. When a pair of drive belts is used, the drive belts must be replaced as a pair. When a pair of drive belts is used, adjust the tension for the tightest belt.

A gauge is available that will indicate the tension in the drive belt. Fit the gauge at the center of the longest length of the drive belt and measure the tension. See Figure 152. The correct tension is approximately 355 N (80 lbf).

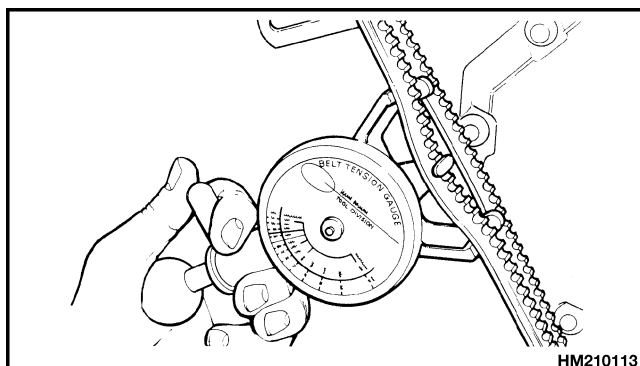
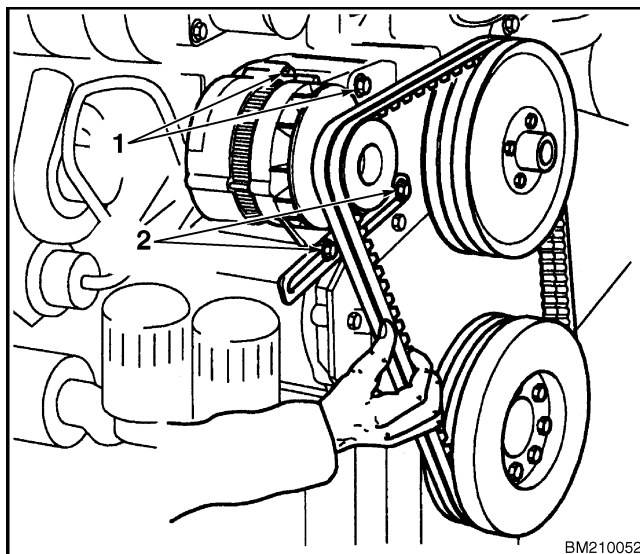


Figure 152. Gauge to Check Drive Belt Tension



- | | |
|-------------------|--------------------|
| 1. PIVOT FASTENER | 2. ADJUSTMENT LINK |
|-------------------|--------------------|

Figure 153. Drive Belt Tension Check and Adjust

Many service people press on the drive belt with their thumb at the center of the longest length of the drive belt and check the deflection. See Figure 153. When the thumb pressure is 45 N (10 lbf), the correct deflection is approximately 10 mm (0.394 in.).

Loosen the bolt on the adjustment link and the pivot fasteners to adjust the tension of the drive belts. Move the alternator pulley against the drive belts to adjust the tension. Tighten the adjustment link and pivot fasteners.

The drive belts are removed from the engine by loosening the tension and then removing them from the pulleys.

ALTERNATOR

NOTE: For repairs to the alternator, contact your approved Perkins dealer.

Remove

1. Disconnect the electrical connection.
2. Loosen the pivot and adjustment link capscrews.
3. Release belt tension and remove the belts.
4. Remove the adjustment link from the alternator and remove the pivot capscrews. Note the position of the washers and spacers. Remove the alternator.

Install

1. Position the alternator in place and loosely install the pivot and adjustment link capscrews. Be sure the washers and spacers are installed in their correct positions. Be sure the alternator is aligned to the crankshaft pulley within ± 2.4 mm (± 0.09449 in.).
2. Install the drive belts and adjust tension. See Drive Belts for tension adjustment.
3. Tighten all capscrews and check belt tension again.
4. Connect the electrical connection.

ELECTRONIC CONTROL MODULE (ECM)

NOTE: The ECM can be installed on the cylinder block or to a mounting plate on the cylinder head.

Remove

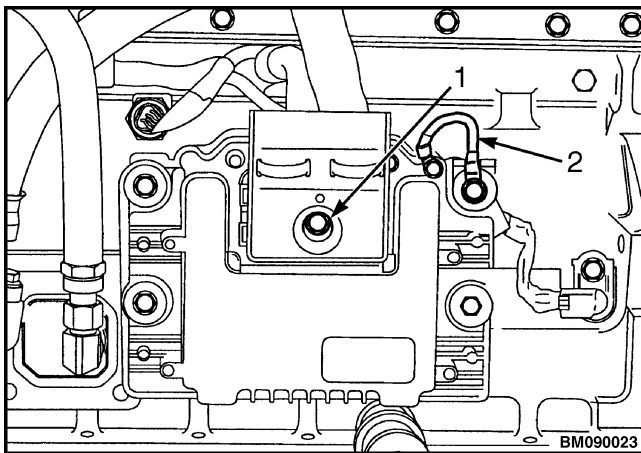
1. Verify the engine start switch is in the OFF position.
2. Disconnect the battery cables.



WARNING

If the ECM connector is removed with the key switch on and/or with the battery still connected, an induction voltage (peak voltage) can be induced which could cause damage to the ECM.

3. Loosen the Allen screw for the connector and remove the connector with the cover from the ECM. See Figure 154.



1. ALLEN SCREW
2. GROUND CABLE

Figure 154. Electronic Control Module (ECM)

4. Remove the nuts that secure the ECM and remove it from the engine. Note the positions of the spacers, washers, and ground cable. See Figure 155.

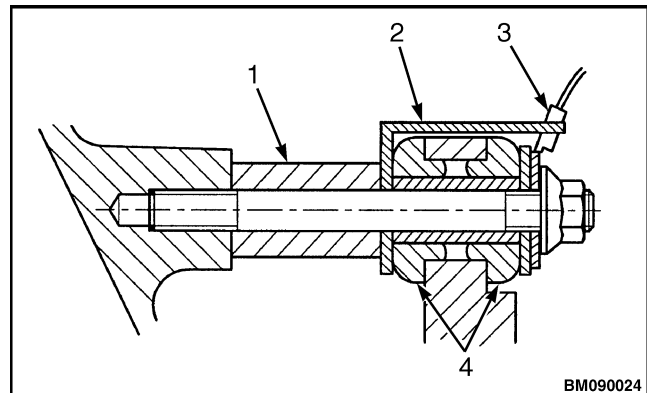
Inspect



CAUTION

The ECM is programmed for the vehicle by Perkins. If the ECM is not programmed correctly or is damaged, contact your closest approved Perkins dealer.

1. Check the connectors and sockets in the ECM for wear or damage. Replace as needed.
2. Check the wiring harness and wiring harness connector for wear or damage. Repair or replace as needed.
3. Check the seal for the ECM connector. Replace as needed.
4. Check the rubber mounts for wear or cracks. If wear or cracks are found, replace the mountings.



1. SPACER
2. GROUND CABLE BRACKET
3. GROUND CABLE
4. RUBBER MOUNTINGS

Figure 155. ECM Mounting Bolt Arrangement

Install



CAUTION

To prevent damage to electrical components, the ground cable must be installed correctly.

1. Verify that the spacers and rubber mountings are in the correct positions.
2. Place the ECM in position on the engine.
3. Install the four nuts and torque to 22 N•m (16 lbf ft).



CAUTION

Do not use the Allen screw to pull the cover and connector in position. This will cause damage to the connector.

**CAUTION**

Do not overtorque the Allen screw or it will cause damage to the connector body.

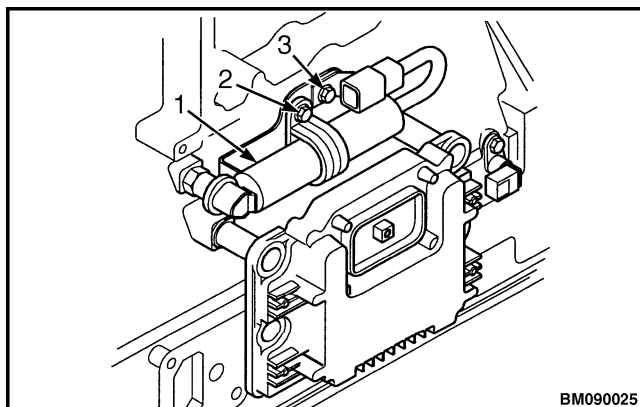
4. Insert the harness connector into the ECM. Lightly push the connector into the ECM as the Allen screw is tightened to 6 N•m (4 lbf ft).
5. Connect the battery cables.

VOLTAGE LOAD AND PROTECTION MODULE (VLPM)

Remove

NOTE: The VLPM can be mounted above the ECM or to the right of the ECM depending on the ECM location.

1. Disconnect the harness wiring electrical connector from the VLPM.
2. Remove the capscrew that holds the bracket for the directional connector to the cylinder block. See Figure 156.



1. ELECTRICAL CONNECTOR BRACKET
2. VLPM BRACKET
3. VOLTAGE LOAD PROTECTION MODULE

Figure 156. Voltage Load Protection Module (VLPM)

3. Remove the capscrew that holds the VLPM bracket to the cylinder block.
4. Remove the VLPM.

Install

1. Carefully place the VLPM into the VLPM bracket and onto the cylinder block. Install the capscrew and torque to 22 N•m (16 lbf ft).
2. Position the electrical connector bracket and install the capscrew. Torque the capscrew to 22 N•m (16 lbf ft).
3. Connect the wiring harness connector to the VLPM. Verify the connector is fully inserted and locked into position.

ENGINE SPEED AND TIMING SENSOR

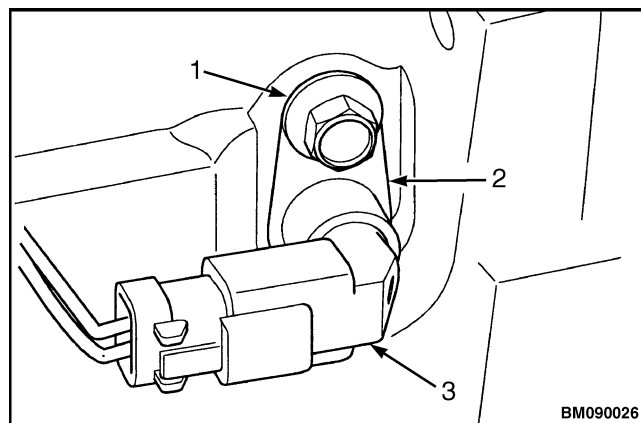
Remove

**WARNING**

The O-ring on the engine speed and timing sensor is made of Viton. See General Safety Rules before removing the engine speed and timing sensor.

NOTE: The engine speed and timing sensor is not adjustable. The sensor and mounting bracket should not be disassembled and are replaced as a single unit.

1. Disconnect wiring harness connector from the sensor connector.
2. Remove the capscrew securing the sensor to the cylinder block. See Figure 157.
3. Remove the sensor from the cylinder block.



