
Perkins 4000 Series

4006-23 TAG1A, TAG2A and TAG3A Inline diesel engine

WORKSHOP MANUAL

6 cylinder turbo charged diesel engine for electric power applications

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Chapters

- 1 General information**
- 2 Specifications**
- 3 Cylinder head assembly**
- 4 Piston and connecting rod assemblies**
- 5 Crankshaft assembly**
- 6 Timing case and drive assembly**
- 7 Cylinder block assembly**
- 8 Engine timing**
- 9 Aspiration system**
- 10 Lubrication system**
- 11 Fuel system**
- 12 Cooling system**
- 13 Flywheel and housing**
- 14 Electrical equipment**
- 15 Auxiliary equipment**
- 16 Special tools**

The following pages contain a detailed table of contents

Contents

1 General information

Introduction	1
Engine views	2
Engine identification	3
General safety precautions	4
Viton seals	5
Engine lift equipment	6
POWERPART recommended consumable products	7

2 Specifications

Basic engine data	9
Data and dimensions	10

3 Cylinder head assembly

General description	17
Rocker box and valve gear	
Operation 3-1 To remove and fit the rocker box and valve gear	18
Valve gear	
Operation 3-2 To inspect rockers, bridge pieces and rocker shaft	20

Operation 3-3 To replace the bridge piece pressure pad	21
Cylinder head	
Operation 3-4 To remove and fit the cylinder head	22
Valves and springs	
Operation 3-5 To remove and fit the valve and the valve springs	24
Operation 3-6 To inspect	26
Valves seats	
Operation 3-7 To remove and fit, and reface the valve seats	27
Valves guides	
Operation 3-8 To remove and fit the valve guides	28
Fuel injector bush	
Operation 3-9 To remove and fit a fuel injector bush	29
Cylinder head	
Operation 3-10 To inspect and pressure test	33
Manifolds	
Operation 3-11 To remove and fit the induction manifold	34
Operation 3-12 To remove and fit the exhaust manifold	35
 4 Piston and connecting rod assemblies	
General description	39
Piston and connecting rod	
Operation 4-1 To remove	40
Operation 4-2 To fit	43
Piston rings	
Operation 4-3 To remove	45
Operation 4-4 To fit	46
Piston and connecting rod assembly	
Operation 4-5 To dismantle	47
Operation 4-6 To assemble	47
Piston and piston rings	
Operation 4-7 To inspect	49
Connecting rod	
Operation 4-8 To inspect	50

Small end bush

Operation 4-9 To inspect	51
Operation 4-10 To remove and fit	51

Piston cooling jets

Operation 4-11 To remove	52
Operation 4-12 To fit	53

5 Crankshaft assembly

General description	55
----------------------------------	----

Crankshaft pulley and adaptor

Operation 5-1 To remove	56
Operation 5-2 To fit	57

Crankshaft vibration damper assembly

Operation 5-3 To remove	58
Operation 5-4 To fit	59

Crankshaft

Operation 5-5 To remove	60
Operation 5-6 To fit	61
Operation 5-7 To check the crankshaft end float	63

6 Gearcase and drive assembly

General description	65
----------------------------------	----

Gearcase

Operation 6-1 To remove	66
Operation 6-2 To fit	67

Front oil seal

Operation 6-3 To remove	68
Operation 6-4 To fit	68

Camshaft gear

Operation 6-5 To remove	69
Operation 6-6 To fit	70

Idler gear

Operation 6-7 To remove	71
Operation 6-8 To fit	72
Operation 6-9 To check the hub and renew the idler gear bush	73

Cam followers

Operation 6-10 To remove and fit	74
Operation 6-11 To check	75

Camshaft

Operation 6-12 To remove	76
Operation 6-13 To check the camshaft	77
Operation 6-14 To fit	78
Operation 6-15 To remove and fit the camshaft bush	79

Crankshaft gear

Operation 6-16 To remove	80
Operation 6-17 To fit	81

Back Plate

Operation 6-18 To remove	82
Operation 6-19 To fit	83

7 Crankcase

General Description	85
----------------------------------	----

Crankcase

Operation 7-1 To remove	86
Operation 7-2 To fit	87
Operation 7-3 To inspect	87

Cylinder Liner

Operation 7-4 To inspect	88
Operation 7-5 To remove	89
Operation 7-6 To fit liner	90

8 Engine timing

Operation 8-1 To set number 1 piston to Top Dead Centre (TDC)	91
Operation 8-2 Calibrating fuel injectors	92
Operation 8-3 Setting governor on zero fuel	94
Operation 8-4 Applying pressure to the timing pin	95
Operation 8-5 Timing the fuel injectors	96

9 Aspiration system

General description	99
----------------------------------	----

How to check the air restriction indicator

Operation 9-1 To check and reset	100
--	-----

Air filter element

Operation 9-2 To remove and fit	101
---------------------------------------	-----

Air filter and pipe connection

Operation 9-3 To remove	102
Operation 9-4 To fit	103

Air filter bracket

Operation 9-5 To remove	104
Operation 9-6 To fit	104

Turbocharger 105

Operation 9-7 To remove	106
Operation 9-8 To fit	108

Air pipe connection

Operation 9-9 To remove	110
Operation 9-10 To fit	111

Engine breather

Operation 9-11 To remove breather system	112
Operation 9-12 To fit the breather system	113

10 Lubrication system

General Description 115

Filter Canister

Operation 10-1 To renew	117
-------------------------------	-----

Filter head

Operation 10-2 To remove and to fit	118
---	-----

Lubricating oil sump

Operation 10-3 To remove	119
Operation 10-4 To fit	120

Dipstick tube

Operation 10-5 To remove and to fit	121
---	-----

Oil strainer and suction pipe

Operation 10-6 To remove and to fit	122
---	-----

Lubricating oil pump

Operation 10-7 To remove	123
Operation 10-8 To fit	124
Operation 10-9 To dismantle	125
Operation 10-10 To assemble	126
Operation 10-11 To inspect	128

Relief Valve

Operation 10-12 To dismantle and to assemble	129
Operation 10-13 To inspect	130

Fuel lift pump drive unit

Operation 10-14 To renew	131
--------------------------------	-----

Rotor end float

Operation 10-15 To inspect	132
----------------------------------	-----

Drive shaft bearings

Operation 10-16 To remove and to fit	133
--	-----

11 Fuel system

General description	135
----------------------------------	-----

Fuel filter

Operation 11-1 To remove and fit	136
--	-----

Fuel injector unit

Operation 11-2 To remove the fuel injector unit	137
Operation 11-3 To disassemble and to check a fuel injector unit	139
Operation 11-4 To assemble the fuel injector unit	143

To test and set the fuel injector

Operation 11-5 To test and set	146
Operation 11-6 To fit a fuel injector	151

Fuel Lift pump

Operation 11-7 To remove and to fit	152
---	-----

Fuel control shaft

Operation 11-8 To remove	153
Operation 11-9 To inspect	154
Operation 11-10 To fit	155

12 Cooling system

Coolant pipework

Operation 12-1 To remove and fit the coolant pipework	158
---	-----

Thermostat

Operation 12-2 To remove the thermostat	159
Operation 12-3 To fit the thermostat	160
Operation 12-4 To test	161

Thermostat housing

Operation 12-5 To remove and fit the thermostat housing	162
---	-----

Coolant pump

Operation 12-6 To remove the coolant pump	164
Operation 12-7 To fit the coolant pump	166
Operation 12-8 To disassemble the coolant pump	168
Operation 12-9 To assemble the coolant pump	169

Fan Guards

Operation 12-10 To remove and fit	171
---	-----

Fan

Operation 12-11 To remove and fit	171
---	-----

Fan drive belts

Operation 12-12 To check the fan drive belts	172
Operation 12-13 To adjust the fan drive belts	172
Operation 12-14 To remove and fit the drive belts	173

Fan drive

Operation 12-15 To remove and fit	174
---	-----

Lubricating oil cooler

Operation 12-16 To remove	176
Operation 12-17 To fit	177
Operation 12-18 To disassemble and clean the oil cooler tube stack	178
Operation 12-19 To assemble the oil cooler tube stack	179
Operation 12-20 To pressure test the oil cooler	180

Radiator

Operation 12-21 To remove	181
Operation 12-22 To fit	182

13 Flywheel and housing

General description	183
----------------------------------	-----

Flywheel

Operation 13-1 To remove and to fit the flywheel	184
--	-----

Gear ring

Operation 13-2 To remove and to fit the gear ring	186
---	-----

Flywheel Housing

Operation 13-3 To remove and to fit the flywheel housing	187
--	-----

Flywheel housing oil seal

Operation 13-4 To remove and to fit the flywheel housing oil seal	189
---	-----

14 Electrical equipment

General description	191
----------------------------------	-----

Alternator	192
-------------------------	-----

Operation 14-1 To check the drive belts	192
Operation 14-2 To adjust the drive belt tension	193
Operation 14-3 To remove the alternator	193
Operation 14-4 Remove the alternator drive pulley	194
Operation 14-5 To fit the alternator drive pulley	195
Operation 14-6 To fit the alternator	196
Operation 14-7 To maintain	196

Starter motor	197
----------------------------	-----

Operation 14-8 To remove	197
Operation 14-9 To Fit	197

The air starter motor system	198
---	-----

Operation 14-10 To remove	201
Operation 14-11 To fit	201

Stop solenoid

Operation 14-12 To remove	202
Operation 14-13 To fit	202

Digital Electronic Governor	203
--	-----

Description of System	206
------------------------------------	-----

Block diagram of the governor system	207
---	-----

Magnetic pick-up

Operation 14-14 To clean the magnetic pick-up	208
Operation 14-15 To remove the actuator	209
Operation 14-16 To fit	210

Specification of Governor system 211

Operation 14-17 To remove the digital control box	211
Operation 14-18 To Fit the digital control box	211

Feedback Setting

Operation 14-19 To adjust	212
---------------------------------	-----

Configuration 216**External Speed Control Input** 216**Changing the governor configuration** 217

Operation 14-20 To adjust	217
---------------------------------	-----

Single/Parallel Generator (Non Heinzmann Load Sharing)

Operation 14-21 To adjust	218
---------------------------------	-----

Single/Parallel Generator with Droop

Operation 14-22 To adjust	219
---------------------------------	-----

Parallel Generator Heinzmann (SyG02/LMG10-01)

Operation 14-23 To adjust	220
---------------------------------	-----

Parallel Generator Heinzmann Digital Theseus

Operation 14-24 To adjust	221
---------------------------------	-----

Parallel Generator Variable Speed in Droop Range

Operation 14-25 To adjust	222
---------------------------------	-----

Other settings

Operation 14-26 Load Control Settings	223
---	-----

PID parameters

Operation 14-27 To adjust	226
---------------------------------	-----

PID Maps

Operation 14-28 To adjust	227
---------------------------------	-----

Speed Ramps 228**Sectional Speed Ramp**

Operation 14-29 To adjust	229
---------------------------------	-----

External connections – Control box connector	234
Alternative Connections for Speed Setting Inputs	235
Wiring detail, digital control box in IP enclosure – production engines	236
Fault Tracing	237
Error Codes	239
Low oil High water temperature switch	242
Operation 14-30 To remove	242
Operation 14-31 To fit	242
Switch connections	
Operation 14-32 To remove and fit	243
Switch setting	243

15 Auxiliary equipment

Operation 15-1 To remove	246
Operation 15-2 To fit	247
Operation 15-3 To remove	249
Operation 15-4 To fit	250

16 Special tools

List of special tools	252
------------------------------------	-----

1

General information

Introduction

This Workshop Manual has been written to provide assistance in the service and overhaul of Perkins 4006-23, TAG1A, TAG2A and TAG3A engines. It should be used in conjunction with normal workshop practise and information contained in current service bulletins. Mention of certain accepted practices therefore, has been purposely omitted in order to avoid repetition. For overhaul procedures the assumption is made that the engine is removed from the application.

The engine conforms with USA (EPA/CARB) stage 2 and EEC stage 2 emissions legislation for agriculture, construction and industrial applications.

Most of the general information which is included in the relevant User's Handbook has not been repeated in this workshop manual and the two publications should be used together.

Where the information applies only to certain engine types, this is indicated in the text.

When reference is made to the "left" or "right" side of the engine, this is as seen from the flywheel end of the engine.

When not working on the engine, ensure that all covers, blank flanges, doors, etc., are refitted to openings to prevent the ingress of dirt, etc.

Please quote the engine type and serial number with all your enquiries. This will help us to help you. The type and serial number are on a plate fitted to the crankcase.

If any doubt exists regarding the installation, use or application of the engine, the Installation Manual should be consulted for further advice contact Applications Department at Perkins Engines (Stafford) Ltd.

Oil change intervals may be changed according to operating experience by agreement with Perkins Engines (Stafford) Limited and subject to oil analysis being carried out at regular intervals.

Special tools have been made available and a list of these is given in Chapter 16, Special tools. Reference to the relevant special tools is also made at the beginning of each operation.

POWERPART recommended consumable products are listed under "POWERPART recommended consumable products" on page 7. Reference to the relevant consumable products is also made at the beginning of each operation.

Data and dimensions are included in Chapter 2, Specifications.

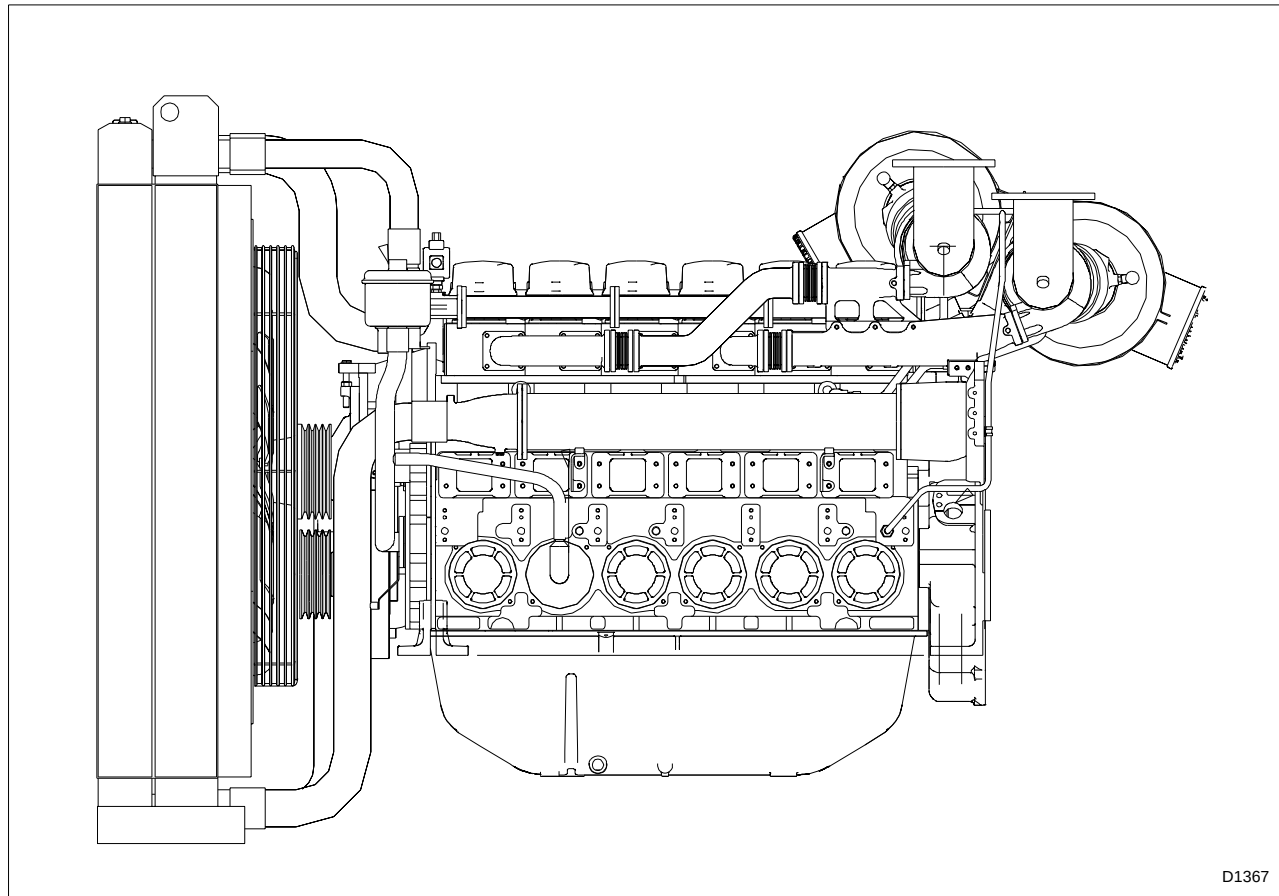
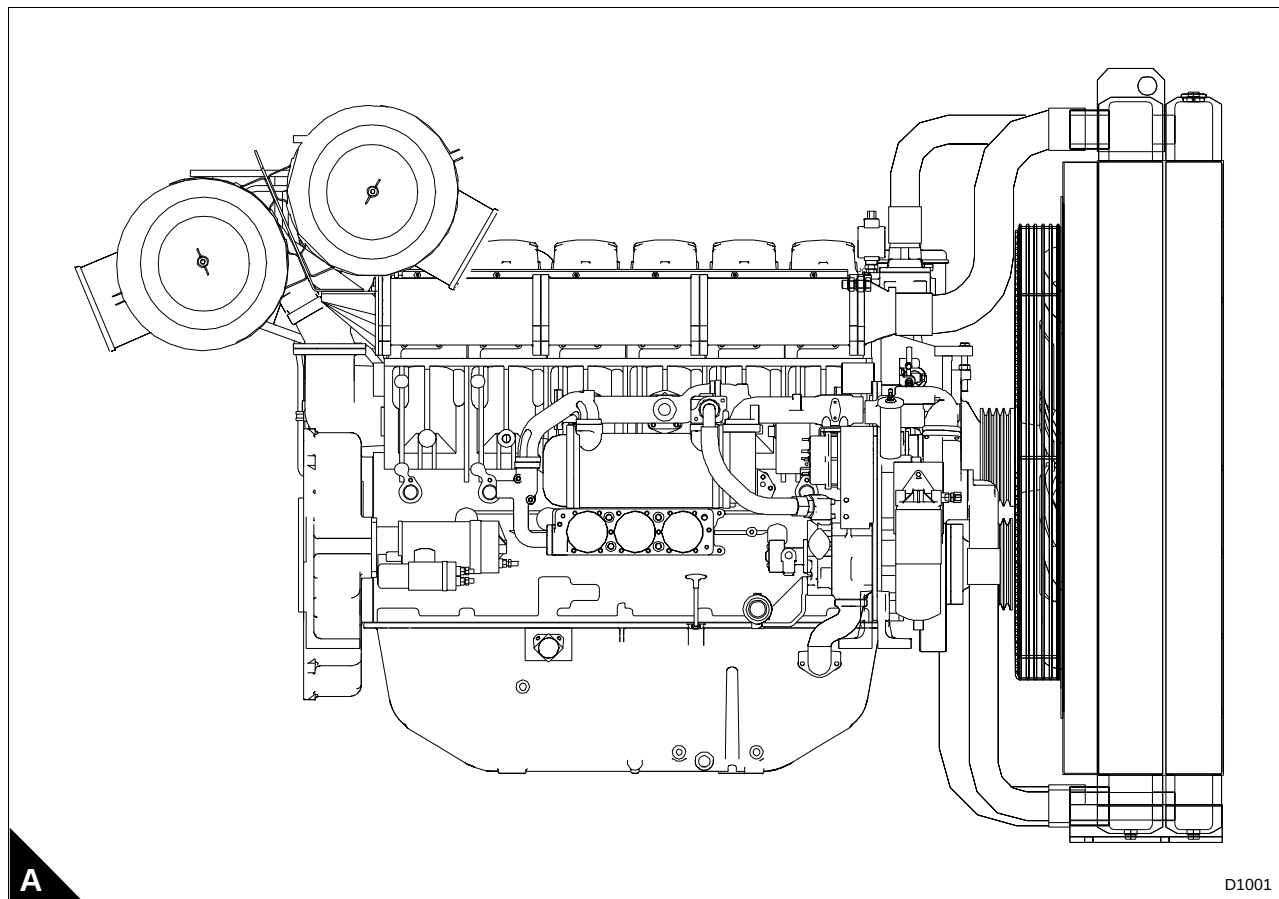
Read and remember the "General safety precautions" on page 4. They are given for your protection and must be used at all times.

Danger is indicated in the text by two methods:

Warning! *This indicates that there is a possible danger to the person.*

Caution: *This indicates that there is a possible danger to the engine.*

Note: Is used where the information is important, but there is not a danger.



Engine identification

The 4006-23 engine consists of a range of six cylinder engines. This range has three basic engine types, TAG1A, TAG2A and TAG3A.

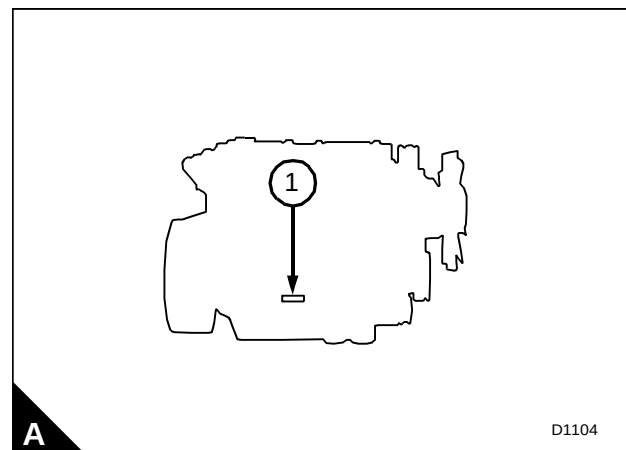
The different engines are identified by their engine number and their type as shown below:

A typical example of an engine number: DGB 060081 U0017 B

Engine number identification	
D	Made in Stafford
G	Application code
B	Engine type
06	Number of cylinders
0081	Fixed build number
U	United Kingdom
0017	Number of engines built
B	Year that the engine was built

Engine type	
A	4006-23TAG1A
B	4006-23TAG2A
D	4006-23TAG3A

The position of the plate for the engine number (A1).



General safety precautions

These safety precautions are important. You must refer also to the local regulations in the country of use. Some items only refer to specific applications.

- Only use these engines in the type of application for which they have been designed.
- Do not change the specification of the engine.
- Do not smoke when you put fuel in the tank.
- Clean away fuel which has been spilt. Material which has been contaminated by fuel must be moved to a safe place.
- Do not put fuel in the tank while the engine runs (unless it is absolutely necessary).
- Do not allow sparks or fire near the batteries (especially when the batteries are on charge) because the gases from the electrolyte are highly flammable. The battery fluid is dangerous to the skin and especially to the eyes.
- Do not smoke when you are in the working area of the engine.
- Isolate the engine and disconnect the battery before a repair is made to the electrical system.
- Do not clean, add lubricating oil, or adjust the engine while it runs (unless you have had the correct training, even then extreme care must be used to prevent injury).
- Do not make adjustments that you do not understand.
- Ensure that the engine does not run in a location where it can cause a concentration of toxic emissions.
- Ensure that the exhaust system from the engine is supported.
- Other persons must be kept at a safe distance while the engine or auxiliary equipment is in operation.
- Do not permit loose clothing or long hair near moving parts.
- Keep away from moving parts during engine operation.

Warning! *Some moving parts cannot be seen clearly while the engine runs.*

- Do not operate the engine if a safety guard has been removed.
- Do not remove the filler cap or any component of the cooling system while the engine is hot and while the coolant is under pressure, because dangerous hot coolant can be discharged.
- Only one person must control the engine.
- Ensure that the engine is operated only from the control panel or from the operator's position.
- If your skin comes into contact with high-pressure fuel, obtain medical assistance immediately.
- Diesel fuel and lubricating oil (especially used lubricating oil) can damage the skin of certain persons. Protect your hands with gloves or a special solution to protect the skin.
- Ensure that all personal protection equipment for your head, ears, eyes and feet etc, are used when you are in the working area of the engine.
- Do not wear clothing which is contaminated by lubricating oil. Do not put material which is contaminated with oil into the pockets of clothing.
- Discard used lubricating oil in accordance with local regulations to prevent contamination.
- Ensure that the control lever of the transmission drive is in the "out-of-drive" position before the engine is started.
- Use extreme care if emergency repairs must be made in adverse conditions.
- The combustible material of some components of the engine (for example certain seals) can become extremely dangerous if it is burned. Never allow this burnt material to come into contact with the skin or with the eyes.
- Always use a safety cage to protect the operator when a component is to be pressure tested in a container of water. Fit safety wires to secure the plugs which seal the hose connections of a component which is to be pressure tested.

Continued

- Do not allow compressed air to contact your skin. If compressed air enters your skin, obtain medical help immediately.
- Turbochargers operate at high speed and at high temperatures. Keep fingers, tools and debris away from the inlet and outlet ports of the turbocharger and prevent contact with hot surfaces.
- Fit only genuine Perkins parts, failure to do so can damage the engine and may effect the warranty.
- Do not wash an engine while it runs or while it is hot. If cold cleaning fluids are applied to a hot engine, certain components on the engine could be damaged.
- Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

Viton seals

Viton is used by many manufacturers and is a safe material under normal conditions of operation.

Some seals used in engines and in components fitted to these engines are made of Viton.

If Viton is burned, a product of this burnt material is an acid which is extremely dangerous. Never allow this burnt material to come into contact with the skin or with the eyes.

If it is necessary to come into contact with components which have been burnt, ensure that the precautions which follow are used:

- Ensure that the components have cooled.
- Use neoprene gloves and discard the gloves safely after use.
- Wash the area with calcium hydroxide solution and then with clean water.
- Disposal of components and gloves which are contaminated must be in accordance with local regulations.

If there is contamination of the skin or eyes, wash the affected area with a continuous supply of clean water or with calcium hydroxide solution for 15 to 60 minutes. **Obtain immediate medical attention.**

Safety cautions when an engine is cleaned

Care should be taken, when an engine is cleaned with a high pressure cleaning system.

Cautions:

- *Do not wash an engine while it runs or while it is hot. If cold cleaning fluids are applied to a hot engine, certain components on the engine could be damaged.*
- *Leave the engine to cool for at least one hour and disconnect the battery connections before cleaning.*
- *Do not wash any part of the fuel injection pump (FIP), cold start device, electrical shut off solenoid (ESOS) or electrical connectors.*
- *Ensure that the alternator, starter motor and any other electrical components are shielded and not directly cleaned by the high pressure cleaning system.*

If these cautions are ignored, the engine or certain components could be damaged, fail to operate and also make the manufacturer's warranty invalid.

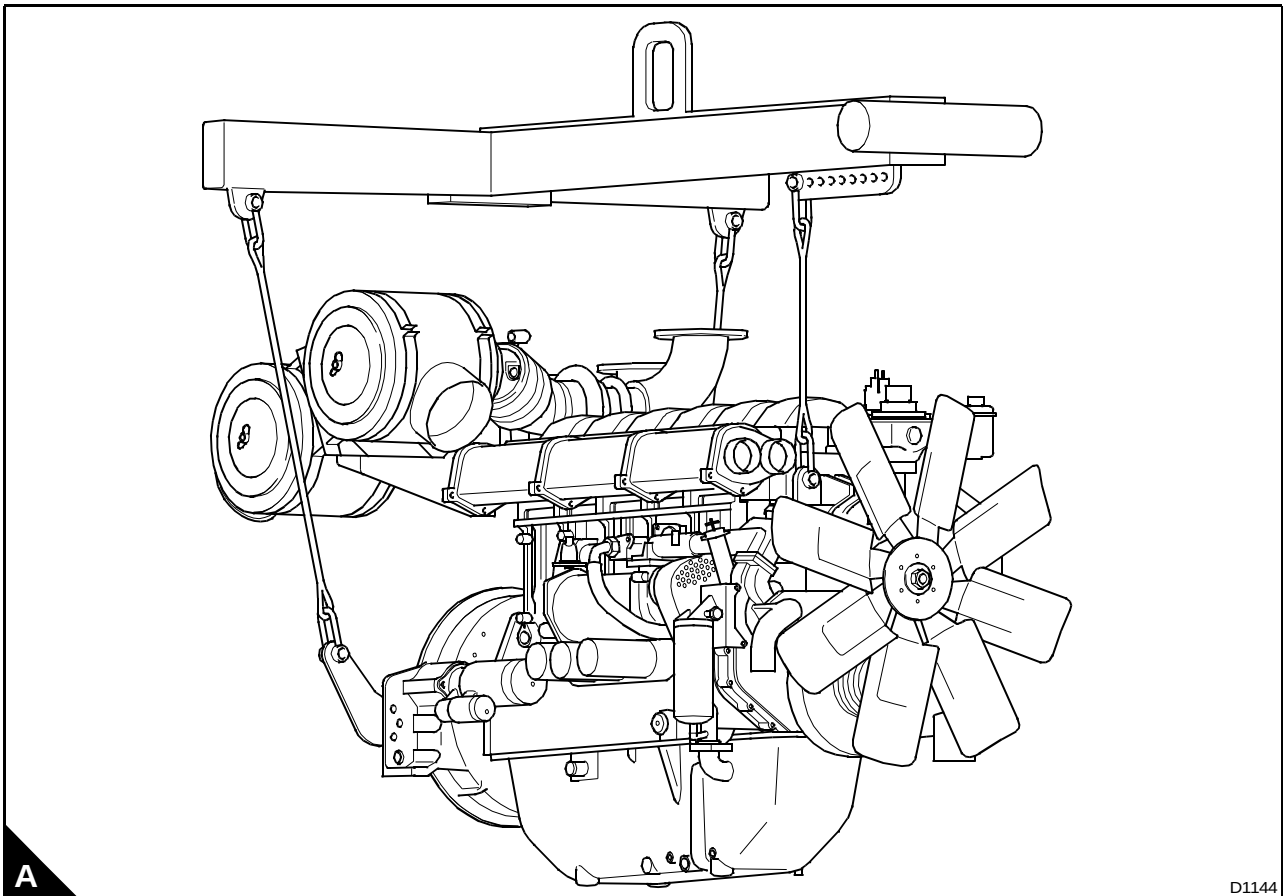
Engine lift equipment

When lifting engine or generating sets, special lifting equipment is required. It is recommended that a spreader lifting beam of the correct lifting load capacity is used and that chains, hooks, shackles and eye bolts etc. are checked that they are well within their safe working loads. The load should be secure, stable and balanced when lifting.

The lifting chains etc must be firmly secured to the load by means of hooks etc on to the purpose-designed lifting points, and that included angle is not exceeded (A).

In order to accommodate the chains for lifting it may be necessary to have to remove engine components such as air filters etc to prevent damage, but this should be avoided where the chains can be clear by non-detrimental means.

Warning! Lifting equipment should be used by trained personnel only. Generating sets must be lifted using the lifting lugs on the engine frame and a spreader lifting beam. The engine lifting brackets and alternator lifting lugs must not be used.



POWERPART recommended consumable products

Perkins have made available the products recommended below in order to assist in the correct operation, service and maintenance of your engine and your machine. The instructions for the use of each product are given on the outside of each container. These products are available from your Perkins distributor.

POWERPART ELC (Extended Life Coolant).

ELC is pre-mixed and protects the cooling system against frost and corrosion. Part number 21820181.⁽¹⁾

POWERPART Easy flush

Cleans the cooling system. Part number 21825001.

POWERPART Gasket and flange sealant

To seal flat faces of components where no joint is used. Especially suitable for aluminium components. Part number 21820518.

POWERPART Gasket remover

An aerosol for the removal of sealants and adhesives. Part number 21820116.

POWERPART Griptite

To improve the grip of worn tools and fasteners. Part number 21820129.

POWERPART Hydraulic threadseal

To retain and seal pipe connections with fine threads. Especially suitable for hydraulic and pneumatic systems. Part number 21820121.

POWERPART Industrial grade super glue

Instant adhesive designed for metals, plastics and rubbers. Part number 21820125.

POWERPART Lay-Up 1

A diesel fuel additive for protection against corrosion. Part number 1772204.

POWERPART Lay-Up 2

Protects the inside of the engine and of other closed systems. Part number 1762811.

POWERPART Lay-Up 3

Protects outside metal parts. Part number 1734115.

POWERPART Metal repair putty

Designed for external repair of metal and plastic. Part number 21820126.

POWERPART Pipe sealant and sealant primer

To retain and seal pipe connections with coarse threads. Pressure systems can be used immediately. Part number 21820122.

Continued

POWERPART Radiator stop leak

For the repair of radiator leaks. Part number 21820127.

POWERPART Retainer (high strength)

To retain components which have an interference fit. Part number 21820638.

POWERPART Retainer (oil tolerant)

To retain components which have an interference fit, but are in contact with oil. Part number 21820608.

POWERPART Safety cleaner

General cleaner in an aerosol container. Part number 21820128.

POWERPART Silicone adhesive

An RTV silicone adhesive for application where low pressure tests occur before the adhesive sets. Used for sealing flange where oil resistance is needed and movement of the joint occurs. Part number 21826038. ⁽²⁾

POWERPART Silicone RTV sealing and jointing compound

Silicone rubber sealant which prevents leakage through gaps. Part number 1861108. ⁽²⁾

POWERPART Stud and bearing lock

To provide a heavy duty seal to components that have a light interference fit. Part number 21820119 or 21820120.

POWERPART Threadlock and nutlock

To retain small fasteners where easy removal is necessary. Part number 21820117 or 21820118.

POWERPART Universal jointing compound

Universal jointing compound which seals joints. Part number 1861117. ⁽²⁾

⁽¹⁾ Powerpart (ELC) is not recommended for the 1300 Series.

⁽²⁾ These product must not be used for the 4006-23 engine.

2

Specifications

Basic engine data

Number of cylinders.	6
Cylinder arrangement..	Vertical, in-line
Cycle	Four stroke
Induction system..	Turbocharged, air cooled C.A. in radiator (air to air)
Combustion system.	Direct injection
Nominal bore	160 mm
Nominal stroke.	190 mm
Compression ratio	13:1
Cubic capacity	22,92 litres
Firing order	1, 5, 3, 6, 2, 4
Direction of rotation	Anti-clockwise viewed on flywheel
Lubricating oil capacity:	
Total system	122,7 litres (27 gallons)
Sump maximum... ..	113,7 litres (25 gallons)
Sump minimum	90,9 litres (20 gallons)
Lubricating oil pressure:	
At rated speed (Min)	200 kPa (29 lb/in ²)
Typical coolant capacity of engine... ..	36 litres (8 gallons)
Typical coolant capacity of engine and radiator	105 litres (23 gallons)

Data and dimensions

Rocker assembly

Rocker shaft diameter	39,975 / 39,950 mm
Valve rocker lever bore	40,025 / 40,000 mm
Clearance between valve rocker levers and shaft	..0,025 to 0,075 mm
Unit fuel injector rocker lever bore	40,025 / 40,000 mm

Valves

Diameter of valve stem	11,0236 / 11,0109 mm
Diameter of valve head:	

Inlet valve	52,12 / 52,00 mm
Exhaust valve	52,12 / 52,00 mm

Angle of face of valve:

Inlet valve	30°30' / 30°00'
Exhaust valve	30°30' / 30°00'

Thickness of valve lip:

Inlet valve and exhaust valve	2,1 / 1,9 mm
Exhaust valve and inlet valve minimum "outside diameter: land" thickness	..1 mm

Length of valve:

Inlet	170,0 / 169,5 mm
Exhaust	170,0 / 169,5 mm

Valve guides

Bore of valve guide when installed	11,118 / 11,082 mm
--	--------------------

Do not use a combination of a valve and valve guide which have a difference of 0,20 mm or more.

Height from cylinder head to top of valve guide	..9 mm
---	--------

Valve springs

Assembled length	..42,545 mm
Load at assembled length	399,6 N
Minimum operating length	..31,369 mm
Load at minimum operating length	695,1 N
Free length after test	..57,658 mm
Outside diameter	..33,934 mm
Minimum free length	..55,6 mm

Valve seat inserts

Depth of bore in cylinder head for valve seat insert (A5):

Inlet valve	11,10 / 11,00 mm
Exhaust valve	11,10 / 11,00 mm

Diameter of valve seat insert (A2):

Inlet valve	56,119 / 56,094 mm
Exhaust valve	56,620 / 56,595 mm

Bore in cylinder head for valve seat insert (A2):

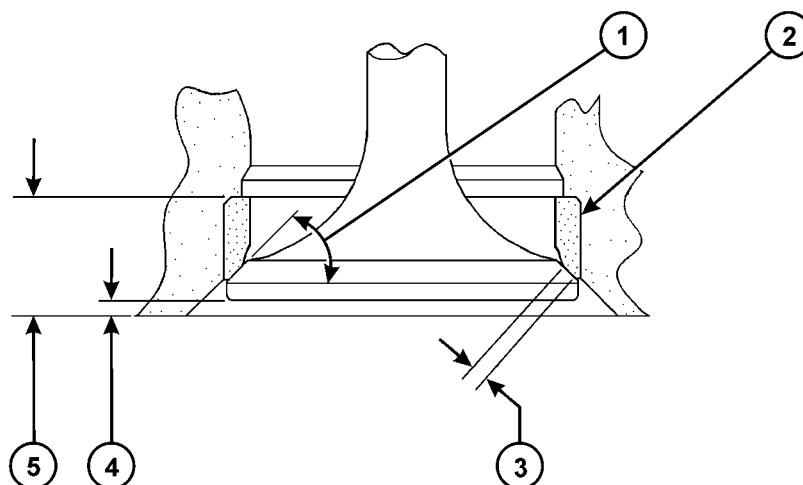
Inlet valve	56 mm H7
Exhaust valve	56,50 mm H7

Angle of face of valve seat insert (A1):

Inlet valve insert	30°30' / 30°00'
Exhaust valve insert	30°30' / 30°00'

Valve recess (A4):

Inlet valve (new parts)	Flush
Exhaust valve (new parts)	Flush
Inlet valve	Maximum: 1 mm
Exhaust valve	Maximum: 1 mm



A

D1366

Cylinder head

Thickness of cylinder head (new) 140,075 / 139,925 mm

Minimum thickness for a used cylinder head. 139,773 mm

Flatness of cylinder head: The cylinder head flame face must be flat within a maximum of 0,03 mm (0.001 in) with the rocker box face parallel within 0,076 mm.

Piston and connecting rod

Piston ring gaps measured with the ring fitted in a new liner with a bore size: 160,025 / 160,000 mm

Top piston ring 0,80 mm, maximum worn 1,05 mm

Intermediate ring (second). 0,60 mm, maximum worn 0,85 mm

Oil control ring 0,60 mm, maximum worn 0,85 mm

Width of groove for oil control ring in new piston 6,065 / 6,040 mm

Thickness of a new oil control ring. 5,990 / 5,975 mm

Clearance between piston ring groove and new oil control ring

Maximum permissible clearance between piston ring groove and a used oil control ring... .. 0,254 mm

Piston gudgeon pin bore 63,525 / 63,515 mm

Gudgeon pin diameter 63,500 / 63,492 mm

Length of gudgeon pin 135,00 / 134,75 mm

Bore in connecting rod for small end bearing 71,450 / 71,425 mm

Bore of connecting rod small end bearing 63,576 / 63,551 mm

Bore in connecting rod for big end bearing shells.. ... 123,025 / 123,000 mm

Distance between centres of big and small end bearings.. ... 336,06 / 335,94 mm

Maximum worn clearance small end..0,15 mm

Conrod end float 0,16 / 0,36 mm

Camshaft and bearings

Diameter of camshaft journal (A3) 91,960 / 91,933 mm

Exhaust cam height (A5) 78,58 mm, service limit 78,1 mm

Inlet cam height (A5).. 78,58 mm, service limit 78,1 mm

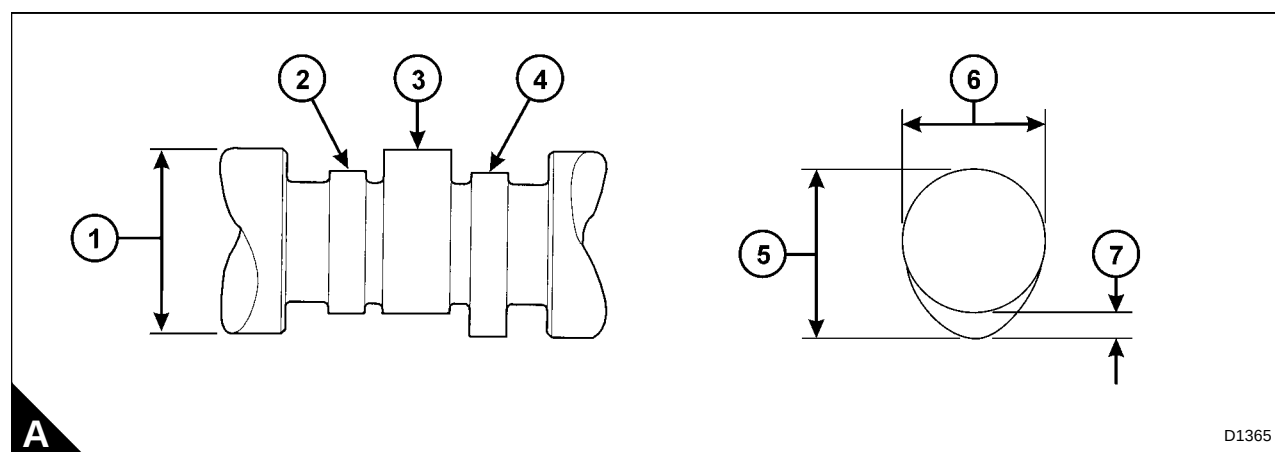
Injector cam height. 78,88 mm, service limit 78,4 mm

Maximum: worn clearance cam journal / bearing0,25 mm

Camshaft end float. 0,10 / 0,25 mm, maximum: worn clearance 0,30 mm

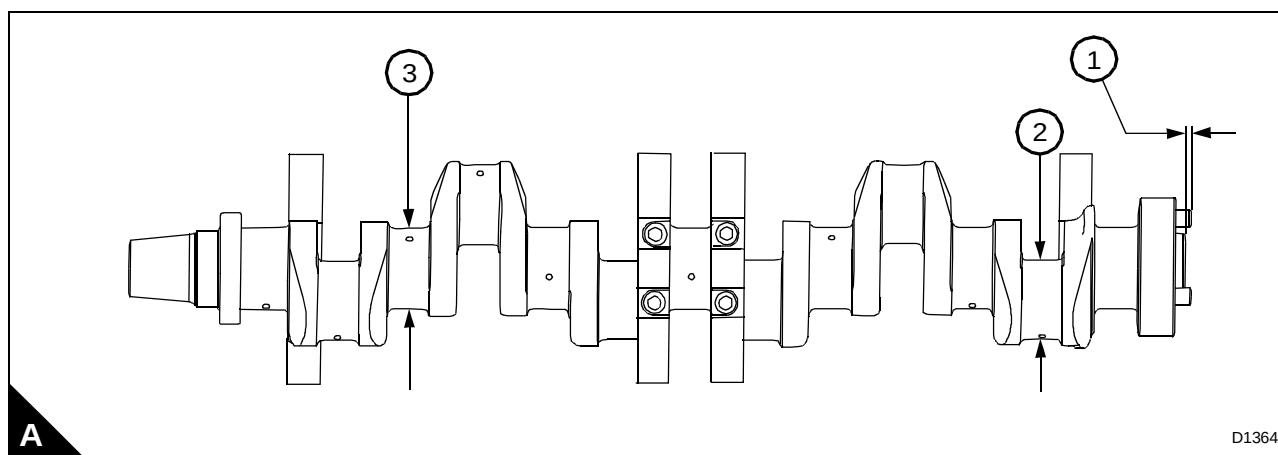
Cam follower lever assembly:

followers, pivot shaft / arms / shims end float 0,50 / 0,25 mm



Crankshaft, main bearings and flywheel

Diameter of main bearing journal (A3).	120,59 / 120,57 mm
Undersize bearings by .	0,254 mm
Undersize bearings by .	0,508 mm
Clearance between a new bearing and the journal .	0,152 / 0,089 mm
Maximum permissible clearance between the bearing and journal..	0,203 mm
Diameter of main bearing bore .	120,726 / 120,675 mm
Diameter of connecting rod journal (A2)..	118,013 / 117,993 mm
Undersize bearings by .	0,254 mm and 0,508 mm
Clearance between a new bearing and the journal .	0,127 / 0,073 mm
Maximum permissible clearance between the bearing and journal..	0,203 mm
End-float of crankshaft. .	0,48 / 0,13 mm
Maximum permissible end-float (with used bearings) .	0,53 mm
Protrusion of dowel (A1) ..	10 mm

**Crankcase and cylinder liners**

Distance from top of crankcase to centre of main bearing bore .	540,15 / 540,00 mm
Block cylinder bore depth (for liner flange) ..	15,20 / 15,12 mm
Distance from bottom of crankcase to centre of main bearing bore .	152,425 / 152,375 mm
Bore in new cylinder liner .	160,025 / 160,000 mm
Thickness of liner flange..	13,05 / 13,00 mm

Lubricating oil pump

Diameter of shaft	41,913 / 41,888 mm
Diameter of bores in bearing bushes for shaft... ..	42,039 / 41,974 mm
Length of rotors.. ..	50,800 / 50,775 mm
Depth of bores for rotors	50,76 / 50,72 mm
Joint O.P. body to cover.	..0,25 mm

Spring:

Spring rate	..1,32 kg/mm
Load at 51 mm length	...30 kg
Load under 30 mm comp: to assembly length... ..	39,6 kg
Free length.	..73,6 mm
Outside diameter	..24,6 mm
Spring plunger bore	..25,4 mm

Coolant pump

Shaft diameter at the position of the coolant seal..	25,095 / 25,087 mm
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Gear train

Idler gear end float.	0,2 / 0,1 mm
Idler gear maximum: worn	..0,25 mm

Backlash:

Idler, camshaft, oil pump gears..	0,375 / 0,125 mm
Maximum: worn..	0,5 mm

Water pump gear in mesh..	0,294 / 0,152 mm
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Torque data

Description	Thread size	Torque		
		Nm	lbf ft	kgf m
Crankcase and crankshaft				
Sump bolts into crankcase	M10	54	40	5,5
Sump bolts into gearcase (aluminium)	M10	40	30	4
Main bearing cap bolts	See Operation 5-6			
Main bearing cap side capscrews	M16	n/a	n/a	n/a
Oil feed block bolts	M10	27	20	2,7
Connecting rod bolts	See Operation 4-2			
Piston cooling jet bolts	M10	27	20	2,7
Camshaft				
Camshaft gear bolts	M12	150	110	15,2
Camshaft thrust plate bolts	M10	50	35	5,1
Idler gear hub bolts	M10	50	35	5,1
Engine feet bolts	M10	50	35	5,1
Cylinder head				
Cylinder head bolts (Factory Fitted)		175 + 120°	130 + 120°	17,8 + 120°
Cylinder head bolts (Waisted) - head marked 'W'	M24	720	530	73,4
General				
M20 - Grade 8.8 steel bolts to BS3692	M20	400	290	40,7
M16 - Grade 8.8 steel bolts to BS3692	M16	210	150	21,4
M12 - Grade 8.8 steel bolts to BS3692	M12	85	60	8,6
M10 - Grade 12.9 steel bolts to BS3692	M10	70	50	7,1
M10 - Grade 8.8 steel bolts to BS3692	M10	50	35	5,1
M8 - Grade 8.8 steel bolts to BS3692	M8	25	18	2,5
M6 - Grade 8.8 steel bolts to BS3692	M6	10	7	1,0
M6 - Grade 12.9 steel capscrews to BS4168: Part 1	M6	16	12	1,6
M5 - Grade 12.9 steel capscrew to BS4168: Part 1	M5	13	10	1,3
3/8" UNF		40	30	4
5/8" UNF		200	150	20,3
1/2" UNC		90	68	9,1
7/16" UNF		66	50	6,7
5/16" UNF		22	16	2,2
Starter motors	M12	95	70	7,1
Alternator nut	M24	75	55	7,6
Taper lockbush	M8	20	15	2
Fuel pipes		50	35	5,1

Main build

Description	Thread size	Torque		
		Nm	lbf ft	kgf m
Camshaft				
Cam follower housing bolts	M10	50	35	5,1
Cylinder head				
Rocker box bolts-graphite joint	M10	70	50	7,1
Exhaust manifold to head bolts (Durlock)	M10	70	50	7,1
Bridge piece adjuster nubs	M10	35	25	3,5
Fuel injector clamp capscrews	M12	95	70	9,6
Rocker shaft capscrew/nuts	M16	240	180	24,9
Rocker adjuster nuts	M12	50	35	5,1
Unit-fuel injector rocker adjuster nuts	M14	70	50	7,1
Rocker cover - plastic	M10	4	3	0,4
Water pump and oil pump				
Water pump to gearcase bolts	M10	50	35	5,1
Water header to oil cooler bolts	M10	50	35	5,1
Crankcase and crankshaft				
Flywheel bolts (Final torque)	See Chapter 13, Flywheel and housing			
T.V. damper bolts (Final torque)	See Chapter 13, Flywheel and housing			
Front crankshaft pulley assembly	M16	340	250	34,6
Unit-fuel injector control linkage				
Capscrews, unit-fuel injector control lever	M5	8	6	0,8
Locknut - control linkage	M5	8	6	0,8
Exhaust bellows				
Bolts / locknuts (torque prevailing)	M10	58	43	
Durlock bolts / locknuts	M10	70	50	
Setscrews	M10	50	35	5,1
Unit- fuel injectors				
Nuts, fuel injector nozzle to nozzle holder	M27	205	150	5,9
Capscrews, fuel injector clamp to cylinder head	M12	95	70	9,6
Clips and clamps				
Hose clips		5	3,5	0,5
V-band clamps (Mitsubishi)		9,5	7	0,96

3

Cylinder head assembly

General description

Note: In the event of failure, valve or valve seat recession reaching the recommended limit, or when the engine is being overhauled, service exchange cylinder heads supplied by your Perkins Dealer/Distributor are recommended. The specialised equipment and liquid nitrogen are not generally available

The cast iron cylinder heads are fastened to the crankcase by flange head bolts and hardened washers. The cylinder head gasket to crankcase consists of a stainless steel flame ring. The individual inlet and exhaust ports are designed to assist and improve air flow. The ports for the inlet are on the right hand side of the engine and the ports for the exhaust are on the left hand side of the engine.

The cylinder head assembly has four overhead valves for each cylinder. Each valve is held in place by a single coil spring, cap and two collets. The cylinder head has valve seat inserts fitted for both the intake and the exhaust. The intake valve seats are made from high speed steel casting and the exhaust valve seats are made from Pleuco PL12 MV400 which both can be renewed. The valves move in cast iron ferrite nitro carburised valve guides which also can be renewed.

The overhead valves are operated by a rocker shaft assembly in the rocker box. The forged steel rocker levers are operated by forged push rods with hardened ball and sockets ends. The rockers and valve gear are lubricated by oil from the drillings in the rocker shaft that receives oil flow from the extruded fuel/oil rail. Tappet adjustment is achieved by adjustment screws and locknuts at the push rod end of each rocker lever.

In a diesel engine there is little carbon deposit and for this reason the number of hours run is no indication of when to overhaul a cylinder head assembly. The factors which indicate when an overhaul is necessary are how easily the engine starts and its general performance.

Rocker box and valve gear

To remove and fit the rocker box and valve gear

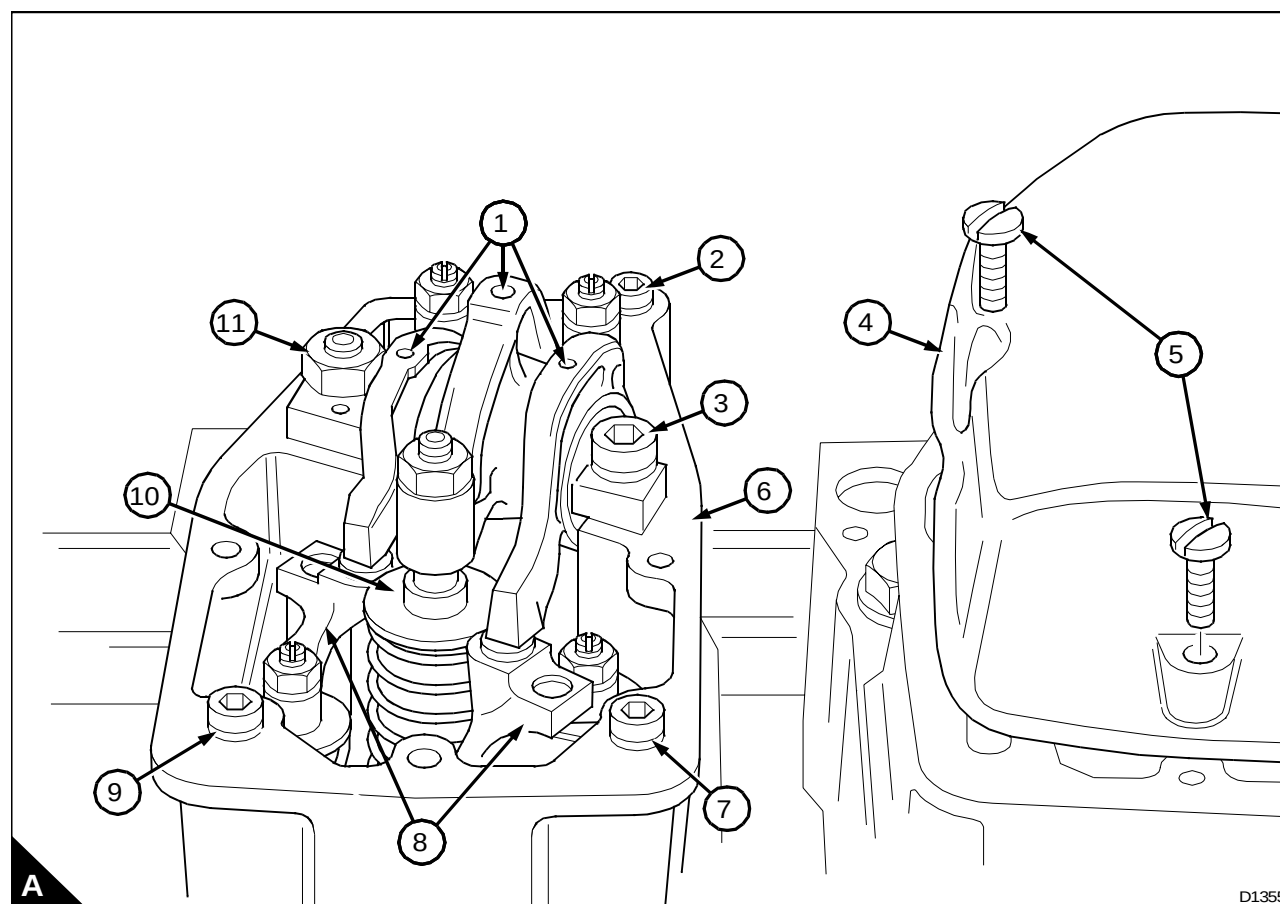
Operation 3-1

Special requirements

Consumable products	
Description	Part number
POWERPART Hydraulic threadseal	21820121

To remove

- 1 Remove the retaining screws (A5) and lift off the rocker cover (A4). Remove the rocker cover joint and discard.
- 2 Remove the nut (A11) and the Allen screw (A3) then lift off the rocker assembly (A1), the cup pad (A10), the bridge pieces (A8) and the push rods.
- 3 Remove the retaining Allen screw (A2, A7, A9) and remove the rocker box (A6).
- 4 A light blow with a hide mallet may be needed to free the rocker box from its joint.



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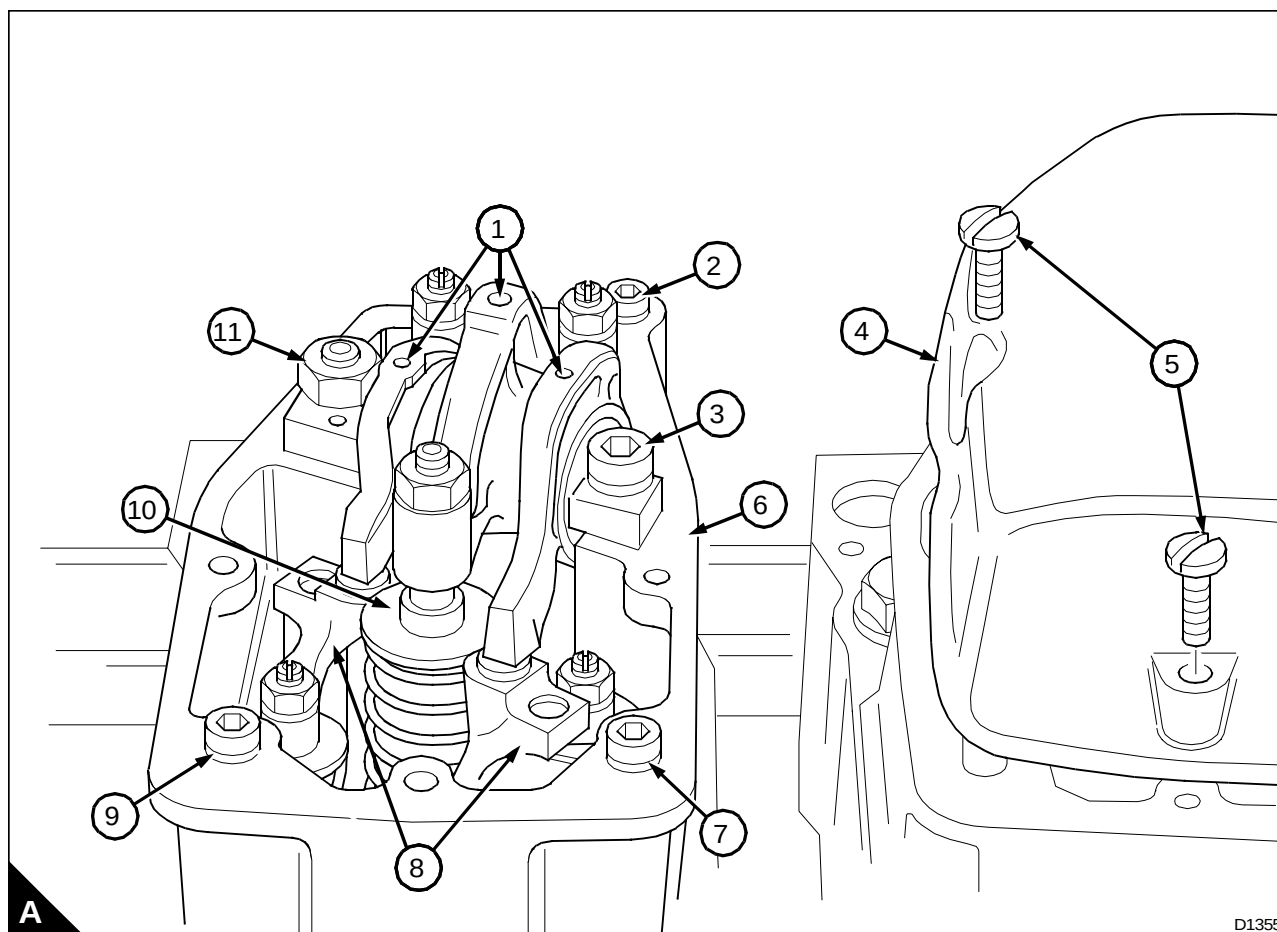
To fit

Note: If water is found to be leaking from the rocker shaft stud, apply POWERPART Threadlock and nutlock.

- 1** Fit the rocker box (A6) using a new joint and 'O' ring, locating it on the two dowel pegs in the cylinder head face.
- 2** Lubricate the threads of the retaining Allen screw (A2,A7, A9) with clean engine oil then torque to 70 Nm (50 lbf ft) 7,1 kgf m.
- 3** Lubricate all valve gear bearing surfaces with clean engine oil then fit each item to its original position.
- 4** Lubricate the thread of the nut (A11) and the Allen screw (A3) with clean engine oil then torque to 250 Nm (180 lbf ft) 25,5 kgf m.

Note: Ensure that the rocker shaft is pulled squarely onto the rocker box.

- 5** Set bridge piece and valve clearances, refer to the relevant User Handbook, Chapter 4, page 33.
- 6** Fit a new joint to the rocker cover (A4), tighten the retaining screws (A5) to a torque of 4 Nm (3 lbf ft) 0.4 kgf m.

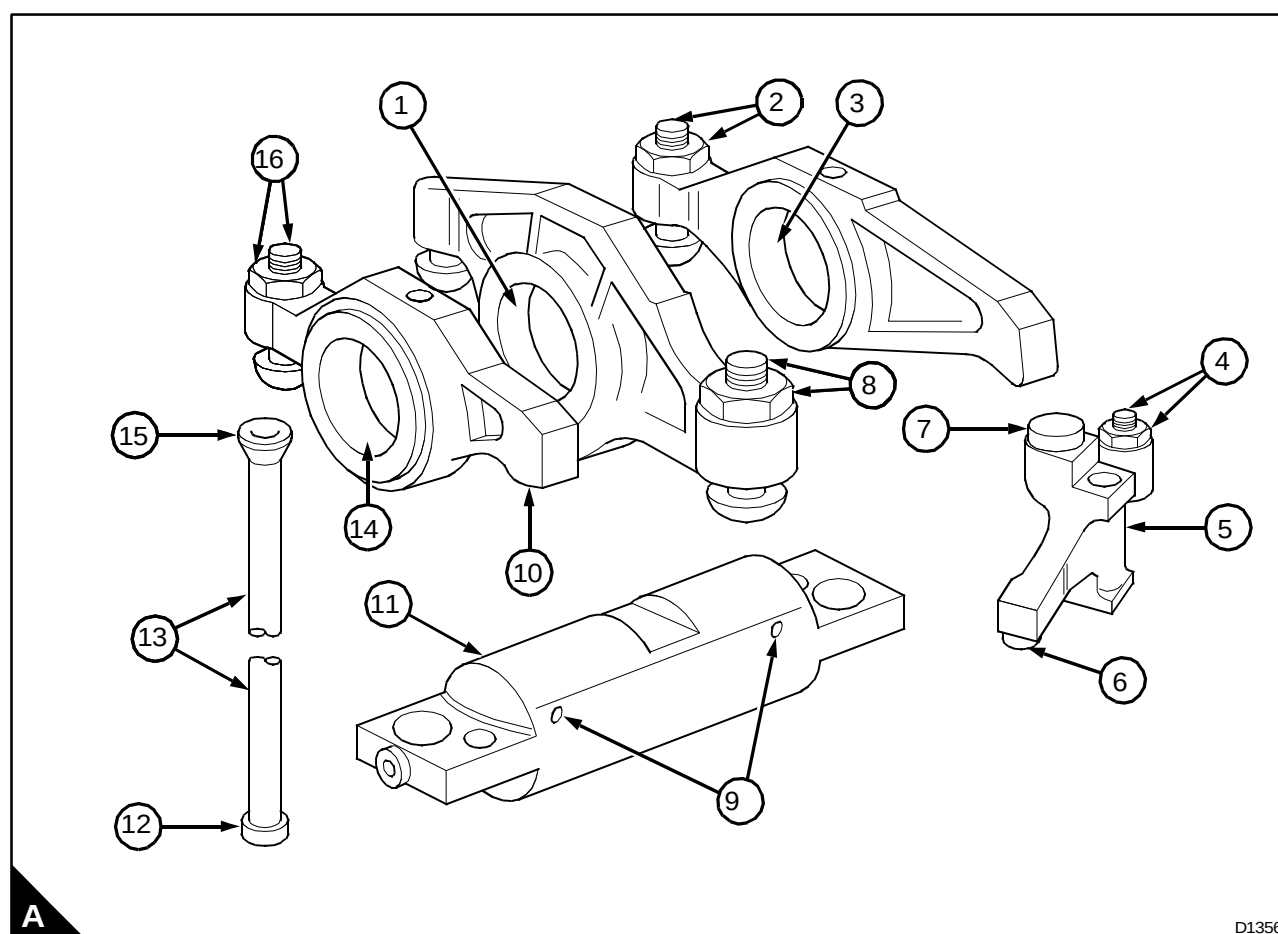


Valve gear

To inspect rockers, bridge pieces and rocker shaft

Operation 3-2

- 1 Check the push rods (A13) are straight, the cup end (A15) and the spherical end (A12) smooth surfaced and concentric.
 - 2 Clean the bore and top surface on the bridge piece.
 - 3 Check the adjuster screws and locknuts (A16) are undamaged.
 - 4 Check the clearance between the bridge pieces (A5) and their guide pillars in the cylinder head. For the maximum clearance, refer to the Data and dimensions for "Rocker assembly" on page 10.
 - 5 Check the valve contact patch (A6) is not indented or chipped.
- Note:** A small indent on the bridge piece pressure pad can be removed with an oil stone.
- 6 Check the bridge piece pressure pad (A7) for indentation.
 - 7 Check the rocker shaft (A11) for wear and the oil galleries (A9) are clear.



To replace the bridge piece pressure pad

Operation 3-3

Special requirements

Consumable products	
Description	Part number
POWERPART Retainer (oil tolerant)	21820603

1 Remove the pressure pad (A2) from the bore of the bridge piece.

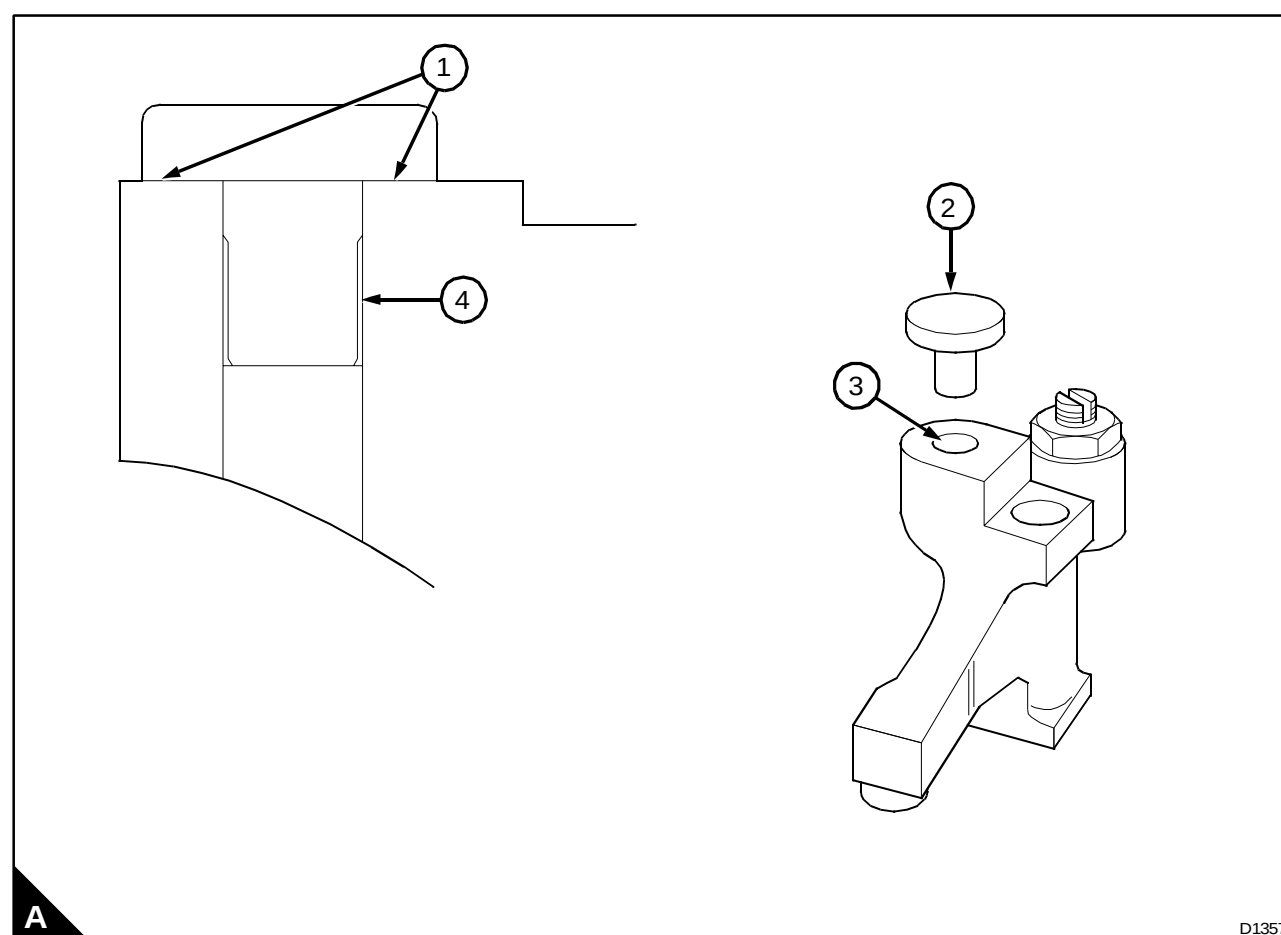
Caution: There must be no POWERPART under the pressure pad area (A1).

2 Check the surfaces (A4) on each bridge piece.

3 Apply Loctite activator 'T' to the pressure pad stem and the bridge piece, allow to dry.

4 Apply POWERPART retainer (oil tolerant) to the bridge piece bore (A3).

5 Fit the pressure pad, then stand the assembly upright and allow to cure for two hours.



D1357

Cylinder head

To remove and fit the cylinder head

Operation 3-4

Special requirements

Special tools	
Description	Part number
Cylinder head lifting tool	T6253/237

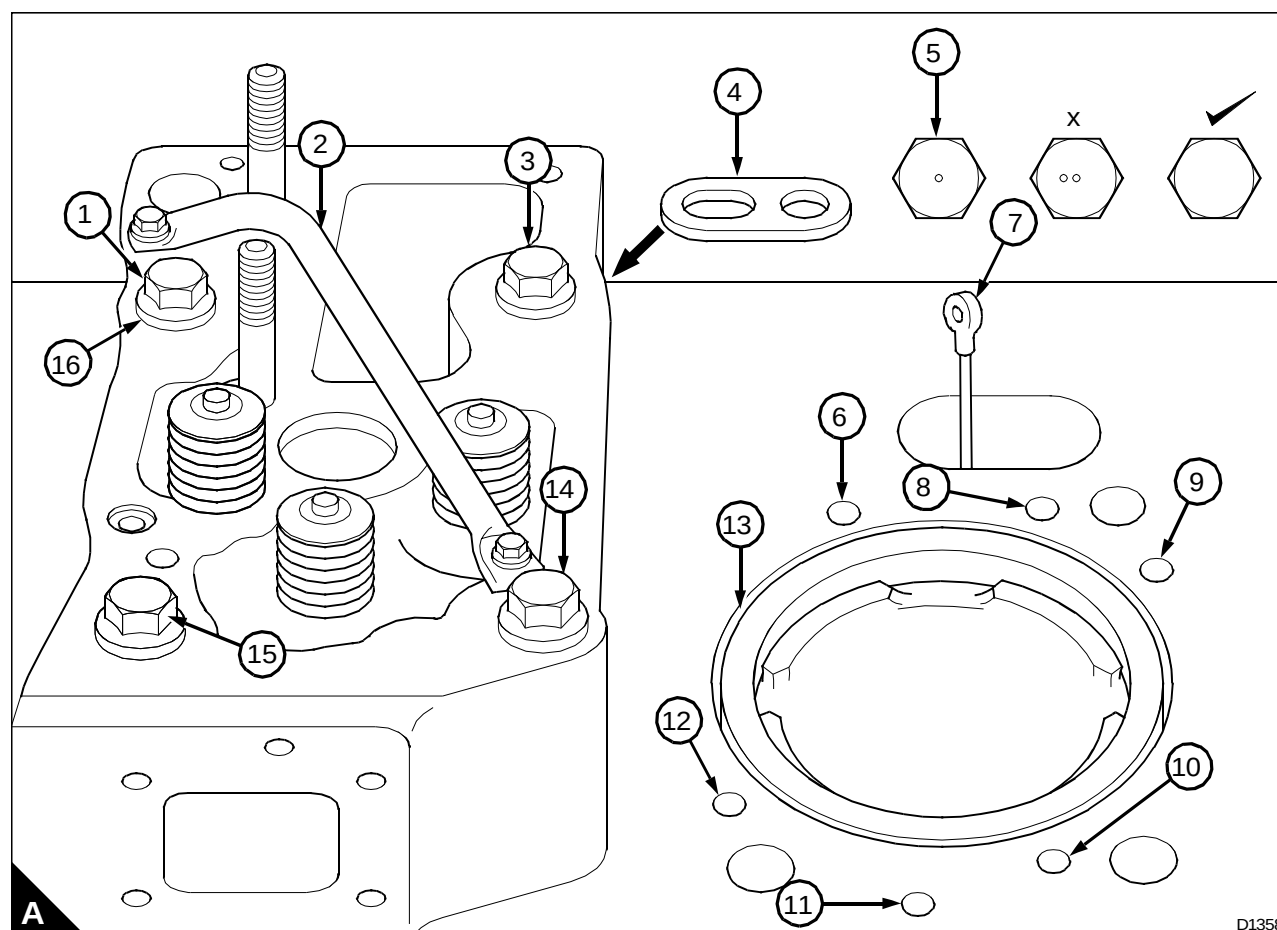
To remove

1 Remove the rocker box and the valve gear, see Operation 3-1, then remove the fuel injector, see Operation 11-2 and the brake-back lever.

Note: The cylinder head bolts can only be used twice. Before removal, mark each bolt head with a centre punch dot (A5). Bolts showing two dots must be replaced.

2 Fit the cylinder head lifting tool (A2) then remove the head bolts in sequence shown (A14, A1, A15, A3). Use a suitable hoist to remove the cylinder head from the crankcase.

3 Discard the 'O' rings (A6, A9, A10, A12), the flame ring (A13) and the push rod tunnel insert and 'O' ring (A4) in the cylinder head, clean the surface of the crankcase.

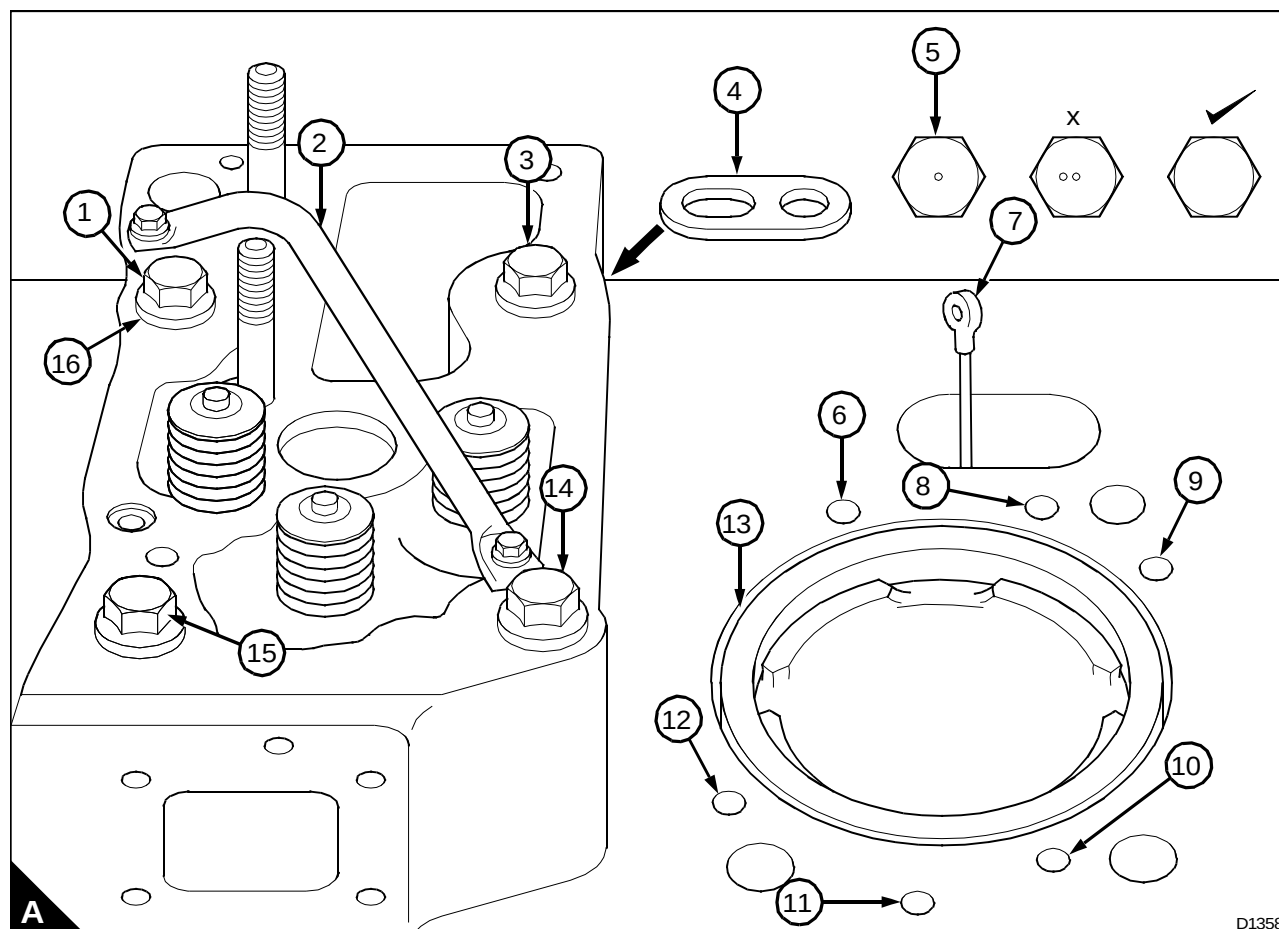


To fit

- 1** Fit the cylinder head lifting tool (A2). Locate the insert and joint (A4) into the cylinder head combustion face secure it in position with suitable petroleum jelly.
- 2** Fit the flame ring (A13) to the liner flange then fit the 'O' rings (A6, A9, A10, A12) secure them in position with petroleum jelly.
- 3** Use suitable lift equipment in order to lift the cylinder head into position. Ensure that the dowels (A8 and A11) are aligned. Also ensure that (A7) is in the push rod tunnel. Remove the lifting tool (A2).
- 4** Using a suitable PBC grease (poly butyl cuprysil) apply one stripe to the bolt thread and coat both sides of the head bolt washers. Fit the bolts and washers hand tight.

Cylinder head bolt torque stages	
Stage	Torque
1	Hand tight
2	135 Nm (100 lbf ft) 13,7 kgf m
3	270 Nm (200 lbf ft) 27,5 kgf m
4	540 Nm (400 lbf ft) 55,0 kgf m
5	715 Nm (530 lbf ft) 73,9 kgf m

- 5** Torque the cylinder head bolts in the stages given, and in the same diagonal sequence (A14, A1, A15, A3).



Valves and springs

To remove and fit the valve and the valve springs

Operation 3-5

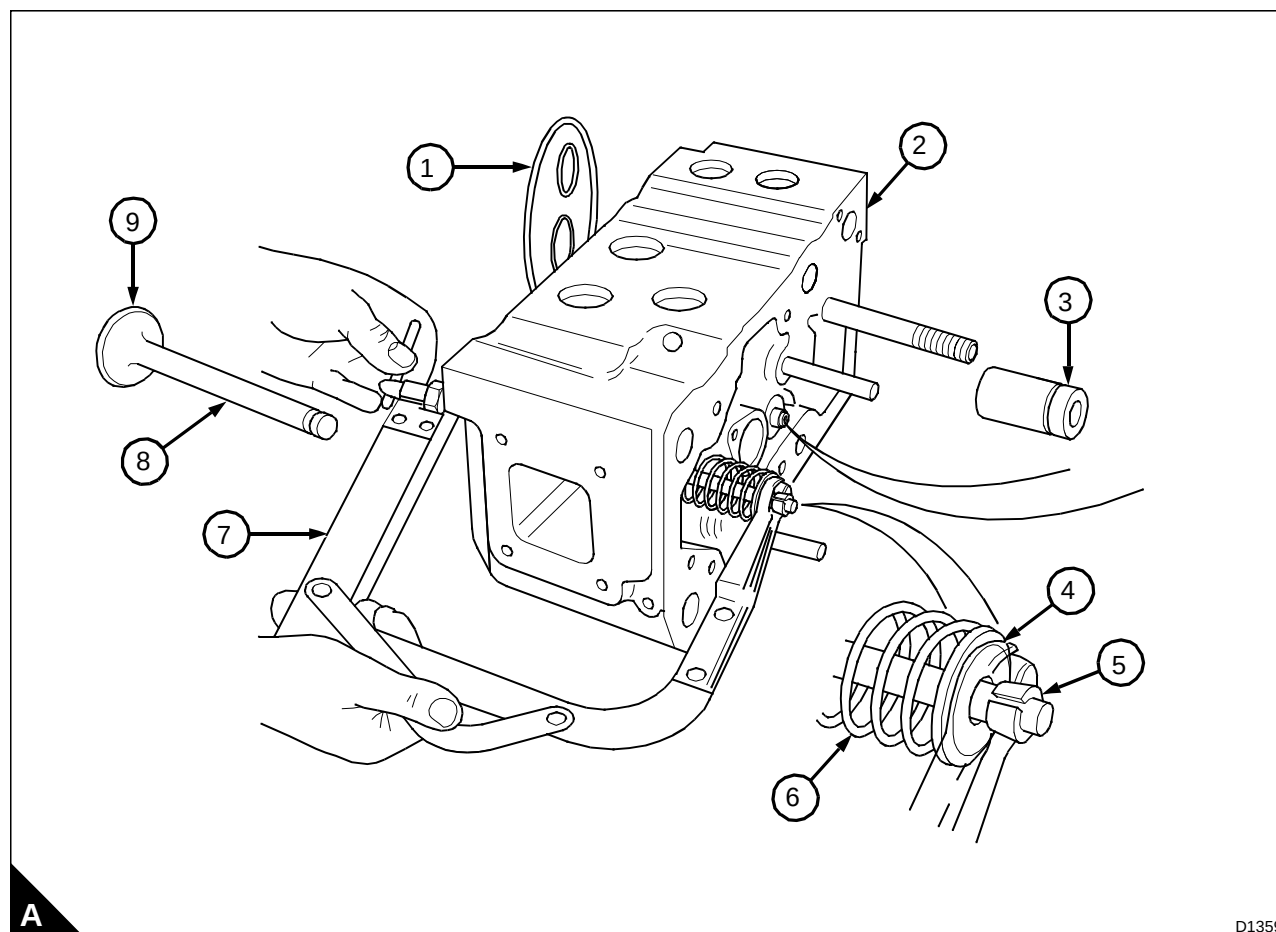
Special requirements

Special tools	
Description	Part number
Valve spring compressor	T6253/243

Warning! Wear eye protection during this operation.

To remove

- 1 Carefully turn the cylinder head on its side (A2) and remove the push rod 'O' ring and insert (A1).
- 2 Using the spring compressor (A7), compress a valve spring and remove the split collets (A5) then release the spring (A6) and retaining collar (A4) then pull the valve (A9) out of the cylinder head.
- 3 Mark valves for correct assembly and keep all valves together.