1. CAPSCREW
2. MOUNTING BRACKET
3. ENGINE SPEED AND TIMING SENSOR

Figure 157. Engine Speed and Timing Sensor

Install

1. Replace the O-ring on the sensor.
2. Verify the sensor body and the bore in the cylinder block are clean and not damaged.
3. Push the sensor fully into the bore in the cylinder block and align the hole in the mounting bracket with the hole in the cylinder block.
4. Install the capscrew and torque to 22 N•m (16 lbf ft).
5. Verify that the mounting bracket is fully seated against the cylinder block.
6. Check the electrical connector seal for wear and damage. Replace as needed.
7. Connect the wiring harness connector to the sensor connector. Verify the connectors are locked in position.

PRESSURE SENSORS (ENGINE OIL AND AIR INTAKE)

Remove



WARNING

The engine oil pressure sensor O-ring is made of Viton. See General Safety Rules.

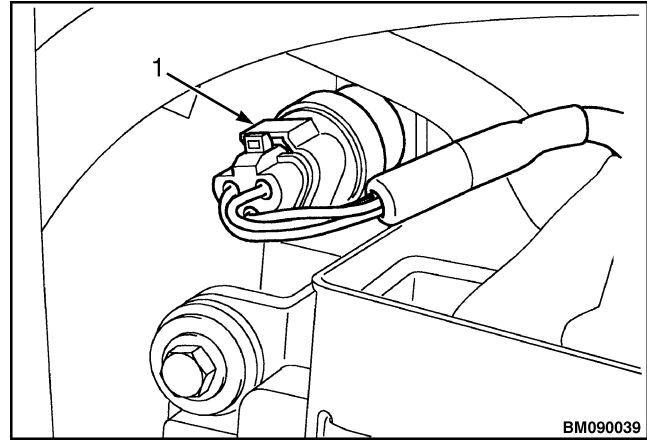
1. Use the following procedure that applies to the pressure sensor that you are removing:

NOTE: The engine oil pressure sensor is located on the cylinder block.

- a. For the engine oil pressure sensor, disconnect the electrical connector from the sensor. See Figure 158.

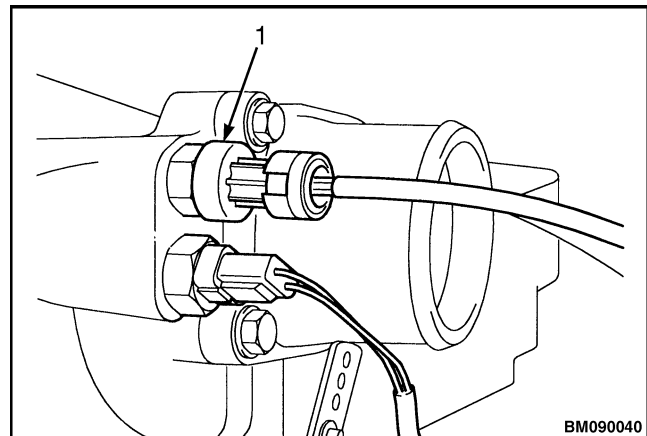
NOTE: The air intake pressure sensor is located on the intake manifold.

- b. For the air intake pressure sensor, disconnect the electrical cable from the wiring harness. See Figure 159.
2. With a suitable wrench, loosen and remove the pressure sensor.
 3. Remove and discard the O-ring. See Figure 160.



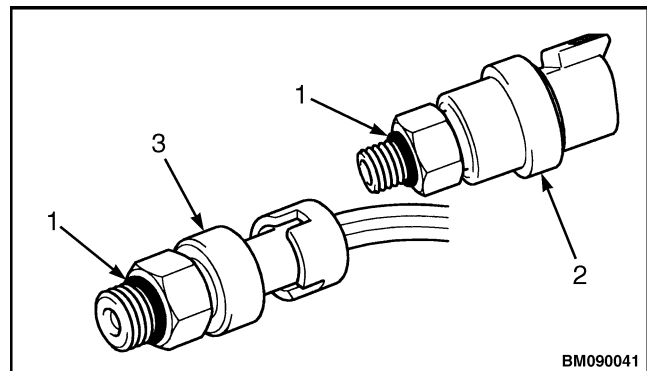
1. OIL PRESSURE SENSOR

Figure 158. Engine Oil Pressure Sensor



1. AIR INTAKE PRESSURE SENSOR

Figure 159. Air Intake Pressure Sensor



1. ENGINE OIL PRESSURE SENSOR O-RING
2. AIR INTAKE PRESSURE SENSOR O-RING

Figure 160. Pressure Sensor O-rings

Install

1. Verify that the threads of the sensor and the cylinder block or intake manifold are clean and not damaged.



CAUTION

Do not apply lubricant to the O-ring.

NOTE: The O-ring for the engine oil pressure sensor is brown. The O-ring for the air intake pressure sensor is yellow.

2. Fit a new O-ring to the sensor.



CAUTION

Do not use air powered tools to install the pressure sensor, as these tools may damage the sensor.

3. Use the following procedure that applies to the pressure sensor that you are installing:
 - a. Fit the engine oil pressure sensor to the cylinder block and torque to 10 N•m (89 lbf in).
 - b. Fit the air intake pressure sensor to the intake manifold and torque to 10 N•m (89 lbf in).
4. Verify that the connector seal is clean and not damaged. Replace as necessary.
5. Connect the electrical connector to the sensor. Verify that the connector is locked in place.

TEMPERATURE SENSOR

Remove

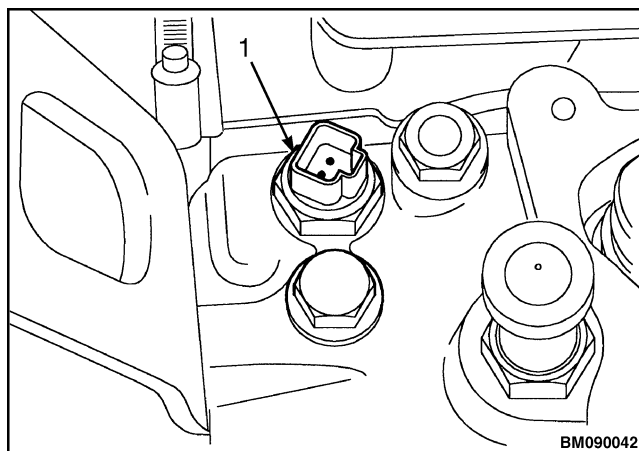


CAUTION

Before removing the coolant sensor from the cylinder head, verify that the coolant level is below the sensor or cylinder head.

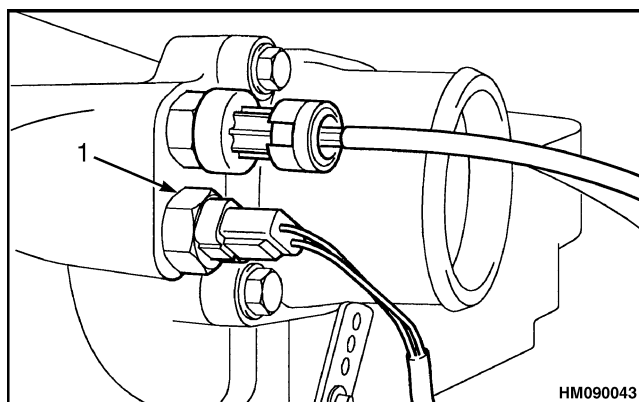
NOTE: There are two temperature sensors installed on this engine. One is on the intake manifold and one is on the cylinder head. See Figure 161 and Figure 162.

1. Disconnect the electrical connector from the sensor.



1. TEMPERATURE SENSOR

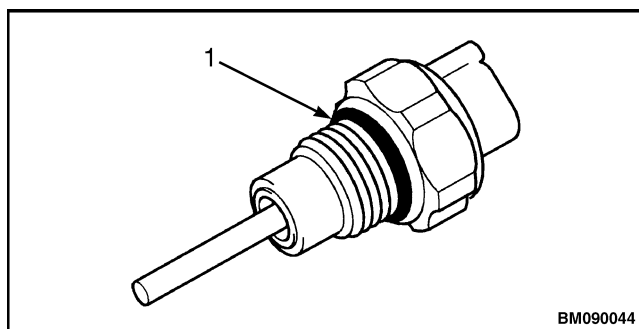
Figure 161. Cylinder Head Temperature Sensor



1. TEMPERATURE SENSOR

Figure 162. Intake Manifold Temperature Sensor

2. Remove the sensor.
3. Remove and discard the O-ring. See Figure 163



1. O-RING

Figure 163. Temperature Sensor O-ring

Install

1. Verify that the threads of the sensor and the cylinder head or intake manifold are clean and not damaged.



CAUTION

Do not apply lubricant to the O-ring.

NOTE: The O-rings for the temperature sensors are black.

2. Fit a new O-ring to the sensor.
3. Fit the sensor to the cylinder head or intake manifold and torque to 20 N•m (177 lbf in).
4. Verify that the connector seal is clean and not damaged. Replace as necessary.
5. Connect the electrical connector to the sensor. Verify that the connector is locked in place.

STARTER MOTOR

For repairs to the starter motor, contact your nearest approved Perkins dealer.

Remove

1. Disconnect the battery.
2. Disconnect the cables to the starter motor.
3. Remove the capscrews and remove the starter motor.

Install

1. Install the starter motor in position on the fly-wheel housing. Install and tighten the capscrews to 44 N•m (32 lbf ft).

2. Connect the cables to the starter motor.
3. Connect the battery.

COLD START AID

The cold start aid is an automatically operating device. Main components are a heater coil and a solenoid valve allowing fuel to enter when it has been activated. The cold start aid becomes activated when the ignition key is turned to the **ON** position and the temperature of the intake manifold air and/or the coolant is -3°C (26.6°F) or colder, the start aid warning light will be **ON**. If the start aid warning light is **ON**, do not immediately start the engine, wait 15 seconds until the light goes **OFF** to indicate that the engine can be started.

When cranking the engine, the fuel lift pump provides fuel to the heater coil through the activated solenoid valve. As soon as engine speed exceeds cranking speed, both the ignition coil and the solenoid valve are deactivated. If the engine has not started after 15 seconds, the cold start aid will automatically switch **OFF**.

If the cold start aid is removed for cleaning or replacement, verify that the surfaces between the induction manifold and the cold start aid are clean to ensure electrical contact. Tighten the cold start aid until one thread or less is remaining and the electrical connection is facing the front of the engine. If air is in the fuel system because the fuel line was disconnected, remove the air as described in Fuel System Air Removal.

Air Compressor

GENERAL

The air compressor is installed in the PTO position on the rear face of the timing case. See Figure 164. The compressor is driven from the main idler gear through an idler gear for the compression.

The cylinder head of the single-cylinder compressor is cooled by coolant from the engine. The compressor

is lubricated from the engine oil system of the engine. Engine oil flows through a pipe from the main oil passage in the engine to the crankcase of the compressor. The engine oil then flows through the bearings of the compressor and the bushing for the drive shaft. The engine oil returns to the oil sump through the timing case.