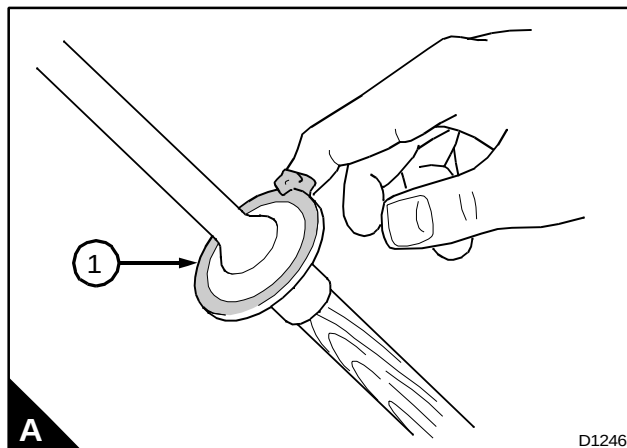


D1359

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To fit

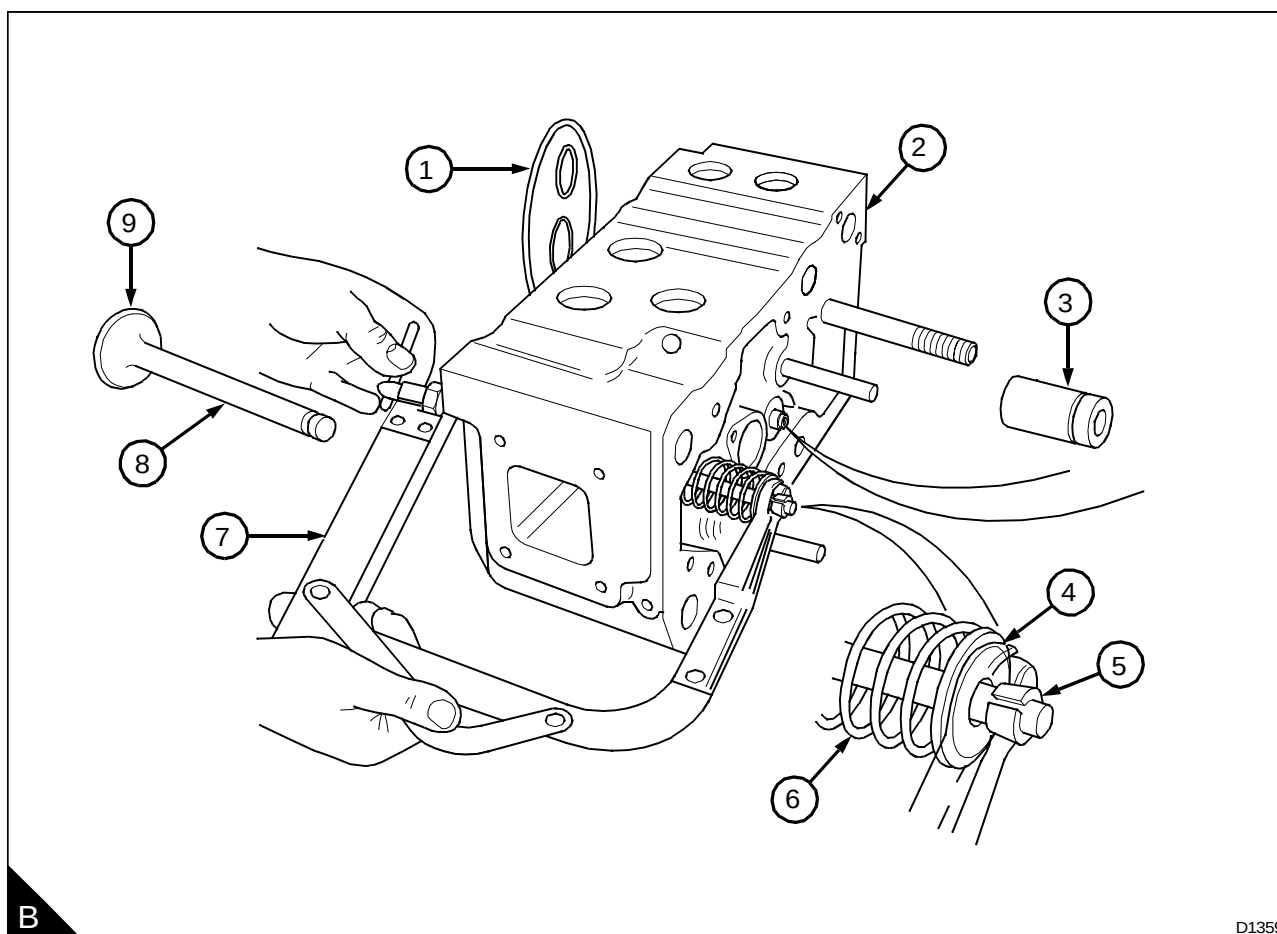
- 1 Fit the appropriate valve to a universal sucker type tool and apply a medium carborundum paste, evenly around the valve seat (A1)
- 2 Fit the valve guides (B3).
- 3 Push the valve into its guide and use a semi rotary motion lap the valve onto its seat.
- 4 The seat of the valve and on the cylinder head must have a grey continuous line of contact.
- 5 Remove all traces of the carborundum paste from the cylinder head and valve seat.



- 6 Lubricate the valve stem and fit the valve (B8) into the cylinder head.

Caution: Ensure that the valve springs (B6) are compressed squarely or the valve stem can be damaged.

- 7 Fit the valve spring and retaining collar onto the valve stem, compress the valve spring and fit the split collets (A6) then slowly release the compressed valve spring, check the collets have seated in the retaining collar.



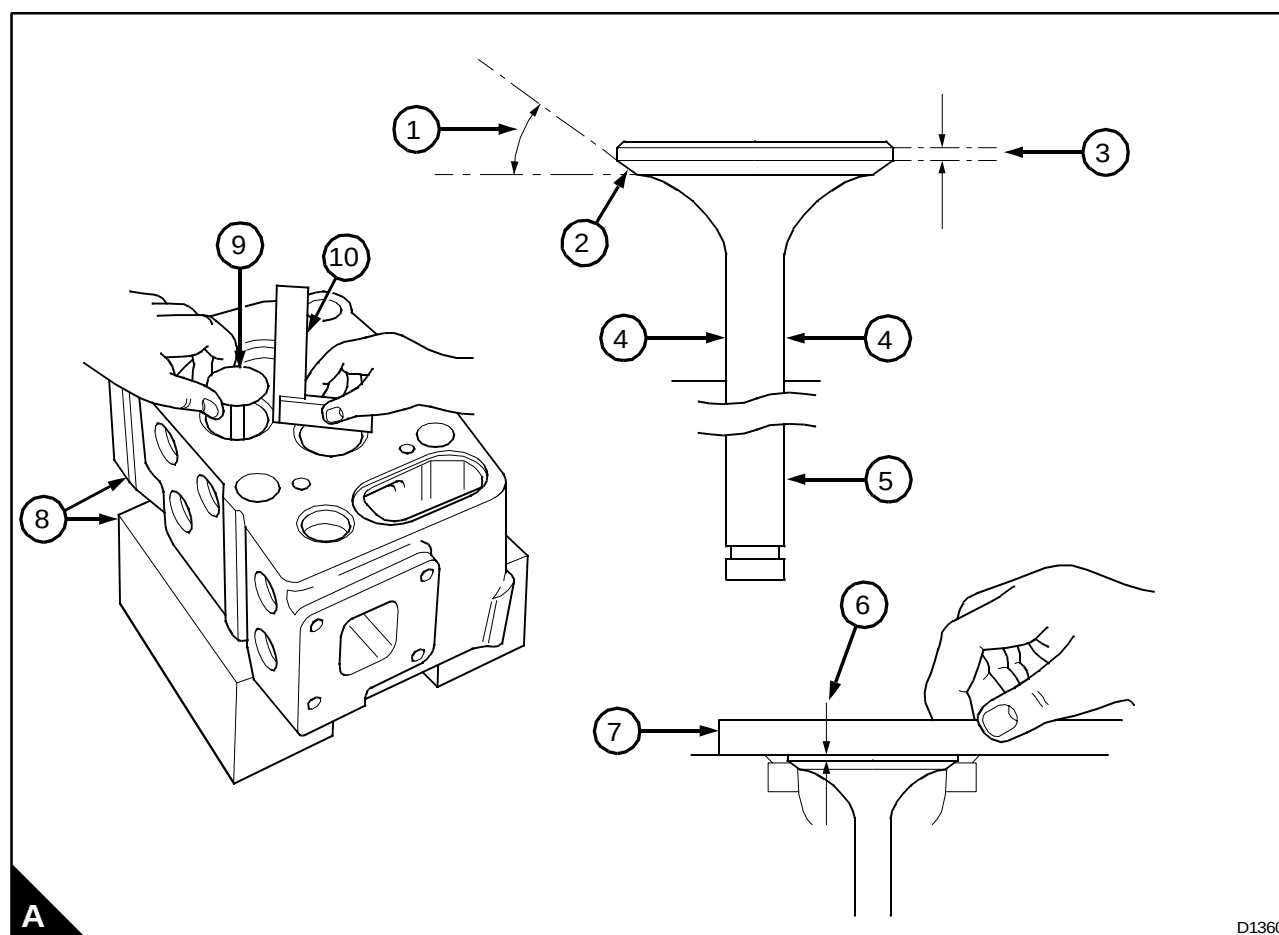
To inspect

Operation 3-6

- 1 Visually examine the valve seating face (A2) for pitting or burning. Examine the valve stem (A4) for score marks or a wear ridge near the collet groove (A5).
- 2 Check the valve stem dimension (A4), refer to the Data and dimensions for "Valves" on page 10.
- 3 If the valve is within service limits but with some pitting on the valve seating face (A2), it can be re-faced at an angle of 30° (A1).

Caution: If the dimension (A3) is less than 1mm after re-facing the valve should be discarded.

- 4 Fit a valve into the cylinder head and using a straight edge (A7), check the valve depth. If the depth exceeds 1mm (A6) the valve must be replaced.
- 5 Support the cylinder head on two blocks of wood (A8). Fit the appropriate valve into the cylinder head, and hold the valve seat so it protrudes 10mm from the surface of the cylinder head. Use an engineer square as a datum (A10) and check the clearance between the valve and valve guide. If the clearance exceeds 0.5mm (0,0196 in) the valve guide must be replaced, see Operation 3-8.
- 6 Check the valve spring free length. If less than 55.6mm (2,188 in), the valve spring must be replaced, see Operation 3-5.



D1360

Valves seats

To remove and fit, and reface the valve seats

Operation 3-7

Special requirements

Special tools	
Description	Part number
Valve seat fitting tool	T85002/4
Valve seat grinding equipment	T6253/240

Warning! Wear eye protection during this operation.

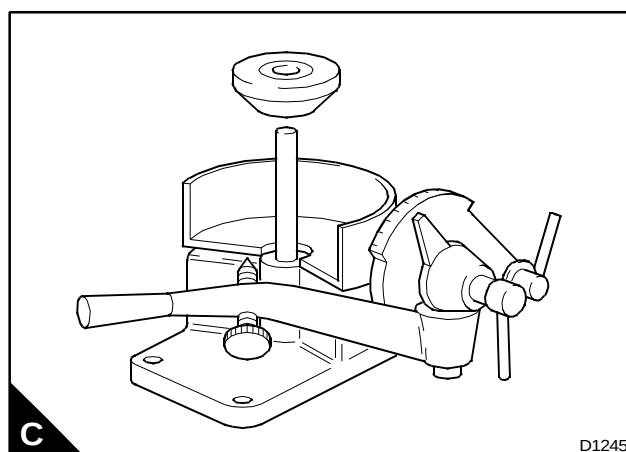
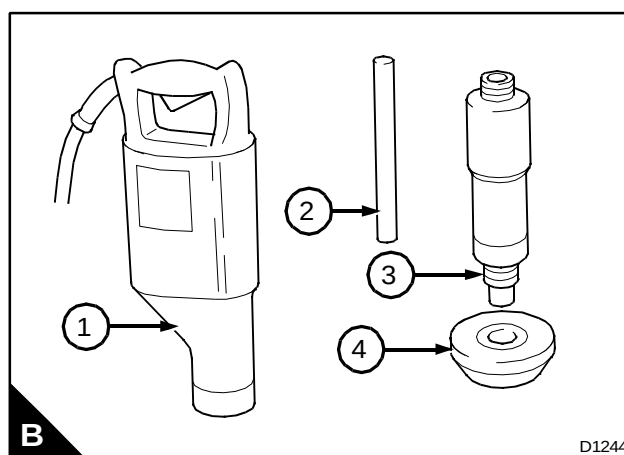
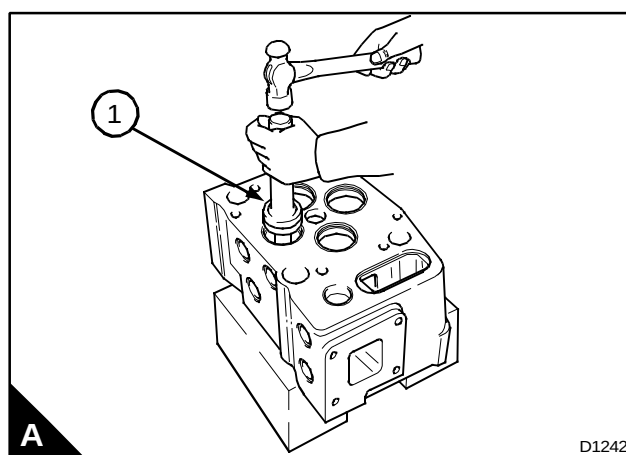
To remove

- 1 Machine down a valve head until it just fits inside a valve seat.
- 2 Using an electrical welding source, tack weld the valve to the seat in three evenly spaced positions.
- 3 Allow time for the valve and seat to cool, then using a soft faced hammer, knock the valve and seat out of the cylinder head.

To fit

- 1 Check that the valve seat bore is free from burrs, and that the valve guide bore is free from carbon.
- 2 Immerse the valve seat in liquid nitrogen for 2 minutes to get the necessary contraction. This makes the seat a light tap fit into the cylinder head using the fitting tool (A1).

Caution: The valve seats are made from a very hard material and the valve seat angle can only be cut with the use of specialist valve grinding equipment (B) and the grinding kit (C) for the stone (B4). Refer to page 10 of data and dimensions for the correct seat angle.



Valves guides

To remove and fit the valve guides

Operation 3-8

Special requirements

Special tools			
Description	Part number	Description	Part number
Valve guide removal tool	T6253/307	Valve guide fitting tool	T85090/2

Warning! Wear eye protection during this operation.

Note: When fitting new valve guides the valve seats must be re-cut or re-ground.

To remove

1 Locate the valve guide removal tool into valve guide, using a suitable press push the valve guide out of the cylinder head from the valve spring side.

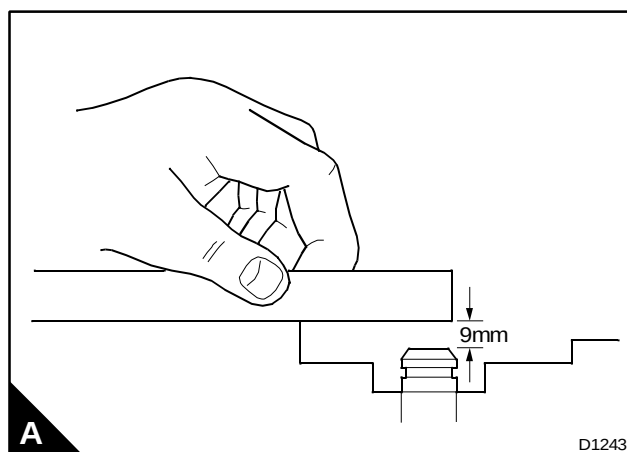
To fit

1 Check that the valve bore is free from burrs and carbon.

Caution: Do not use a hammer to locate or to fit the valve guide.

2 Align the valve guide with its bore.

3 Set the fitting tool on top of the valve guide. Using a suitable press, push the valve guide into the cylinder head until valve guide is 9 mm (0.3543 in) (A) below the face of the cylinder head.



Fuel injector bush

To remove and fit a fuel injector bush

Operation 3-9

Special requirements

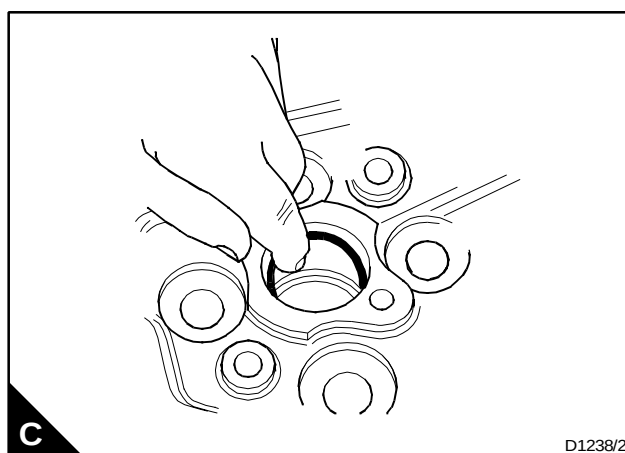
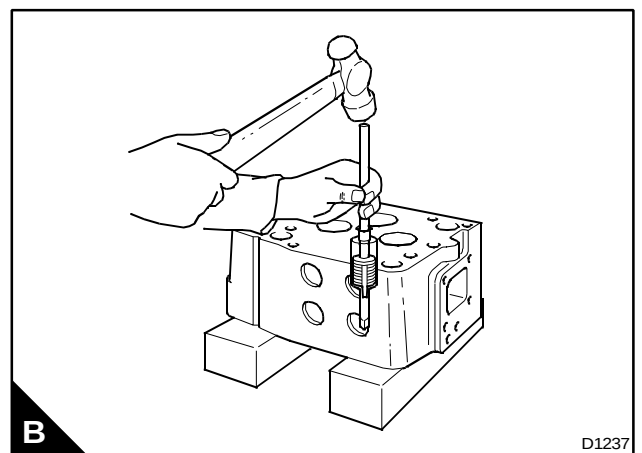
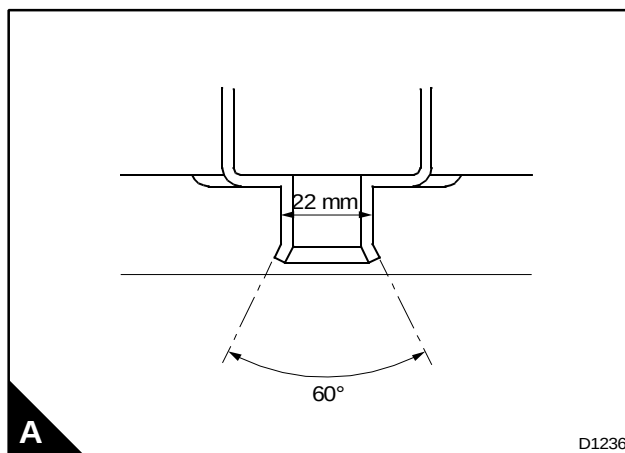
Special tools			
Description	Part number	Description	Part number
Bush insertion tool	T85002/2	Bush swaging tool	T6253/156
Bush expanding tool lower	T85002/6	Facing cutter	T85002/7
Bush expanding tool upper	T85002/58	Depth gauge	T85002/14B

Warning! Wear eye protection during this operation.

Note: If coolant is found to be leaking from between the cylinder and the fuel injector, or if the fuel injector bush is damaged, the fuel injector bush must be replaced.

To remove

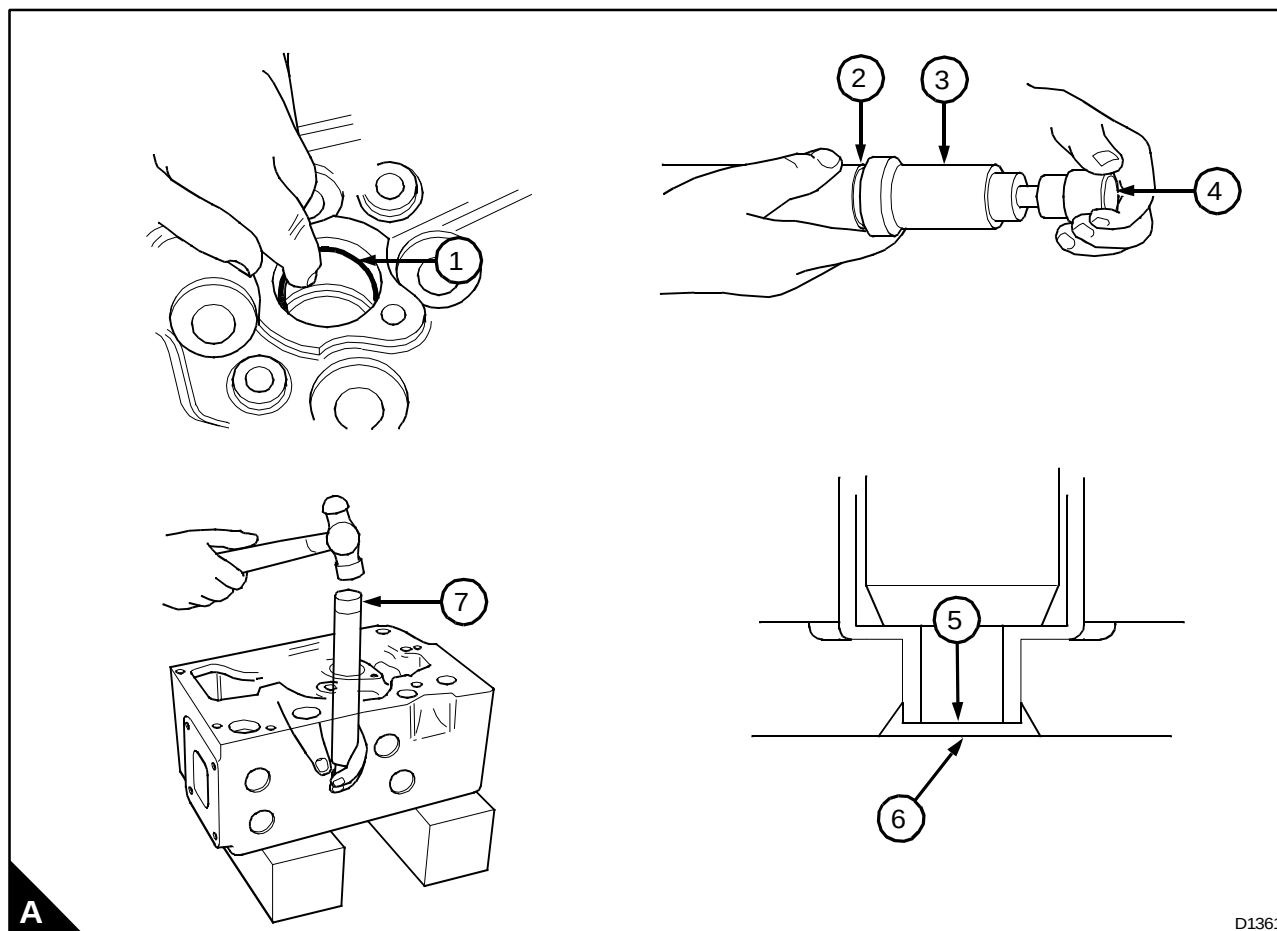
- 1 Use a 22 mm (0.8661) drill with a 60 degree angle (A) to drill the swaging of the fuel injector bush.
- 2 Use a suitable tool (B) from the combustion side of the cylinder head to remove the remaining fuel injector bush. Remove the "O" ring and discard (C).



To fit

Note: When using the fuel injector bush expander tools, the pressure on the bush is automatically controlled by the tools as they rotate.

- 1 Apply a suitable lubricant to the new 'O' ring, then fit the 'O' ring into the recess in the fuel injector bush aperture.
- 2 Slide the fuel injector bush (A3) onto the insertion tool (A2) then fit the locating pin (A4) into the tool and the fuel injector bush.
- 3 Carefully locate the fuel injector bush into the cylinder head, ensuring that the 'O' ring (A1) is still correctly positioned.
- 4 When the fuel injector bush has located in the combustion side of the cylinder head, carefully force the bush into position.
- 5 With the fuel injector bush in the correct position, check that the end of the bush (A5) is 1.5mm (0.0590 in) from the cylinder head face (A6).

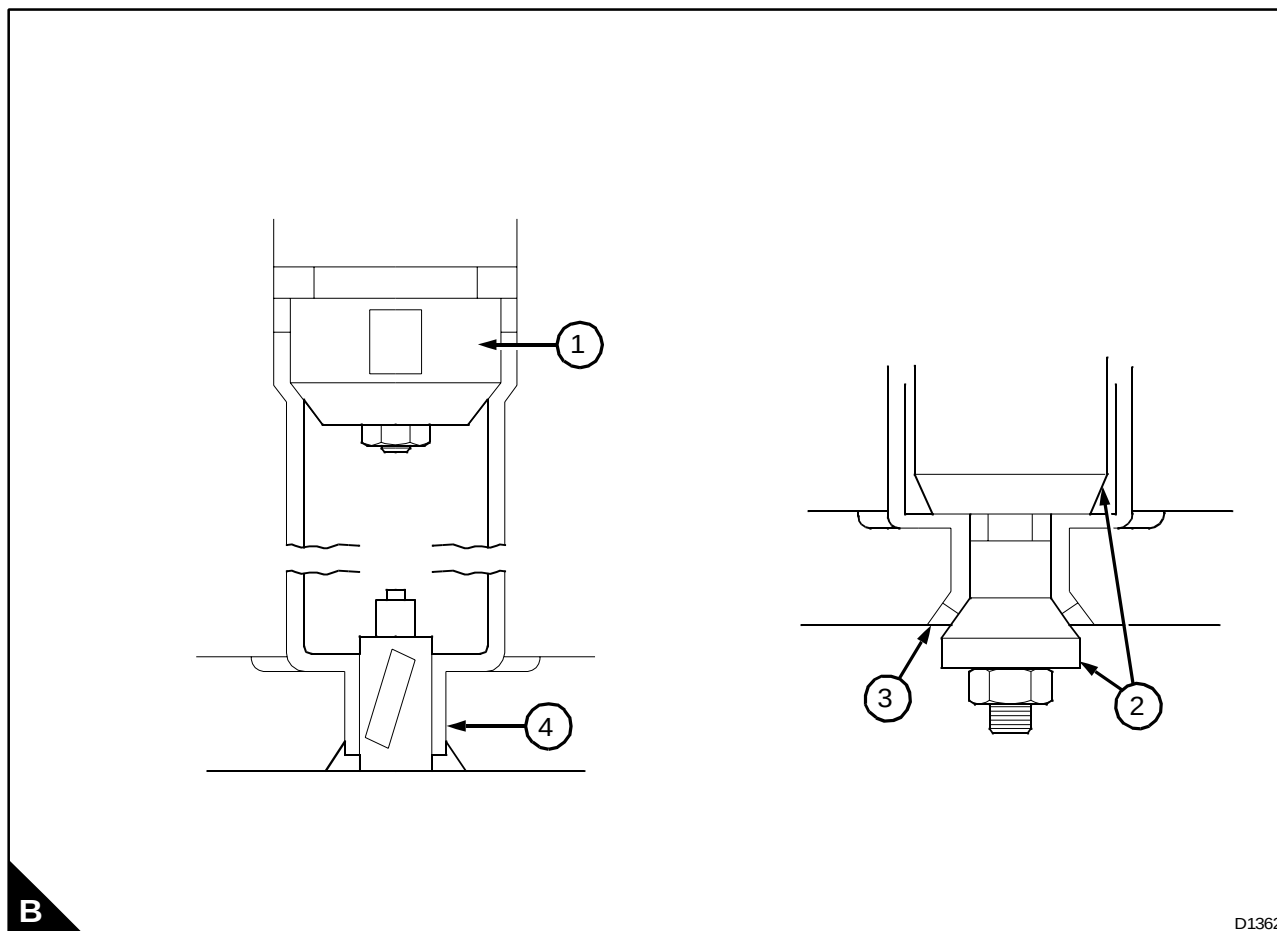


D1361

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6 Using the expander tools, first expand the lower section bush (combustion side) (B4) then the upper section bush (valve spring side) (B1).

7 Fit the coning tool (B2) to the combustion side of the bush, then torque the nut to 55 Nm (40 lb/ft) 5,6 kgf m to swage the bush into the chamfer (B3) in the combustion face of the cylinder head.

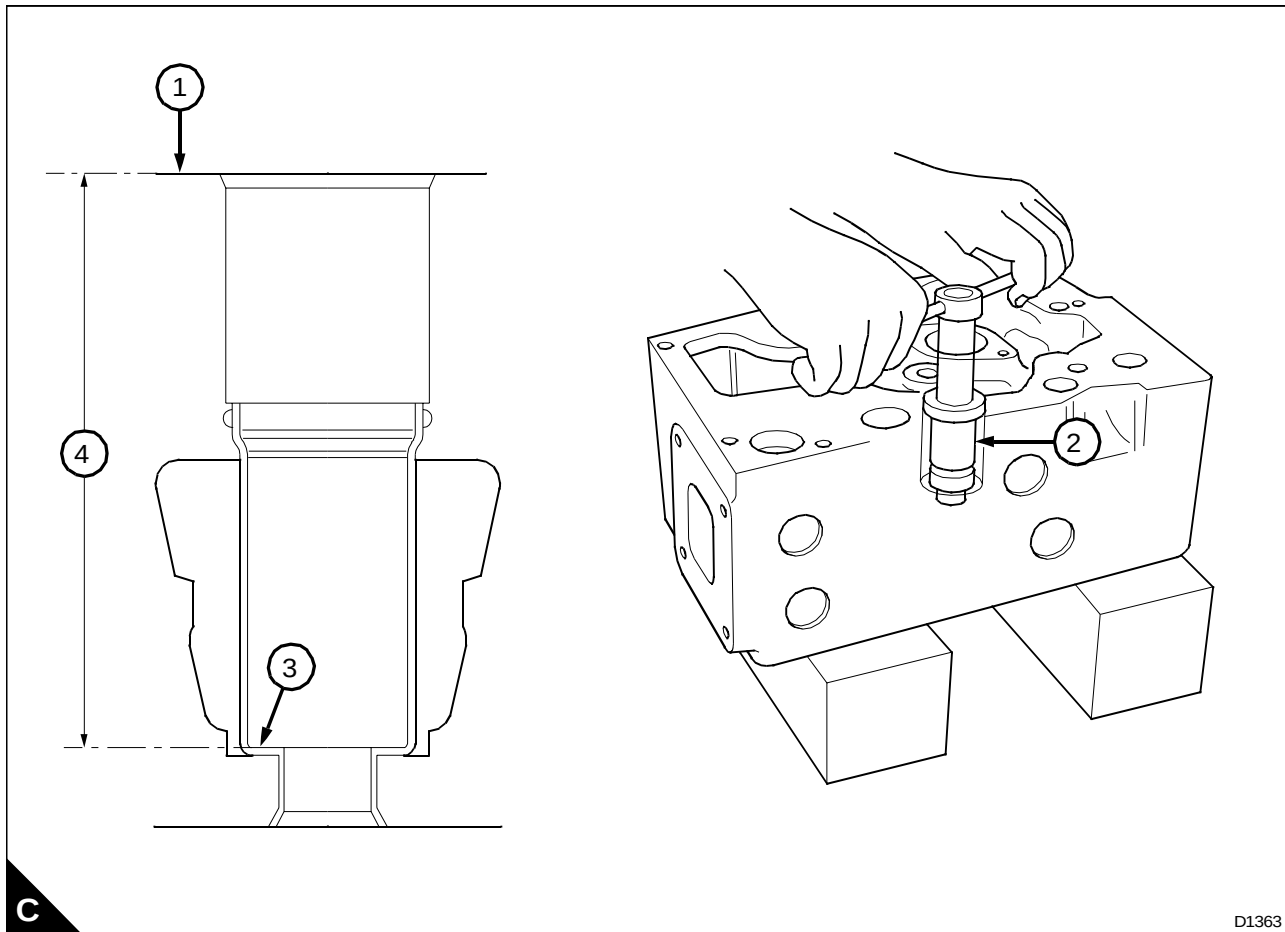


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8 Check the distance between the fuel injector seating face (C3) and the cylinder head face (C1) with a depth gauge. The finished dimension (C4) is $122,6 \pm 0.105$ mm (4.827 ± 0.004 in.).

9 If necessary, use the face cutter (C2) to set the dimension correctly.

10 Remove all debris.



Cylinder head

To inspect and pressure test

Operation 3-10

Warning! *Wear eye protection during this operation.*

1 Remove the valves and springs, see Operation 3-5.

Note: Do not scratch any machined surface on the cylinder head.

2 Clean the carbon deposits from the combustion face and the ports of the cylinder head.

3 Wash the cylinder head with a special solvent which must be used in accordance with the manufacturer's instructions. Dry the cylinder head using compressed air.

4 Test the cylinder head for leaks, refer to the Data and dimensions for "Cylinder head" on page 12.

5 When the cylinder head is thoroughly clean, check it for cracks. Inspect carefully the areas around the valve seats and around the hole for the fuel injector.

Manifolds

To remove and fit the induction manifold

Operation 3-11

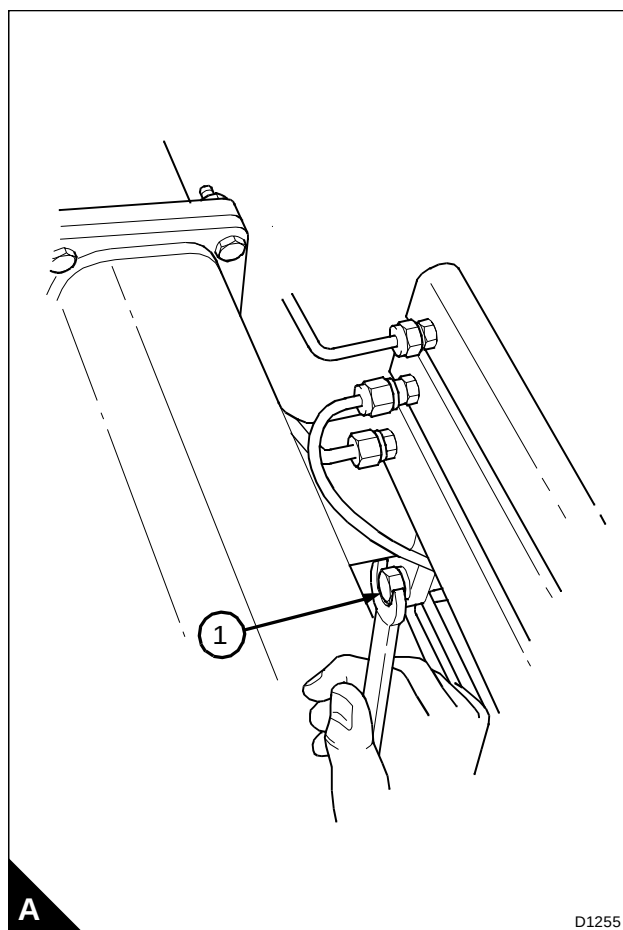
To remove

Note: The induction manifold can be removed as individual sections or as a complete assembly.

- 1 Remove the digital governor control unit, see Operation 14-17.
- 2 Remove the air filter bracket, see Operation 9-5.
- 3 Loosen the hose clips from the induction manifold pipes. Remove the links and setscrews that secure both pipes. Remove the hoses from the induction manifold pipes.
- 4 Remove the inlet manifold to cylinder head setscrews (A1), then remove the inlet manifold. Discard the joints.

To fit

- 1 Fit new joints to the induction manifold. Tighten the setscrews to the induction manifold, gradually and evenly to a torque of 50 Nm (37 lbf ft) 5,1 kgf m.
- 2 Fit the hoses from the induction manifold pipes, and tighten the hose clips to the radiator pipes and the induction manifold pipes.
- 3 Fit the links and setscrews that secure both pipes, and tighten the setscrews to torque of 25 Nm (18,4 lbf ft) 2.5 kgf m.
- 4 Fit the air filter bracket, see Operation 9-6
- 5 Fit the digital governor control unit, see Operation 14-18.

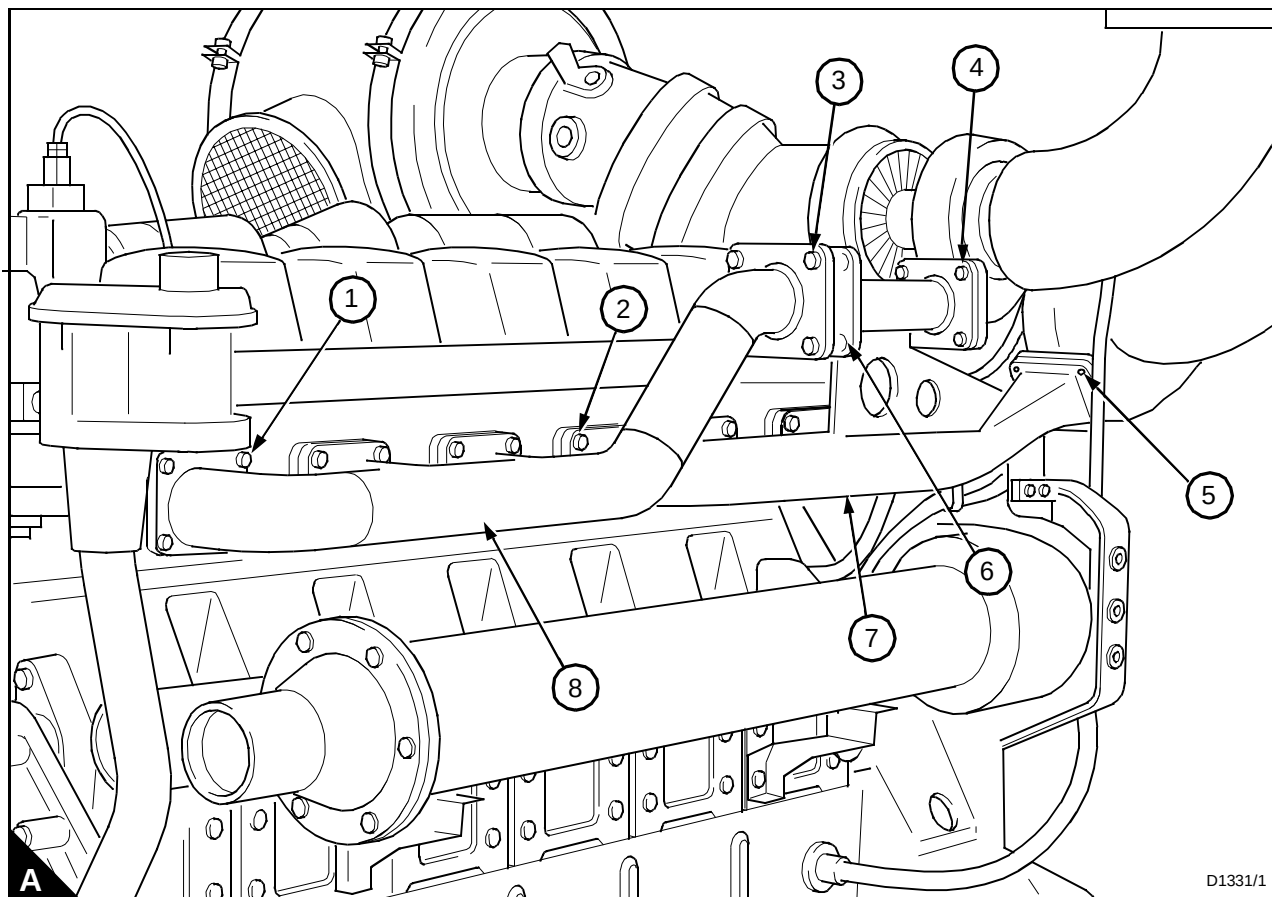


Cautions:

- The exhaust manifolds (A7) and (A8) must be removed as separate items. Damage may be caused to the expansion bellows (A6) if the exhaust manifolds are removed as an assembly.
- Ensure that the turbochargers are supported before the exhaust manifolds are removed.

To remove

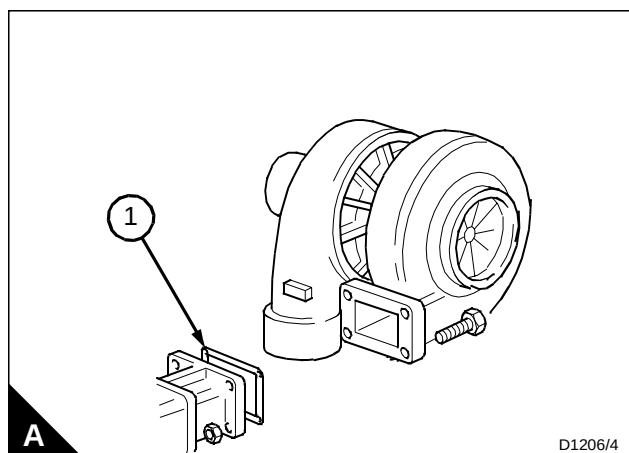
- 1 Remove the 4 nuts and bolts (A3) and remove the 12 setscrews (A1).
- 2 Remove the front section of the exhaust manifold (A8). Discard all the old gaskets.
- 3 Remove the 4 nuts and bolts (A4) and the 4 nuts and bolts (A5).



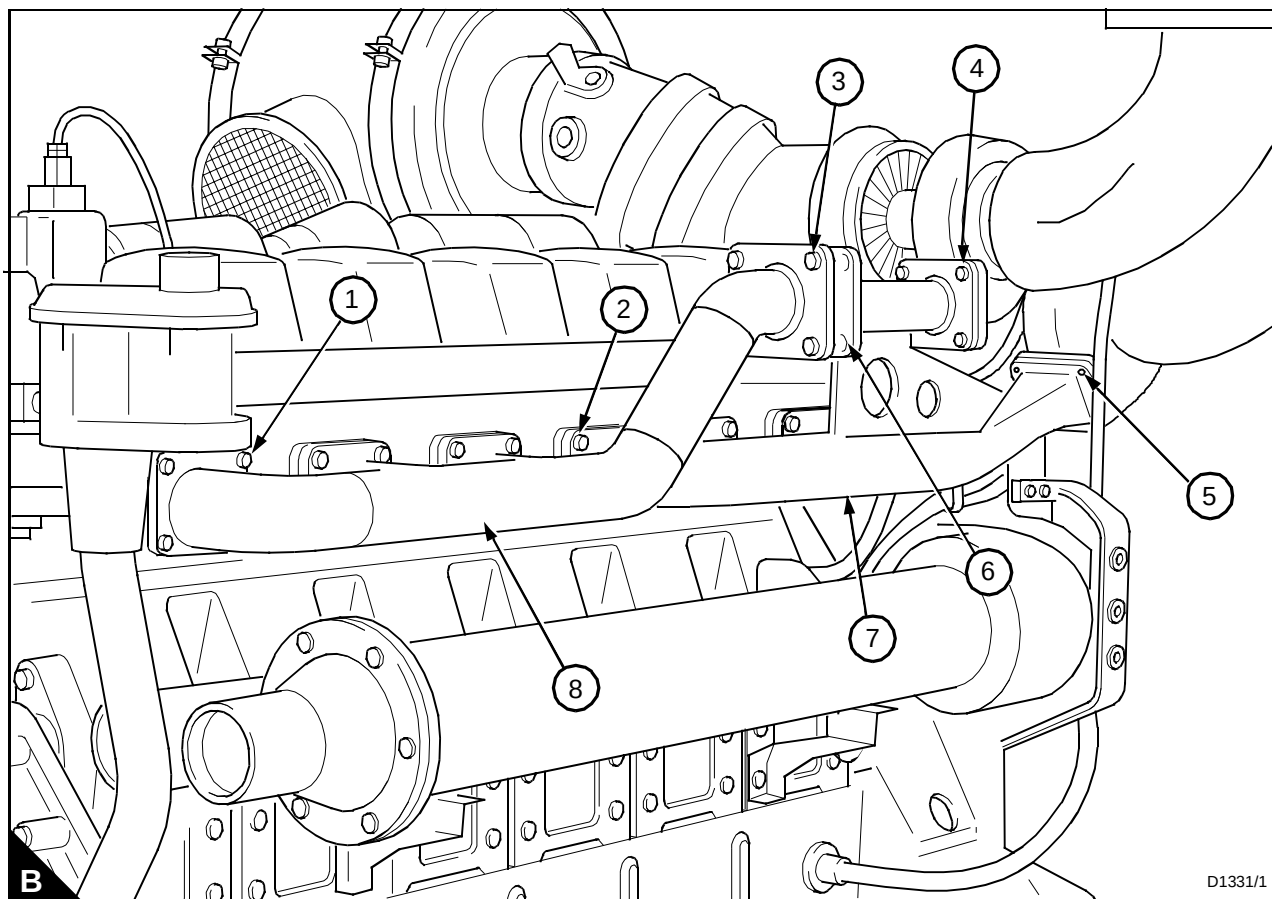
- 4 Remove the 12 setscrews (A2) and remove the rear exhaust manifold (A7). Discard all the old gaskets.
- 5 If necessary remove the rest of the nuts and bolts on the expansion bellows (A6) and remove the expansion bellows. Discard the old gasket.
- 6 Ensure that dirt or fluid can not enter the exhaust system.

To fit

- 1 Ensure that all contact surfaces are clean and dry.
- 2 Align the new gaskets (A1) to both turbochargers and align the 3 new gaskets for the rear exhaust manifold (B7) to the cylinder head.



- 3 Fit loosely the 4 bolts and nuts (B4) and (B5).
- 4 Fit loosely the 12 setscrews (B2).



Caution: Ensure that the arrow marked on the expansion bellow points towards the turbochargers. The arrow indicates the direction that the exhaust gas must flow.

- 5 If removed fit the expansion bellows (B6) complete with a new gasket to the rear exhaust manifold (B7). Tighten the 4 nuts and bolts to 58 Nm (42.8 lbf ft) 5,9 kgf m.

Continued

-
- 6** Align the front exhaust manifold (B8) to the expansion bellows (B6) and a new gasket. Also align the front manifold (B8) to the cylinder head and with 3 new gaskets.
 - 7** Fit loosely fit the 12 setscrews (B1) and the 4 bolts and nuts (B3).
 - 8** Tighten the 12 rear setscrews (B2) evenly to a torque of 70 Nm (52 lbf ft) 7,1 kgf m.
 - 9** Tighten the 12 front setscrews (B1) evenly to a torque of 70 Nm (52 lbf ft) 7,1 kgf m.
 - 10** Tighten the nuts and bolts (B4), (B5) and (B3) to a torque of 58 Nm (42.8 lbf ft) 5,9 kgf m.

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4

Piston and connecting rod assemblies

General description

The pistons are fitted with two compression rings and an oil control ring. The aluminium alloy pistons have a hard wearing reinforced top ring groove. The high specification tapered top ring, with a cut back piston land, provides a pressure balance that, along with improved oil removal, ensures low emissions in operation.

The pistons are cooled by the piston cooling jets.

Axial location of the fully floating gudgeon pin is by circlips.

The connecting rods are machined from 'H' section forgings. The connecting rods have a wedge shaped small end and bush.

Piston and connecting rod

To remove

Operation 4-1

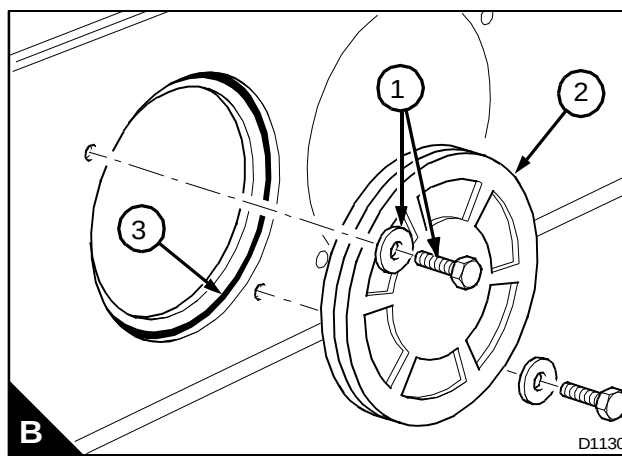
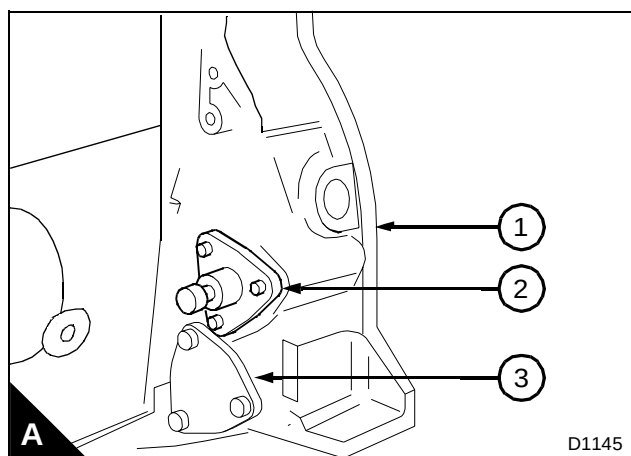
Special requirements

Special tools	
Description	Part number
Engine cranking device	SE253
Piston removal and installation tool	T6253/212

Warning! Disconnect the batteries and any other power that can start the engine.

Note: The cylinder heads are separate items and can be removed separately.

- 1 Remove the required cylinder head, see Operation 3-4.
- 2 To remove the piston cooling jets, see Operation 4-11.



- 3 Fit the engine cranking device (A2).

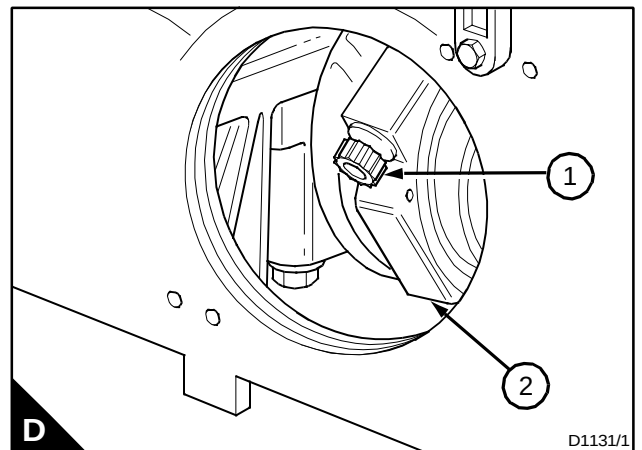
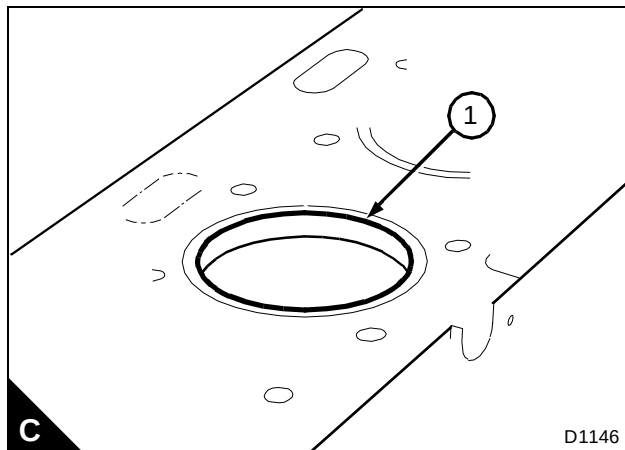
Note: The cranking device (A2) may be fitted either side of the flywheel housing (A1). To fit the cranking device remove the inspection cover (A3) or the starter motor.

- 4 Thoroughly clean the area around the inspection cover (B2). Remove the 2 fasteners and the washers (B1) from the crankcase. Remove the inspection cover (B2). Also remove the "O" ring (B3).
- 5 Use the engine cranking device to rotate the crankshaft to allow access to the big end fasteners.

Continued

6 Remove the carbon build up from around the top of the cylinder liner bore (C1).

Caution: Do not damage the cylinder liner when the carbon is removed.

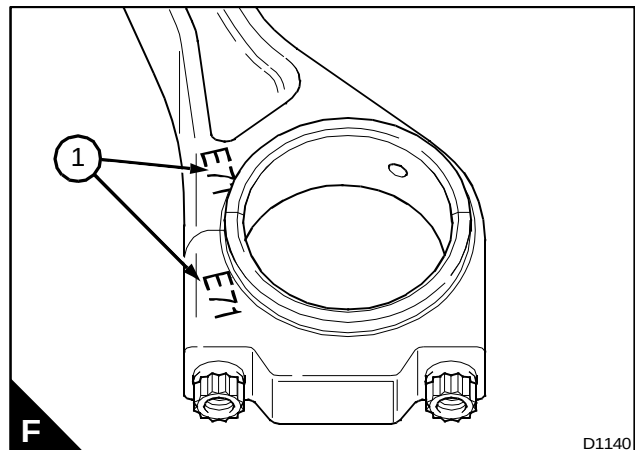
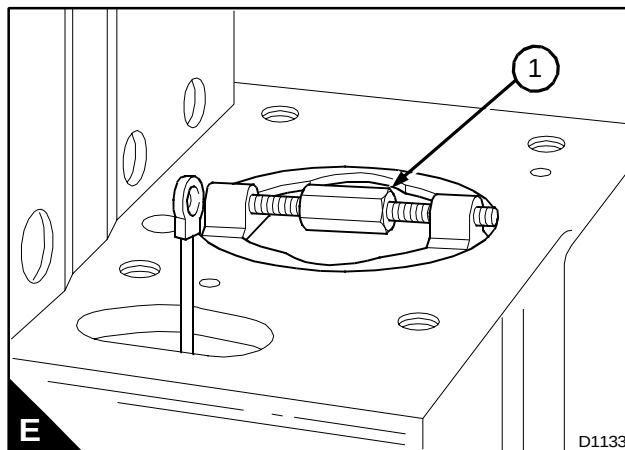


7 Remove the fasteners (D1) and remove the bearing cap (D2).

8 Rotate the crankshaft until the relevant connecting rod is just after TDC.

Note: Make sure that the bearing shell is still in the connecting rod.

9 Fit the removal tool (E1) into the valve cut-out in the top of the piston.



10 Carefully remove the piston and connecting rod, complete with the bearing shell.

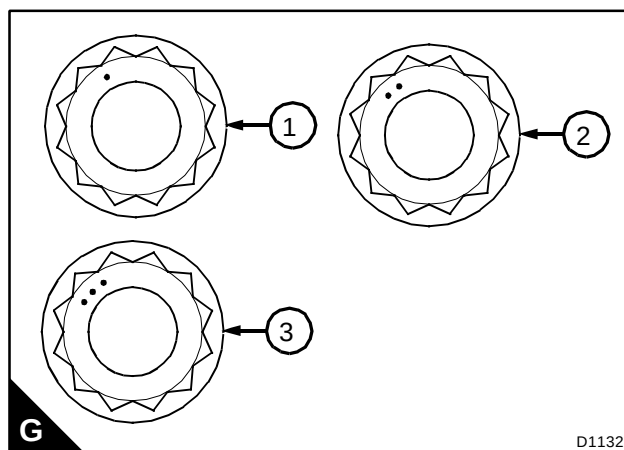
11 Remove the tool (E1) from the piston.

Caution: Do not etch or centre punch the connecting rod assembly to identify the cylinder bore it was removed from.

12 Check that the connecting rod and cap have the correct identification marks (F1). Keep the relevant connecting rod, cap and bearing shells together. Also mark the connecting rod assembly to identify the cylinder bore it was removed from.

Continued

13 Mark the big end fasteners to show the number of times that it has been used (G).



- (G1) First time removed.
- (G2) Second time removed.
- (G3) Third time removed.

Caution: At the fourth time of removal, the fastener (G3) must be renewed.

Special requirements

Special tools	
Description	Part number
Piston ring compression tool	T6253/139
Piston removal and installation tool	T6253/212
A 30° indicator socket	SE671K

Caution: If the original piston and rings are not renewed they must be fitted in the original cylinder.

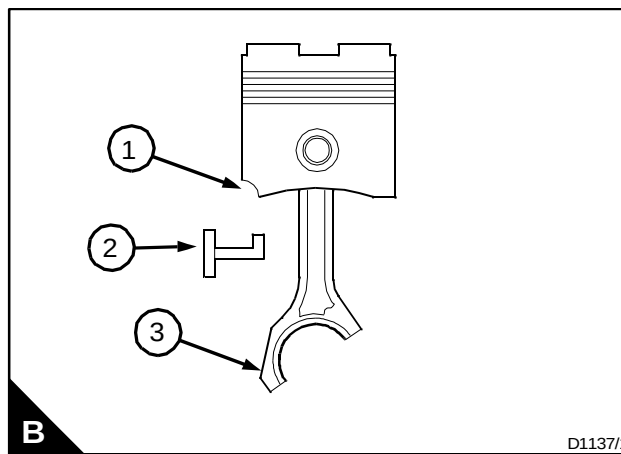
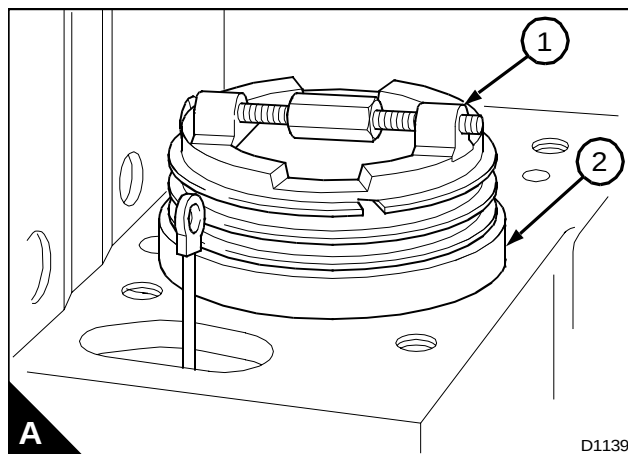
Note: If a new connecting rod is to be fitted, the weight of the new connecting rod must be within the range of of the original connecting rod. The weight of the connecting rod is marked on the rod.

- 1 Ensure that the piston, cylinder bore, crank pin and the big end of the connecting rod are clean and free from damage. Lubricate the piston and the cylinder liner with clean engine lubricating oil.
- 2 Check that the bearing shells are fitted correctly in the connecting rod and cap, see Operation 4-6. Lubricate the bearing shells with clean engine lubricating oil.
- 3 Fit the piston installation tool (A1) into the valve cut-out in the top of the piston.
- 4 Check that the piston cut out (B1) is aligned correctly to the long side of the connecting rod (B3).

Caution: Do not fit the piston cooling jet until the piston assembly is fitted.

5 Check that the piston ring gaps are 120° apart. Fit the ring compression tool to the piston (A2). Check that the cut out in the piston (B1) is aligned to the piston cooling jet (B2), when the piston cooling jet is fitted in the engine. Fit the assembly into the correct cylinder.

6 Push the piston and connecting rod assembly through the piston ring compression tool (A2) and down the cylinder bore, onto the crank pin.



7 Remove the piston ring compression tool (A2).

Continued

8 Lubricate the threads and the head of the big end fasteners with clean engine oil.

9 Check the identification marks on the cap (D1) are correct for the connecting rod and the cylinder. Fit the cap and fasteners and ensure that the marks (D1) are on the same side.

10 Fit the bolts, hand tight whilst checking the end cap has pulled fully up to the connecting rod.

11 Torque the connecting rod bolts to 82 lb.ft (110 Nm)

Note: To complete the operation a further 60° tightening is required but due to a restricted access this is carried out in two 30° steps. To perform this procedure two people are required.

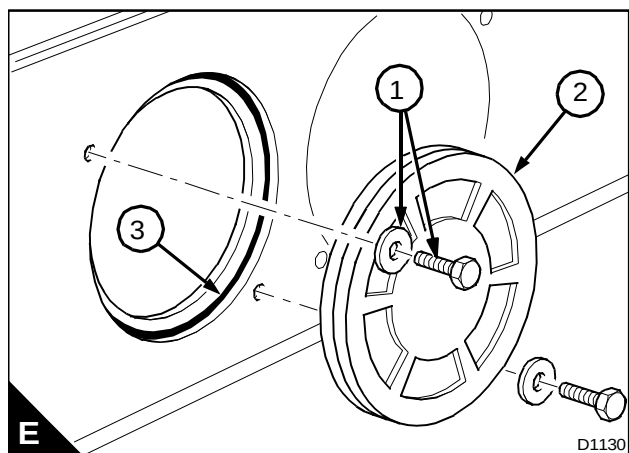
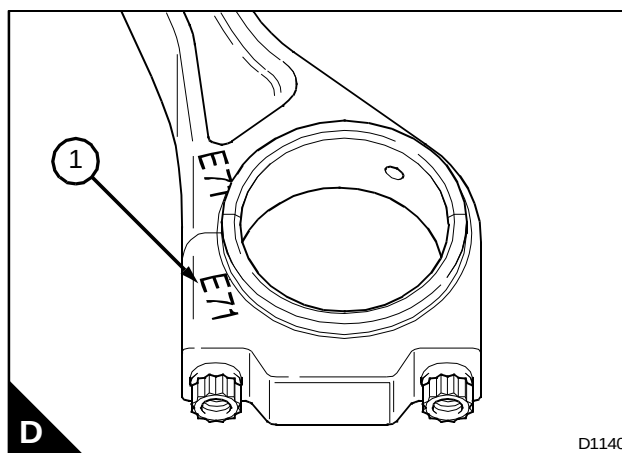
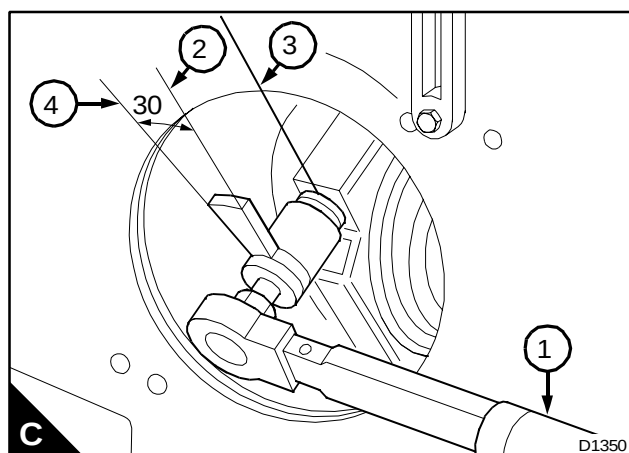
12 Locate the socket indicator on the big end bolt and apply light pressure to the wrench (C1).

13 Set the leading edge of the indicator (C2) on the centre line of the big end bolt (C3).

14 Tighten the big end bolt until the trailing edge of the indicator (C4) is in line with the centre line of the big end bolt (C3).

15 Remove the socket indicator from the big end bolt head and turn it back one serration of the big end bolt. This will bring the leading edge of the indicator (C2) again in line with the centre line of the big end bolt.

16 Tighten the big end bolt until the trailing edge of the indicator is again in line with the centre line of the big end bolt completing the required 60° angle.



17 Fit the "O" ring (E3) into the recess in the inspection hole and fit the inspection cover (E2). Fit the washers and the fasteners (E1). Torque the fasteners to 50 Nm 37 lbf ft

18 Fit the piston cooling jet or jets, see Operation 4-12.

19 Fit the required cylinder head or heads, see Operation 3-4.

Piston rings

To remove

Operation 4-3

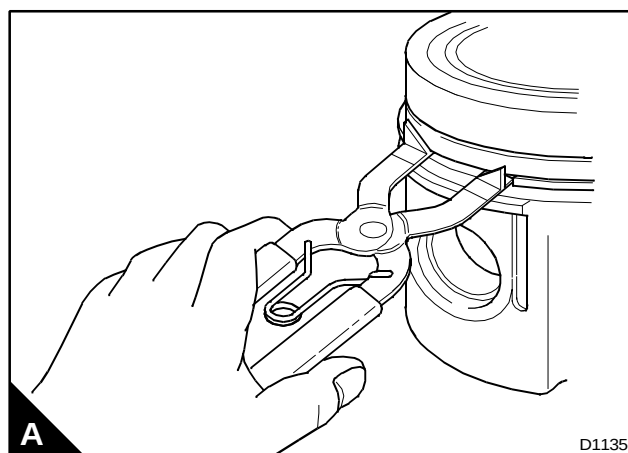
Special requirements

Special tools	
Description	Part number
Piston ring tool	T6253/256

Note: The pistons are fitted with two compression rings and an oil control ring. All the piston rings are above the gudgeon pin. To ensure that the correct type of piston ring is obtained always use the engine identification number to order new parts.

Caution: Only expand the ring gaps enough to ensure that the ends of the rings do not damage the piston when the ring is removed.

- 1 Remove the piston rings with the piston ring tool (A). Keep the rings with their relevant piston.
- 2 Identify each ring as they are removed.



To fit

Operation 4-4**Special requirements**

Special tools	
Description	Part number
Piston ring tool	T6253/256

Cautions:

- Only expand the ring gaps enough to ensure that the ends of the rings do not damage the piston when the ring is put into position.
- If the old piston rings are to be fitted, they must be fitted into the original cylinder bore. Care must be taken to fit the rings the correct way up.

Note: Use the piston ring tool to fit the piston rings.

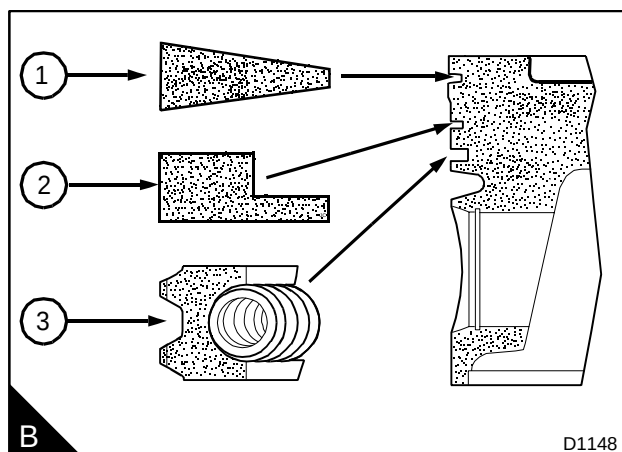
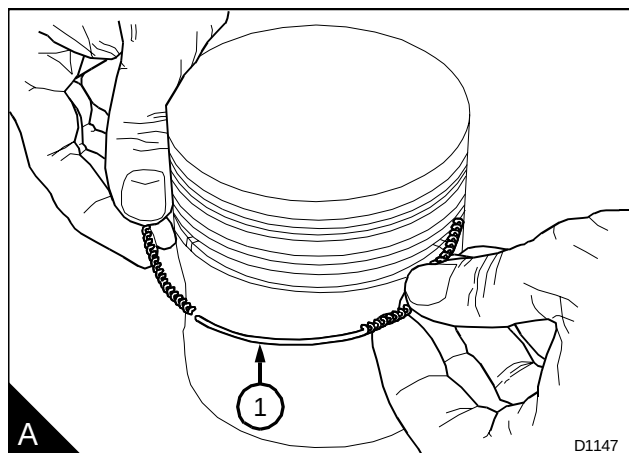
1 Fit the spring of the oil control ring in the bottom groove with the latch pin (A1) inside both ends of the spring. Fit the oil control ring over the spring (B3). Ensure that the ring gap is at 180° to the latch pin.

Note: The two compression rings may have a paint mark or the word "TOP". The ring must be fitted to face the top of the piston.

2 Fit the stepped ring (B2) into the second groove, with the word "TOP" towards the top of the piston.

3 Fit the tapered, top ring (B1) with the word 'TOP' towards the top of the piston.

4 Ensure that the ring gaps are 120° apart.



Piston and connecting rod assembly

To dismantle

Operation 4-5

Special requirements

Special tools	
Description	Part number
Circlip pliers	T6253/238

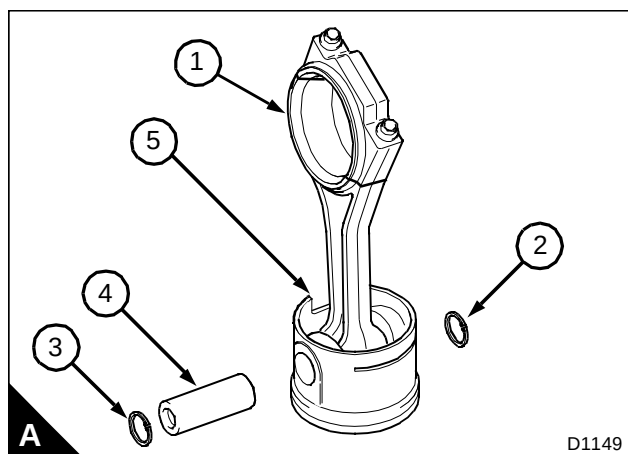
Caution: Make a temporary mark on the piston. Do not scratch, etch or stamp the piston surface.

- 1 Put a temporary mark on the piston to indicate the cylinder number the piston was removed from.
- 2 Remove the circlips (A2) and (A3) that retain the gudgeon pin (A4). Discard the old circlips.
- 3 Push the gudgeon pin out by hand. If the gudgeon pin is tight to move, heat the piston to 40/50 °C (100/120 °F) for easy removal of the gudgeon pin.
- 4 Remove the bearing shells from the connecting rod and the bearing cap.
- 5 Inspect the piston, see Operation 4-7 and connecting rod assembly, see Operation 4-8.

To assemble

Operation 4-6

- 1 Clean the bore of the small end bush and lubricate it with clean engine lubricating oil.
- 2 Fit a new circlip (A2) in the circlip groove of one of the gudgeon pin bosses. Ensure that it fits correctly in the groove.
- 3 With the piston upside down, put the connecting rod in position. Align the long side of the connecting rod (A1) to the cut out in the piston (A5).



Notes:

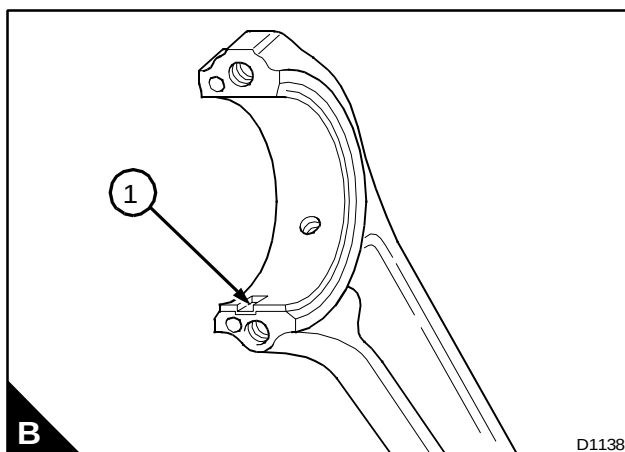
- If the original piston is used, ensure that it is assembled to the correct connecting rod and is used in the original cylinder.
- If a new connecting rod is fitted, ensure that it is of the correct weight grade.

4 Lubricate the gudgeon pin bosses with clean engine lubricating oil and push in the gudgeon pin (A4) towards the circlip. If the gudgeon pin is a tight fit in the piston, heat the piston to 40/50 °C (100/120 °F) before the gudgeon pin is fitted.

Note: The gudgeon pin is a fully floating type.

- 5 Fit a new circlip (A3) in the other groove in the gudgeon pin boss. Ensure that it fits correctly in the groove.

Continued



6 Clean the bearing face of the connecting rod and the bearing cap. Install the location tag of the bearing shell (B1) into the recess in the connecting rod and fit together.

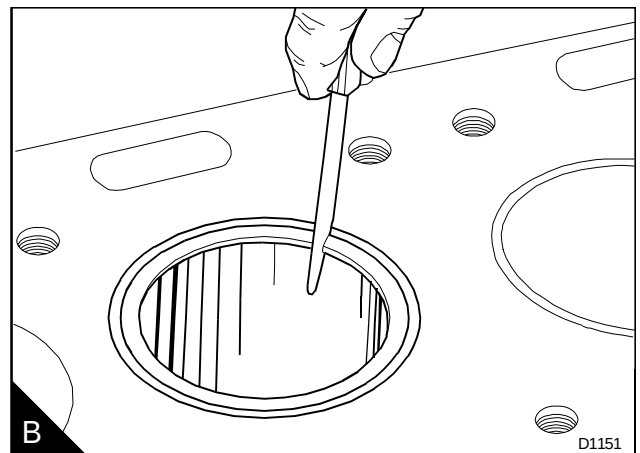
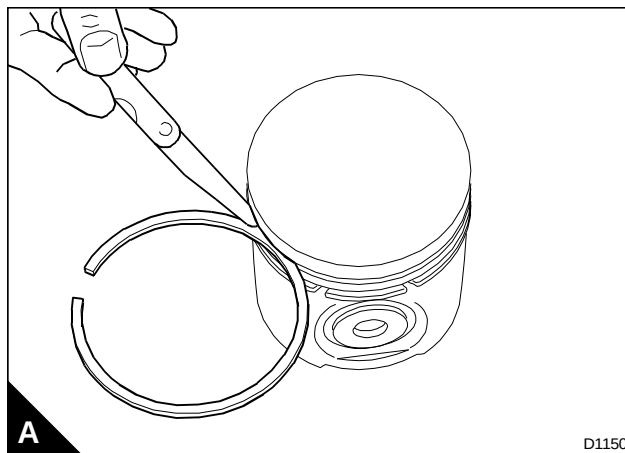
7 Install the location tag of the bearing shell into the recess in the bearing cap and fit together.

Piston and piston rings

To inspect

Operation 4-7

- 1 Check the piston for wear, other damage, and remove all debris in and around the oil cooling gallery. Renew as necessary.
 - 2 Remove the piston rings, see Operation 4-3 and clean the piston ring grooves and the piston rings.
 - 3 Fit new piston rings in the grooves and check for wear of the grooves with feeler gauges (A). Compare the piston ring clearance in the groove to that given for new components, refer to the Data and dimensions for "Piston and connecting rod" on page 12, and renew the piston and rings, if necessary.
- Note:** The pistons have a tapered top groove and the piston ring is wedged shaped. The top piston ring clearance cannot be checked by this method.
- 4 Clean all carbon from the top of the cylinder liners. Fit each piston ring in the top part of the cylinder liner and measure the ring gap with feeler gauges (B). The coil spring must be removed from the oil control ring when the gap of this piston ring is measured. For piston ring gaps on new components, refer to the Data and dimensions for "Piston and connecting rod" on page 12.
 - 5 Fit the piston rings, see Operation 4-4.



Connecting rod

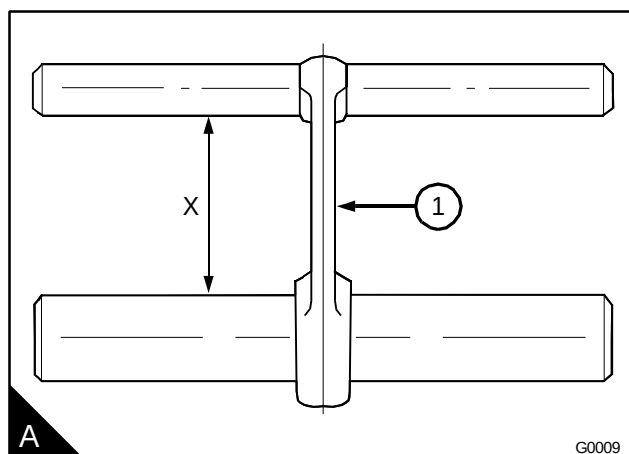
To inspect

Operation 4-8

- 1 Check the small end bush for wear or for other damage and renew it, if necessary.
- 2 Check the connecting rod for distortion (A). See "Piston and connecting rod" on page 12 to identify the correct mandrel sizes.

Note: The large and small end bores in the connecting rod (A1) must be square and parallel with each other within the limits of $\pm 0,0508$ mm (0.002 in) each side of the connecting rod axis on a test mandrel.

- 3 Check the fit of the gudgeon pin in the small end bush and check the gudgeon pin for wear, see "Piston and connecting rod" on page 12.



Small end bush

To inspect**Operation 4-9**

Check that the small end bush is not damaged and is in tolerance, see "Piston and connecting rod" on page 12. Renew if necessary.

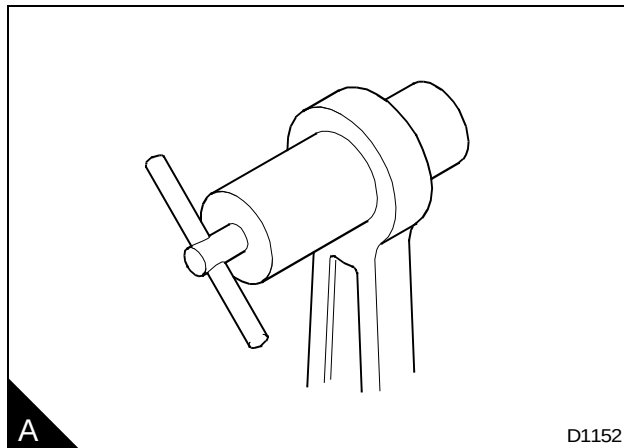
To remove and fit**Operation 4-10**

Special requirements

Special tools	
Description	Part number
Small end bush extractor and insertion tool	T6253/159

The special tool (A) is design to remove and fit the small end bush. The tool as angled side that help keeps the bush aligned.

Caution: *The bush of the connecting rod must be aligned to the parent bore and when fitted the bush must not protrude from the parent bore.*



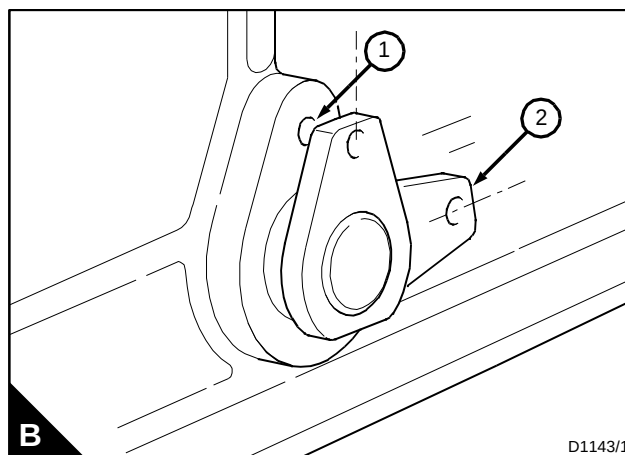
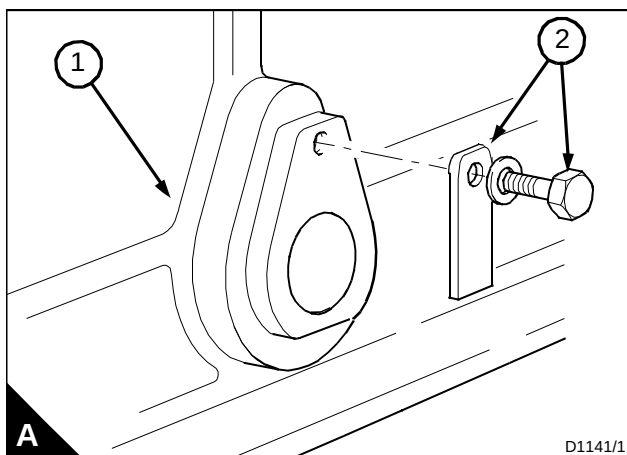
Piston cooling jets

To remove

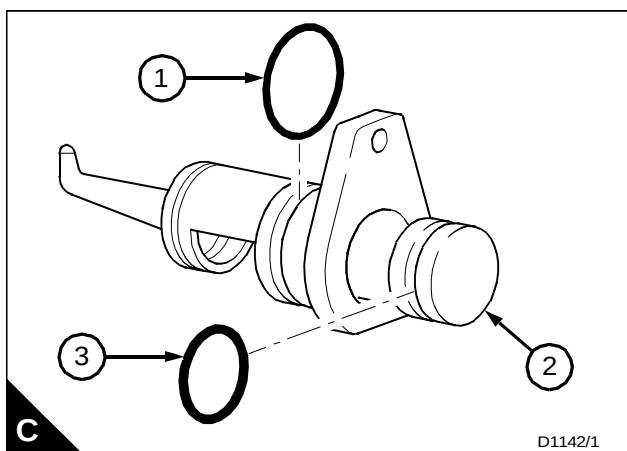
Operation 4-11

Caution: Before the piston cooling jet is removed from the crankcase, ensure that the piston is at TDC for this particular cylinder.

- 1 Thoroughly clean the area around the piston cooling jet (A1). Remove the setscrew and the clamp (A2) from the crankcase.
- 2 Rotate the cooling jet (B1) 90° to the right (B2) and remove the cooling jet from the crankcase.



- 3 Remove the plug (C2) and discard both 'O' ring (C1) and (C3).
- 4 Clean the cooling jet and check for damage. Renew the cooling jet if necessary.



To fit

Operation 4-12

Special requirements

Special tools	
Description	Part number
Drift	T9142/21

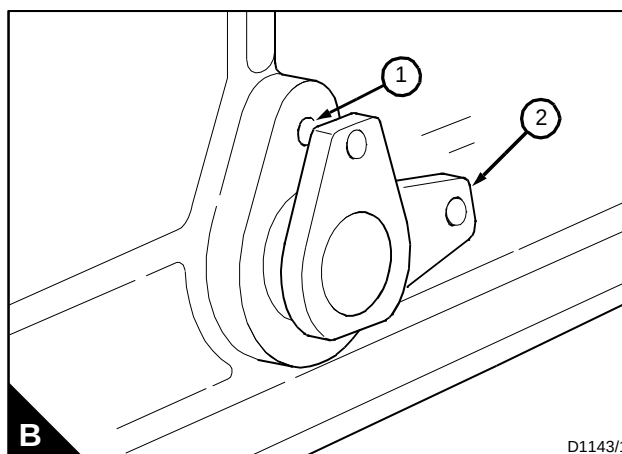
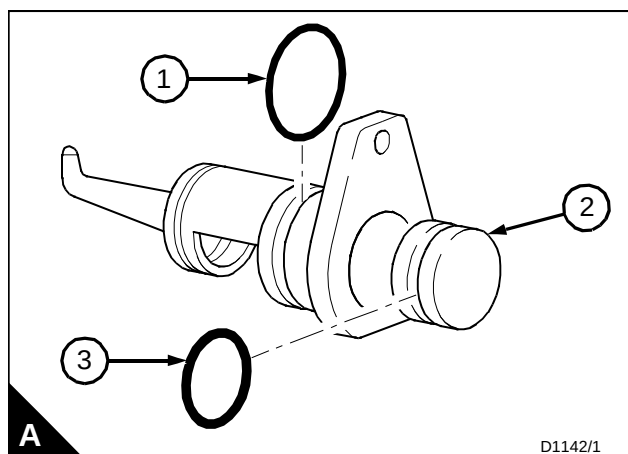
Cautions:

- Before the piston cooling jet is fitted into the engine, ensure that the piston is at TDC.
- The piston cooling jet must be renewed if it is found to be damaged. Failure to do so will damage the engine.

1 Fit a new 'O' ring (A1) to the cooling jet and fit a new 'O' ring (A3) to the plug (A2).

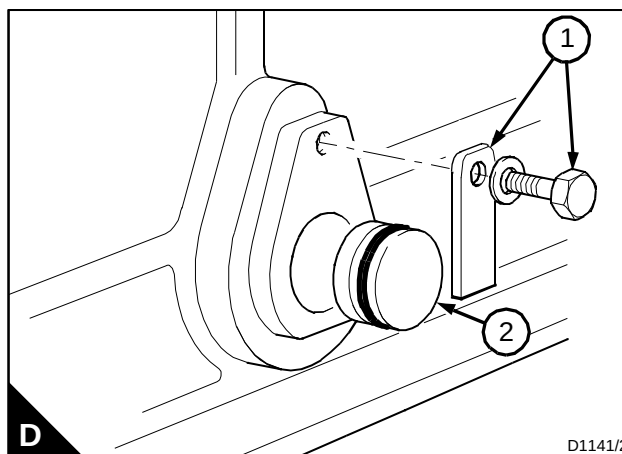
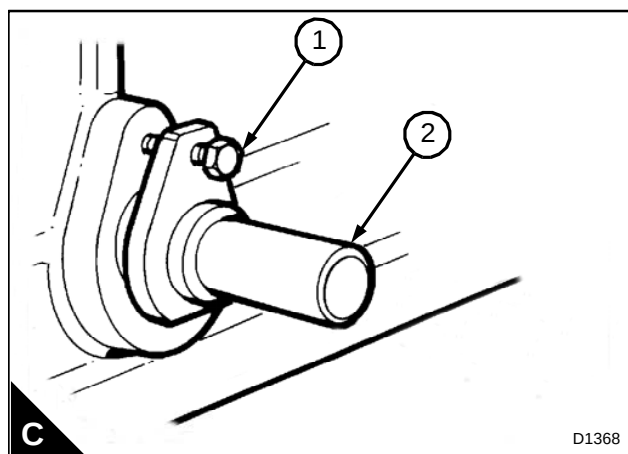
2 Lubricate the cooling jet and the cooling jet hole with clean engine lubricating oil.

3 Hold the cooling jet in position (B2). Push the cooling jet into the crankcase.



4 Rotate the cooling jet 90° to the left and align the cooling jet to the setscrew hole (B1).

5 Loosely fit the setscrew (C1). Hold the drift (C2) on the end of the cooling jet and insert fully.



6 Remove the setscrew (C1). Lubricate the 'O' ring and plug (D2) with clean engine lubricating oil and push the plug into the cooling jet body.

7 Align the clamp and fit the setscrew (D1). Tighten the setscrew to 50 Nm. 37 lbf ft 5 kgf m.

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5

Crankshaft assembly

General description

The crankshaft is forged from chromium molybdenum steel and has seven main journals. There is a large flange at the rear of the crankshaft to which the flywheel is fitted.

End-float and thrust movements are controlled by two 180° thrust washers on both sides of the rear main crankcase bearing.

All of the main bearings have steel backs with an aluminium/tin bearing material. The main bearing caps are made of spheroidal graphite iron.

The front and the rear oil seals are made from two materials. A outer metal cage and a inner synthetic material. The front seal is fitted in the oil seal housing. The housing assembly is fitted to the gear case. The rear seal is a fitted part of the flywheel housing, which is fitted to the crankcase.

These engines have a viscous damper which is fastened to the crank adaptor. The damper is designed for the suppression of torsional vibrations in the engine crankshaft.