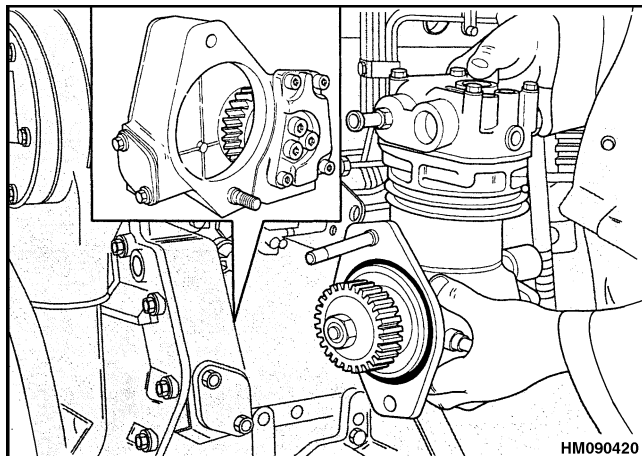
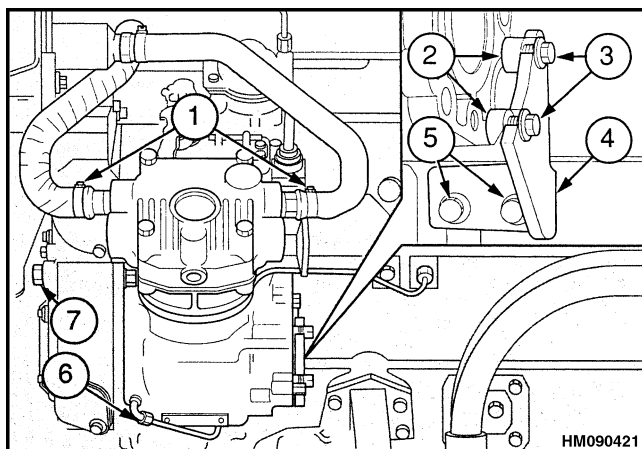


Figure 164. Air Compressor Installation

REPAIR

Remove

1. Drain the cooling system.
2. Release the air pressure in the air system and disconnect all the pipe connections to and from the cylinder head of the compressor.
3. Remove the oil tube for the engine oil between the compressor and the engine block. See Figure 165.



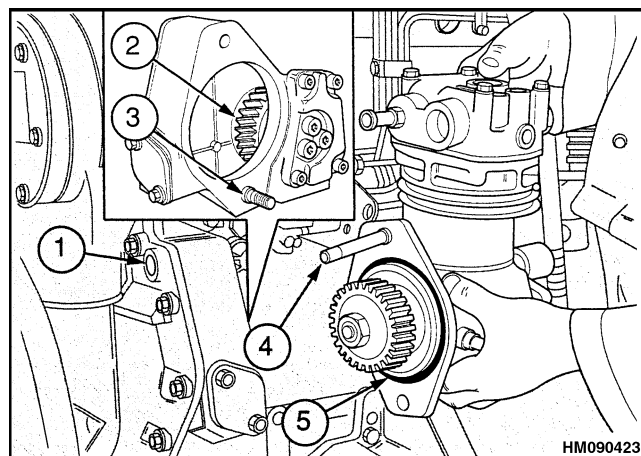
- | | |
|--------------------------|--------------------------|
| 1. COOLANT HOSES | 5. CAPSCREWS |
| 2. SPACERS (1W150R ONLY) | 6. OIL TUBE, LUBRICATION |
| 3. CAPSCREWS | 7. NUT |
| 4. SUPPORT BRACKET | |

Figure 165. Bendix Compressor Removal and Installation

4. If an oil pump for the steering system is fastened to the back of the compressor housing, remove it.
5. Loosen the two capscrews. Remove the two capscrews. Remove the support bracket.
6. Remove the nut from the stud at the bottom of the compressor flange. Remove the nut from the stud at the front of the timing case and remove the air compressor from the engine.

Install

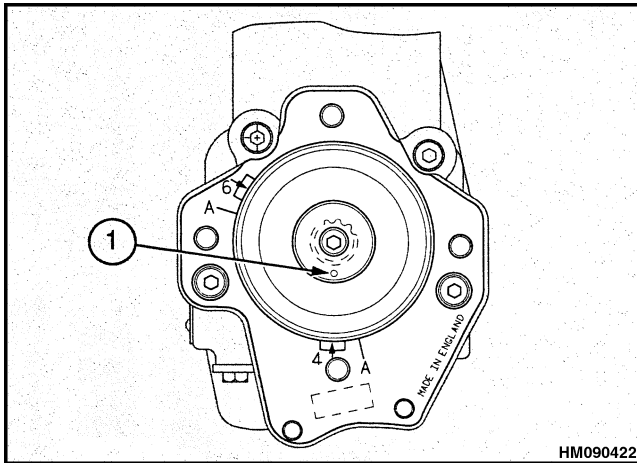
1. Set the piston of number one cylinder to TDC.
2. Install a new O-ring in its recess in the drive housing. See Figure 166.



- | | |
|--------------------------------|-----------|
| 1. THROUGH HOLE IN TIMING CASE | 3. STUD |
| 2. IDLER GEAR | 4. STUD |
| | 5. O-RING |

Figure 166. Bendix Compressor Installation into Drive Assembly

3. Turn the crankshaft of the air compressor until the timing mark on the rear face of the crankshaft is aligned with the 6A line on the label at the rear face of the air compressor. See Figure 167.
4. Install the end of the stud with the shortest thread into the flange of the air compressor. See Figure 166. Install the nut fully on the stud. Move the air compressor into its position and engage the stud in its hole in the timing case. Slide the compressor onto the stud for the bottom of the flange.



1. TIMING MARK

Figure 167. Bendix Compressor Installation into Drive Assembly

5. Slide the compressor into the timing case until the teeth of the drive gear are against the teeth of the idler gear. Slowly turn the rear of the crankshaft of the air compressor clockwise until the teeth of the drive gear and the idler gear are fully engaged. Check that the timing mark on the crankshaft of the air compressor is aligned with the 6A area on the timing label.
6. Install the nut (Figure 165) on the stud. Install the nut on the stud (Figure 166). Tighten both nuts to 75 N•m (55 lbf ft).
7. Install the support bracket. Install the capscrews loosely. See Figure 165. Install the spacers, if used, and the capscrews. Adjust the support bracket so that it only holds the air compressor and does not put tension on it. Tighten the two capscrews to 22 N•m (16 lbf ft). Tighten the two capscrews to 44 N•m (32 lbf ft).
8. Check that the O-ring in the cover at the rear of the air compressor is not damaged. Install the cover and tighten the two capscrews.
9. Verify the oil tube (Figure 165) is in good condition and does not have a restriction. Verify the engine stop solenoid is disconnected or the engine stop control is in the STOP position. Operate the started motor until engine oil flows from the oil tube. Connect the oil tube. Connect the engine stop solenoid.
10. Connect the coolant hoses and air pipes to the air compressor.
11. Install the engine coolant. When the engine can be operated, check for oil, air, and coolant leaks.

Rotary Exhauster Replacement

REMOVE

NOTE: The rotary exhauster is used to provide vacuum for vehicle brake system.

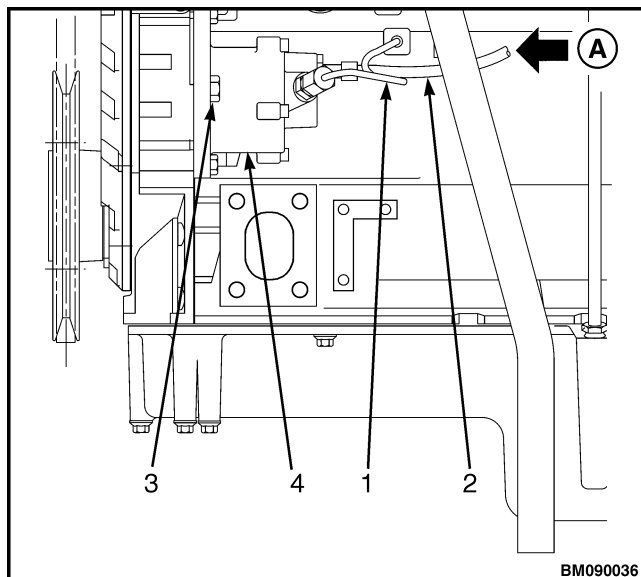
1. Disconnect lubricating oil and vacuum lines from rotary exhauster. See Figure 168. Install covers on the oil and vacuum lines and plugs in the open ports of the rotary exhauster to prevent dust and dirt from getting into the lines or the rotary exhauster.
2. Remove capscrews, rotary exhauster, and gasket from the back of timing case cover.

CLEAN

Clean all gasket material from timing case cover and rotary exhauster surfaces.

INSTALL

1. Install rotary exhauster into the back of timing case cover. Install capscrews and tighten to 35 N•m (26 lbf ft).
2. Remove plugs from ports of the rotary exhauster and covers from lubricating oil and vacuum lines. Connect lubricating oil and vacuum lines to rotary exhauster.

**Legend for Figure 168**

- A.** TO BRAKE BOOSTER
1. LUBRICATING OIL LINE
 2. VACUUM LINE
 3. CAPSCREW
 4. ROTARY EXHAUSTER

Figure 168. Rotary Exhauster

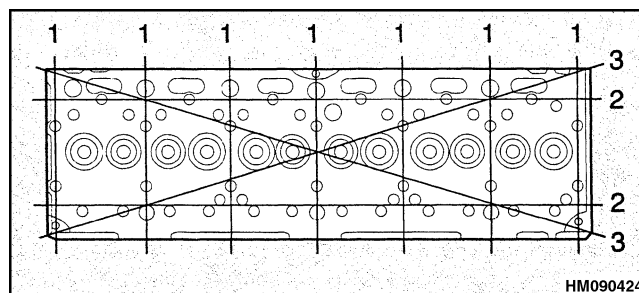
Engine Specifications

CYLINDER HEAD ASSEMBLY

Refer to the following tables and figures for specifications for the cylinder head assembly.

Table 1. Cylinder Head

Angle of valve seat	46° (88° included angle) or 31° (118° included angle)
Diameter of parent bore for valve guide	
Inlet	13.00 to 13.027 mm (0.5118 to 0.5128 in.)
Exhaust	14.00 to 14.027 mm (0.5512 to 0.5522 in.)
Leak test pressure.....	200 kPa (29 psi)
Head thickness.....	102.79 to 103.59 mm (4.047 to 4.078 in.)
Maximum distortion of cylinder head. See Figure 169.	

**Figure 169. Cylinder Head Distortion Check****Table 2. Valve Guides**

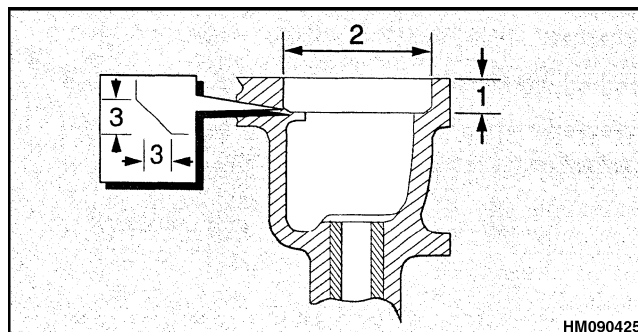
Inside diameter (finished surface)	9.000 to 9.022 mm (0.3543 to 0.3552 in.)
Outside diameter	
Inlet	13.034 to 13.047 mm (0.5131 to 0.5137 in.)
Exhaust	14.034 to 14.047 mm (0.5525 to 0.5530 in.)