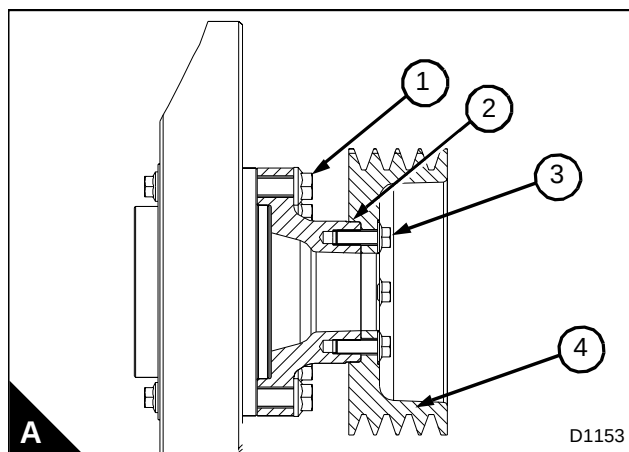
Crankshaft pulley and adaptor

To remove

Operation 5-1

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

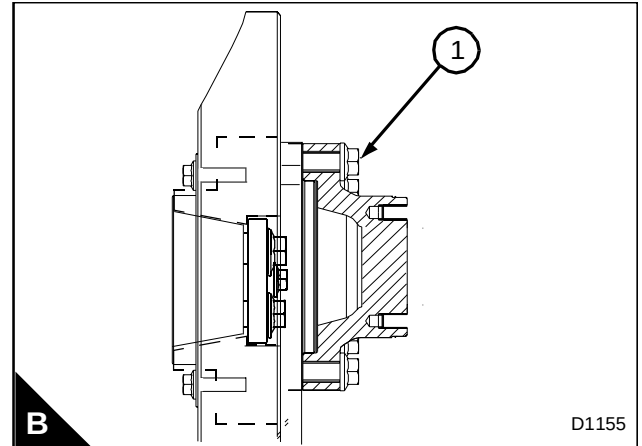
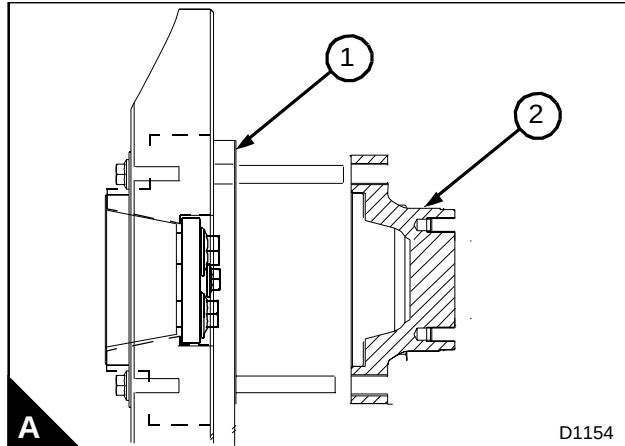
- 1 Remove the radiator, see Operation 12-21.
- 2 Remove the fan belts, see Operation 12-14.
- 3 Remove the 2 fasteners (A3) and fit 2 suitable studs. Remove the other 2 fasteners and remove the pulley (A4) from the pulley adaptor (A2). Remove the two studs.
- 4 Remove the 2 fasteners (A1) and fit 2 suitable studs. Remove the other 6 fasteners and remove the pulley adaptor (A2). Remove the two studs.



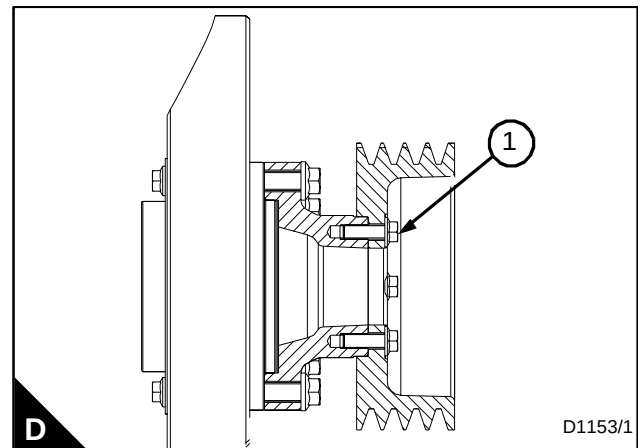
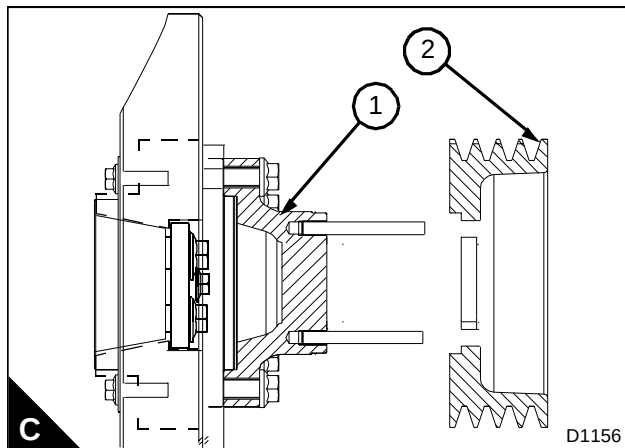
To fit

Operation 5-2

- 1 Check that all the components are clean and free from damage.
- 2 Fit 2 suitable studs into the damper adaptor (A1) and fit the pulley adaptor (A2).
- 3 Loosely fit the fasteners (B1) and remove the studs and loosely fit the remainder.



- 4 Tighten the pulley adaptor fasteners (B1) to a torque of 340 Nm (250.7 lbf ft) 34,6 kgf m.
- 5 Fit 2 suitable studs into the pulley adaptor (C1) and fit the pulley (C2).
- 6 Loosely fit the fasteners (D1) and remove the studs and loosely fit the remainder.
- 7 Tighten the pulley fasteners (D1) to a torque of 85 Nm (62 lbf ft) 8,6 kgf m.



- 8 Fit the fan belts, see Operation 12-14.
- 9 Fit the radiator, see Operation 12-22.

Crankshaft vibration damper assembly

To remove

Operation 5-3

Special requirements

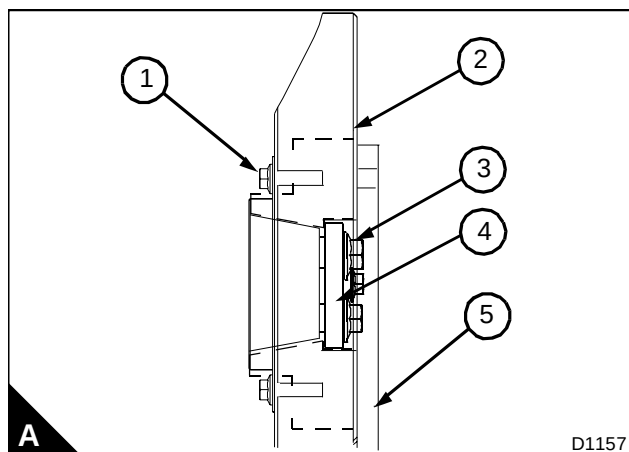
Special tools	
Description	Part number
Puller	T6253/209

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

- 1 Remove the mounting bracket for the fan belt adjuster see Operation 12-13.
- 2 Remove the crankshaft pulley and adaptor, see Operation 5-1.

Note: Use suitable lift equipment in order to remove the damper assembly.

- 3 Remove the fasteners (A3) and the plate (A4). Use the special puller remove the damper assembly.
- 4 Remove the fasteners (A1) and remove the damper adaptor (A5) from the damper (A2).



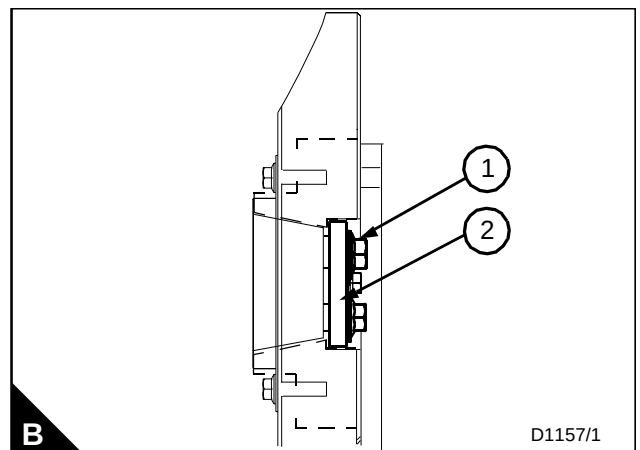
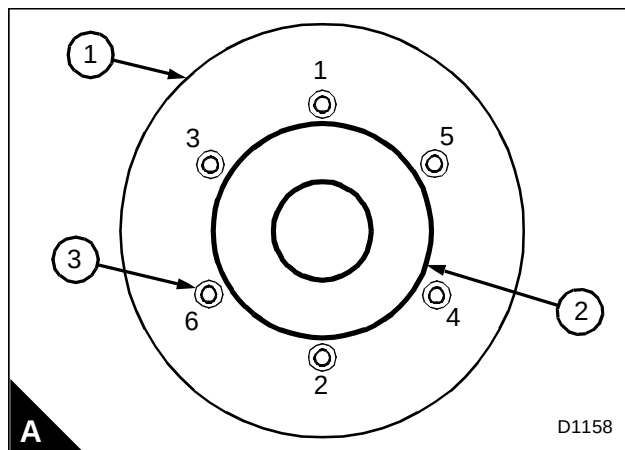
To fit

Operation 5-4

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

- 1 Check that all parts are clean and free from damage. Align the damper (A1) to the damper adaptor (A2) and loosely fit the 6 fasteners (A3).
- 2 Tighten the fasteners to the following procedure and sequence in the table below and in graphic (A).

Stage	Torque
1	Hand tighten
2	160 Nm (118 lbf ft)



Note: Use suitable lift equipment in order to lift the assembly into position.

- 3 Fit the retaining plate (B2) and the 3 fasteners (B1). Torque the fasteners to 340 Nm (250 lbf ft) 34,6 kgf m.

Crankshaft

To remove

Operation 5-5

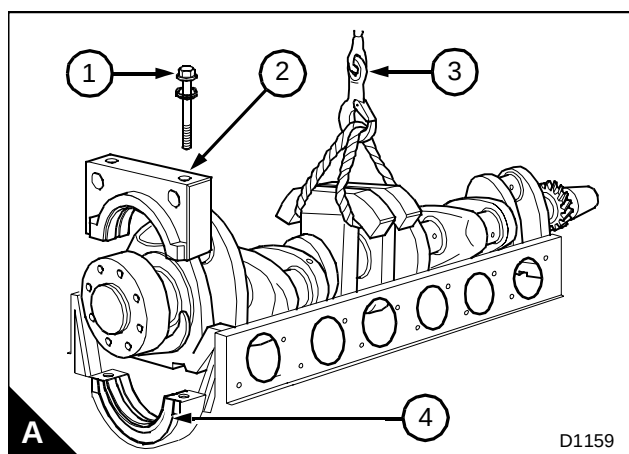
Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

Caution: To remove the crankshaft is a major overhaul. The engine must be rotated to allow access to the crankshaft.

- 1 Remove the cylinder heads, see Operation 3-4.
- 2 Remove piston and connecting rods, see Operation 4-1.
- 3 Remove the flywheel housing, see Operation 13-3.
- 4 Remove the gear case, see Operation 6-1.
- 5 Remove the crankshaft idler gear and the camshaft gear, see Operation 6-7 and Operation 6-5.

Note: Check that the bearing caps are marked correctly.

- 6 Remove the main bearing setscrews and washers (A1). Remove the main bearing caps (A2) from the engine. Each setscrew must be marked to show the number of times that it has been used.



- 7 Remove the two thrust washers (A4) from both sides of the rear main bearing.

Note: Use suitable lift equipment (A3) and carefully remove the crankshaft from the crankcase.

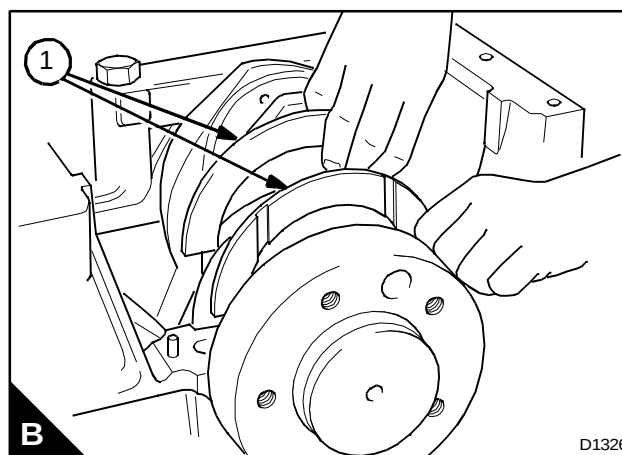
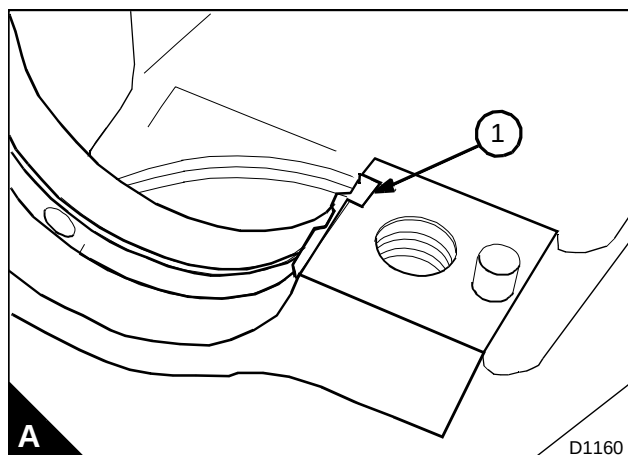
- 8 Remove the main bearing shells from the crank case.
- 9 Clean all the crankshaft components and check for wear, see "Crankshaft, main bearings and flywheel" on page 13.

To fit

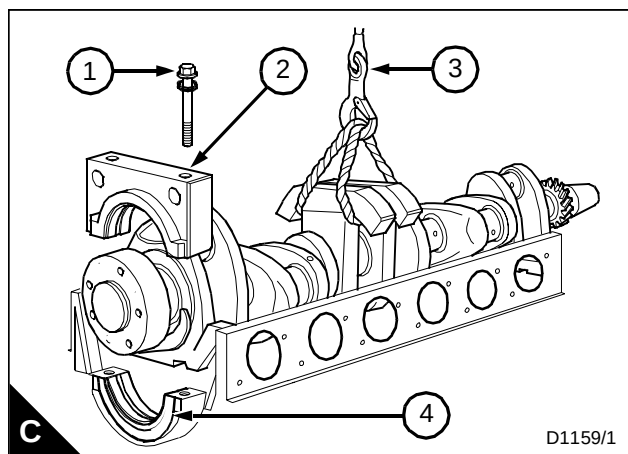
Operation 5-6

Caution: Do not use a main bearing setscrew that has 3 marks on the head of the setscrew.

- 1 Ensure that all internal lubricating oil passages are clean and free from restriction. Ensure that the crankshaft journals are clean.
- 2 Clean the main bearing housings and fit new bearing shells. Ensure the bearing shell location tags are fitted correctly in their recesses (A1). Lubricate the bearings with clean engine lubricating oil.
- 3 Use suitable lift equipment to put the crankshaft above the crank case bearing journals and carefully lower the crankshaft onto the bearing shells.
- 4 Clean and lubricate the two halves of the thrust washers (B1) and slide them into their recesses on both sides of the bearing housing. Ensure that the slotted sides of the thrust washers are fitted away from each other.



- 5 Clean the bearing caps (C2). Fit the bearing shells to the caps with the location tags fitted correctly in their recesses. Lubricate the bearings with clean engine lubricating oil.
- 6 The identification number stamped on the bearing caps must be the same as the number stamped on the bottom face of the crank case. Fit the bearing caps (C2), lubricate the main bearing setscrews and washers (C1) with clean lubricating engine oil. Fit the setscrews (C1).



Continued

7 Tighten the main bearing setscrews in the sequence give in (D). Tighten the main bearing setscrews to torque given in table 1. At each stage check that the crankshaft will rotate freely.

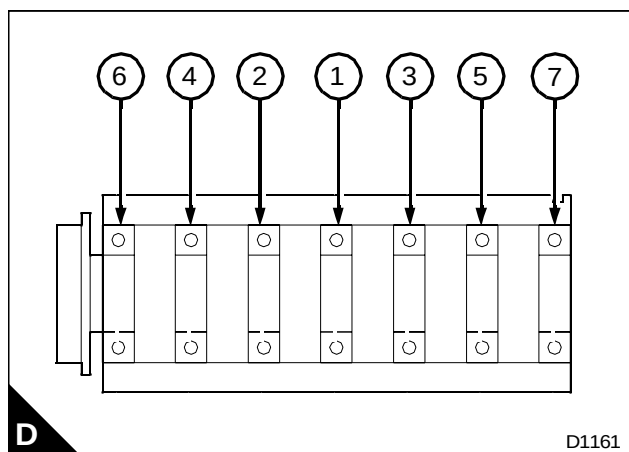


Table 1

Stage	Torque
1	Tighten by hand
2	135 Nm (100 lbf ft)
3	270 Nm (200 lbf ft)
4	540 Nm (389 lbf ft)
5	783 Nm (577 lbf ft)

8 Check the crankshaft end float, see Operation 5-7.

9 Rotate the crankshaft in order to align the timing marks.

10 Fit the crankshaft idler gear and camshaft gear, see Operation 6-8 and Operation 6-6.

11 Fit the gear case, see Operation 6-2.

12 Fit the flywheel housing, see Operation 13-1.

13 Fit piston and connecting rods, see Operation 4-2.

14 Fit the cylinder heads, see Operation 3-4.

15 Fill the engine with coolant and lubrication oil and prime the fuel system. Refer to the relevant Users Handbook.

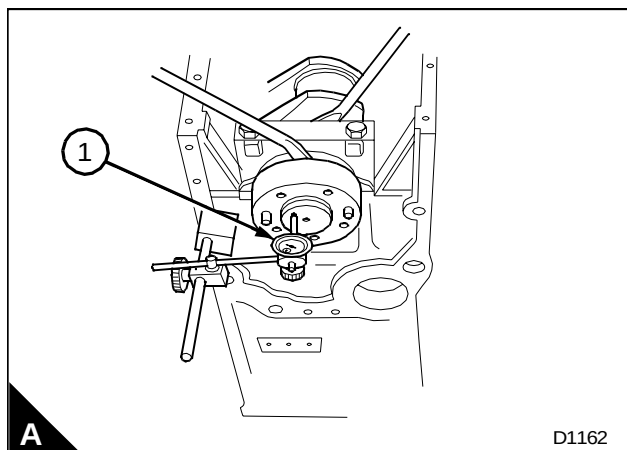
To check the crankshaft end float

Operation 5-7

The axial movement of the crankshaft is controlled by thrust washers fitted to both sides of the rear main bearing.

Force the crankshaft towards the front of the engine and back to the rear of the engine. Check the end-float with a dial gauge (A1).

To check the tolerance for the crankshaft, refer to "Crankshaft, main bearings and flywheel" on page 13



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6

Gearcase and drive assembly

General description

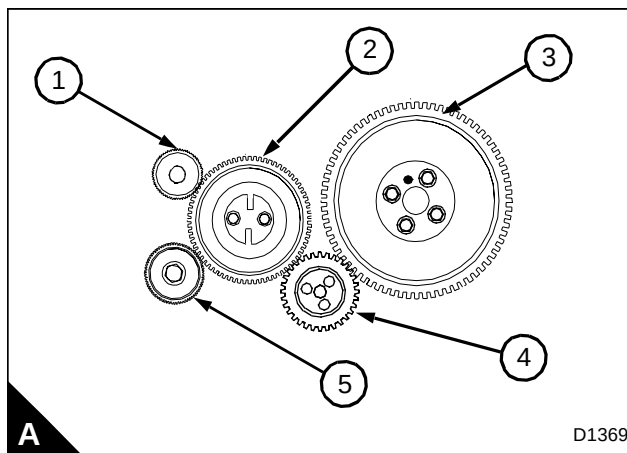
The gear case is made of aluminium, the gears and the camshaft are made of case hardened steel. The gears are of a helical design.

The back plate is made of steel and the gear case is mounted on the back plate.

The drive from the crankshaft gear (A4) is passed through an idler gear (A2) to the oil pump gear (A5). The water pump transmits the drive through a shaft in order to drive the alternator. The oil pump is mounted on the rear of the back plate.

The idler gear also transmits the power to the coolant pump gear (A1). The coolant pump is mounted on the front of the gear case.

The camshaft gear (A3) is driven by the crankshaft gear. The camshaft rotates at half crankshaft speed.

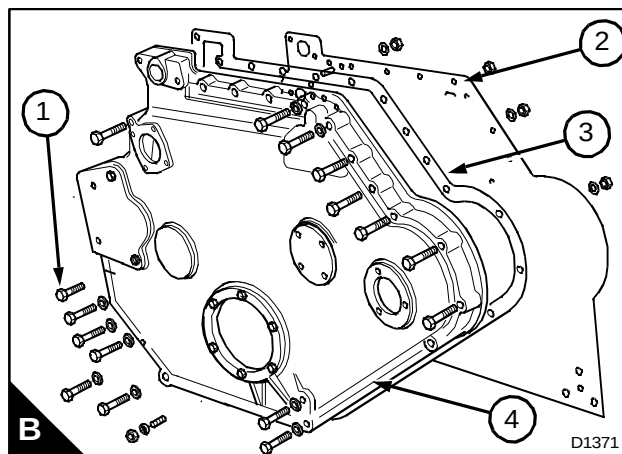
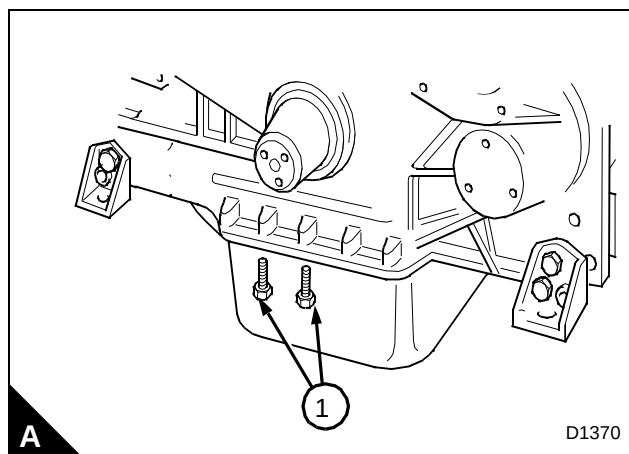


Gearcase

To remove

Operation 6-1

- 1 Drain the engine coolant, Refer to the relevant Users Handbook.
- 2 Remove the fan drive, see Operation 12-15.
- 3 Remove the vibration damper, see Operation 5-3.
- 4 Remove the coolant pump, see Operation 12-6.
- 5 Remove the stop solenoid, see Operation 14-12.
- 6 Remove stop lever.
- 7 Remove the engine breather, see Operation 9-11.
- 8 Remove the thermostat housing, see Operation 12-5.
- 9 Remove all the setscrew (A1) that hold the sump to the gear case.
- 10 Loosen the suction pipe from the oil pump. Loosen all other sump setscrew and allow the sump to move down onto the loosened setscrews.



- 11 Remove the fasteners (B1) that hold the gear case (B4) to the back plate (B2).

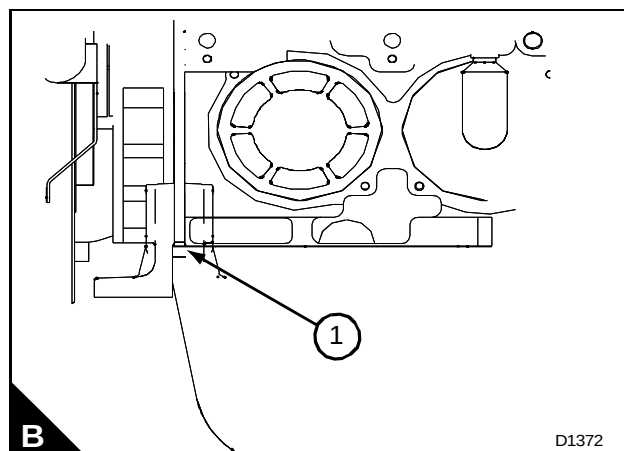
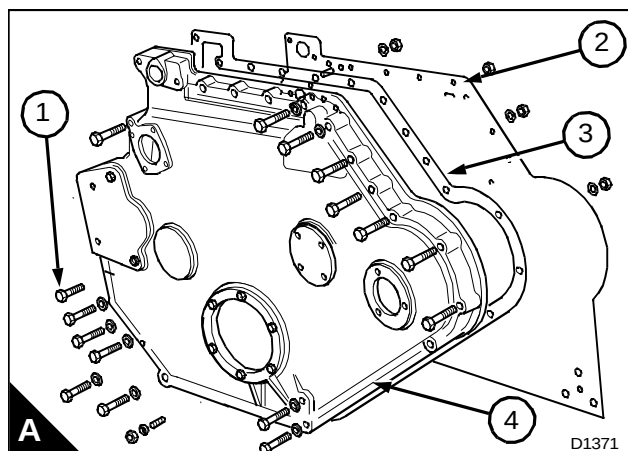
Note: The gear case is dowelled to the back plate.

- 12 Remove the gear case from the back plate.
- 13 Remove the joint (B3).

To fit

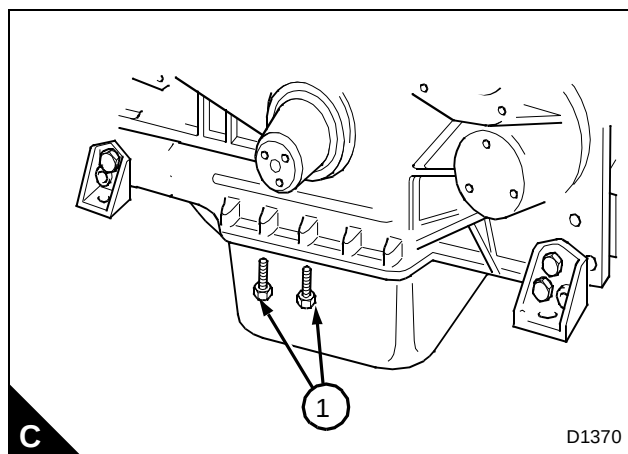
Operation 6-2

- 1 Ensure that the back plate, gears and gear case are clean and free from damage.
- 2 Fit a new joint (A3) on to the back plate (A2).



Note: In order to help seal the gear case to the sump face, apply a suitable sealant across the sump joint on both sides of the sump (B1).

- 3 Align the gear case (A4) to dowels and fit the gear case on to the back plate (A2).
- 4 Fit the fasteners (A1) and tighten by hand.
- 5 Fit the setscrews (C1) and tighten by hand.
- 6 Tighten the fasteners (A1) evenly to 50 Nm (36.8 lbf ft) 5 kgf m.
- 7 Tighten the sump setscrews (C1) to 40 Nm (30 lbf ft) 4 kgf m. Tighten the other sump setscrews to 50 Nm (36.8 lbf ft) 5 kgf m.



- 8 Tighten the oil suction pipe from the sump to the oil pump to the following torque 50 Nm 936.8 lbf ft) 5 kgf m0.
- 9 Fit the thermostat housing, see Operation 12-5.
- 10 Fit the engine breather, see Operation 9-12.
- 11 Fit the coolant pump, see Operation 12-7.
- 12 Fit the stop solenoid, see Operation 14-13.
- 13 Fit stop lever.
- 14 Fit the alternator, see Operation 14-6.
- 15 Fit the fan drive, see Operation 12-15.
- 16 Fit the crankshaft vibration damper assembly, see Operation 5-4.
- 17 Fill the engine with clean lubrication oil, Refer to the relevant Users Handbook.
- 18 Fill the engine coolant, Refer to the relevant Users Handbook.

Front oil seal

To remove

Operation 6-3

Caution: Care must be taken not to damage the oil seal housing when the oil seal is removed.

- 1 Remove the crankshaft vibration damper, see Operation 5-3.
- 2 Remove the nuts from the housing and remove from the gearcase.
- 3 Use a suitable tool in order to remove the oil seal from the housing.
- 4 Discard the oil seal from the housing.
- 5 Ensure that all of the seal is removed from the housing and gearcase.

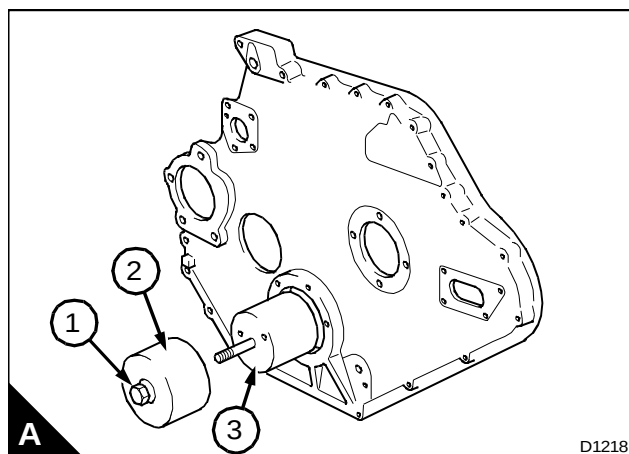
To fit

Operation 6-4

Special requirements

Special tools	
Description	Part number
Carrier alignment tool	T6253/354

- 1 Inspect the housing and the gearcase for damage.
- 2 Fit a new joint over the studs and into the gearcase.
- 3 Fit the housing onto the studs and put the nuts back on the housing. Do not tighten the nuts.
- 4 Use the alignment tool. Place the alignment tool over the crankshaft and push inwards to locate the housing.
- 5 Ensure that the alignment tool is inserted fully into the housing.
- 6 Tighten the nuts on the housing.



- 7 Remove the alignment tool and fit oil seal locator (A3). Then slide the oil seal along the locator, seat it squarely in the housing. Fit the outer sleeve (A2) on (A3) and tighten the nut (A1) until the outer sleeve is fully inserted.

Note: Ensure that the lip side of the seal is towards the oil seal housing.

- 8 Fit the crankshaft vibration damper, see Operation 5-4.

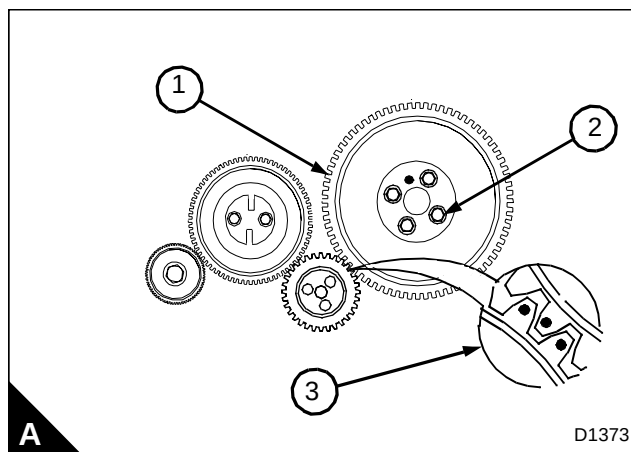
Camshaft gear

To remove

Operation 6-5

Note: The camshaft end float should be checked before the gear is removed, to allow the thrust plate to be fitted correctly. To check the camshaft end float value, refer to "Camshaft and bearings" on page 12.

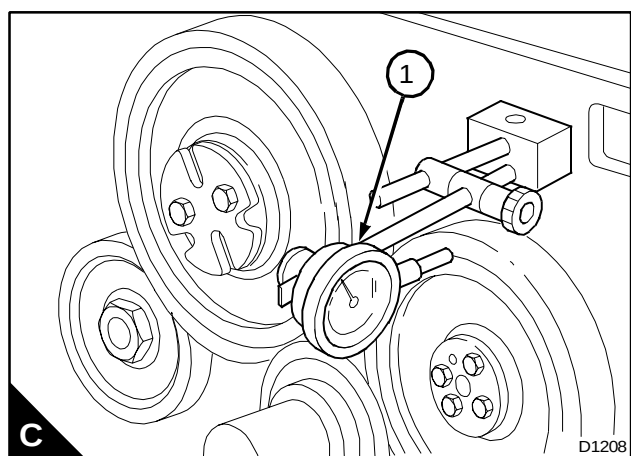
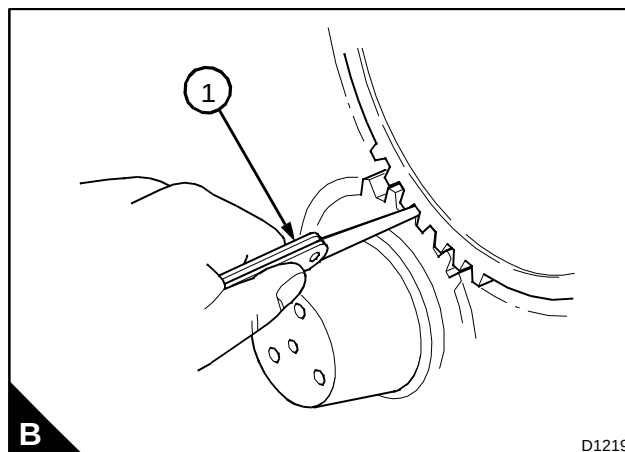
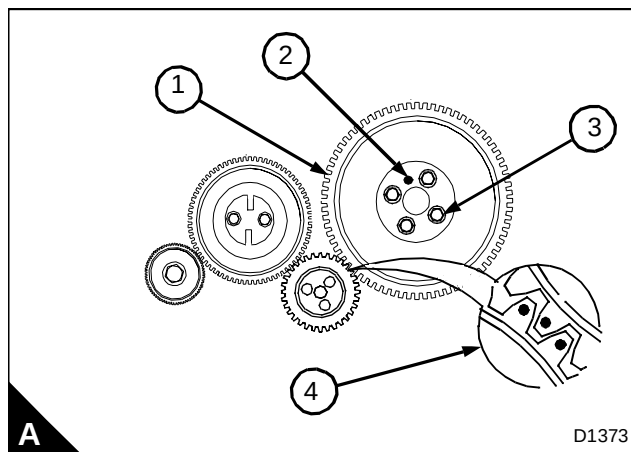
- 1 Remove the gear case, see Operation 6-1.
- 2 Ensure that the timing marks (A3) on the camshaft gear and the crankshaft gear are aligned.
- 3 Remove the setscrews (A2) and remove the camshaft gear (A1).



To fit

Operation 6-6

- 1 Ensure that all the components are clean and free from damage.
- 2 Align the dowel (A2) in the camshaft to the camshaft gear (A1) and align the timing marks (A4) on both gears.
- 3 Check the camshaft end float value, reference "Camshaft and bearings" on page 12.
- 4 Fit the gear (A1) onto the camshaft.
- 5 Fit the setscrews (A3).
- 6 Tighten the setscrews to 150 Nm (110 lbf ft) 15,2 kgf m.
- 7 Use a dial gauge or feeler gauge (B1) to check the camshaft gear back lash.
- 8 Use a dial gauge (C1) to check the camshaft end float.

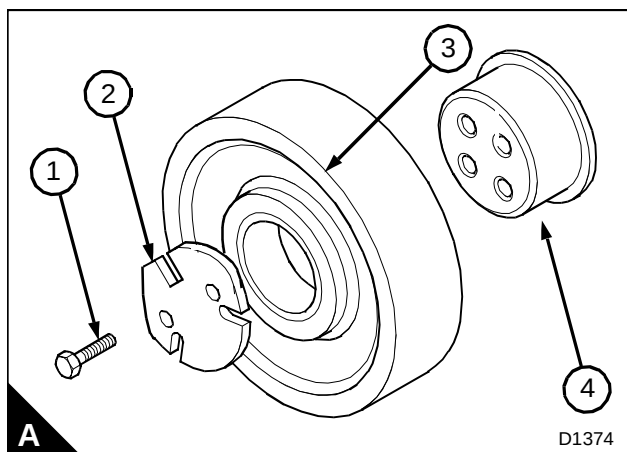


Idler gear

To remove

Operation 6-7

- 1 Remove the 2 setscrews (A1) and remove the plate (A2).
- 2 Remove the gear (A3) and the hub (A4), from the back plate.

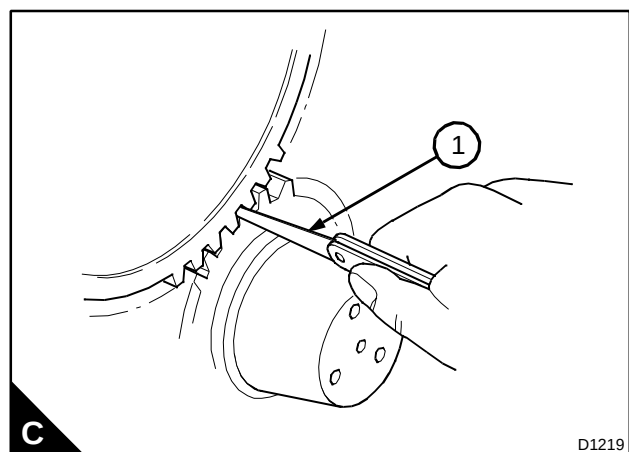
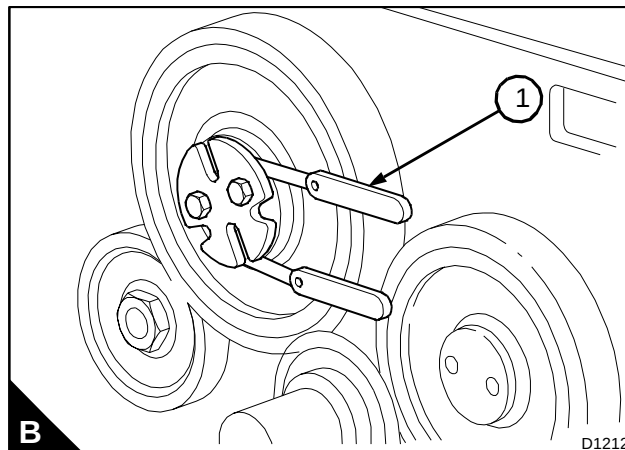
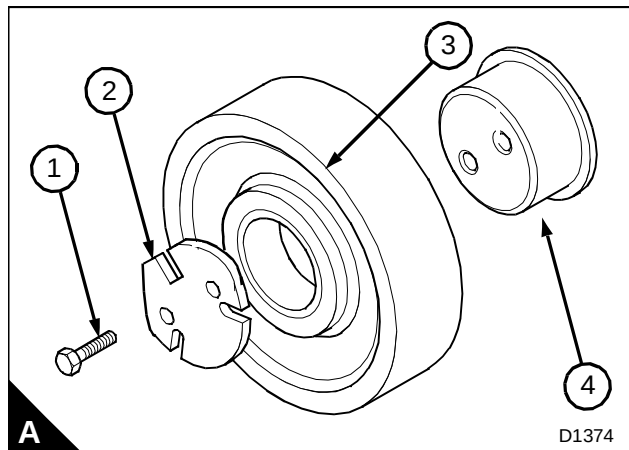


To fit

Operation 6-8

1 Ensure that all the components are clean and free from damage. Check that the oil holes are free from debris.

2 Lubricate the bush in the gear (A3) with clean Lubricating engine oil.



3 Align the hub (A4) to the back plate and fit.

4 Fit the gear (A3) onto the hub (A4).

5 Align the plate (A2) to the hub and fit the setscrews (A1).

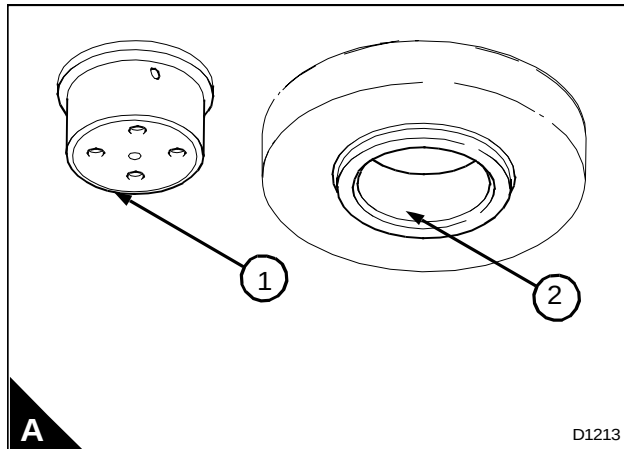
6 Tighten the setscrews to a torque of 50 Nm (36,8 lbf ft) 5 kgf m.

7 Check the end float (B1) and check the back lash (C1) see "Gear train" on page 14.

To check the hub and renew the idler gear bush

Operation 6-9

- 1 Clean the hub (A1) and check for wear, see "Gear train" on page 14
- 2 Use a suitable tool in order to press out the old bush (A2).



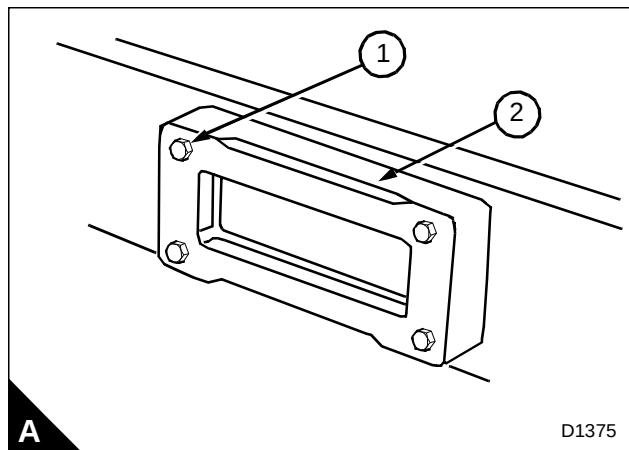
- 3 Ensure that the gear and new bush are clean and free from damage.
- 4 Align the new bush to the gear.
- 5 Use a suitable tool in order to press in the new bush.

Cam followers

To remove and fit

Operation 6-10

- 1 Remove the rockers, see Operation 3-1.
- 2 Remove the air pipe from the charge cooler to the turbocharger, see Operation 9-9.
- 3 Remove the 4 setscrews (A1).



- 4 Remove the cam follower assembly (A2) and the joint. Identify each assembly.
- 5 Remove all the cam follower assemblies from the crank case.
- 6 Clean and check each cam follower assembly, see Operation 6-11.
- 7 Lubricate the assembly with clean lubricating engine oil.
- 8 Fit a new joint to the assembly and fit the assembly into the crank case.
- 9 Fit the 4 setscrews (A1) and torque the setscrews to 50 Nm (36,8 lbf ft) 5 kgf m.
- 10 Fit the rockers, see Operation 3-1.
- 11 Fit the air pipe from the charge cooler, see Operation 12-22.

To check

Operation 6-11

A visual inspection is required of the load bearing surface. If excessive wear or play is present the assembly must be repaired or renewed.

Note: A service exchange unit can be supplied if the cam follower is out of tolerance.

- 1 Mark the position of each cam follower arm.