Table 2. Valve Guides (Continued)

Interference fit of valve guide in cylinder head.....	0.047 to 0.007 mm (0.0018 to 0.00027 in.)
Total length	51.25 mm (2.018 in.)
Extension from bottom of recess for valve spring	14.85 to 15.15 mm (0.585 to 0.596 in.)

Table 3. Inlet Valves

Diameter, valve stem	8.953 to 8.975 mm (0.3525 to 0.3533 in.)
Clearance in valve guide	0.025 to 0.069 mm (0.001 to 0.0027 in.)
Maximum clearance in valve guide	
Production limit	0.089 mm (0.0035 in.)
Service limit	0.100 mm (0.004 in.)
Diameter, valve head	42.88 to 43.12 mm (1.688 to 1.698 in.)
Angle of valve face	45°
Depth of valve head below face of cylinder head to Production limit (see Figure 170 and Figure 171)	1.40 to 1.70 mm (0.055 to 0.067 in.)
Depth of valve head below face of cylinder head to Service limit (see Figure 170 and Figure 171)	1.95 mm (0.077 in.)
Total length	122.65 to 123.30 mm (4.829 to 4.854 in.)
Seal arrangement.....	Rubber seal installed on valve guide (green)

**Inlet Valves**

- 1 = 10.585 to 10.715 mm (0.4167 to 0.4219 in.)
 2 = 45.535 to 45.560 mm (1.7927 to 1.7937 in.)
 3 = Radius 0.38 mm (0.015 in.) Maximum

Exhaust Valves

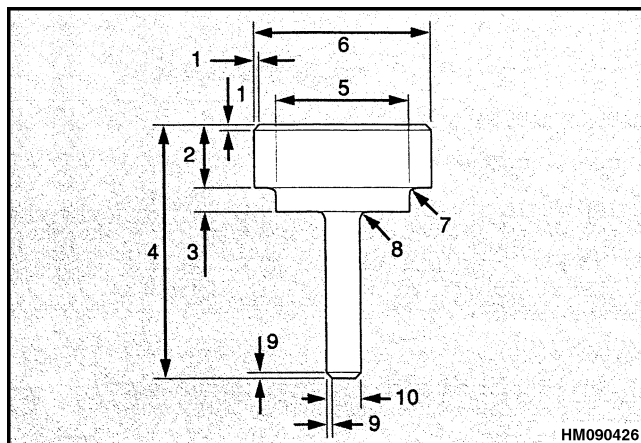
- 1 = 10.585 to 10.715 mm (0.4167 to 0.4219 in.)
 2 = 43.535 to 43.560 mm (1.7139 to 1.7149 in.)
 3 = Radius 0.38 mm (0.015 in.) Maximum

Figure 170. Dimensions of Recesses for Valve Seat Inserts**Table 4. Exhaust Valves**

Diameter, valve stem	8.938 to 8.960 mm (0.3519 to 0.3528 in.)
Clearance in valve guide	0.040 to 0.084 mm (0.0016 to 0.0033 in.)
Maximum clearance in valve guide	
Production limit	0.104 mm (0.0041 in.)
Service limit	0.121 mm (0.0048 in.)
Diameter, valve head	42.88 to 43.12 mm (1.685 to 1.698 in.)
Angle of valve face	30°
Depth of valve head below face of cylinder head to Production limit (see Figure 170 and Figure 171)	1.50 to 1.80 mm (0.059 to 0.071 in.)
Depth of valve head below face of cylinder head to Service limit (see Figure 170 and Figure 171)	2.05 mm (0.081 in.)

Table 4. Exhaust Valves (Continued)

Total length	122.65 to 123.30 mm (4.829 to 4.854 in.)
Seal arrangement.....	Rubber seal installed on valve guide (brown)

**Inlet Valves**

- 1 = 1.5 mm (0.06 in.)
- 2 = 20 mm (0.800 in.)
- 3 = 7.0 mm (0.28 in.)
- 4 = 100 mm (4.00 in.)
- 5 = 37.25 to 37.45 mm (1.467 to 1.474 in.)
- 6 = 44.75 to 45.00 mm (1.762 to 1.772 in.)
- 7 = Radius 1.4 mm (0.055 in.) Maximum
- 8 = Radius 1.5 mm (0.06 in.)
- 9 = 1.5 mm (0.06 in.)
- 10 = 8.54 to 8.57 mm (0.336 to 0.337 in.)

Exhaust Valves

- 1 = 1.5 mm (0.06 in.)
- 2 = 20 mm (0.80 in.)
- 3 = 7.0 mm (0.28 in.)
- 4 = 100 mm (4.00 in.)
- 5 = 34.38 to 34.58 mm (1.354 to 1.361 in.)
- 6 = 42.75 to 43.00 mm (1.683 to 1.693 in.)
- 7 = Radius 1.4 mm (0.055 in.) Maximum
- 8 = Radius 1.5 mm (0.06 in.)
- 9 = 1.5 mm (0.06 in.)
- 10 = 8.54 to 8.57 mm (0.336 to 0.337 in.)

Table 5. Valve Springs

Installed length	39.0 mm (1.54 in.)
Load, installed length	246 to 277.5 N (55.3 to 62.4 lbf)
Active coils, number	3.3
Damper coils, number	0
Direction of coils	Left hand

Table 6. Tappets

Diameter, tappet stem	18.99 to 19.01 mm (0.7475 to 0.7485 in.)
Diameter, tappet bore in cylinder block	19.05 to 19.08 mm (0.7500 to 0.7512 in.)
Clearance of tappet in engine block	0.04 to 0.09 mm (0.0015 to 0.0035 in.)

Table 7. Rocker Arm Shaft

Outside diameter	19.01 to 19.04 mm (0.7484 to 0.7496 in.)
------------------------	---

Table 8. Rocker Arms and Bushings

Diameter, bore in rocker arm for bushing	22.23 to 22.26 mm (0.8752 to 0.8764 in.)
Diameter, outside of bushing	22.28 to 22.31 mm (0.8772 to 0.8783 in.)
Interference fit of bushing in rocker arm	0.020 to 0.089 mm (0.0008 to 0.0035 in.)
Internal diameter, bushing (finished size)	19.06 to 19.10 mm (0.7505 to 0.7520 in.)

**Figure 171. Pilot Tool to Insert Valve Seats for
45° or 30° Valves**

**Table 8. Rocker Arms and Bushings
(Continued)**

Clearance between rocker arm and rocker arm shaft	0.03 to 0.09 mm (0.001 to 0.0035 in.)
Maximum clearance (service) between rocker arm and rocker arm shaft	0.13 mm (0.005 in.)

PISTON AND CONNECTING RODS

Refer to the following tables and Figure 172 for specifications for the piston and connecting rods.

Table 9. Pistons

Type: "Fastram" combustion bowl, top ring groove has insert, graphite skirt.

Diameter, bore for piston pin	39.703 to 39.709 mm (1.5631 to 1.5633 in.)
--	---

Height of piston above top face of engine block	0.38 to 0.50 mm (0.015 to 0.020 in.)
--	---

Width of groove for top ring	Tapered
---------------------------------------	---------

Width of groove for second ring	2.56 to 2.58 mm (0.1008 to 0.1016 in.)
--	---

Width of groove for third ring	3.54 to 3.56 mm (0.1393 to 0.1401 in.)
---	---

Table 10. Piston Rings

Top compression ring	Barrel face, molybdenum insert, wedge
Second compression ring	Taper face, cast iron, outside bottom step
Oil ring	Coil spring, chromium face
Width of top ring	Tapered

Table 10. Piston Rings (Continued)

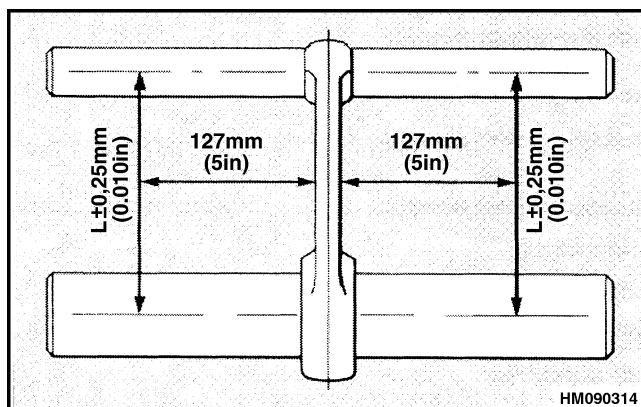
Width of second ring	2.47 to 2.49 mm (0.097 to 0.098 in.)
Width of third ring	3.47 to 3.49 mm (0.1366 to 0.1374 in.)
Clearance of top ring in groove	Wedge
Clearance of second ring in groove	0.07 to 0.11 mm (0.003 to 0.004 in.)
Clearance of third ring in groove.....	0.05 to 0.09 mm (0.002 to 0.003 in.)
Gap of top ring	0.28 to 0.43 mm (0.011 to 0.017 in.)
Gap of second ring	0.30 to 0.55 mm (0.012 to 0.022 in.)
Gap of third ring	0.30 to 0.55 mm (0.012 to 0.022 in.)

Table 11. Piston Pins

Type	Full floating
Outside diameter	39.694 to 39.700 mm (1.5628 to 1.5630 in.)
Clearance fit in piston	0.003 to 0.015 mm (0.0001 to 0.0006 in.)

Table 12. Connecting Rods

Type	"H" section, wedge shape at small end
Location of cap to connecting rod	Flat joint face with serrations
Diameter, parent bore at big end	67.21 to 67.22 mm (2.6460 to 2.6465 in.)
Diameter, parent bore at small end	43.01 to 43.04 mm (1.693 to 1.694 in.)
Length grades.....	H, J, K, L
Length between centers..	219.05 to 219.10 mm (8.624 to 8.626 in.)



NOTE: THE LARGE AND SMALL BORES IN THE CONNECTING ROD MUST BE SQUARE AND PARALLEL WITH EACH OTHER WITHIN THE LIMITS OF ± 0.25 mm (0.010 in.). THE MEASUREMENT IS MADE AT 127 mm (5.0 in.) ON EACH SIDE OF THE AXIS OF THE CONNECTING ROD. IF THE BUSHING IS INSTALLED IN THE SMALL END OF THE CONNECTING ROD, THE LIMITS ARE REDUCED TO ± 0.06 mm (0.0025 in.).

Figure 172. Connecting Rod Alignment Check

Table 13. Small End Bushings

Type	Steel back, lead bronze tin bearing material
Outside diameter	43.11 to 43.15 mm (1.6972 to 1.6988 in.)
Inside diameter	39.723 to 39.738 mm (1.5638 to 1.5645 in.)
Surface finish grade	Ra 0.8 micrometers
Clearance between bushing and piston pin	0.023 to 0.044 mm (0.0009 to 0.0017 in.)

Table 14. Connecting Rod Bearings

Type	Steel back, lead bronze bearing material with lead finish
Width	31.55 to 31.88 mm (1.240 to 1.255 in.)
Thickness.....	1.835 to 1.844 mm (0.0723 to 0.0726 in.)