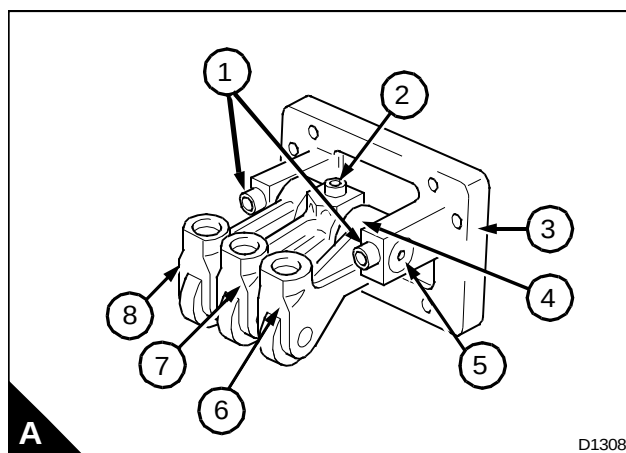
Exhaust arm	Fuel arm	Inlet arm
(A8)	(A7)	(A6)

- 2 Remove the allen screw (A2) and remove the oil thrower.

- 3 Remove the allen screws (A1) and remove the shaft (A5).

Note: The arms are shimmed in order to allow end float of 0,5 to 0,25 mm (0.019 in to 0.0098 in).

- 4 Mark the shims in order to help assemble the unit.



- 5 Clean and inspect all the parts. Renew as necessary.

- 6 Align the cam follower arms (A6) (A7) and (A8). Lubricate the shaft (A5) with clean lubricating oil. Shim the cam follower arms and install the shaft (A5). Align the shaft in order to allow the allen screws (A1) to be fitted.

- 7 Apply Powerpart hydraulic threadseal part number 21820121 to the allen screw threads. Fit the allen screws (A1) and tighten the allen screws to Nm 68 (50,1 lbf ft) 6.9 kgf m.

- 8 Align the oil thrower and fit the allen screw (A2). Tighten the allen screw securely.

Camshaft

To remove

Operation 6-12

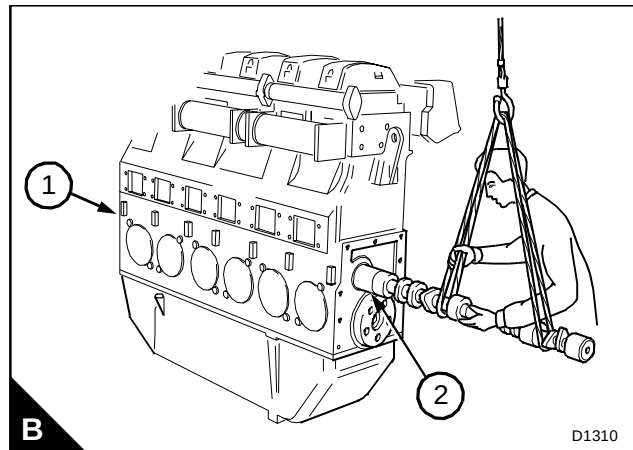
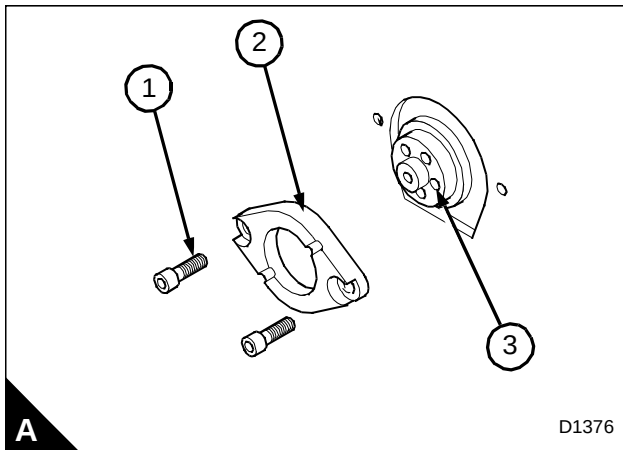
Special requirements

Special tools	
Description	Part number
Camshaft guide tube	T6253/142

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

Note: To remove the camshaft is a major operation.

- 1 Remove rocker assembly, see Operation 3-1
- 2 Remove the gear case, see Operation 6-1.
- 3 Remove the camshaft gear, see Operation 6-5.
- 4 Remove all the cam followers, see Operation 6-10.
- 5 Remove the flywheel housing, see Operation 13-1.



6 Remove the allen screws (A1) and remove the thrust plate (A2).

7 Fit the camshaft guide tube (B2) to the camshaft (A3).

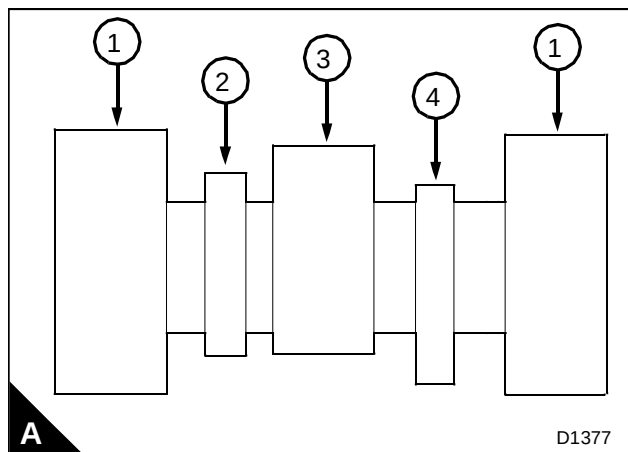
Note: Use suitable lift equipment to help remove the camshaft.

8 From the front (B1) push the camshaft out of the crank case and remove the camshaft guide tube from the camshaft.

To check the camshaft

Operation 6-13

- 1 Visually check the journals (A1) the exhaust lobe (A2) the fuel injector lobe (A3) and the inlet lobe for damage.
- 2 To check the tolerance of the camshaft lobes and journals, see "Camshaft and bearings" on page 12



To fit

Operation 6-14**Special requirements**

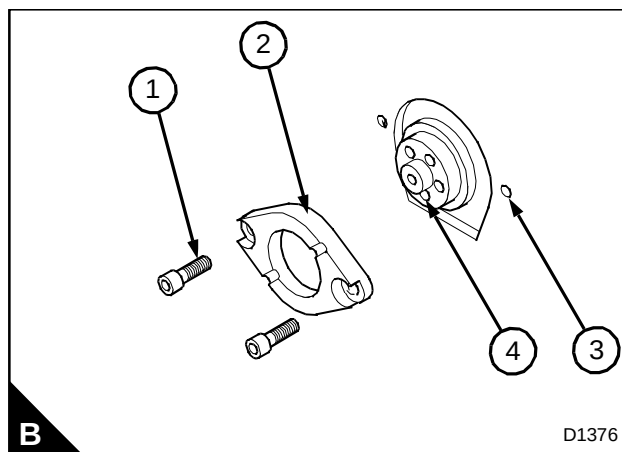
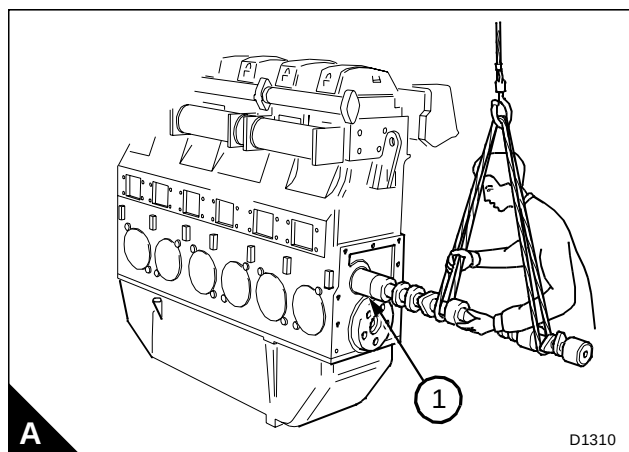
Special tools	
Description	Part number
Camshaft guide tube	T6253/142

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

- 1 Fit the camshaft guide tube (A1) to the camshaft.
- 2 Lubricate the journals on the camshaft with clean engine lubricating oil.

Note: Use suitable lift equipment to help fit the camshaft.

- 3 From the rear of the engine align the camshaft guide tube to the camshaft bore. Push the assembly into the crank case.
- 4 When the camshaft is in the correct position, remove the camshaft guide tube from the camshaft (B4).
- 5 Fit the thrust plate (B2) and allen screws (B1) onto the back plate (B3).



- 6 Fit the flywheel housing, see Operation 13-1.
- 7 Fit the camshaft gear, see Operation 6-6.
- 8 Fit the gear case, see Operation 6-2.
- 9 Fit all the cam followers, see Operation 6-10.
- 10 Fit the rocker assembly, see Operation 3-1.

To remove and fit the camshaft bush

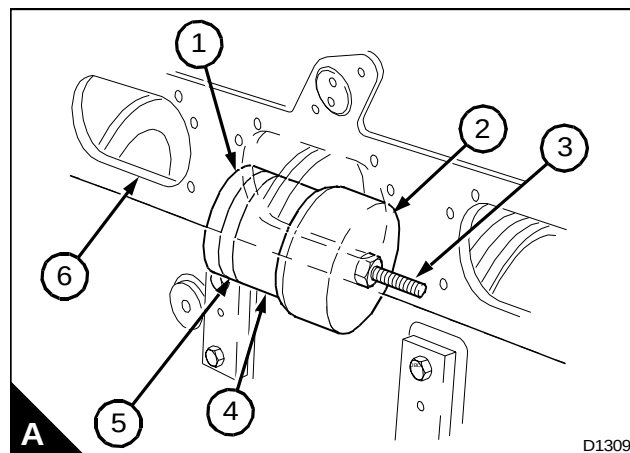
Operation 6-15

Special requirements

Special tools	
Description	Part number
Camshaft bearing removal and fitting tool	T6253/199

The camshaft bush for the 4006-23 litre engine is a pre-finished item.

The camshaft bearing removal and fitting tool is a three piece item. The end cap (A2). The adaptor sleeve (A5). The adaptor sleeve is fitted into the camshaft bush.

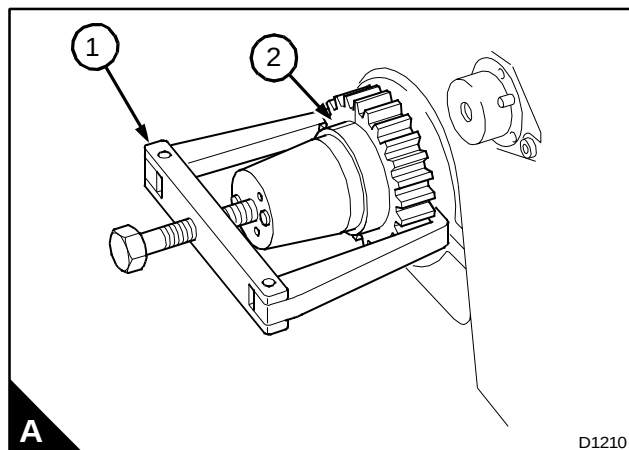


Crankshaft gear

To remove

Operation 6-16

- 1 Remove the idler gear, see Operation 6-7.
- 2 Remove the camshaft gear, see Operation 6-5.
- 3 Rotate the crankshaft gear until the timing marks (A2) are vertical.



- 4 Fit a suitable puller (A1) and remove the crank gear.

Note: The crank gear is an interference fit. In order to remove the gear it may need to be ground, drilled and then split to release the gear from the crank shaft.

To fit

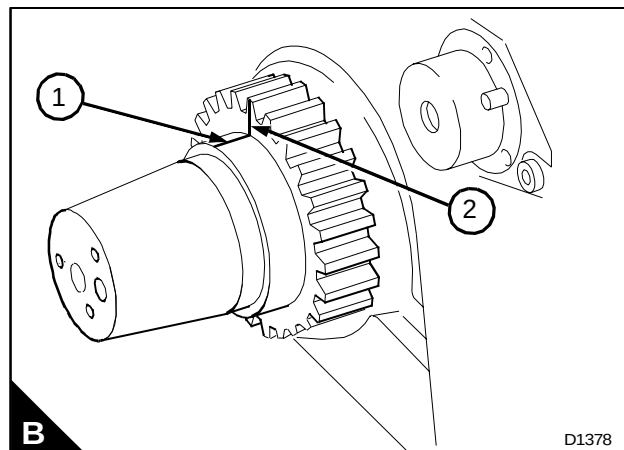
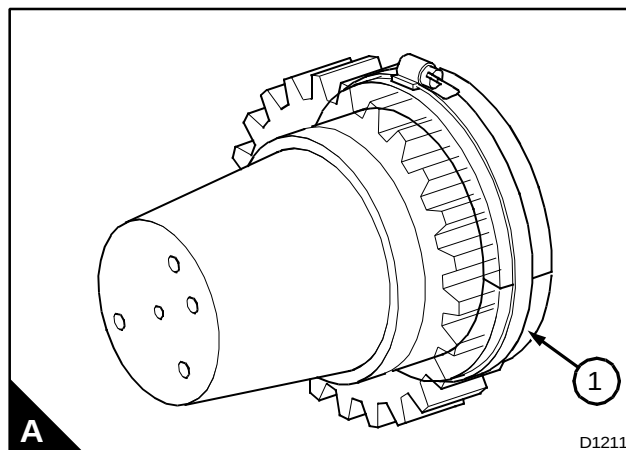
Operation 6-17

Special requirements

Special tools	
Description	Part number
Gear space tool	T85001/33

Caution: Ensure that the timing marks on the crankshaft (B1) and the crank gear (B2) are aligned. Failure to align the timing marks will result in the loss of valve timing.

- 1 Fit the gear space tool (A1) to the crankshaft.



- 2 Heat the crankshaft gear to 250 °C (482 °F).
- 3 Align the timing mark (B2) on the gear to the timing mark (B1) on the crankshaft.
- 4 Push the crankshaft gear on to the crankshaft, until the gear is stopped by the space tool (A1). Ensure that the timing marks are aligned,
- 5 Allow the crankshaft gear to cool and then remove the space tool.
- 6 Fit the camshaft gear, see Operation 6-6.
- 7 Fit the idler gear, see Operation 6-8.

Back Plate

To remove

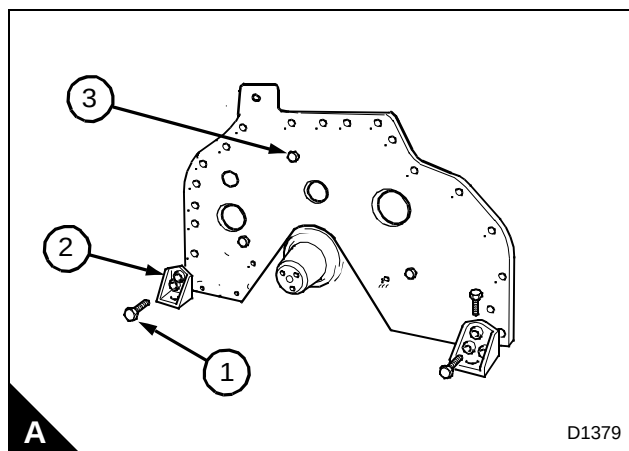
Operation 6-18

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

Caution: With the engine in a workshop, the removal of the back plate can only be carried out with the use of the correct lift equipment and would be part of a major overhaul.

Note: Use suitable lift equipment in order to remove the back plate from the crank case.

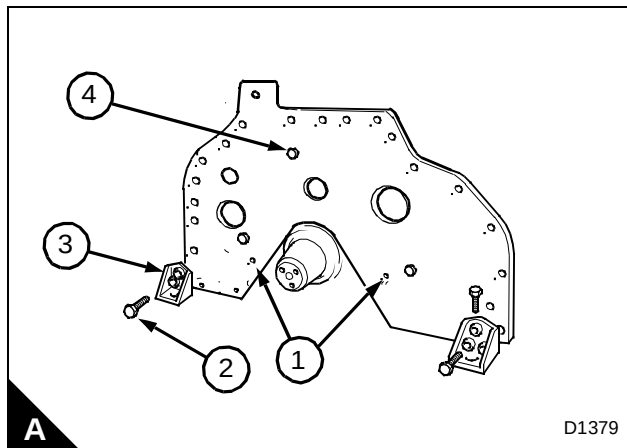
- 1 Remove the setscrews (A1) and remove the front feet (A2).
- 2 Remove the setscrews (A3) and remove the back plate from the crank case.
- 3 Remove joint and discard.



To fit

Operation 6-19

- 1 Check that all the components are clean and free from damage.
- 2 Align joint to crankcase and fit.
- 3 Align the back plate to the dowels (A1) in the crank case and fit the back plate.



- 4 Fit the setscrews (A4) and tighten the setscrews (A4) to 50 Nm (36,8 lbf ft) 5 kgf m.
- 5 Align the front mounting feet (A3). Fit the setscrews (A2) and tighten to 50 Nm (36,8 lbf ft) 5 kgf m.

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7

Crankcase

General Description

The crankcase is made from cast iron. The sides of the crankcase extend below the crankshaft centre line to give added strength. The crankcase provides support for the wet liners, which are made of centrifugally cast iron.

All liners are honed with silicon carbide stones to a cross-hatched finish to ensure long life and low oil consumption. The cylinder liners have a flame ring above the flange. Bushes are fitted in the cylinder block for the front camshaft journal and the other camshaft journals.

Crankcase

To remove

Operation 7-1

Note: All of the components that need to be removed for access to the crankcase are referred to in the following procedures. As a result some of the stages within operations may be repeated.

- 1 Ensure that all the engine fluids have been drained.
- 2 Remove the digital control box, see Operation 14-17.
- 3 Remove the fuel filter, fuel lift pump and fuel priming pump, see Chapter 11, Fuel system.
- 4 Remove the alternator, see Operation 14-3.
- 5 Remove the starter motor, see Operation 14-8.
- 6 Remove the lubricating oil canisters and the filter head, see Chapter 10, Lubrication system.
- 7 Remove lubricating oil cooler, see Operation 12-16.
- 8 Remove the lubricating oil pump, see Operation 10-7.
- 9 Remove the gear assembly, see Chapter 6, Gearcase and drive assembly.
- 10 Remove air filters and turbochargers, see Chapter 9, Aspiration system.
- 11 Remove exhaust manifold, see Operation 3-12.
- 12 Remove induction manifold, see Operation 3-11.
- 13 Remove coolant pump, thermostat and the coolant pipe, see Chapter 12, Cooling system.
- 14 Remove cylinder head, see Operation 3-4.
- 15 Remove the pistons and the connecting rod assemblies, see Chapter 4, Piston and connecting rod assemblies.
- 16 Remove the camshaft, see Operation 6-12.
- 17 Remove the crankshaft, see Operation 5-5.
- 18 Remove the piston cooling jets, see Operation 4-11.
- 19 Remove the threaded plugs from the crankcase block.

To fit

Operation 7-2

Special requirements

Consumable products	
Description	Part number
POWERPART Threadlock and nutlock	21820117 or 21820118

- 1 Clean thoroughly the new crankcase block. Ensure that all the oil passages are clean and free from debris.
- 2 Clean the threads of the old crankcase block plugs. Seal the threads with POWERPART Threadlock and nutlock, and fit the threaded plugs into the new crankcase block.
- 3 Fit the crankshaft, see Operation 5-6.
- 4 Fit the piston and connecting rod assembly, see Chapter 4, Piston and connecting rod assemblies.
- 5 Fit the piston cooling jets, see Operation 4-12.
- 6 Fit the camshaft, see Operation 6-14.
- 7 Fit the cylinder head, see Operation 3-4.
- 8 Fit the coolant pump, thermostat and the coolant pipe, see Chapter 12, Cooling system.
- 9 Fit the induction manifold, see Operation 3-11.
- 10 Fit the exhaust manifold, see Operation 3-12.
- 11 Fit the air filters and turbochargers, see Chapter 9, Aspiration system.
- 12 Fit the gear case assembly, see Chapter 6, Gearcase and drive assembly.
- 13 Fit the lubricating oil pump, see Operation 10-8.
- 14 Fit the lubricating oil cooler, see Operation 12-17.
- 15 Fit the lubricating oil canisters and the filter head, see Chapter 10, Lubrication system.
- 16 Fit the fuel filter, fuel lift pump and fuel priming pump, see Chapter 11, Fuel system.
- 17 Fit the starter motor, see Operation 14-9.
- 18 Fit the alternator, see Operation 14-6.
- 19 Fit the digital control box, see Operation 14-18.
- 20 Fill the cooling system, refer to relevant Users Handbook.
- 21 Fill the lubricating oil sump to the correct level with the recommended grade of lubricating oil, refer to relevant Users Handbook.
- 22 Eliminate the air from the fuel system, refer to relevant Users Handbook.

To inspect

Operation 7-3

- 1 Clean the internal passages for the coolant and for the oil.
 - 2 Check the crankcase for cracks and for other damage.
- Note:** The top face of the crankcase block must not be machined because this will affect the liner flange depth and the piston height above the top face of the crankcase block.

Cylinder Liner

To inspect

Operation 7-4

To ensure the best performance during the life of the engine it is important that worn or damaged cylinder liners are renewed. If a change of liner becomes necessary in service, liners are available.

The condition of a cylinder liner is decided by:

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

Note: It will not be necessary to renew the liner if:

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

To check the condition of a cylinder liner

1 Inspect the liner surface for cracks and deep scratches.

2 Check the liner wall for areas where the honed finished has been polished away. 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.

Cautions:

- *Do not use "Flex-hone" to repair cylinder liners.*
- *Damaged or worn liners must be discarded.*
- *New piston rings must be fitted when the cylinder liner is renewed.*
- *An engine can have high oil consumption with very little wear of the liner bores, if the surfaces of the liners are glazed.*

To remove

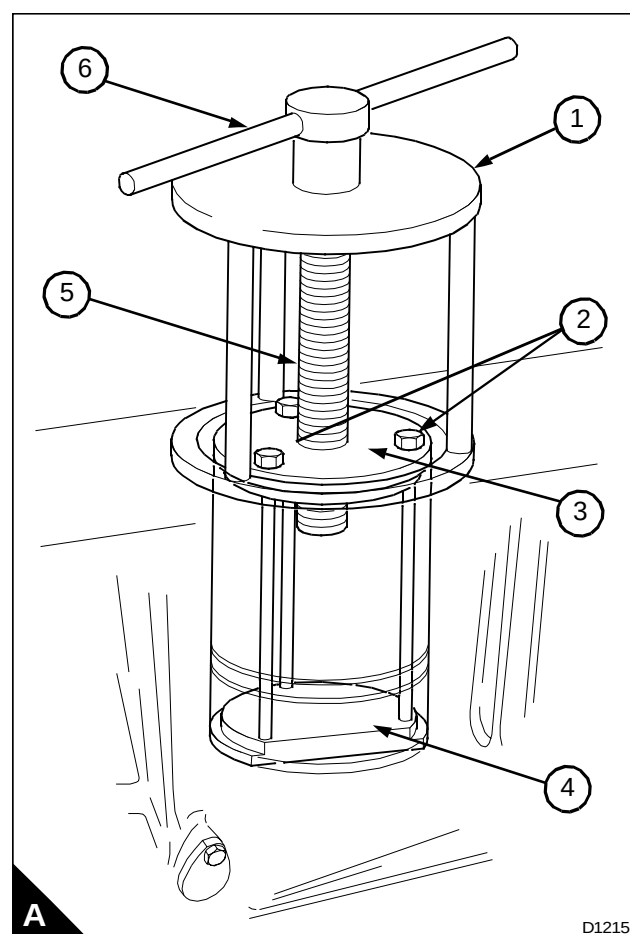
Operation 7-5

Special requirements

Special tools	
Description	Part number
Remover tool for the cylinder liner	T6253/152

Warning! Clean any particles of rust from the inside of the crankcase block and from all bearing surfaces.

- 1 Remove the piston cooling jets, see Operation 4-11.
- 2 Remove the cylinder head of the appropriate cylinder, see Operation 3-4.
- 3 Remove the piston and connecting rod assembly, see Chapter 4, Piston and connecting rod assemblies.
- 4 Clean the top of the crankcase, if the crankshaft is still in position, protect the crankshaft with a cover.
- 5 Put the cylinder liner tool (A1) on the top surface of the crankcase block and over the centre of the liner.
- 6 Fit the three long bolts (A2) through the tool plate (A3). Fit the adaptor (A4) onto the three long bolts and adjust the threaded bar (A5) until the adaptor is against the bottom of the cylinder liner.
- 7 Operate the handle on the tool (A6) and carefully pull the cylinder liner out of the top of the crankcase block.



To fit liner

Operation 7-6

Special requirements

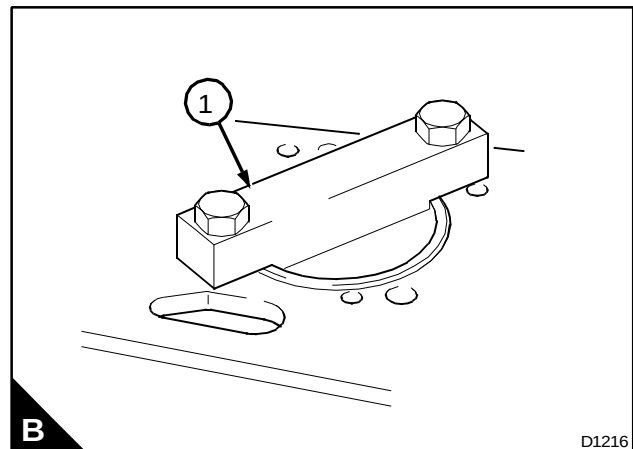
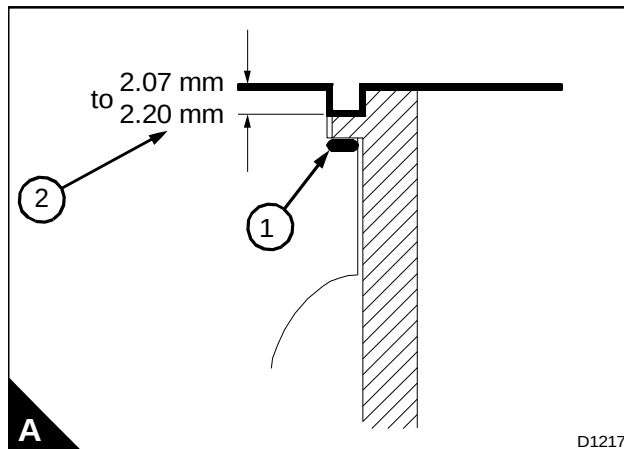
Special tools	
Description	Part number
Tool to fit the cylinder liner	T6253/200

Caution: Do not hit the liner with any kind of hammer.

- 1 Clean the inside of the crankcase block.
- 2 Clean the outer surface of the liner with an appropriate safety cleaner.
- 3 Fit two 'O'rings onto the new cylinder liner.
- 4 Apply a suitable lubricant to the lower crankcase liner bore.

Caution: Do not put grease on the 'O' rings as this will cover the top surface of the crankcase block and will affect the sealant properties of loctite used in this operation.

- 5 Apply Loctite 638 to the flange face of the crankcase block (A1).
- 6 Engage the cylinder liner into the crankcase block, ensure that the liner is always vertical.
- 7 Clamp the cylinder liner into position with the special tool (B1).
- 8 Allow a minimum of 3 hours to elapse to allow the loctite sealer to cure before the clamp is removed.
- 9 Check the dimension relative to the crankcase block face and the flame ring groove (A2).
- 10 Fit the piston and connecting rod assembly, see Chapter 4, Piston and connecting rod assemblies.
- 11 Fit the cylinder head of the appropriate cylinder, see Operation 3-4.
- 12 Fit the piston cooling jets, see Operation 4-12.



8

Engine timing

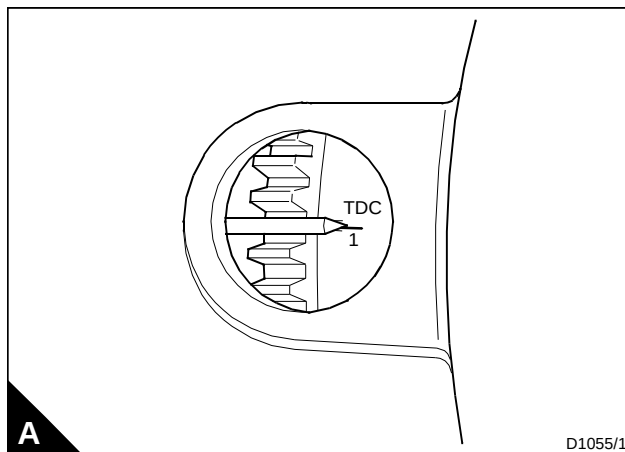
To set number 1 piston to Top Dead Centre (TDC)

Operation 8-1

Special Requirement

Special Tool	
Description	Part Number
Engine Cranking Device	SE253

- 1 Disconnect the batteries.
- 2 Fit the engine cranking device to the starter motor hole in the flywheel housing.
- 3 Use the flywheel housing inspection hole directly below the turbocharger to view TDC 1 (A1).



Calibrating fuel injectors

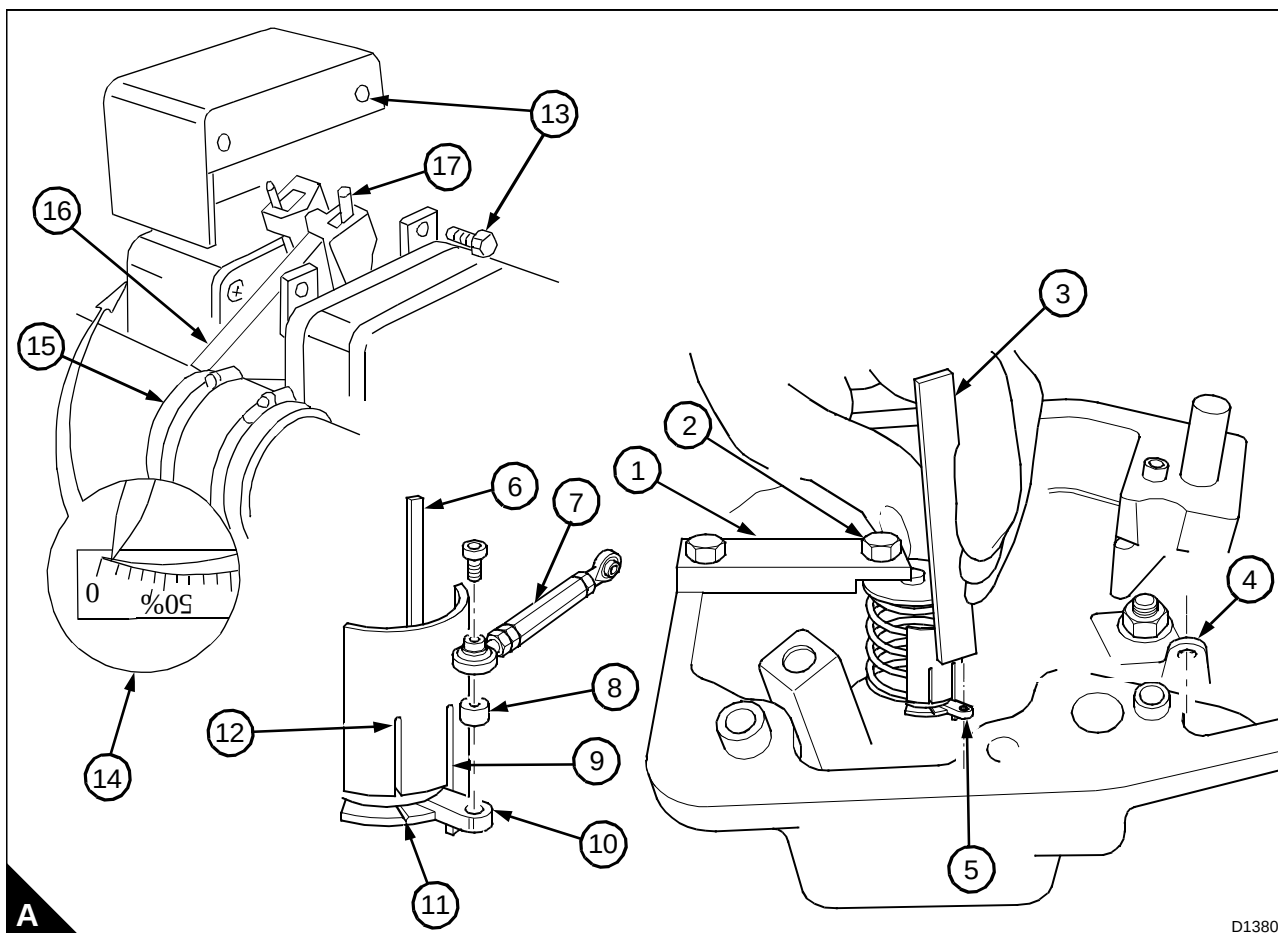
Operation 8-2

Special requirements

Special tools			
Description	Part number	Description	Part number
Fuel injector clamp tool	T6253/147	Calibration tool	T6253/177

Notes:

- This operation is only required if the governor linkage inside the gearcase has been disturbed.
 - Ensure that the spacer (A8) is fitted between the adjustable link and the fuel control arm.
- 1 Fit the fuel injector clamp tool (A1) to each rocker box.
 - 2 Tighten the adjustable screw (A2) down onto the fuel injector until the fuel control arm (A10) is able to move freely.
 - 3 Remove the cover (A13).
 - 4 Using a tapered wedge (A16) between the actuator lever (A17) on the gearcase side and the coolant pipe (A15) to set the governor to 5% open (A14).
 - 5 Place the step side of the calibration tool (A6) with the line (A9) against the fuel control arm (A10). Move the calibration tool and fuel control arm setting the no fuel line (A12) to the line (A11) on the fuel injector body.
 - 6 Set the adjustable link (A7) on the centre-line measurement (A8) between the fuel control arm (A10) and the break-back lever (A7).
 - 7 Fit the adjustable link (A7) and torque the link to 8 Nm (6 lbf ft) 0.6 kgf m.



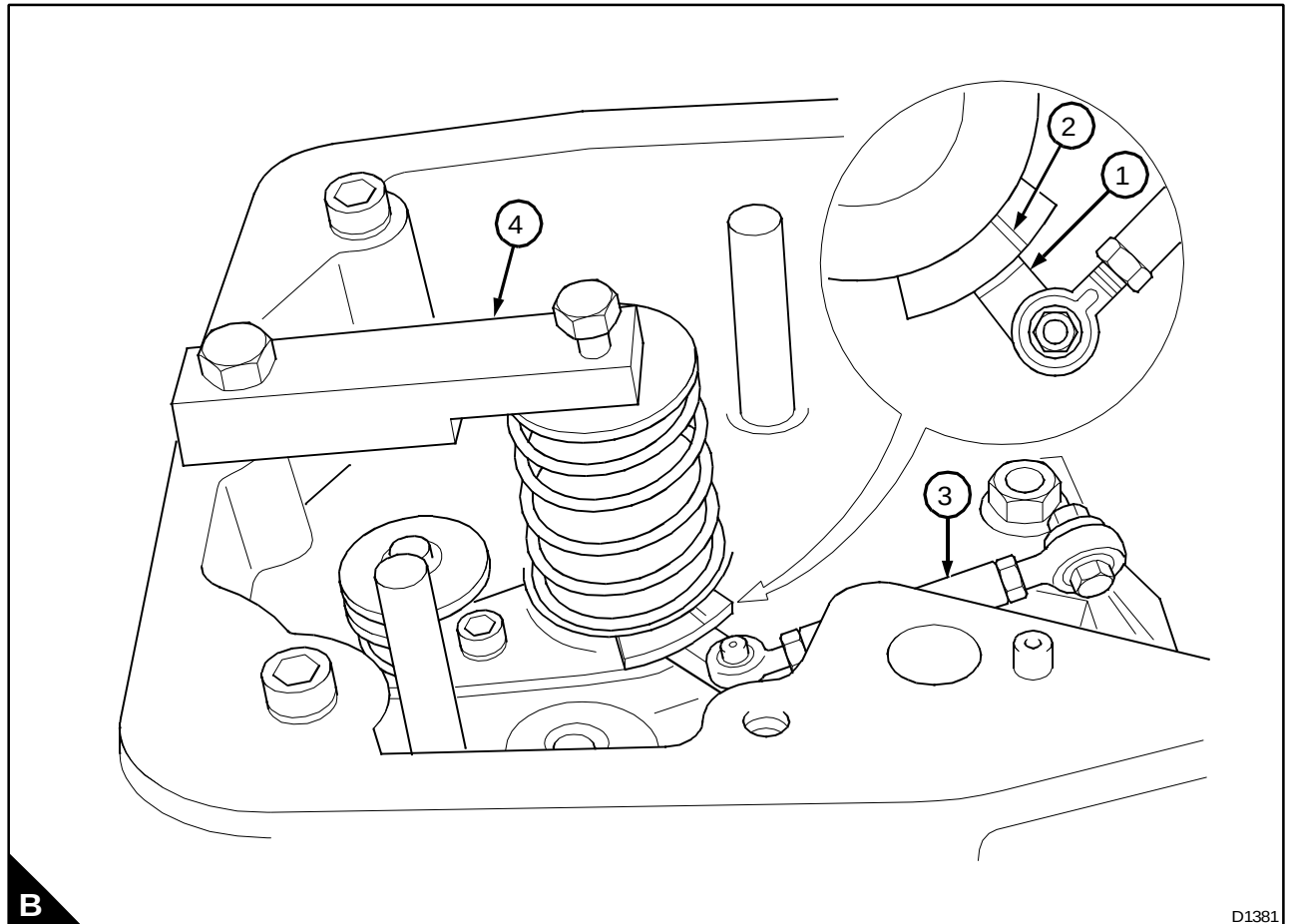
- 8 Remove the wedge (A16).
- 9 To set the governor actuator lever to position fuel injector number 1 in the "calibration position", use the tapered wedge (A16) with the side of the fuel control arm (B1) set to the line (B2) on the fuel injector body.

10 Check the calibration position of all fuel injectors. If the fuel control arm (B1) is past the calibration line (B2), reset the adjustable link (B3) to bring it into position.

11 If any fuel control arm is before the calibration line, reset the governor linkage to position the fuel control arm in line with the calibration line. Then alter the adjustable links on the other cylinders to correspond with their calibration lines.

Warning! Do not use the adjustable link (B3) to bring a fuel control arm up to the calibration line as it will allow the fuel injector to "fuel" when other fuel injectors are in the "no fuel position".

12 When this operation is completed, check all fittings for tightness and ensure that ball joints move freely. Remove the fuel injector clamp tool (B4) and the wedge (B5).



Setting governor on zero fuel

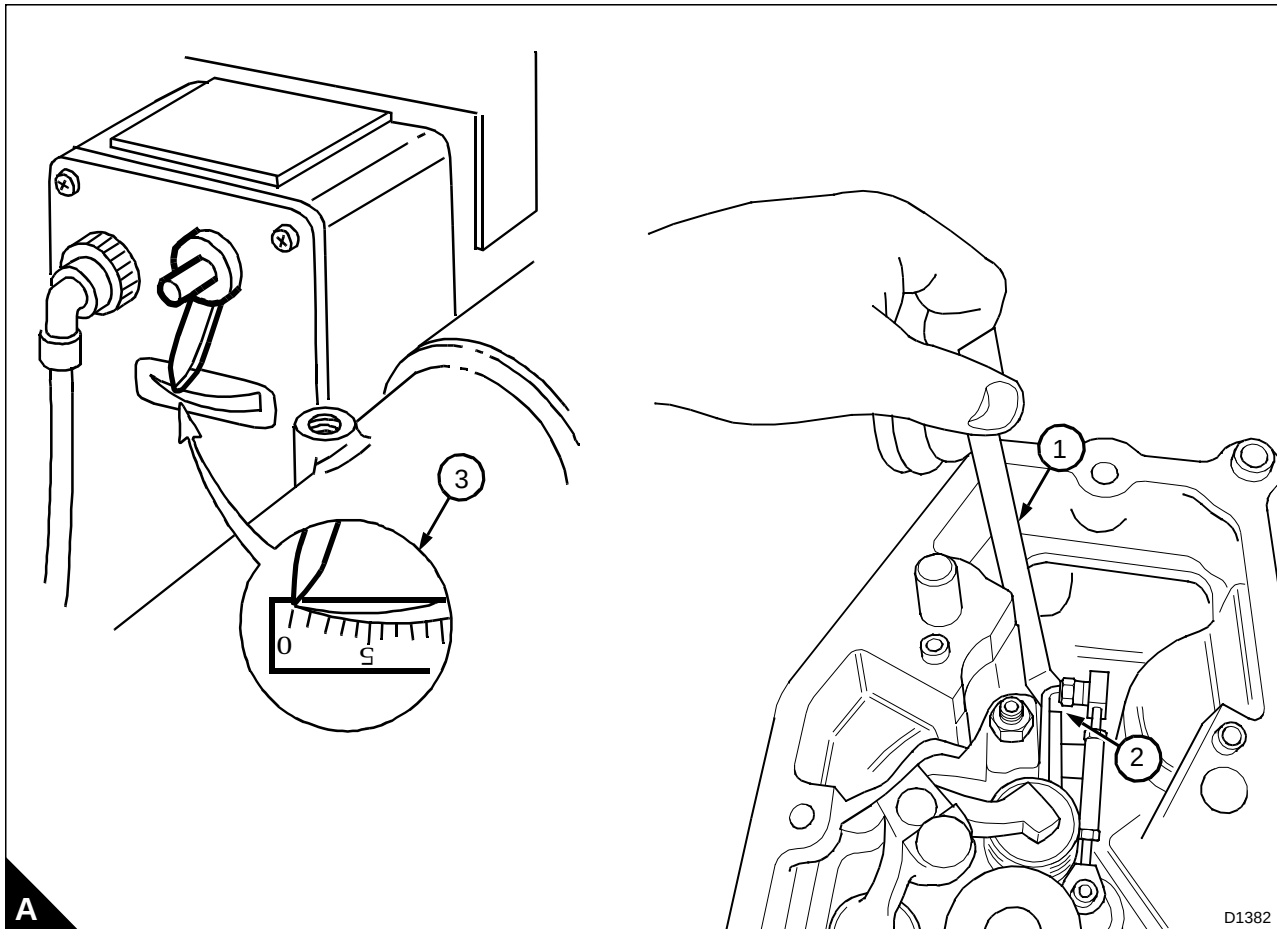
Operation 8-3

Special requirements

Special tools	
Description	Part number
Spacer tool	T6253/197

- 1 Remove the rocker cover and the rocker shaft assembly from the cylinder head, see Operation 3-1.
- 2 Set the spacer tool (A1) between the break-back lever (A2) and the cylinder head face of cylinder number 1 gearcase end of the engine. This should set the governor in the zero fuel position (A3).
- 3 Fit the rocker cover of the cylinder head, see Operation 3-1.