Table 14. Connecting Rod Bearings (Continued)

Bearing clearance.....	0.030 to 0.081 mm (0.0012 to 0.0032 in.)
Available undersize bearings	-0.25 mm (-0.010 in.) -0.51 mm (-0.020 in.) -0.76 mm (-0.030 in.)

Table 15. Piston Cooling Jets

Valve open pressure	178 to 250 kPa (26 to 36 psi)
---------------------------	----------------------------------

CRANKSHAFT ASSEMBLY

Refer to the following tables for specifications for the crankshaft assembly.

Table 16. Crankshaft

Diameter, main journal...	76.159 to 76.190 mm (2.9984 to 2.9996 in.)
Maximum wear and oval wear on main and crank journals.....	0.004 mm (0.00016 in.)
Width of front journal	36.93 to 37.69 mm (1.454 to 1.484 in.)
Width of center journal...	44.15 to 44.22 mm (1.738 to 1.741 in.)
Width of all other main journals.....	39.24 to 39.35 mm (1.545 to 1.549 in.)
Diameter of crank journals.....	63.47 to 63.49 mm (2.499 to 2.500 in.)
Width of crank journals.....	40.35 to 40.42 mm (1.589 to 1.591 in.)
Diameter of flange.....	133.27 to 133.37 mm (5.247 to 5.251 in.)
Depth of recess for spigot bearing.....	14.72 to 15.48 mm (0.579 to 0.609 in.)
Bore of recess for spigot bearing.....	51.97 to 51.99 mm (2.046 to 2.047 in.)

Table 16. Crankshaft (Continued)

Axial movement	0.05 to 0.38 mm (0.002 to 0.015 in.)
Maximum axial movement (service)	0.51 mm (0.020 in.)
Fillet radii, all journals.....	3.68 to 3.96 mm (0.145 to 0.156 in.)
Undersize journals, all....	−0.25 mm (−0.010 in.) −0.51 mm (−0.020 in.) −0.76 mm (−0.030 in.)

Table 17. Main Bearings

Type	Steel back, with a bearing surface of lead/bronze and plated
Width, center bearing	36.32 to 36.70 mm (1.430 to 1.445 in.)
Width, other bearings	30.86 to 31.12 mm (1.215 to 1.225 in.)
Bearing thickness	2.083 to 2.89 mm (0.0820 to 0.11378 in.)
Bearing clearance	0.047 to 0.117 mm (0.0018 to 0.0046 in.)
Available undersize bearings:	−0.25 mm (−0.010 in.) −0.51 mm (−0.020 in.) −0.76 mm (−0.030 in.)

Table 18. Crankshaft Thrust Washers

Type	Steel back, lead bronze bearing material
Position	Each side of the center main bearing
Thickness:	
to Standard	2.26 to 2.31 mm (0.089 to 0.091 in.)
to Oversize.....	2.45 to 2.50 mm (0.096 to 0.098 in.)

Table 19. Crankshaft Heat Treatment

The following part number is
nitrocarburized:..... 3131H051

Crankshaft Overhaul

Nitrocarburized crankshafts must be hardened again each time after they have been machined. If nitrocarburized or nitrided hardening methods are not available, the crankshaft must be replaced or exchanged with a crankshaft from the manufacturer.

Check the crankshaft for cracks before and after it is machined (ground). Remove any magnetism, after the crankshaft has been checked for cracks.

After the crankshaft has been machined, remove any sharp edges from the oil holes for lubrication.

Surface finish and fillet radii must be according to the specifications. The finished sizes for machined crankshafts are shown in Table 20.

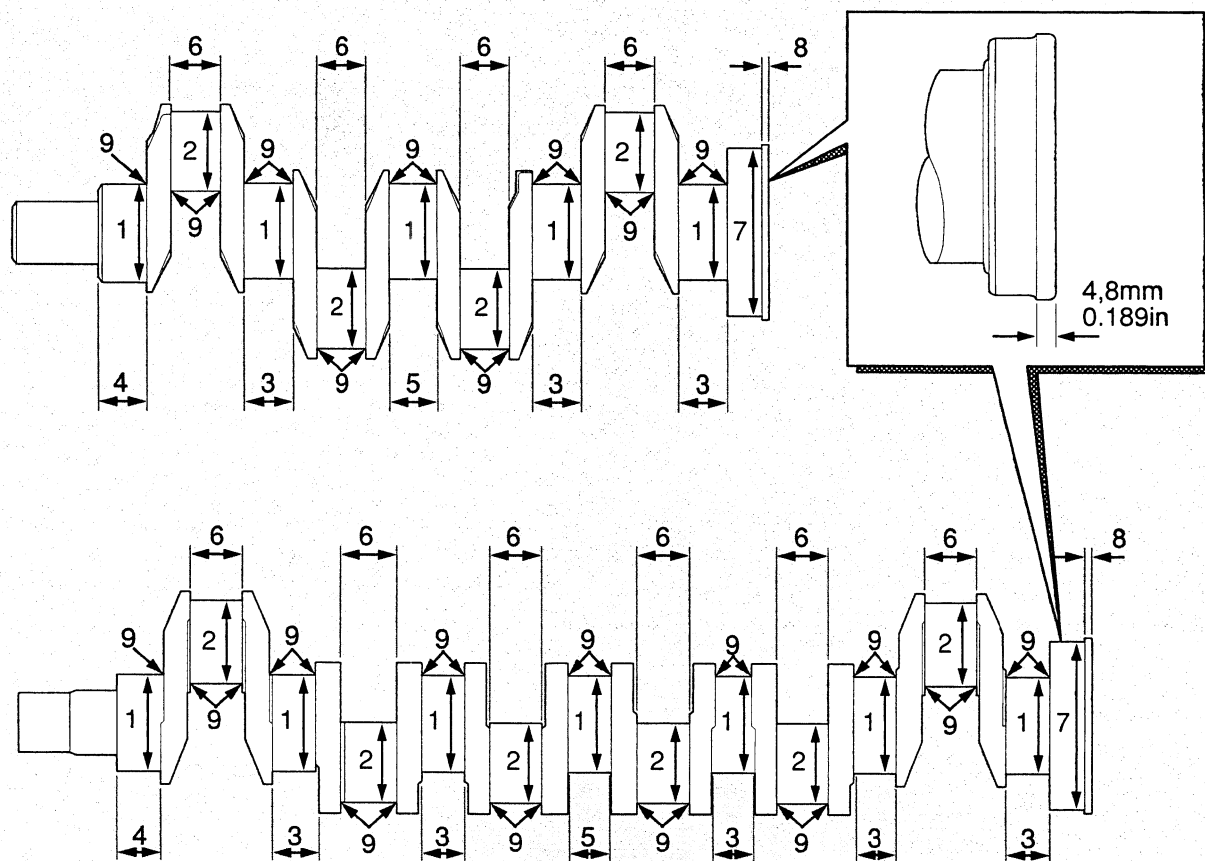
Table 20. Crankshaft Overhaul Specifications

Item	Undersize		
	0.25 mm (0.010 in.)	0.51 mm (0.020 in.)	0.76 mm (0.030 in.)
1	75.905 to 75.926 mm (2.9884 to 2.9892 in.)	75.651 to 75.672 mm (2.9784 to 2.9792 in.)	75.397 to 75.418 mm (2.9684 to 2.9692 in.)
2	63.216 to 63.236 mm (2.4888 to 2.4896 in.)	62.962 to 62.982 mm (2.4788 to 2.4796 in.)	62.708 to 62.728 mm (2.4688 to 2.4696 in.)
3	39.47 mm (1.554 in.) maximum		
4	37.82 mm (1.489 in.) maximum		
5	44.68 mm (1.759 in.) maximum		
6	40.55 mm (1.596 in.) maximum		

Table 20. Crankshaft Overhaul Specifications (Continued)

Item	Undersize		
	0.25 mm (0.010 in.)	0.51 mm (0.020 in.)	0.76 mm (0.030 in.)
7	133.17 mm (5.243 in.) minimum		
8	Do not machine this diameter		
9	3.68 to 3.96 mm (0.145 to 0.156 in.)		

Surface finish for journals, crank fins and fillet radii must be 0.4 microns (16 micro inches).
 Surface finish for seal area of crankshaft palm must be 0.4 to 1.1 microns (16 to 43 micro inches).



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When the crankshaft is on mounts at the front and rear main journals, the maximum variation (run-out) (total indicator reading) at the other main journals cannot be greater than in Table 24.

The run-out must not be opposite. The difference in run-out between one journal and the next must not

be more than 0.10 mm (0.004 in.). The run-out on the crankshaft pulley diameter, rear oil seal diameter, and the rear flange diameter must not be more than 0.05 mm (0.002 in.) total indicator reading.

Table 21. Maximum Variation (Run-Out)

Journal	Crankshafts
1	Mount
2	0.10 mm (0.004 in.)
3	0.20 mm (0.008 in.)
4	0.25 mm (0.010 in.)
5	0.20 mm (0.008 in.)
6	0.10 mm (0.004 in.)
7	Mount

TIMING CASE AND DRIVE ASSEMBLY

Refer to the following tables for specifications for the timing case and drive assembly.

Table 22. Camshaft

Diameter, journal	
No. 1	50.71 to 50.74 mm (1.9965 to 1.9975 in.)
Diameter, journal	
No. 2	50.46 to 50.48 mm (1.9865 to 1.9875 in.)
Diameter, journal	
No. 3	50.20 to 50.23 mm (1.9765 to 1.9775 in.)
Diameter, journal	
No. 4	49.95 to 49.98 mm (1.9665 to 1.9677 in.)
Clearances, all journals.....	0.06 to 0.14 mm (0.0024 to 0.0055 in.)
Cam lift to inlet.....	7.62 to 7.69 mm (0.2999 to 0.3029 in.)
Cam lift to exhaust	7.71 to 7.79 mm (0.3036 to 0.3066 in.)
Maximum out-of-round and wear on journals	0.05 mm (0.0020 in.)
Axial movement:	
to Production limit.....	0.10 to 0.41 mm (0.004 to 0.016 in.)

Table 22. Camshaft (Continued)

to Service limit.....	0.53 mm (0.021 in.)
Width, thrust washer space	5.64 to 5.89 mm (0.222 to 0.232 in.)

Table 23. Camshaft Thrust Washer

Type	360°
Clearance fit, thrust washer in engine block ...	5.46 to 5.54 mm (0.215 to 0.218 in.)
Thickness, thrust washer	5.49 to 5.54 mm (0.216 to 0.218 in.)
Extension of thrust washer beyond front face of engine block.....	−0.05 to +0.08 mm (−0.002 to +0.003 in.)

Table 24. Camshaft Gear

No. of teeth.....	68
Diameter, bore	34.93 to 34.95 mm (1.3750 to 1.3760 in.)
Outside diameter, hub of camshaft	34.90 to 34.92 mm (1.3741 to 1.3747 in.)
Clearance fit, gear on hub	0.008 to 0.048 mm (0.0003 to 0.0019 in.)

Table 25. Gear for Fuel Injection Pump

No. of teeth.....	68
Bore.....	36.00 to 36.06 mm (1.417 to 1.419 in.)
Clearance fit, gear on hub	0.003 to 0.075 mm (0.0001 to 0.0030 in.)