Note: If the governor control shaft in the gearcase has been renewed, see Chapter 11, Fuel system.

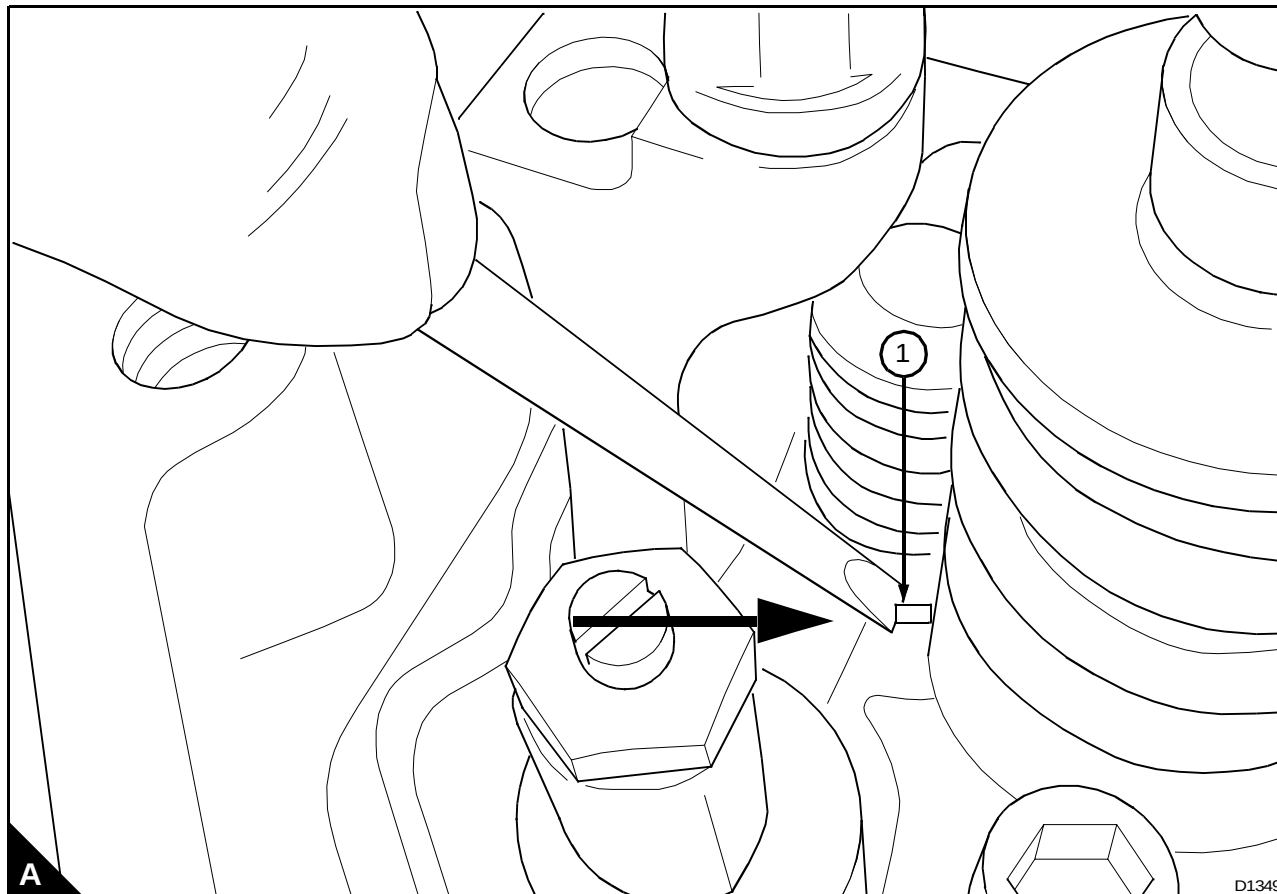


Applying pressure to the timing pin

Operation 8-4

Caution: The timing pin is the reference point for the start of the fuel injection process, fuel injector timing.

- 1 Use a screwdriver to apply light pressure to the timing pin as shown in graphic (A1).



Timing the fuel injectors

Operation 8-5

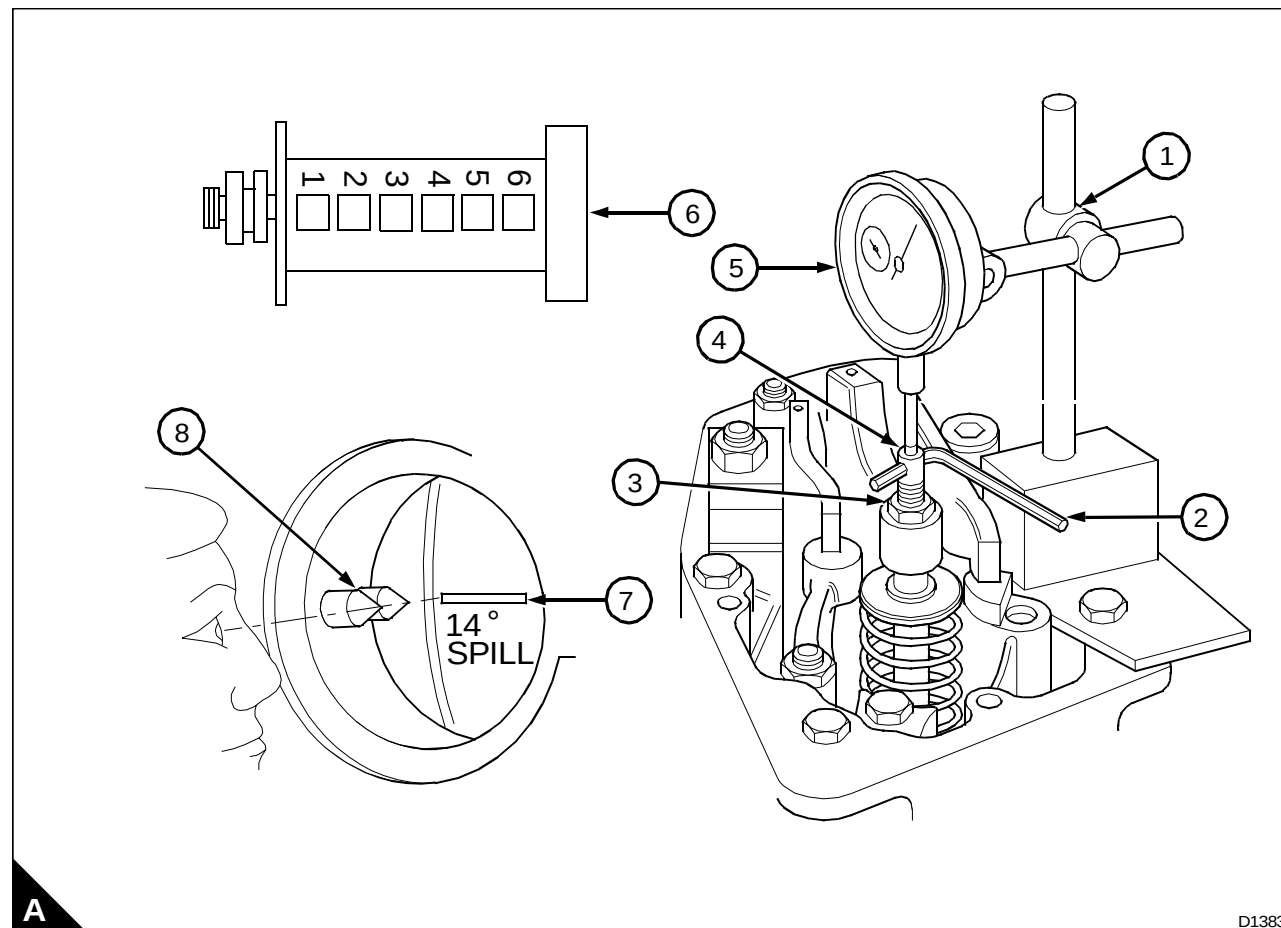
Notes:

- Do not use the starter motor to turn the engine.
 - The spill timing of the engine is recorded on the engine data plate and marked for each cylinder on the flywheel.
 - Set the spill timing of the engine in the order of the positions identified in the engine plan view (A6)
- 1 Set the engine on Number 1 cylinder to TDC (Top Dead Centre) valves closed.
 - 2 Set bridge piece and tappet clearance, see Chapter 3, Cylinder head assembly.
 - 3 Turn the engine backwards until the spill mark (A7) passes the timing pointer (A8). Then turn the engine in the normal direction of rotation until the spill is in line with the timing pointer.
 - 4 Loosen the fuel rocker adjustable locking screw (A3).
 - 5 Fit a 3 mm allen key (A2) through the hole in the fuel rocker adjuster (A4) and turn anticlockwise fully.
 - 6 Apply pressure to the timing pin, see Operation 8-4.
 - 7 Turn the fuel rocker adjuster until the timing pin is engaged, release and ensure the timing pin springs out freely
 - 8 Position the DTi gauge (A5) (Dial Test indicator) on top of the fuel rocker adjuster (A4) and set the dial to zero by moving the DTi up and down the shaft (A1).
 - 9 Turn the fuel rocker adjuster clockwise until the dial indicator reads 3 mm (0,118 in).
 - 10 Remove the DTi gauge (A5).
 - 11 Tighten the fuel rocker adjustable locking screw to 68 Nm (50 lbf ft).

Continued

12 Repeat the steps 1 to 11 in order of firing sequence for all remaining cylinders (A6).

	Firing Sequence					
TDC Valves closed	1	5	3	6	2	4
TDC Valves overlap	6	2	4	1	5	3



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9

Aspiration system

General description

Warning! When the engine is in operation, many of the components in the aspiration system work at very high temperatures. Allow the engine to cool before a service or repairs are carried out. If a service or repairs are to be carried out while the engine is hot ensure that all safety equipment is used.

The filtered air from the two air filters is passed through the twin air shut off valves, if fitted, and into the air intakes of the twin turbochargers. The air in the turbochargers is compressed and the flow of the air is increased. The air is passed through the air to air charge cooler and then to the intake manifold. The intake manifold directs the air into the cylinder heads

The exhaust gases from the engine pass along the twin exhaust manifolds and are used to drive the compressor in the turbochargers.

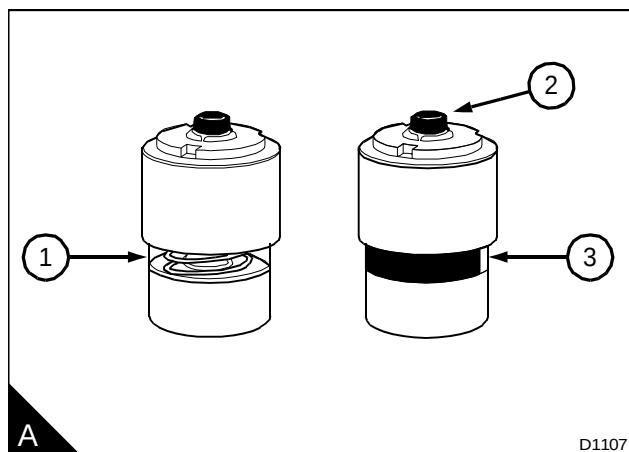
How to check the air restriction indicator

To check and reset

Operation 9-1

Note: The middle section of the restriction indicator (A1) will remain clear while the air cleaner is in a serviceable condition. When the filter reaches its contamination limit the restriction indicator will sense the change in air filter depression and middle section (A3) will change to red. At this point the air filter must be changed.

When the air filters have been changed in order to reset the indicators operate the button (A2).



Air filter element

To remove and fit

Operation 9-2

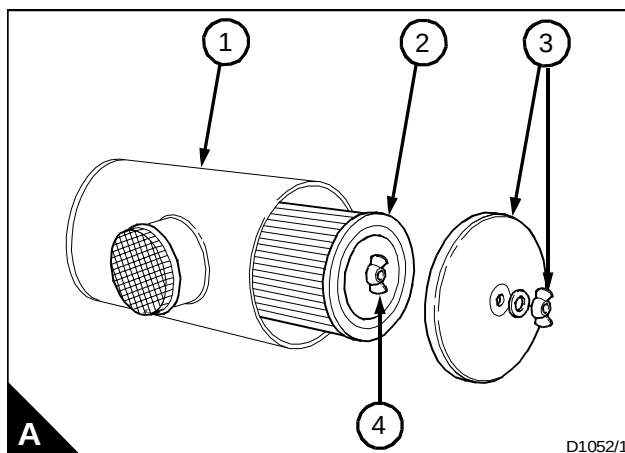
Warning! Discard the used element in a safe place and in accordance with local regulations.

Cautions:

- Do not operate the engine if there is a blockage in the air filter or the induction hose.
- The air filter element is a non-serviceable item, do not clean the element.
- Never blow dirt out of the filter housing. This may introduce dirt into the induction system. The housing must be removed to be cleaned.

Note: Environmental conditions have an important effect on the frequency at which the air filters need to be serviced.

- 1 Remove the wing nut and the end cover (A3) together.
- 2 Remove inner wing nut (A4).
- 3 Remove the element (A2) and discard.
- 4 Fit the new element into the filter housing (A1).
- 5 Fit the end cover onto the filter housing (A1) and tighten the wing nut securely. Check that end cover is correctly aligned.

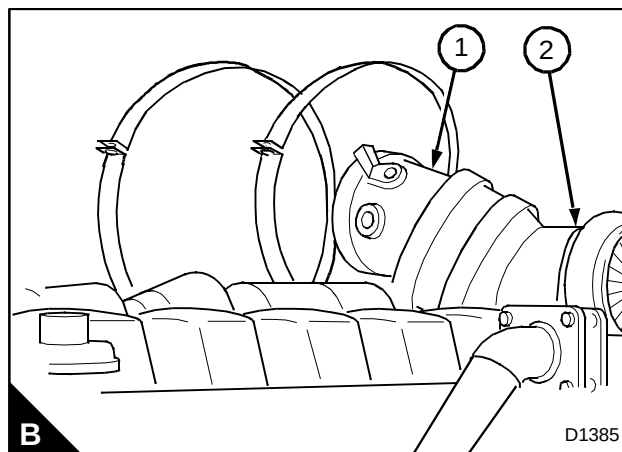
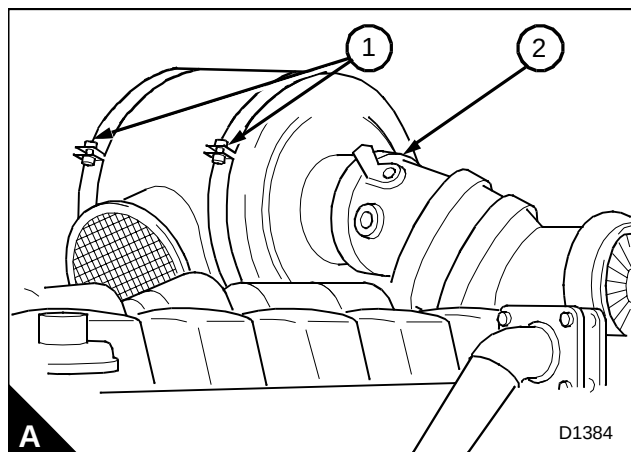


Air filter and pipe connection

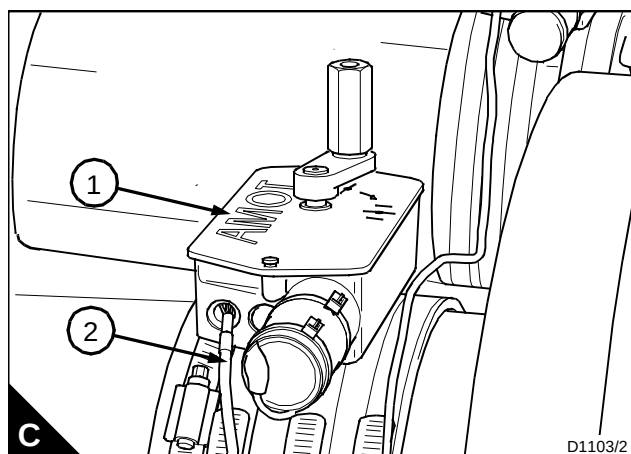
To remove

Operation 9-3

- 1 Loosen the clip (A2).
- 2 Remove the two nuts and bolts (A1).
- 3 Remove the air filter housing.
- 4 Loosen the clip (B2) and remove the assembly (B1).



Note: If fitted the air shut off valve (C1) must have the cable connection (C2) removed before the assembly (B1) is removed.



To fit

Operation 9-4

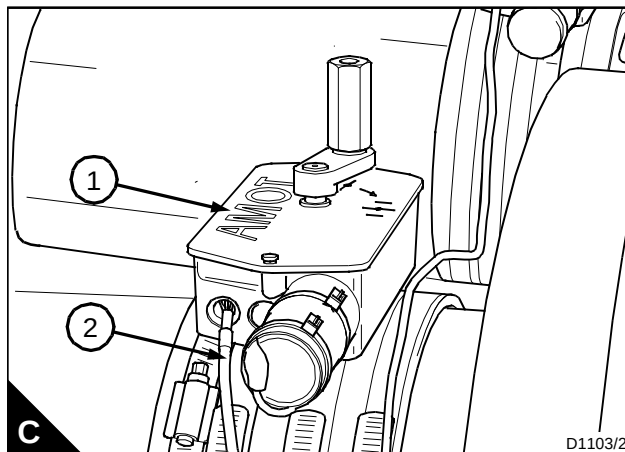
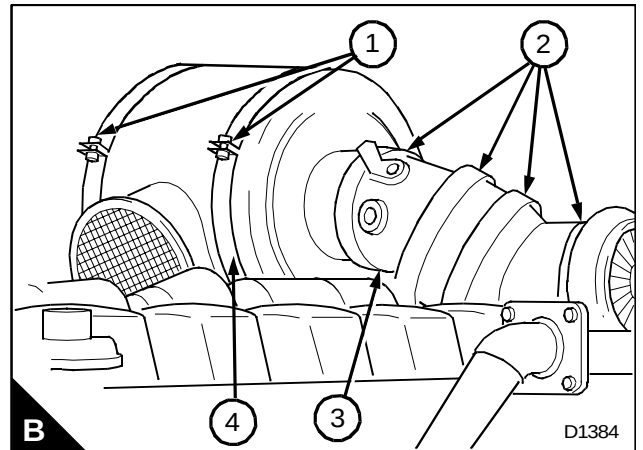
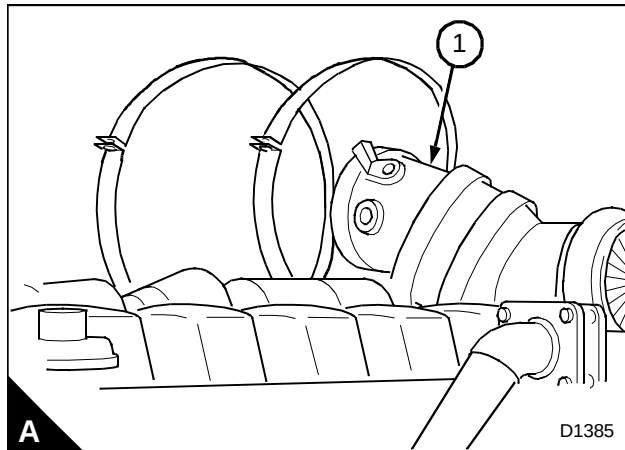
1 Fit the assembly (A1) onto the turbocharger.

Note: If fitted the air shut off valve (C1) must have the cable connection (C2) fitted.

2 Fit the air filter housing (B4) onto the pipe assembly (B3). Check the alignment of the air filter housing and pipe assembly to the turbocharger.

3 Tighten the nuts and bolts (B1) securely.

4 Tighten the clips (B2) securely.



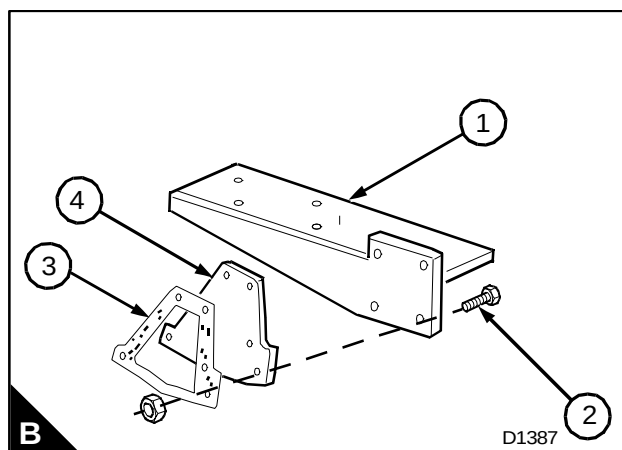
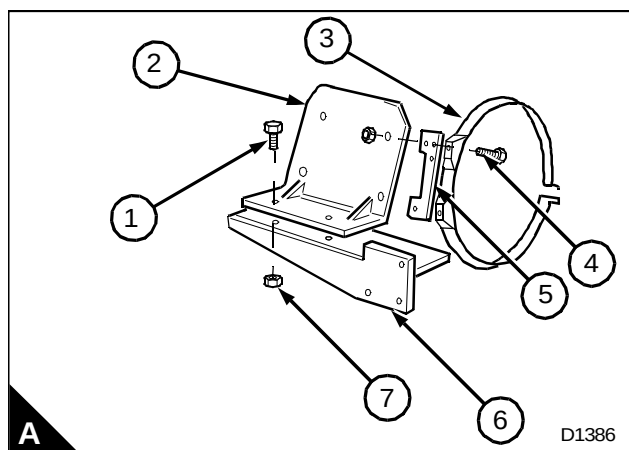
Air filter bracket

To remove

Operation 9-5

- 1 Remove the air filter, see Operation 9-3.
- 2 Remove the nuts (A7) and bolts (A1) and remove the angle bracket (A2) from the support bracket (A6)

Note: If necessary remove the bolts (A4) and remove the bands (A3) with the spacer (A5).



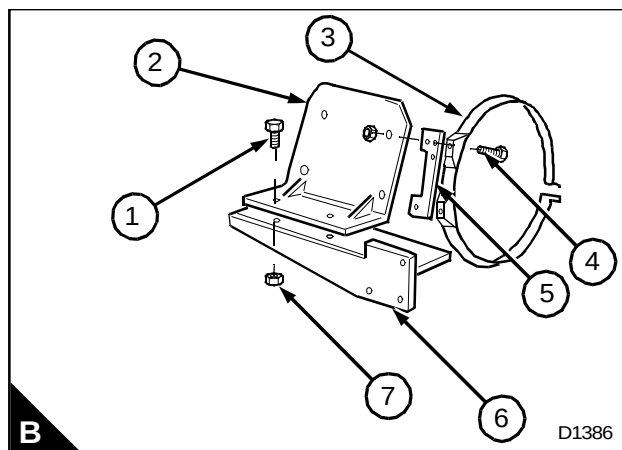
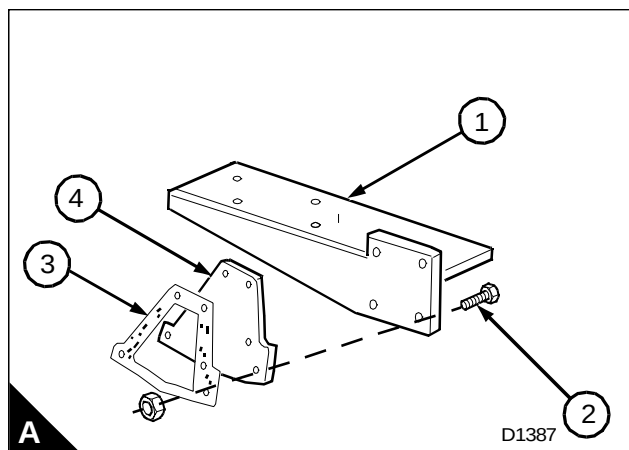
- 3 Remove the bolts (B2) and remove the support bracket (B1).

Note: The bolts (B2) also secure the end plate (B4) of the intake manifold. The joint (B3) must be removed and discarded.

To fit

Operation 9-6

- 1 Align the new joint (A3) the plate (A4) and the support bracket (A1) to the intake manifold. Fit the bolts (A2) and tighten to 50 Nm (36.8 lbf ft) 5 kgf m.



- 2 Align the angle bracket (B2) to the support bracket (B6). Fit the bolts (B1) and the nuts (B7) and tighten to 50 Nm (36.8 lbf ft) 5 kgf m.

Note: If the bands (B3) are removed, align the spacer (B5) the band (B3) and fit the bolts (B4). Tighten the bolts to 50 Nm (36.8 lbf ft) 5 kgf m.

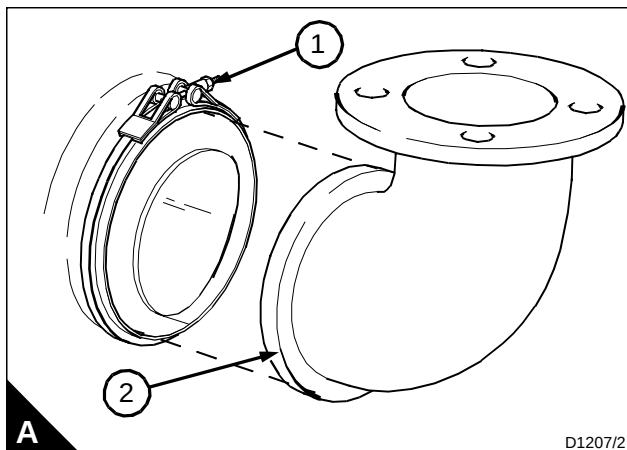
To remove

Operation 9-7

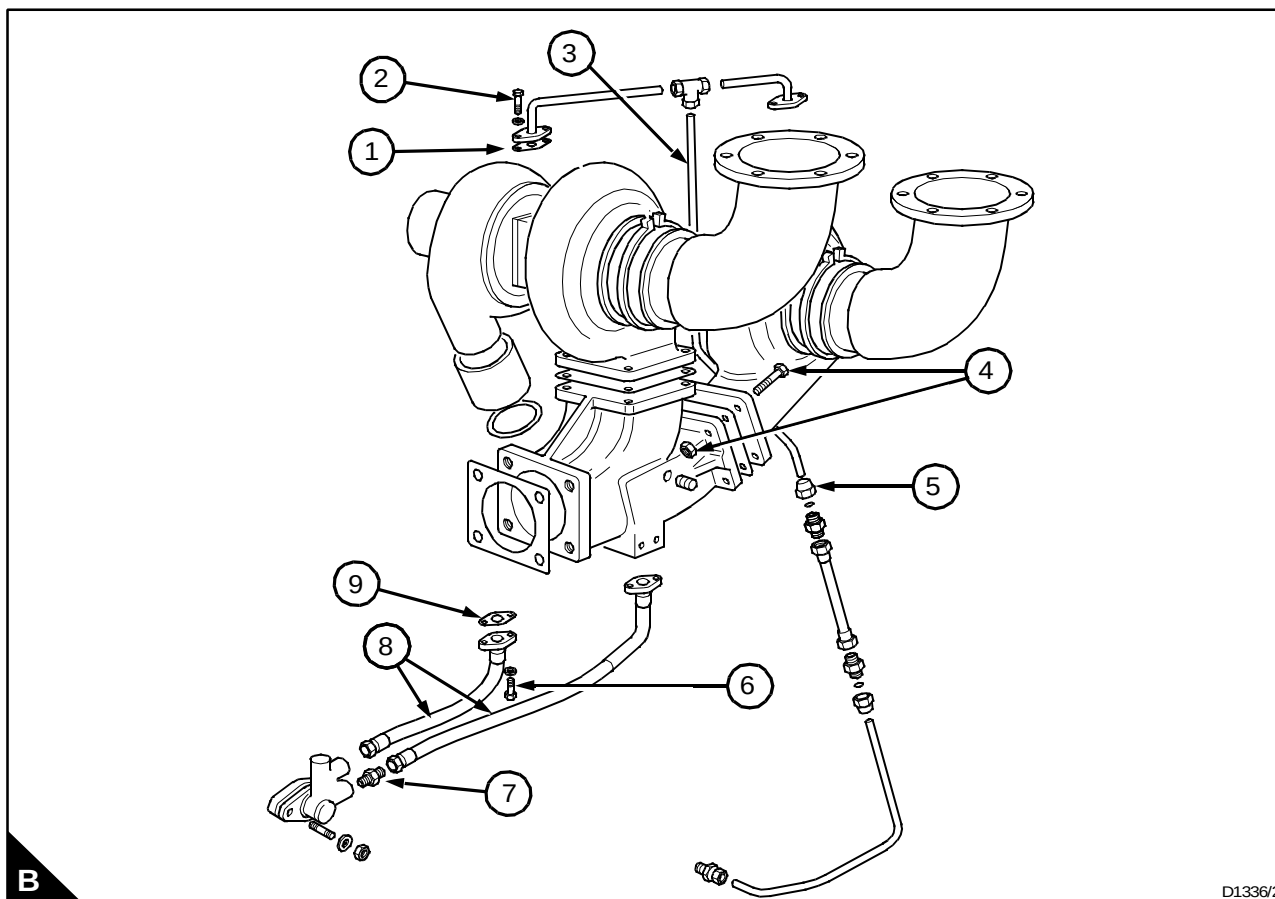
Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

Note: The removal of the turbocharger is written with the exhaust system from the exhaust elbow removed.

- 1 Loosen the V band clamp (A1) and remove the exhaust elbow (A2).



- 2 Remove the allen screws (B2) and disconnect the union (B5).



- 3 Remove the oil supply pipe (B3) and the joints (B1).
- 4 Remove the allen screws (B6) and disconnect the unions (C7). Remove the oil drain pipes (B8). Also remove the joints (B9).
- 5 Remove the bolts (B4).

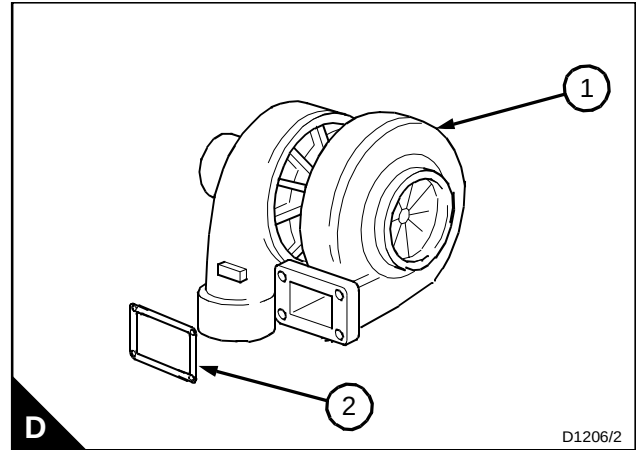
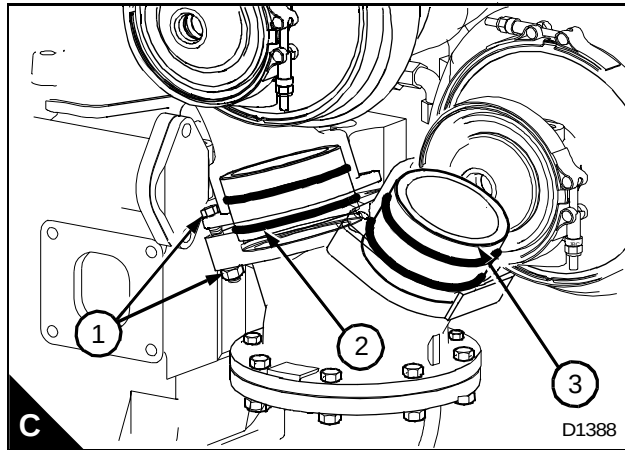
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6 Remove the bolt (C1) and the flat washers.

7 Remove the turbocharger assembly (D1) and the gasket (D2). Remove the internal connectors (C3) and the two O rings (C2) from each connector.

8 Discard all old joints and gaskets. Cover the open ports in the manifold, the turbocharger and the pipes to ensure that dirt can not enter.

9 Check the air hose and the oil pipes for damage, renew if necessary.

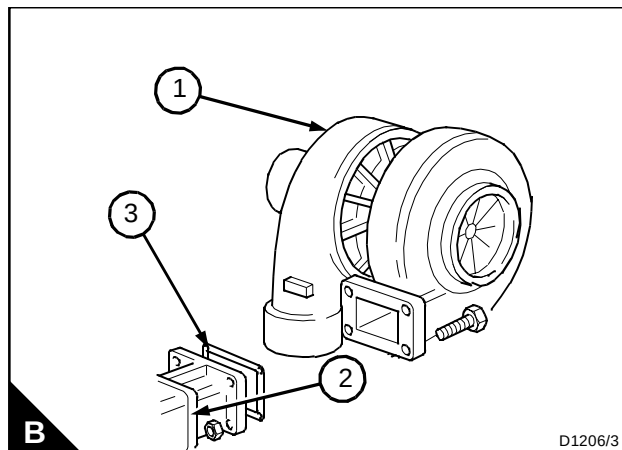
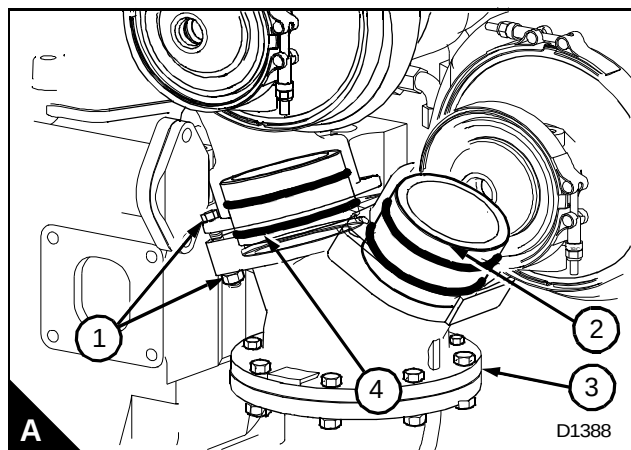


To fit

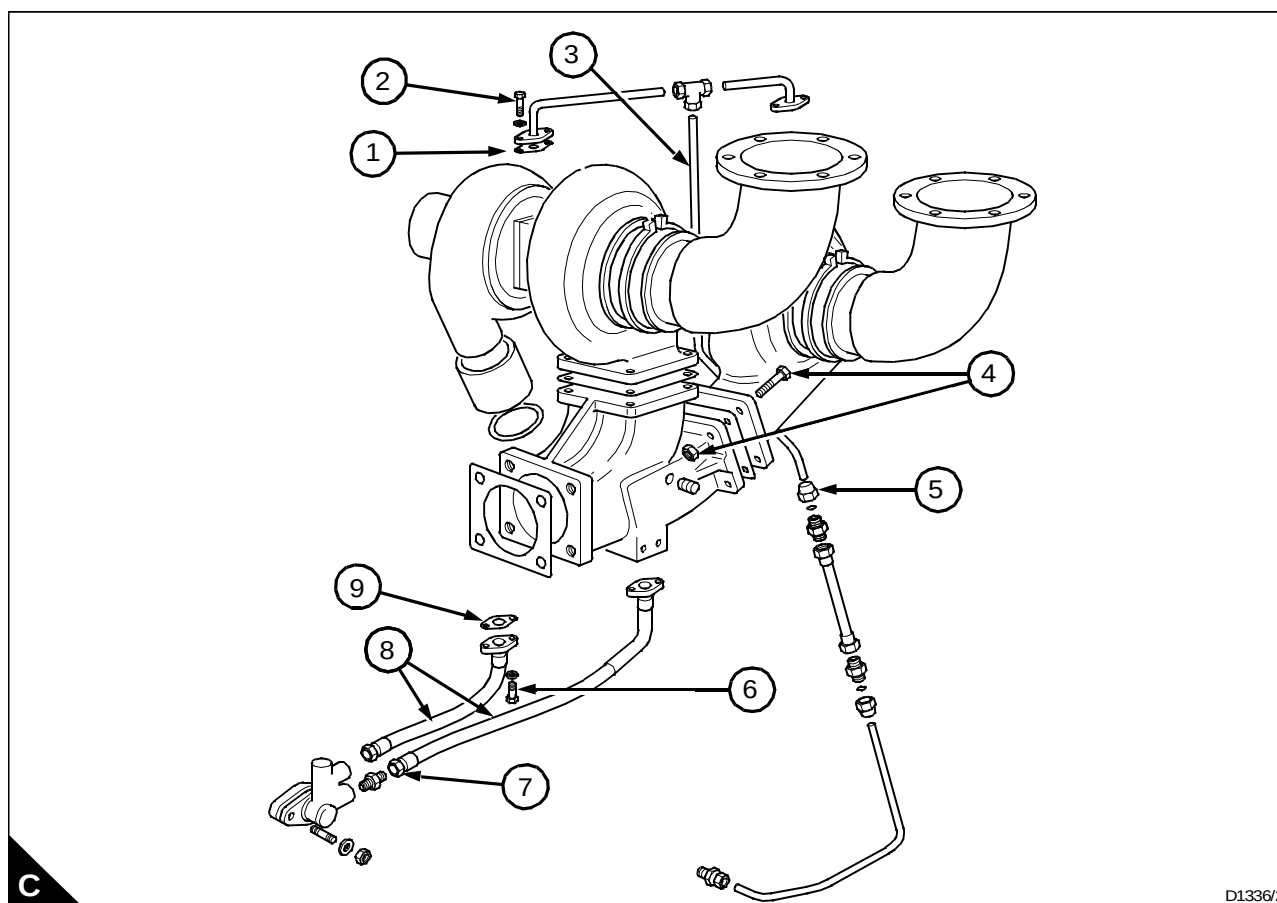
Operation 9-8

Caution: Ensure that all components are clean and that dirt has not enter the system.

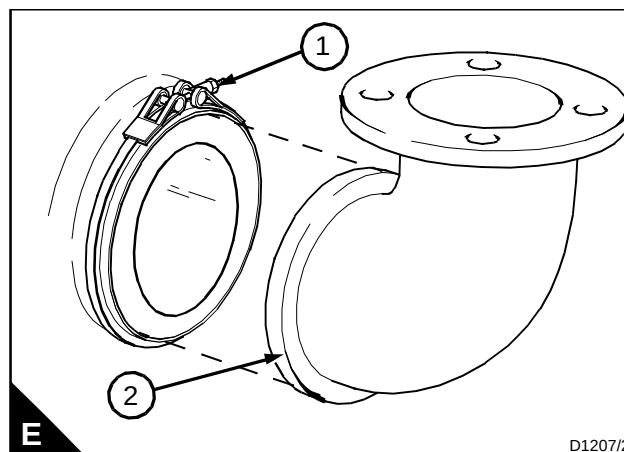
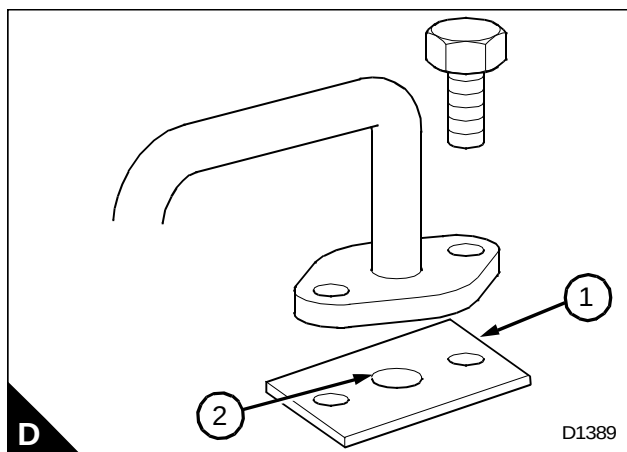
- 1 Fit new 'O' rings (A4) to the internal connectors (A2).
- 2 Align the connector to the adaptor (A3) and align the new gasket (B3).
- 3 Fit the turbocharger (B1) on to the connector (A2) and align to the exhaust manifold (B2).



- 4 Fit the bolt and flat washer (A1) and the bolts (C4). Tighten the bolts (C4) to 50 Nm (36.8 lbf ft) 5 kgf m and tighten the bolt (A1) to seat the turbocharger to the adaptor with a gap maintained by the flat washer.



Continued



5 Fit the joints (D2) and the oil supply pipe.

Note: The joint (D2) is a special joint that has a filter (D1) as part of the joint. This is used to filter the oil supply to the turbocharger after a repair or a service exchange unit has been fitted.

Caution: The joints (D2) must be removed after 15 minute of engine operation. Renew the joint with the standard joint (C1). Failure to do so may damage the engine.

6 Tighten the allen screws (C2) to 70 Nm (51,6 lbf ft) 7.1 kgf m. Tighten the union (C5) securely.

7 Align the oil drain pipes (C8) and fit the allen screws (C6). Tighten the allen screws to 70 Nm (51, 6 lbf ft) 7.1 kgf m. Tighten the union (C7) securely.

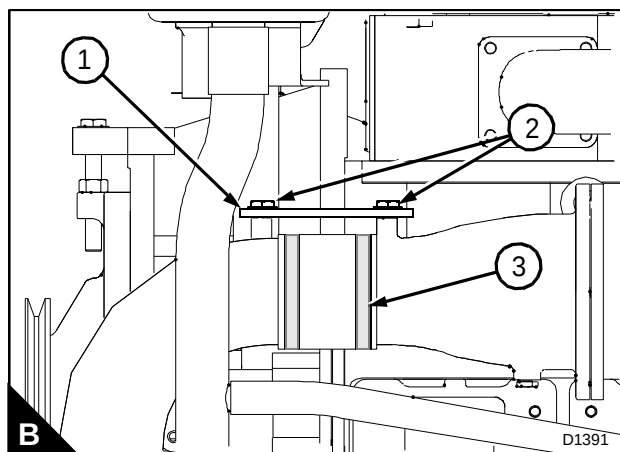
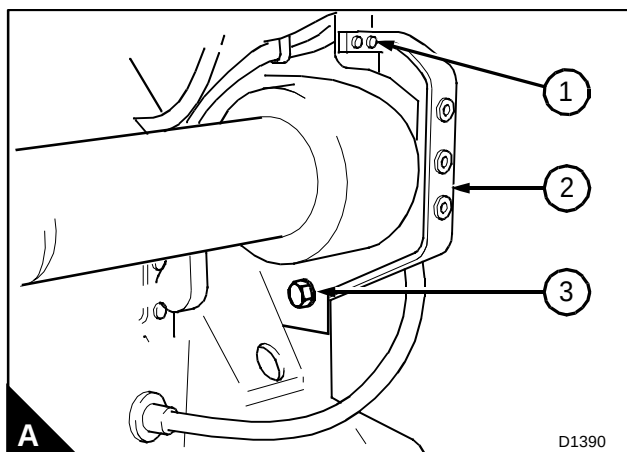
8 Align the exhaust elbow (E2) to the turbocharger outlet. Fit the V band and tighten the nut (E1) to 9,5 Nm (7 lbf ft) 0.9 kgf m. Ensure that the V band is seated correctly and check the torque again.