Table 26. Crankshaft Gear

No. of teeth.....	34
Diameter, bore.....	47.625 to 47.650 mm (1.8750 to 1.8760 in.)
Diameter, hub for gear on crankshaft.....	47.625 to 47.645 mm (1.8750 to 1.8758 in.)
Press fit of gear on crankshaft.....	−0.020 to +0.048 mm (−0.0008 to +0.0019 in.)

Table 27. Idler Gear and Hub

No. of teeth.....	73
Diameter, gear bore.....	57.14 to 57.18 mm (2.2495 to 2.2512 in.)
Width, gear with split bushing assembly.....	30.14 to 30.16 mm (1.186 to 1.187 in.)
Width, gear with flange bushing assembly.....	50.78 to 50.80 mm (1.9992 to 2.000 in.)
Outside diameter, hub	50.70 to 50.74 mm (1.9960 to 1.9975 in.)
Clearance, bushings on hub	0.04 to 0.10 mm (0.0016 to 0.0039 in.)
Axial movement:	
to Production limit.....	0.10 to 0.20 mm (0.004 to 0.008 in.)
to Service limit.....	0.38 mm (0.015 in.)
to Service limit.....	0.38 mm (0.015 in.)
Gear clearance (all).....	0.08 mm (0.003 in.)

ENGINE BLOCK ASSEMBLY

Refer to the following tables for specifications for the engine block assembly.

Table 28. Cylinder Block

Height between top and bottom faces.....	441.12 to 441.33 mm (17.367 to 17.375 in.)
Diameter, bore for cylinder liner	104.20 to 104.23 mm (4.103 to 4.104 in.)
Depth of space for flange of cylinder liner	3.81 to 3.91 mm (0.150 to 0.154 in.)
Diameter of space for flange of cylinder liner	107.82 to 107.95 mm (4.245 to 4.250 in.)
Diameter of bore for main bearing.....	80.416 to 80.442 mm (3.1660 to 3.1670 in.)
Diameter, camshaft bore	
to No. 1	55.56 to 55.59 mm (2.188 to 2.189 in.)
to No. 2.....	50.55 to 50.60 mm (1.990 to 1.992 in.)
to No. 3.....	50.29 to 50.34 mm (1.980 to 1.982 in.)
to No. 4.....	50.04 to 50.09 mm (1.970 to 1.972 in.)
Bore in bushing for No. 1 camshaft journal	50.79 to 50.85 mm (2.000 to 2.002 in.)

Table 29. Cylinder Liners

Outside diameter, production cylinder liner.....	104.25 to 104.28 mm (4.105 to 4.106 in.)
Fit of production cylinder liner.....	0.025 to 0.076 mm (0.001 to 0.003 in.)
Inside diameter of production cylinder liner.....	100.00 to 100.025 mm (3.937 to 3.9379 in.)
Fit of service cylinder liner.....	±0.03 mm (±0.001 in.)

Table 29. Cylinder Liners (Continued)

Inside diameter of service cylinder liner (installed) ..	100.00 to 100.06 mm (3.937 to 3.939 in.)
Maximum wear of liner bore	0.25 mm (0.010 in.)
Thickness of flange	3.81 to 3.86 mm (0.150 to 0.152 in.)
Top of flange even with face of engine block	0.10 mm (0.004 in.) above 0.10 mm (0.004 in.) below

Table 30. Cylinder Liner Specifications (Partially Finished)**CAUTION**

Special training and equipment is needed to machine the finish of a partially finished line. For further information, contact your nearest Perkins distributor.

Partially finished liner

Interference fit of liner in parent bore	0.025 to 0.076 mm (0.0010 to 0.0030 in.)
--	---

Inside diameter of partially machined liner	99.162 to 99.415 mm (3.9040 to 3.9139 in.)
---	---

Preliminary bore

Final size of liner before it is honed	99.873 to 99.924 mm (3.9320 to 3.9340 in.)
--	---

Surface finish Ra 3.2 to 4.0 micrometers

Maximum ovality and taper	0.02 mm (0.0008 in.)
---------------------------------	----------------------

Diamond hone

Hone angle (cross hatch) 35°

Finish size, diamond honed 99.95 mm (3.9350 in.)

Surface finish Ra 1.3 to 1.6 micrometers

Table 30. Cylinder Liner Specifications (Partially Finished) (Continued)

Maximum ovality and taper 0.010 mm (0.0004 in.)

Silicone carbide base hone

Hone angle (cross hatch) 35°

Finish size, silicone carbide base hone 100.012 mm (3.9374 in.)

Surface finish Ra 1.3 to 1.6 micrometers

Maximum ovality and taper 0.010 mm (0.0004 in.)

Silicone carbide plateau hone

Final finish size, carbide (plateau hone) 100.017 mm (3.9376 in.)

Final surface finish grade 0.65 to 1.3 micrometers

**CAUTION**

Special training and equipment are needed to correctly finish the internal bore of a cylinder liner with a hone. Contact your nearest Perkins dealer.

TURBOCHARGER

Refer to the following table for specifications for the Garrett T35 engine turbocharger.

Part Number	Waste-Gate Pressure		
	(kpa) (±3)	(lbf/in ²) (±0.43)	(kgf/cm ²) (±0.05)
2674A342	145	21.03	1.48
2674A343	145	21.03	1.48
2674A344	145	21.03	1.48
2674A345	145	21.03	1.48
2674A346	145	21.03	1.48
2674A347	145	21.03	1.48
2674A348	145	21.03	1.48
2674A349	127.5	18.49	1.30

LUBRICATION SYSTEM

Refer to the following tables for specifications for the lubrication system.

Table 31. Oil Pump

Type	Differential rotor, gear-driven
Number of lobes	Inner rotor 4, outer rotor 5
Clearance of outer rotor to pump body	0.15 to 0.34 mm (0.006 to 0.013 in.)
Clearance of inner rotor to outer rotor	0.04 to 0.13 mm (0.0015 to 0.0050 in.)
End clearance	
to Inner rotor	0.043 to 0.118 mm (0.0017 to 0.0046 in.)
to Outer rotor	0.031 to 0.106 mm (0.0012 to 0.0042 in.)

Table 32. Idler Gear for Oil Pump

End float	0.015 to 0.570 mm (0.0006 to 0.0224 in.)
Inside diameter of bush (fitted)	22.23 to 22.26 mm (0.875 to 0.876 in.)
Outside diameter of idler shaft	22.19 to 22.21 mm (0.873 to 0.874 in.)
Clearance of bush of idler gear on shaft	0.024 to 0.030 mm (0.0009 to 0.0012 in.)

Table 33. Relief Valve

Diameter, bore for plunger	18.24 to 18.27 mm (0.718 to 0.719 in.)
Outside diameter, plunger	18.16 to 18.18 mm (0.715 to 0.716 in.)
Clearance of plunger in bore	0.06 to 0.11 mm (0.002 to 0.004 in.)
Length of spring, installed	55.6 mm (2.2 in.)
Load on spring, installed	12.9 to 18.6 N (2.9 to 4.2 lbf)
Pressure to open valve	345 to 414 kPa (50 to 60 psi)

Table 34. Oil Filter

Type	Full flow, canister
Pressure to open bypass valve in oil filter	55 to 83 kPa (8 to 12 psi)

Refer to the following tables for specifications for the fuel system.

Table 35. Bosch Fuel Injection Pump

Type	Bosch VP30 pin timed, with locking screw
Direction of rotation (from drive end)	Clockwise

Table 36. Fuel Injector Codes

Code	Holder	Nozzle	Set and Reset Pressure		
			atm	(lbf/in ²)	MPa
KB	2645A308	2645A624	300	4410	30.4
KC	2645A309	2645A625	290	4263	29.4
KD	2645A310	2645A626	290	4263	29.4
KE	2645A311	2645A627	290	4337	29.9
KF	2645A311	2645A628	295	4337	29.9
KG	2645A314	2645A629	300	4410	30.4
KH	2645A314	2645A630	290	4263	29.4
KJ	2645A315	2645A631	250	3675	25.3
KK	2645A312	2645A632	300	4410	30.4
KL	2645A312	2645A633	300	4410	30.4
KM	2645A313	2645A634	300	4410	30.4
KN	2645A315	2645A635	290	4263	29.4
KP	2645A311	2645A636	290	4410	30.4
KR	2645A311	2645A608	290	4263	29.4
KT	2645A311	2645A638	290	4263	29.4
KS	2645A316	2645A637	290	4263	29.4
KU	2645A317	2645A627	290	4322	29.8
KV	2645A304	2645L615	250	3675	25.3
KW	2645A311	2645K609	290	4263	29.4
NX	2645L306	2645L617	290	4263	29.4
NY	2645L308	2645L618	290	4263	29.4
NZ	2645L307	2645L619	290	4263	29.4
PA	2645L309	2645L620	290	4263	29.4
PB	2645L310	2645L621	290	4263	29.4
PC	2645L310	2645L622	290	4263	29.4
PD	2645L310	2645L622	275	4043	27.9
RZ	0430 133 005	DSLA140P707	250	3675	25.3
SA	2645F316	2645F620	250	3675	25.3
SB	2645F316	2645F621	250	3675	25.3
SC	0430 133 06	DSLA150PV3378123	250	3675	25.3
The code letters are on the side of the fuel injector body and just below the connection for the nut of the high pressure line.					

Table 37. Fuel Pump

Type	A.C. Delco, types LU
Method of drive	Eccentric on camshaft
Static pressure (no delivery)	73 to 80 kPa (10.6 to 11.6 psi)
Test pressure (75% of minimum static pressure)	55 kPa (8 psi)

Table 38. Fuel Filter

Type	Single element
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COOLING SYSTEM

Refer to the following tables for specifications for the cooling system.

Table 39. Coolant Pump

Type	Centrifugal, gear drive
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Table 40. Thermostat

Type	Single, wax element, bypass blanking
"Start to open"	82°C (180°F)
"Fully open"	96°C (205°F)
Valve lift, fully open	9.0 mm (0.35 in.)

Table 41. Fan Drive Housing

Bore of housing for bearing	41.9655 to 41.9785 mm (1.6529 to 1.6522 in.)
Outside diameter, bearing	41.987 to 42.00 mm (1.6535 to 1.6530 in.)
Press fit, bearing in housing	0.0085 to 0.0345 mm (0.00033 to 0.00136 in.)
Bore of hub	21.938 to 21.958 mm (0.8637 to 0.8645 in.)

Table 41. Fan Drive Housing (Continued)

Outside diameter of shaft	21.987 to 22.00 mm (0.8656 to 0.8661 in.)
Press fit, shaft in hub	0.029 to 0.062 mm (0.0011 to 0.0024 in.)
Maximum axial movement	0.200 mm (0.0079 in.)

FLYWHEEL AND HOUSING

Refer to the following table for specifications for the flywheel and housing.

Table 42. Limits for Flywheel Run Out and Alignment (Total Indicator Reading)

Diameter of Housing Flange Bore		Maximum Limit (Total Indicator Reading)	
mm	in.	mm	in.
410	16.14	0.25	0.010
448	17.63	0.28	0.011

ELECTRICAL EQUIPMENT

Refer to the following tables for specifications for the electrical equipment.

Table 43. Alternator

Type	Denso
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Table 44. Starter Motor

Type	Denso
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Table 45. Cold Start Aid

Type	Diesel fuel, electrically operated heater
Voltage	12 volts
Fuel flow	3.5 to 5.9 milliliters/minute

Torque Specifications

CYLINDER HEAD ASSEMBLY

Capscrews, Cylinder Head 1/2 UNF (Special Procedure, See Cylinder Head Assembly, Install)

Fasteners, Rocker Arm Brackets

Cast Iron M12 75 N•m (55 lbf ft)

Cap Nuts, Valve Cover

M6 9 N•m (7 lbf ft)

Capscrews, Inlet Manifold to Cylinder Head

M8 22 N•m (16 lbf ft)

Nuts (Nonplated), Exhaust Manifold to Cylinder Head

M8 25 N•m (18 lbf ft)

Capscrews, Engine Lift Brackets

M10 44 N•m (33 lbf ft)

PISTON AND CONNECTING ROD ASSEMBLIES

Nuts, Connecting Rods

1/2 UNF 125 N•m (92 lbf ft)

Banjo Bolts, Piston Cooling Jets

3/8 UNF 27 N•m (20 lbf ft)

CRANKSHAFT ASSEMBLY

Capscrews, Main Bearings

5/8 UNF 265 N•m (195 lbf ft)

Capscrews, Crankshaft Pulley

7/16 UNF 115 N•m (85 lbf ft)

Capscrews, Engine Front Mounting Bracket to Cylinder Block

M16 190 N•m (140 lbf ft)

Capscrews, Viscous Damper to Crankshaft Pulley

M12 75 N•m (55 lbf ft)

Capscrews, Damper to Crankshaft Pulley

M8 35 N•m (26 lbf ft)

Capscrews, Rear Oil Seal Housing to Engine Block

M8 22 N•m (16 lbf ft)

Capscrews, Bridge Piece to Cylinder Block

M6 16 N•m (12 lbf ft)

Capscrews, Rear Oil Seal Housing to Bridge Piece

M6 13 N•m (10 lbf ft)

TIMING CASE AND DRIVE ASSEMBLY

Capscrews, Timing Case to Engine Block

M8 22 N•m (16 lbf ft)

Capscrews, Hub of Idler Gear

M10 44 N•m (32 lbf ft)

Capscrew, Camshaft Gear

M12 95 N•m (70 lbf ft)

Capscrews, Timing Case Cover to Timing Case

M8 22 N•m (16 lbf ft)

Nuts, Timing Case Cover to Timing Case

M8 22 N•m (16 lbf ft)

TURBOCHARGER

Nuts, Turbocharger to Manifold

M10 44 N•m (32 lbf ft)

LUBRICATION SYSTEM

Plug, Oil Sump

3/4 UNF 34 N•m (25 lbf ft)

Capscrews, Oil Pump to Front Bearing Cap

M8 22 N•m (16 lbf ft)

Capscrews, Cover for Oil Pump

M8 28 N•m (21 lbf ft)

Fasteners, Oil Sump

M8 22 N•m (16 lbf ft)

FUEL SYSTEM

Nuts, High to Pressure Fuel Lines

M12 27.5 N•m (20 lbf ft)

Bolt, Leak-Off Connection

M8 9 N•m (7 lbf ft)

Capscrews, Fuel Lift Pump

M8 22 N•m (16 lbf ft)

Nut for Fuel Injector Body

40 N•m (30 lbf ft)

Capscrews for Gear of Fuel Injection Pump

M10 28 N•m (20 lbf ft)

Special (Torx) Screws for Gear of Fuel Injection Pump

M10 22 N•m (16 lbf ft)

Nuts for Flange of Fuel Injection Pump

M8 22 N•m (16 lbf ft)

COOLING SYSTEM**Capscrews for Fan Drive Housing to Timing Case**

M10 44 N•m (32 lbf ft)

Capscrews, Thermostat Housing to Cylinder Head

M8 22 N•m (16 lbf ft)

Capscrews, Fan Drive Pulley to Hub

M10 44 N•m (32 lbf ft)

Capscrews, Fan

M8 22 N•m (16 lbf ft)

FLYWHEEL**Capscrews, Flywheel to Crankshaft**

1/2 UNF 107 N•m (79 lbf ft)

AUXILIARY EQUIPMENT**Nut, Air Compressor Drive Gear to Compressor Drive Shaft**

5/8 UNF 120 N•m (88 lbf ft)

Capscrew, Bracket to Compressor

M10 22 N•m (16 lbf ft)

Capscrew, Bracket to Cylinder Block

M8 44 N•m (32 lbf ft)

Special Torque Specifications**FLYWHEEL AND HOUSING****Capscrews, Flywheel to Crankshaft**

1/2 UNF 107 N•m (79 lbf ft)

Capscrews, Cast Iron Flywheel Housing to Cylinder Block

M10 44 N•m (32 lbf ft)

Head Stamped 8.8

M12 75 N•m (55 lbf ft)

Head Stamped 10.9

M10 63 N•m (46 lbf ft)

Head Stamped 10.9

M12 115 N•m (85 lbf ft)

Capscrews, Flywheel Housing to Cylinder Block (Paper Joint)

M10 70 N•m (52 lbf ft)

ELECTRICAL EQUIPMENT**Nut, Alternator Pulley**

Denso

M17 80 N•m (59 lbf ft)

Fueled Start Aid to Induction Manifold

7/8 UNF 31 N•m (23 lbf ft)

Port Heater to Induction Manifold

M22 60 N•m (44 lbf ft)

Nut/Screw, Starter Motor

3/8 UNF 30 N•m (22 lbf ft)

Capscrew, ECM to Cylinder Head or Cylinder Block

M8 22 N•m (16 lbf ft)

Capscrew, ECM Wiring Harness Connector

M6 6 N•m (4 lbf ft)

AUXILIARY EQUIPMENT**Nut, Compressor Drive Gear to Compressor Crankshaft**

5/8 UNF 120 N•m (88 lbf ft)

Nut, Compressor Flange to Timing Case

M12 75 N•m (55 lbf ft)

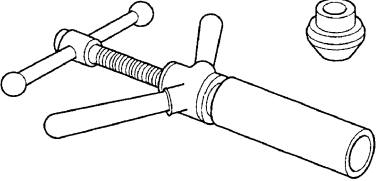
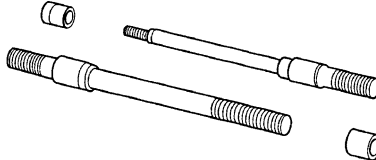
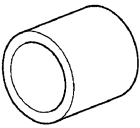
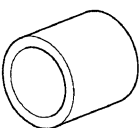
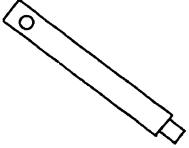
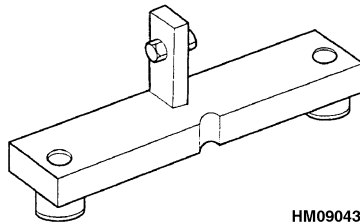
Capscrew, Bracket to Cylinder Block

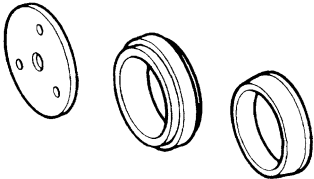
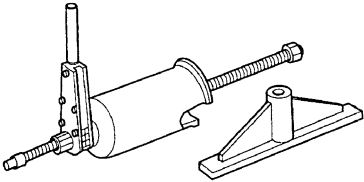
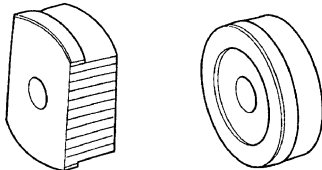
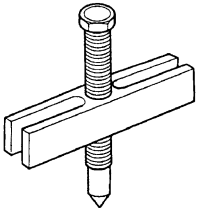
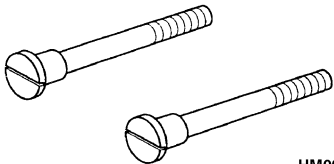
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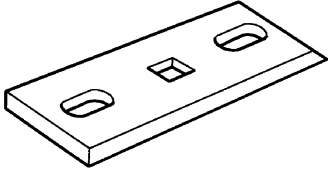
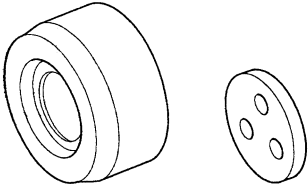
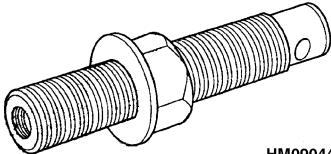
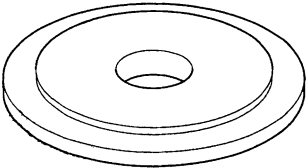
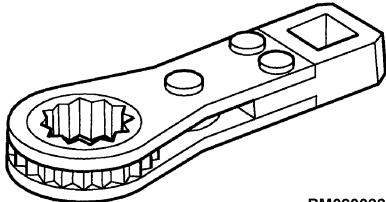
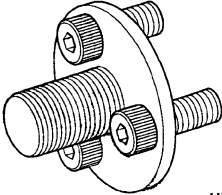
Capscrew, Bracket to Compressor

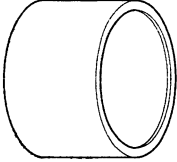
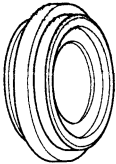
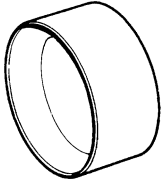
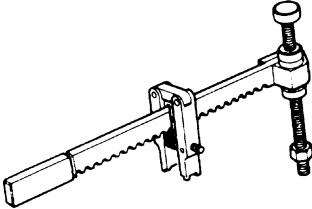
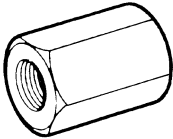
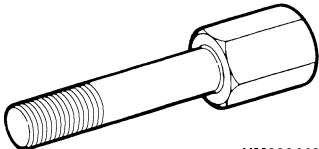
M8 22 N•m (16 lbf ft)

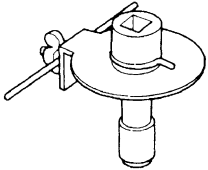
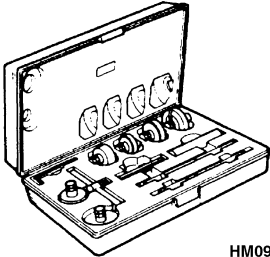
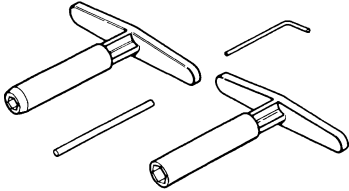
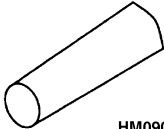
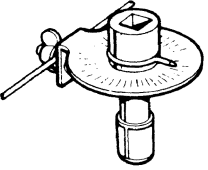
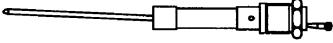
Special Tools

 HM090428	PD.1D Remove and replace tool for valve guides.
 HM090429	PD.1D-13 Adapter tool for use with PD.1D.
 HM090430	PD.1C-6 Adapter tool (inlet valves) for use with PD.1D and PD.1D-13.
 HM090430	PD.248 Adapter tool (exhaust valves) for use with PD.1D and PD.1D-13.
 HM090431	PD.245 Timing pin for Bosch fuel injection pumps.
 HM090432	PD.41D Gauge for piston height, valve depth, and cylinder liner flange; for use with PD.208.

 HM090433	PD.208 Dial gauge for use with PD.41D.
 HM090434	PD.145D Replacement tool for rear seal of crankshaft.
 HM090435	PD.150B Remove and replace tool for cylinder liner.
 HM090436	PD.150B-17A Adapters for use with PD.150B.
 HM090437	PD.155C Puller for camshaft gear.
 HM090438	PD.155B-5 Adapters for use with PD.155C.

 BM090032	PD.165B Crankshaft rotation adaptor.
 HM090440	PD.163A Alignment tool for timing case cover (six-cylinder engines).
 HM090441	PD.170 Replacement tool for seal of timing case cover.
 HM090442	PD.170-1 Pressure plate for use with PD.170.
 BM090033	PD.170-2 Sleeve for use with PD.170.
 HM090443	PD.170-3 Fastener plate for use with PD.170.

 HM090444	PD.239 Spanner for flange nuts on Bosch fuel injection pumps.
 HM090445	PD.170-4 Seal adapter for use with PD.170.
 HM090446	PD.206 Replacement tool for pistons.
 HM090447	PD.6118B Valve spring compressor.
 HM090448	PD.6118-7 Stud adapter for use with PD.6118B.
 HM090449	PD.6118-8 Capscrew adapter for use with PD.6118B.

 HM090450	PD.198 Angle gauge to tighten cylinder head capscrews.
 HM090451	PD.242 Set of adjustable cutters for valve seats.
 HM090452	PD.242 Handle set for valve seat cutters.
 HM090453	PD.247 Coolant pump oil seal replacer tool.
 HM090454	MS.1531 Angle gauge to tighten cylinder head capscrews.
 BM090030	Piston displacement tool.

Troubleshooting

For troubleshooting of the electronic components and for fault codes, see the section **Perkins Tier**

2 Diesel Engine Electronic Troubleshooting Guide 600 SRM 1072.

Trouble	Possible Causes	
	Checks by User	Checks by Service Personnel
The starter motor turns the engine too slowly	1, 2, 3, 4	
The engine does not start	5, 6, 8, 9, 10, 12, 13, 14, 15, 17	34, 35, 36, 37, 38, 42, 43, 67
The engine is difficult to start	5, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19	34, 36, 37, 38, 40, 42, 43, 44, 67
Not enough power	8, 9, 10, 11, 12, 13, 16, 18, 19, 20, 21	34, 36, 37, 38, 39, 42, 43, 44, 63, 64, 66, 67
Misfire	8, 9, 10, 12, 13, 15, 20, 22	34, 36, 37, 38, 39, 40, 41, 43, 67
High fuel consumption	11, 13, 15, 17, 18, 19, 23, 22	34, 36, 37, 38, 39, 40, 42, 43, 44, 63
Black exhaust smoke	11, 13, 15, 17, 19, 21, 22	34, 36, 37, 38, 39, 40, 42, 43, 44, 63, 64, 67
Blue or white exhaust smoke	4, 15, 21, 23	36, 37, 38, 39, 42, 44, 45, 52, 58, 61, 62
The engine oil pressure is low	4, 24, 25, 26	46, 47, 48, 50, 51, 59
The engine "knocks"	9, 13, 15, 17, 20, 22, 23	36, 37, 40, 42, 44, 46, 52, 53, 60
The engine operation is not constant	8, 9, 10, 11, 12, 13, 15, 16, 18, 20, 22, 23	34, 38, 40, 41, 44, 52, 60, 67
Unusual vibration	13, 18, 20, 27, 28	34, 38, 39, 40, 41, 44, 52, 54, 67
The engine oil pressure is too high	4, 25	49
The engine oil temperature is too high	11, 13, 15, 19, 27, 29, 30, 32, 65	34, 36, 37, 39, 52, 55, 56, 57, 66
High crankcase pressure	31, 33	39, 42, 44, 45, 52, 61
Bad compression	11, 22	37, 39, 40, 42, 43, 44, 45, 53, 60
The engine starts and stops	10, 11, 12	67

Table 46. List of Possible Causes

1	Battery capacity is low.
2	Bad electrical connections.
3	Fault in starter.
4	Wrong grade of lubricating oil.
5	Starter turns too slowly.
6	Fuel tank is empty.
7	Fault in engine "STOP" control.

Table 46. List of Possible Causes (Continued)

8	Restriction in fuel line.
9	Fault in fuel pump.
10	Dirty fuel element.
11	Restriction in air cleaner or air induction system.
12	Air in fuel system.
13	Fault in fuel injector.

Table 46. List of Possible Causes (Continued)

14	Cold air start used incorrectly.
15	Fault in cold start system.
16	Restriction in vent of fuel tank.
17	Wrong type or wrong grade of fuel.
18	Malfunction in engine speed control.
19	Restriction in exhaust pipe.
20	Engine temperature is too high.
21	Engine temperature is too low.
22	Valve clearances are wrong.
23	Air filter has restriction.
24	Not enough engine oil in the sump.
25	Pressure gauge has a malfunction.
26	Filter for engine oil is dirty.
27	Cooling fan is damaged.
28	Engine mount has problem.
29	Too much engine oil in the sump.
30	Restriction in the air or coolant passages in the radiator.
31	Restriction in the breather pipe.
32	Cooling system needs coolant.
33	Vacuum line leak or fault in the exhaust.
34	Fuel injection pump has a fault.
35	Broken drive on the fuel injection pump.
36	Timing of fuel injection pump is wrong.
37	Valve timing is wrong.
38	Low compression.
39	Leak in the cylinder head gasket.
40	A valve is damaged.
41	High pressure fuel lines are wrong.
42	Worn cylinder bores.

Table 46. List of Possible Causes (Continued)

43	Leaks between a valve and its seat.
44	Piston rings are worn, broken, or frozen in piston.
45	Valve stems and valve guides are worn.
46	Crankshaft bearings are worn or damaged.
47	Engine oil pump is worn.
48	Relief valve on engine oil pump does not close.
49	Relief valve on engine oil pump does not open.
50	Relief valve spring on engine oil pump is broken.
51	Fault in suction pipe of engine oil pump.
52	A piston is damaged.
53	The piston height is wrong.
54	Flywheel or flywheel housing is not aligned correctly.
55	Thermostat has a fault or is the wrong temperature range.
56	Restriction in coolant passages.
57	Coolant pump is damaged.
58	A seal on a valve stem is leaking.
59	Restriction in the strainer in the oil sump.
60	A valve spring is broken.
61	Turbocharger impeller is damaged or dirty.
62	Lubrication oil seal of turbocharger leaks.
63	Induction system leaks.
64	Turbocharger impeller is damaged or dirty.
65	The coolant pump drive belt is loose.
66	Induction system (with turbocharger) leaks.
67	Engine management system has a malfunction.

Turbocharger Troubleshooting

Trouble	Possible Causes
Not enough power	1, 4, 5, 6, 7, 8, 9, 10, 11, 18, 20, 21, 22, 25, 26, 27, 28, 34, 35, 36
Black exhaust smoke	1, 4, 5, 6, 7, 8, 9, 10, 11, 18, 20, 21, 22, 25, 26, 27, 28, 34, 35, 36
Blue exhaust smoke	1, 2, 4, 6, 8, 9, 17, 19, 20, 21, 22, 30, 31, 32, 34
High oil consumption	2, 8, 15, 17, 19, 20, 28, 29, 31, 32, 34
Excessive oil at turbine end	2, 8, 15, 17, 19, 20, 28, 29, 31, 32, 34
Excessive oil at compressor end	1, 2, 4, 5, 6, 8, 19, 20, 21, 28, 31, 32
Not enough lubrication	8, 12, 14, 15, 16, 23, 24, 29, 32, 33, 37, 38
Oil in the exhaust manifold	2, 7, 17, 18, 19, 20, 22, 28, 31, 32
Intake manifold wet on the inside	1, 2, 3, 4, 5, 6, 8, 10, 11, 17, 18, 19, 20, 21, 28, 32, 34, 39, 40
Compressor impeller is damaged	3, 4, 6, 8, 12, 15, 16, 20, 21, 23, 24, 29, 32, 33, 37, 38
Turbine rotor is damaged	7, 8, 12, 13, 14, 15, 16, 18, 20, 22, 23, 24, 25, 27, 29, 32, 33, 37, 38
Rotating assembly is binding, does not turn freely	3, 6, 7, 8, 12, 13, 14, 15, 16, 18, 20, 21, 22, 23, 24, 29, 32, 33, 37, 38
Worn bearings, bearing bores, journals	6, 7, 8, 12, 13, 14, 15, 16, 23, 24, 29, 33, 37, 38
Turbocharger is making noises	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 20, 21, 22, 23, 24, 29, 32, 33, 34, 37, 38
Bearing housing has sludge and/or carbon deposits	2, 11, 13, 14, 15, 17, 18, 24, 29, 33, 37, 38

Table 47. List of Possible Causes

1	Air filter element is dirty.
2	Closed circuit breather is restricted.
3	Air filter element is not fitted or sealing correctly. Turbocharger connection is loose.
4	Internal distortion or restriction in the pipe from the air filter to the turbocharger.
5	Crossover pipe from turbocharger to intake manifold is damaged or restricted.
6	Restriction between the air filter and the turbocharger.
7	Restriction in the exhaust system.
8	Turbocharger is loose or clamps/setscrews are loose.
9	Intake manifold is damaged, has cracks, is loose, or has flange distortion.

Table 47. List of Possible Causes (Continued)

10	Exhaust manifold is damaged, has cracks, is loose, or has flange distortion.
11	Exhaust system is restricted.
12	Delay of oil to turbocharger at engine start.
13	Insufficient lubrication.
14	Lubricating oil is dirty.
15	Lubricating oil is incorrect type.
16	Oil supply pipe is restricted.
17	Oil drain pipe is restricted.
18	Turbine housing is damaged or is restricted.
19	Turbocharger seals have leakage.
20	Turbocharger bearings are worn.
21	Excessive dirt in the compressor housing.

Table 47. List of Possible Causes (Continued)

22	Excessive carbon behind turbine rotor.
23	At initial start, the engine speed was raised too rapidly.
24	Engine idle period was not sufficient.
25	Fuel injection pump is faulty.
26	Fuel injectors are worn or damaged.
27	Valves are burned, worn, or damaged.
28	Piston rings are worn or damaged.
29	Supply pipe is leaking oil.
30	On initial start there was excessive preservation fluid.
31	Engine idle period was excessive.

Table 47. List of Possible Causes (Continued)

32	Turbocharger bearing housing has restrictions.
33	Oil filter is restricted.
34	Wet type air cleaner: Restricted, dirty element, incorrect oil.
35	Waste-gate actuator is faulty or damaged.
36	Waste-gate valve is not free.
37	Engine was stopped too soon after a high load.
38	Insufficient oil.
39	Fuel leakage from cold start aid.
40	Compressor backplate is cracked.