Air pipe connection

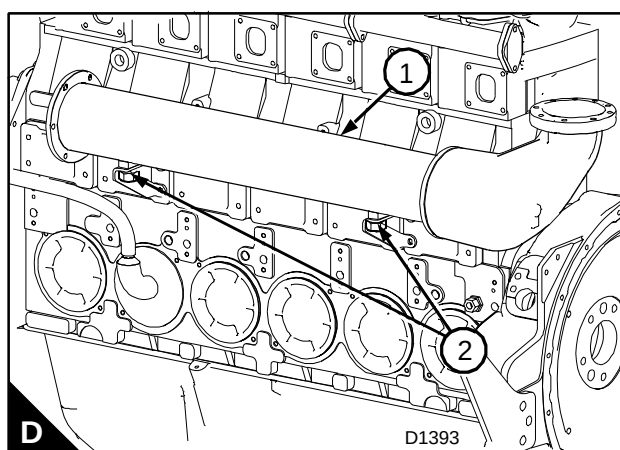
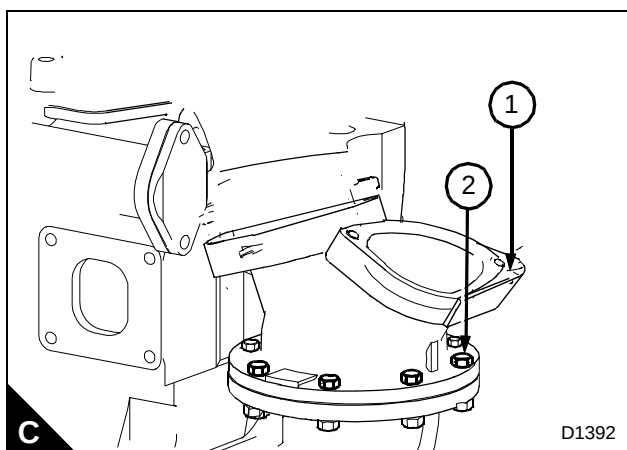
To remove

Operation 9-9

- 1 Remove the turbocharger, see Operation 9-7.
- 2 Remove the setscrews (A1) and (A3). Remove the support bracket (A2).



- 3 Remove the setscrews (B2) and the links (B1). Loosen the hose clamps (B3) on each of the hose.
- 4 Remove the bolts (C2) and remove the adaptor (C1).
- 5 Remove the setscrews (D2) and remove the air pipe (D1).



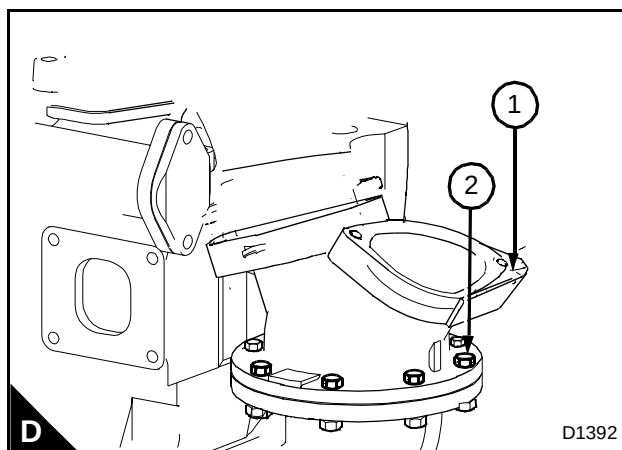
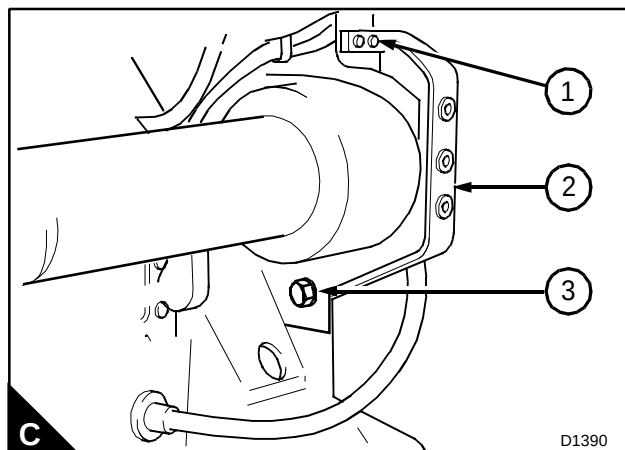
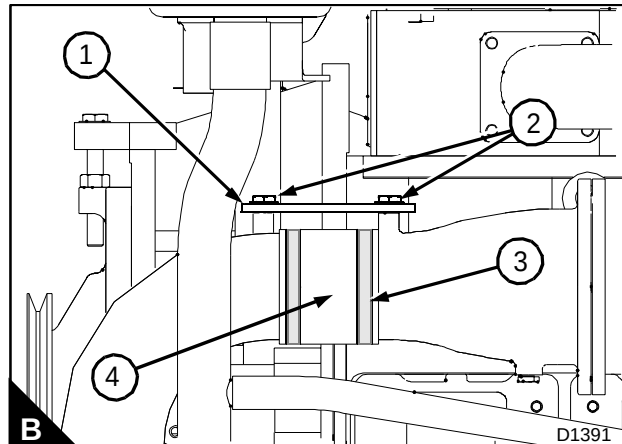
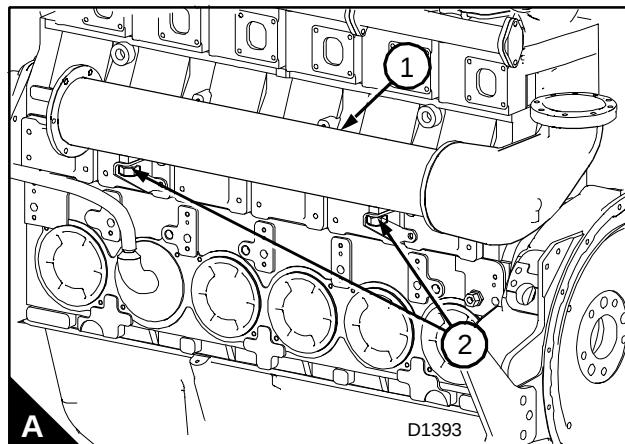
- 6 Cover all open ports in order to ensure that no dirt enters the engine. Clean all components and check for damage, renew as necessary.

To fit

Operation 9-10

1 Align the air pipe (A1) to the hose (B4) and align the setscrews (A2). Fit the setscrews (A2) and tighten to 25 Nm (18,4 lbf ft) 2.5 kgf m. Tighten the hose clamp 15 Nm (36.8 lbf ft) 5 kgf m.

2 Fit the link (B1) and the setscrews (B2). Tighten the setscrews to 50 Nm (11 lbf ft) 1.5 kgf m.



3 Align the support bracket (C2) and fit the setscrews (C1) and (C3). Tighten the setscrews (C1) to 70 Nm (51,6 lbf ft) 7.1 kgf m. Tighten the setscrews (C3) to 50 Nm (11 lbf ft) 1.5 kgf m.

4 Align the adaptor (D1) and a new joint to the air pipe. Fit the bolts (D2) and tighten to 50 Nm (11 lbf ft) 1.5 kgf m.

5 Fit the turbocharger, see Operation 9-8.

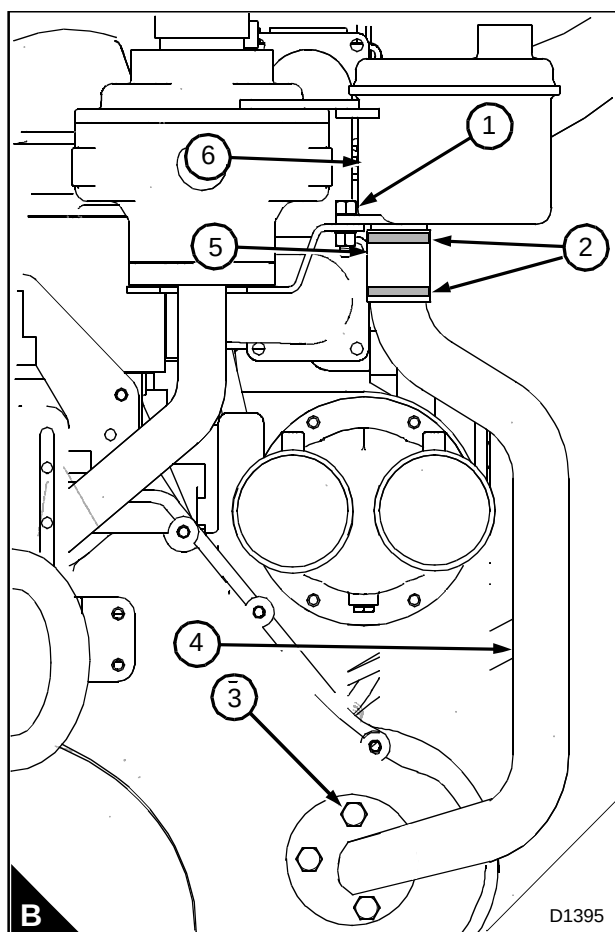
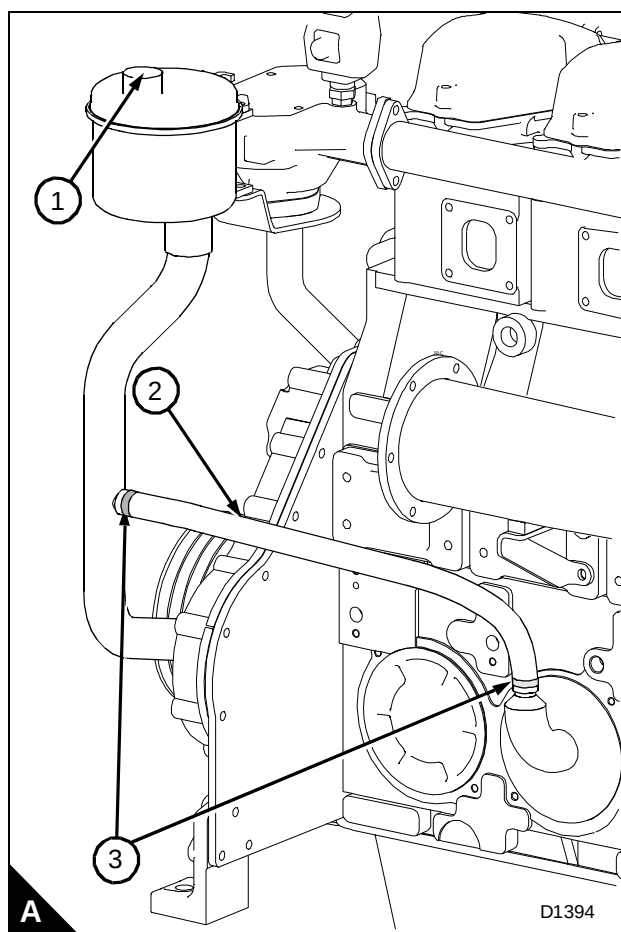
Engine breather

To remove breather system

Operation 9-11

Caution: Ensure that the breather filters are cleaned and maintained in accordance with the maintenance schedules in the relevant User's Handbook.

- 1 Remove the fan guards, see Operation 12-10.
- 2 Loosen the hose clip and remove the hose from the breather vent (A1).
- 3 Loosen the hose clips (A3) and remove the hose (A2).
- 4 Loosen the hose clips (B2). Remove the fasteners (B1) and remove breather filter housing (B6).
- 5 Remove the hose (B5).



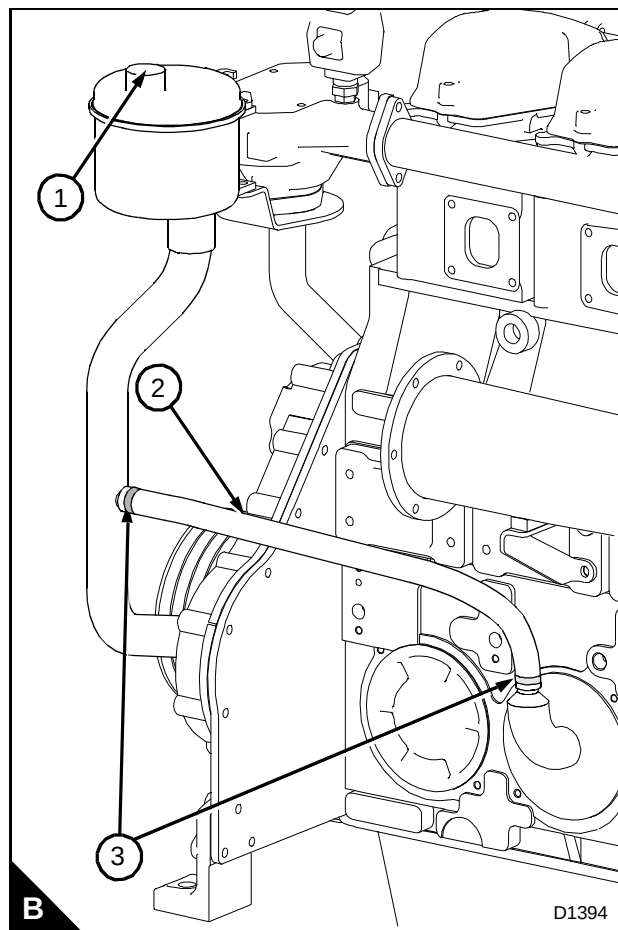
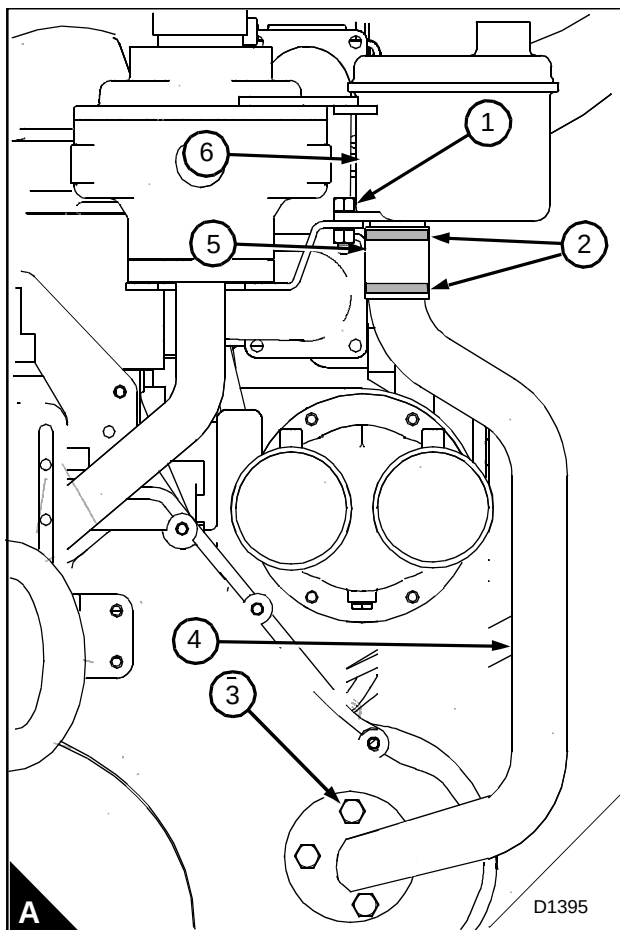
- 6 Remove the setscrews (B3). Remove the pipe (B4) and the joint from the gear case.
- 7 Cover all open ports in order to ensure that no dirt enters the engine. Clean all components and check for damage, renew as necessary.

To fit the breather system

Operation 9-12

Caution: Ensure that the breather filters are cleaned and maintained in accordance with the maintenance schedules in the relevant User's Handbook.

- 1 Align a new joint and the pipe (A4) to the gear case. Fit the setscrews (A3) and tighten by hand.
- 2 Fit the hose (A5) complete with the hose clips (A2).
- 3 Fit the breather filter housing (A6) and the fasteners (A1). Tighten the setscrews (A3) to 50 Nm (11 lbf ft) 1.5 kgf m. and tighten (A1) to 50 Nm (11 lbf ft) 1.5 kgf m.



- 4 Tighten the hose clips (A5) securely.
- 5 Fit the hose (B2) complete with the hose clips (B3) and tighten securely.
- 6 Fit the outlet hose to the breather vent and tighten the hose clip securely.
- 7 Fit the fan guards, see Operation 12-10.

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10

Lubrication system

General Description

Lubrication oil is taken from the Lubricating oil sump by an oil pump mounted on the rear of the back plate and driven from the timing gear train.

Oil from the oil pump is sent to the oil cooler. Once the oil is cooled it is split into two supplies. One supply is sent to the piston cooling gallery inside the crankcase, and the rest is sent to the filter head.

Engine relief oil returns to the sump through the crankcase. Oil pump relief oil returns to the sump through the gearcase.

Oil from the oil gallery inside the crankcase is directed to the piston cooling jets assembly. Each jet directs a spray of oil up towards a drilling in the piston, which connects with an oil gallery inside the piston crown. Once the oil has circulated the gallery inside the piston, the oil drains back to the lubricating oil sump through a second drilling in the piston crown.

Oil from the oil pump flows to the oil cooler, then enters the filter head, which flows through three full flow canister type oil filters, with integral by-pass the oil filters if blocked.

In the case of engines fitted with change over type filters, these filters may be remotely mounted. The oil flows from the filter head inlet gallery through pipes to and from the change over filters and returns to the outlet gallery in the filter head. The third filter port is blocked as it is not required in this option.

Oil from the outlet gallery inside the filter head directs oil through two cross passages. Both passages flow through the crankcase to the opposite side (Camshaft side) and joins with a main oil passage to carry oil the full length of the engine.

From the main oil passage, cross passages opposite each main bearing take oil to the centre of the main bearing housing. From the main bearings, passages in the crankshaft and connecting rods take the oil to the big end and small end bearings.

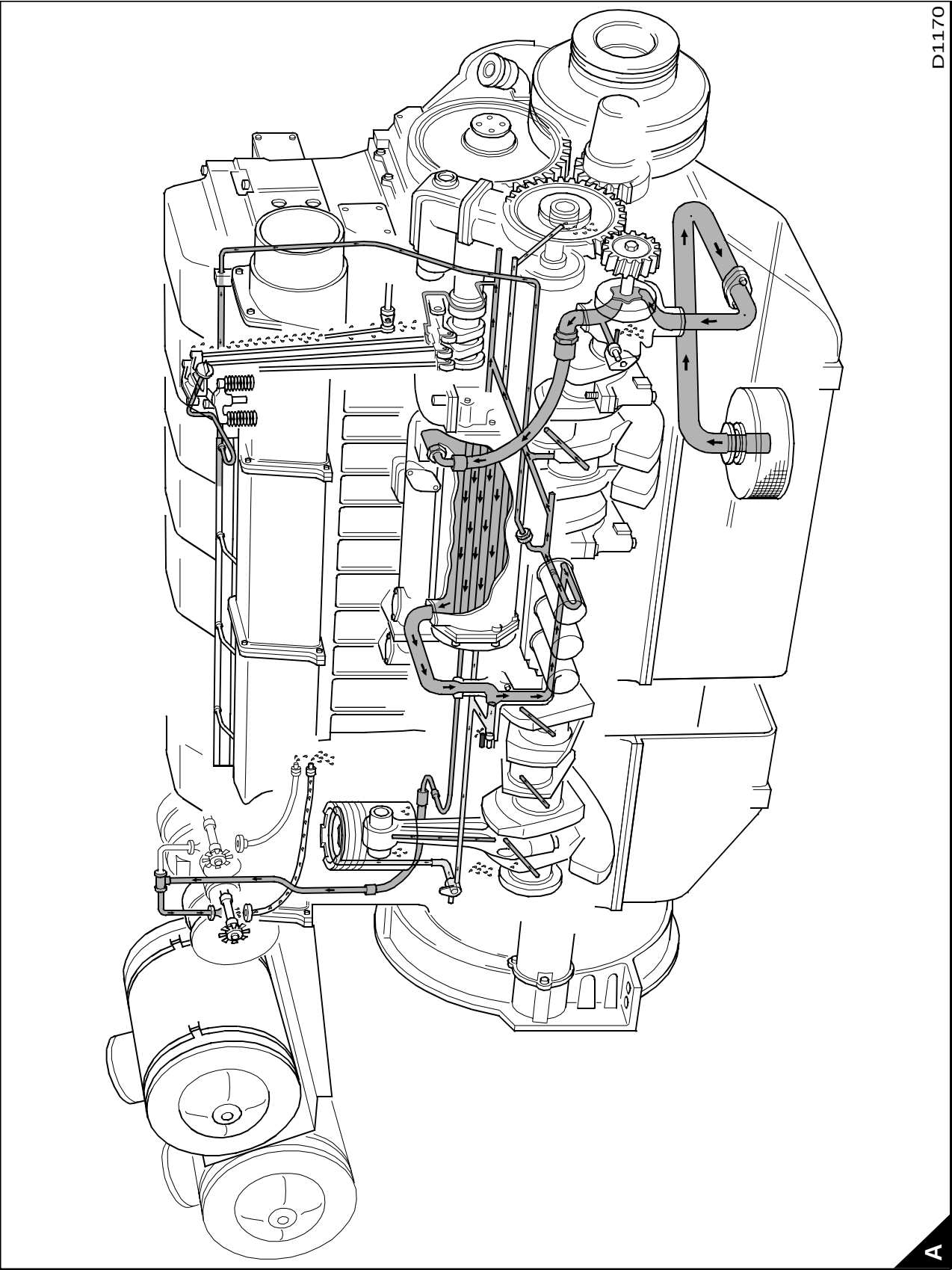
The camshaft bearings are lubricated by oil from the main oil passage through transfer blocks mounted on the side of the crankcase, which line up with passages from the main oil passage and to the camshaft bearing housing.

The oil from the camshaft bearings is directed by passages in the camshaft follower housing to lubricate the pivot shaft for the camshaft followers. The camshaft follower rollers are lubricated by spray jets.

The cylinder head valves are lubricated through an external pipe from the filter head, to the oil feed rail. Oil flows from the feed rail to each rocker box and through the rocker shaft to reach the rocker arm bearings.

The oil supply to the turbo-chargers is taken from the flywheel end of the main oil passage and the drain from the turbo-charger is returned to the lubricating oil sump through a passage in the crankcase.

Lubrication system flow diagram



Filter Canister

To renew

Operation 10-1

Warning! Discard the used lubricating oil filters in a safe place and in accordance with local regulations.

Cautions:

- Ensure that the application is on a level surface to ensure an accurate reading on the dipstick.
- It is important that only genuine Perkins parts are used. The use of a canister that is not a genuine Perkins part may damage the engine and the warranty.
- All three oil filters must be changed as a set.

1 Put a suitable container below the lubricating oil filter.

Note: An oil filter will hold approximately 5 litres (1 gal) of lubricating oil.

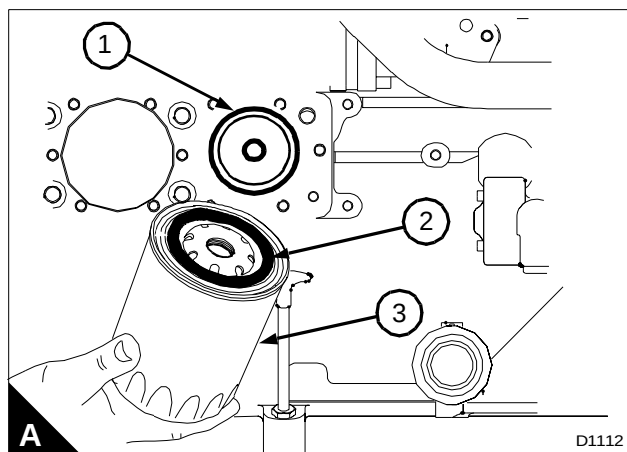
2 Remove the filter canister (A3) with a suitable strap wrench. Discard the canister.

3 Clean the filter head (A1).

4 Lubricate the top of the canister seal (A2) with clean engine lubricating oil.

5 Fit the new canister and tighten it by hand only. Do not use a strap wrench.

6 Remove the container and discard the old lubricating oil.



Note: After all the oil filters have been fitted, check that the air shut off valves are in the open position and prime the oil system. Refer to the relevant User Handbook. Do not start the engine.

7 With the starter motor disengaged, check the oil level on the dipstick and add more oil into the sump if necessary.

8 Run the engine off load and check for oil leaks from the oil system.

Filter head

To remove and to fit

Operation 10-2

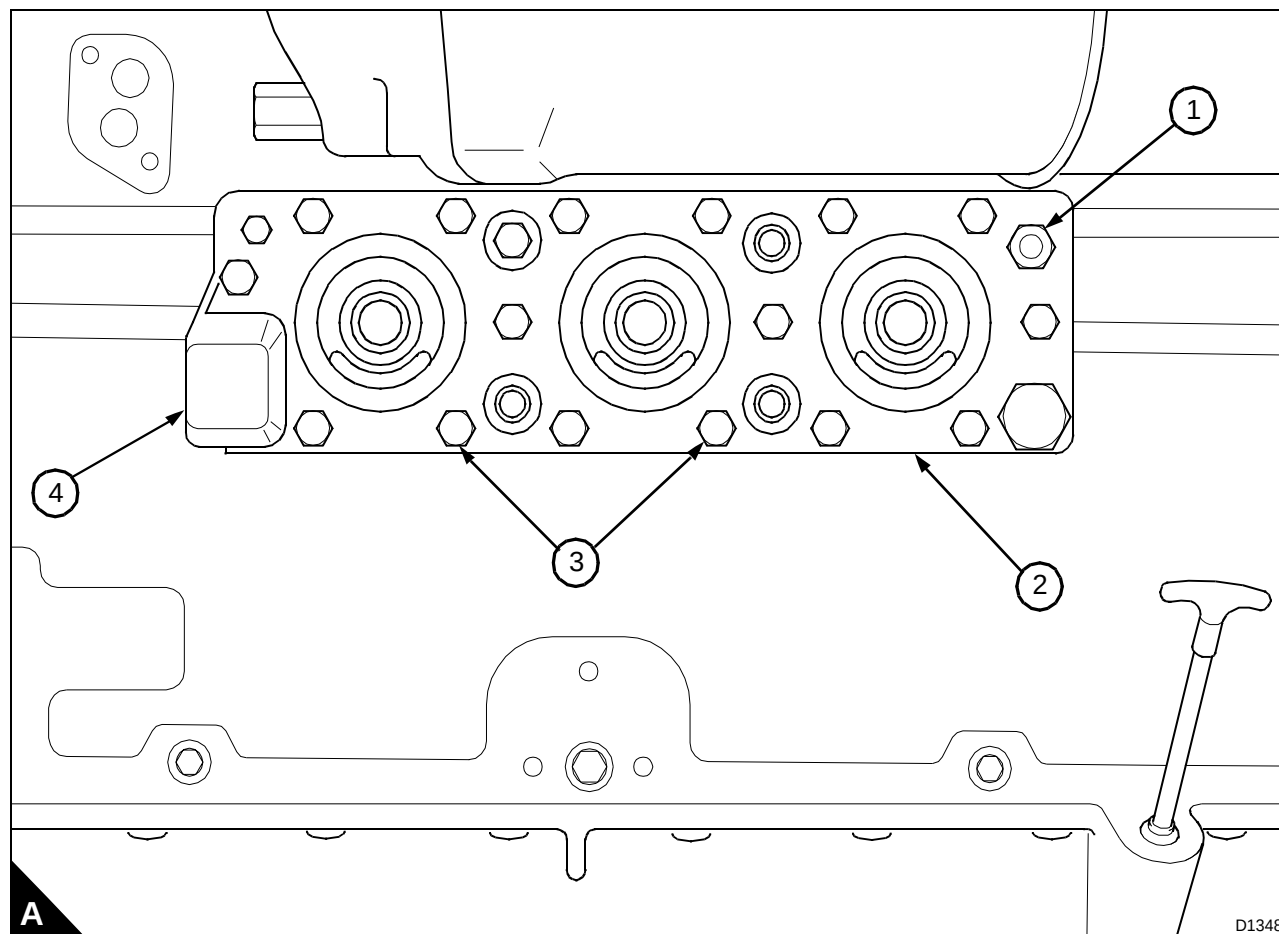
Warning! Use protective eye wear in the use of compressed air.

To remove

- 1 Put a suitable container below the oil filter head to hold spilled oil.
- 2 Remove all three filter canisters, see Operation 10-1.
- 3 Remove the two setscrews that hold the oil pipe (A4) from the oil cooler in position and the outlet pipe to the oil feed rail (A1).
- 4 Remove all setscrews (A3) and lift off the oil filter head (A2).
- 5 Clean all components using a suitable solvent and blow out the oil galleries with compressed air.
- 6 Discard the 'O' rings and remove joint material from any contact surfaces.

To fit

- 1 Fit the oil filter head to the crankcase, with a new joint.
- 2 Fit all setscrews, hand tighten.
- 3 Fit oil cooler pipe (A4), hand tighten setscrews and align flanges.
- 4 Torque the setscrews to 50 Nm (35 lbf ft) 4,84 kgf m.
- 5 Fit the outlet pipe to the oil feed rail (A1).
- 6 Torque all setscrews (A3) on the filter head to 50 Nm (36.88 lbf ft) 5,09 kgf m
- 7 Fit the three filter canisters, see Operation 10-1.



Lubricating oil sump

To remove

Operation 10-3

Warnings!

- Discard the used lubricating oil in a safe place and in accordance with local regulations.
- Before the sump is removed, ensure that the sump is fully supported before the setscrews are removed.

1 Operate the engine until warm.

2 Stop engine.

3 Put a suitable container below the lubricating oil sump to hold the drained oil.

Note: The lubricating oil sump will hold approximately 114 Litres (25 gals) of lubrication oil.

4 Remove both lubricating oil sump drain plugs (A1) and washers.

5 Remove pipe from oil pump to the lubricating oil sump.

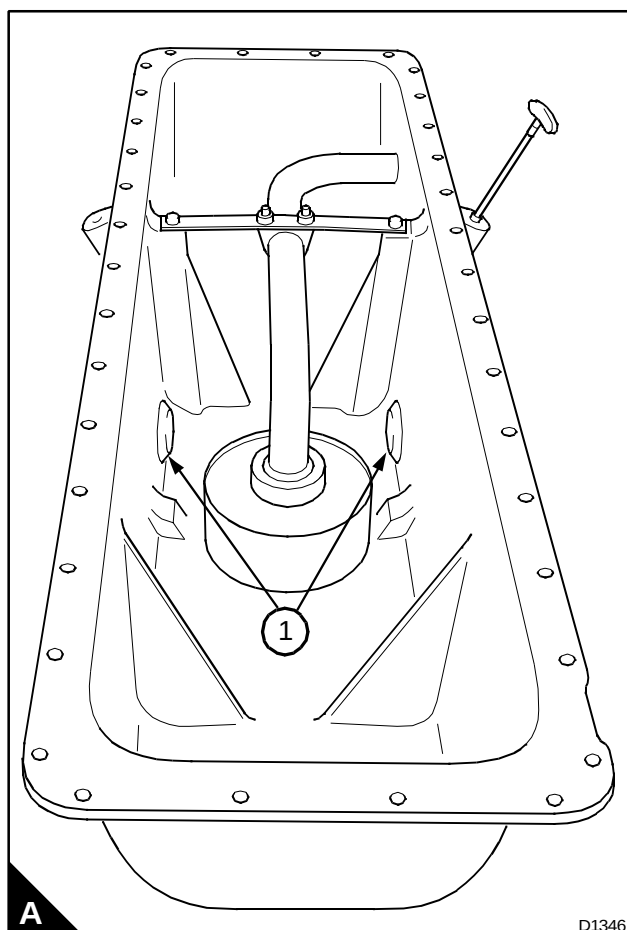
6 Remove the dipstick tube, see Operation 10-5.

7 Provide a support for the lubricating oil sump and remove all the setscrews that hold the sump in place.

8 Lower the lubricating oil sump and discard the joint.

9 Wash the lubricating oil sump with an approved cleaning fluid, ensure that all cleaning fluid is removed.

10 Clean the flange face of the lubricating oil sump and of the cylinder block.



To fit

Operation 10-4

Notes:

- If either the cylinder block or the timing case have just been fitted. Then fit the lubricating oil sump before the timing case sealant has been allowed to cure.
 - If the lubricating oil sump is to be fitted, remove old sealant from the crankcase and the timing case.
- 1 Remove any old sealant from the cylinder block joint surfaces and timing case.
 - 2 Ensure that the joint faces of the cylinder block and the sump are both free from dirt and damage.
 - 3 Insert four alignment studs into holes.
 - 4 Apply a bead of non-silicone sealant to the joints between the sump and the timing case.
 - 5 Place the joint onto the sump and ensure that all of the fixing holes align correctly.
 - 6 Raise the sump up to the crankcase and align over the studs.
 - 7 Loosely fit the setscrews into all of the available holes by hand.
 - 8 Remove the alignment studs and fit the remainder of the setscrews.
 - 9 Fit oil pipe from the oil pump to the suction pipe and hand tighten.
 - 10 Tighten the four setscrews to 40 Nm (30 lbf ft) 4,08 kgf m.
 - 11 Tighten the remaining setscrews to 54 Nm (40 lbf ft) 5,51 kgf m.
 - 12 Fit the drain plugs and new washers and tighten to 68 Nm (50.2 lbf ft) 6,93 kgf m.
 - 13 Fill the engine to the correct level on the dipstick and with new lubricating oil of an approved grade, see the relevant User's Handbook.

Dipstick tube

To remove and to fit

Operation 10-5

Special requirements

Consumable products	
Description	Part number
POWERPART Threadlock and Nutlock	21820117 or 21820118

- 1 Remove the dipstick tube M15 gland nut and remove the tube from the sump.
- 2 Clean the gland nut and the thread in the lubricating oil sump of all old sealant.
- 3 Fit a new 'O' ring to the dipstick handle / blade assembly.
- 4 Apply POWERPART threadlock and nutlock to the threads of the gland nut.
- 5 Fit the dipstick tube to the sump in the correct position, tighten the gland nut to 18 Nm (14 lbf ft) 1,8 kgf m.

Oil strainer and suction pipe

To remove and to fit

Operation 10-6

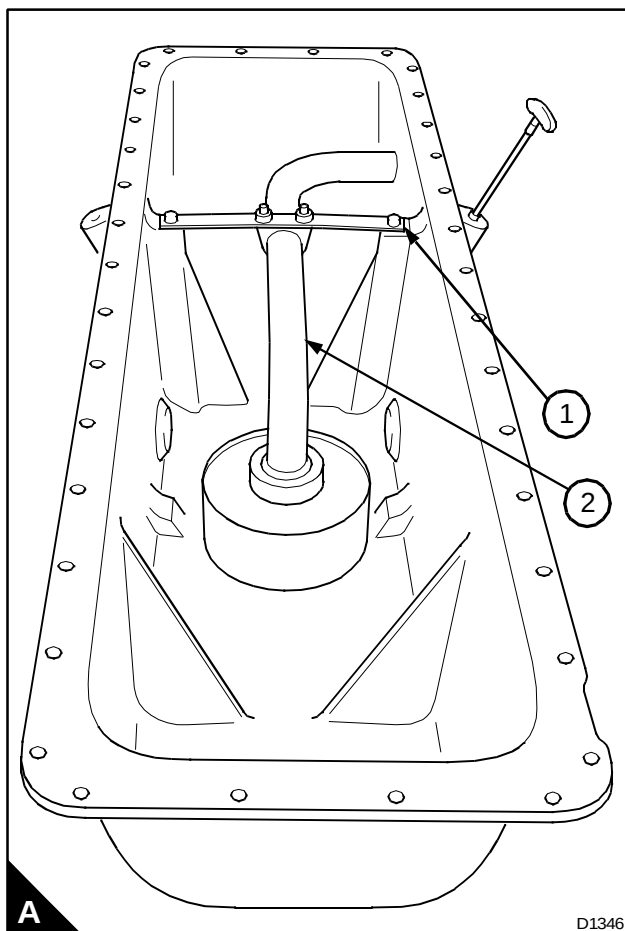
The oil strainer is an integral part of the suction pipe. No regular service is necessary but wash the strainer when it is removed.

To remove

- 1 Remove the lubricating oil sump, see Operation 10-3.
- 2 Remove the setscrews from the support bracket (A1) that holds the suction pipe.
- 3 Remove the suction pipe and strainer (A2).
- 4 Remove all 'O' rings and discard.
- 5 Wash the assembly in an approved cleaning fluid and dry.
- 6 Check the pipe, the strainer and the welded joints for cracks and other damage.
- 7 If a component is damaged, renew as necessary.

To fit

- 1 Clean the strainer and suction pipe.
- 2 Renew the 'O'ring on the suction pipe that fits in through the hole on the side of the lubricating oil sump.
- 3 Fit the suction pipe (A2) into the correct position inside the lubricating oil sump.
- 4 Fit the support bracket (A1) to the lubricating oil sump and tighten the setscrews.
- 5 Fit the lubricating oil sump, see Operation 10-4.



Lubricating oil pump

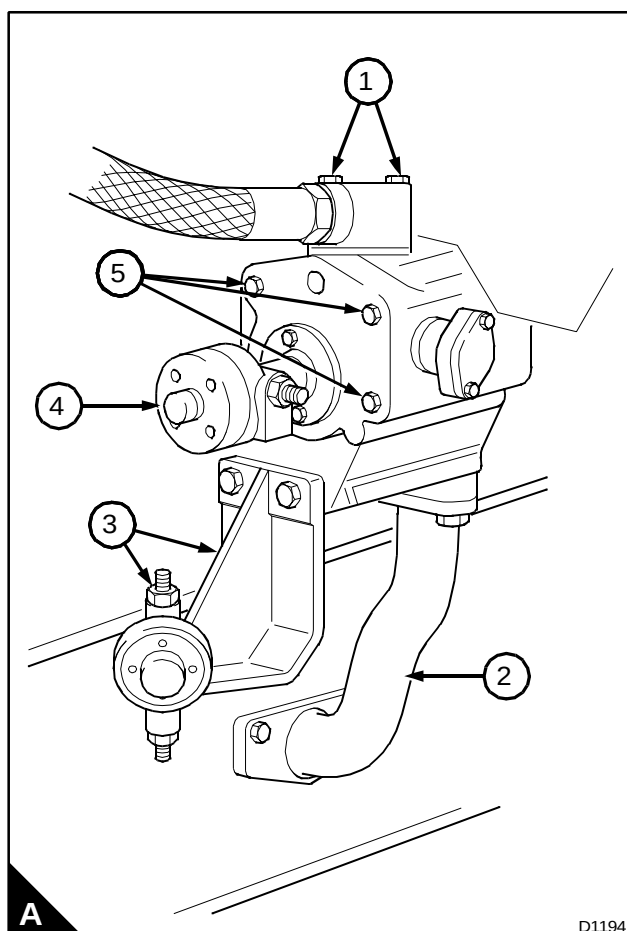
To remove

Operation 10-7**Warnings!**

- Use a hoist with a sling around the body of the oil pump to lift it.
- Disconnect the battery or turn off any other starting aids before work is done to the engine.

Note: In the event of a failure or major overhaul new pumps can be obtained from your nearest Perkins Dealer/Distributor.

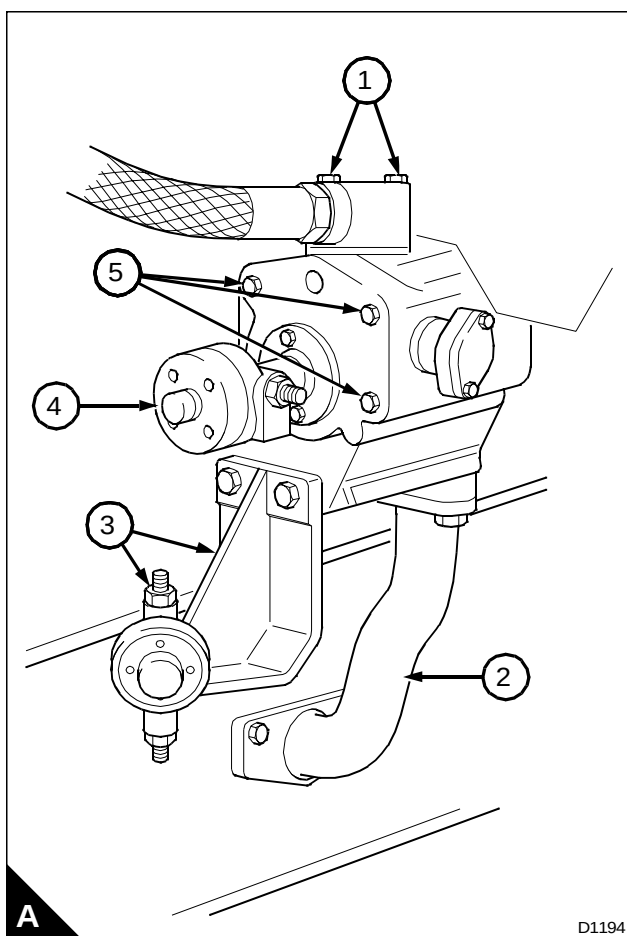
- 1 Turn off fuel supply to the engine.
- 2 Drain and remove the pipes that supply the fuel pump and priming pump.
- 3 Remove the hand priming pump and the mounting bracket (A3).
- 4 Remove the fuel pump from the back of the oil pump, see Chapter 11, Fuel system.
- 5 Place an empty container under the oil pump to hold any spilled oil.
- 6 Remove the two setscrews (A1) on top of the oil pump.
- 7 Remove the flexible oil feed pipe from the oil pump and discard the oil 'O' ring seal.
- 8 Remove the two screws from the bottom of the oil pump to free the pipe (A2) from the oil pump to the sump and discard the oil seal.
- 9 Remove the last four nuts that hold the oil pump in place (A5).
- 10 Slide the oil pump away from the engine, along the mounting studs.



To fit

Operation 10-8

- 1 Lubricate the oil pump drive gear, then carefully slide the oil pump down its mounting studs into position.
- 2 Hand tighten the four nuts (A5) that hold the oil pump in position.
- 3 Fit a new 'O' ring to the oil pipe (A2) from the engine sump body to the oil pump and fit the setscrews and hand tighten.
- 4 Fit the second oil pipe (A1) from the oil pump to the oil cooler, fit a new 'O' ring and fit the bolts and hand tighten.
- 5 Torque the oil pump studs (A5) and oil pipe setscrews (A2) to 50 Nm (36.8 lbf ft) 5.1 kgf m.
- 6 Fit the hand priming pump and the bracket (A3).
- 7 Fit the fuel pump (A4) with a new joint.

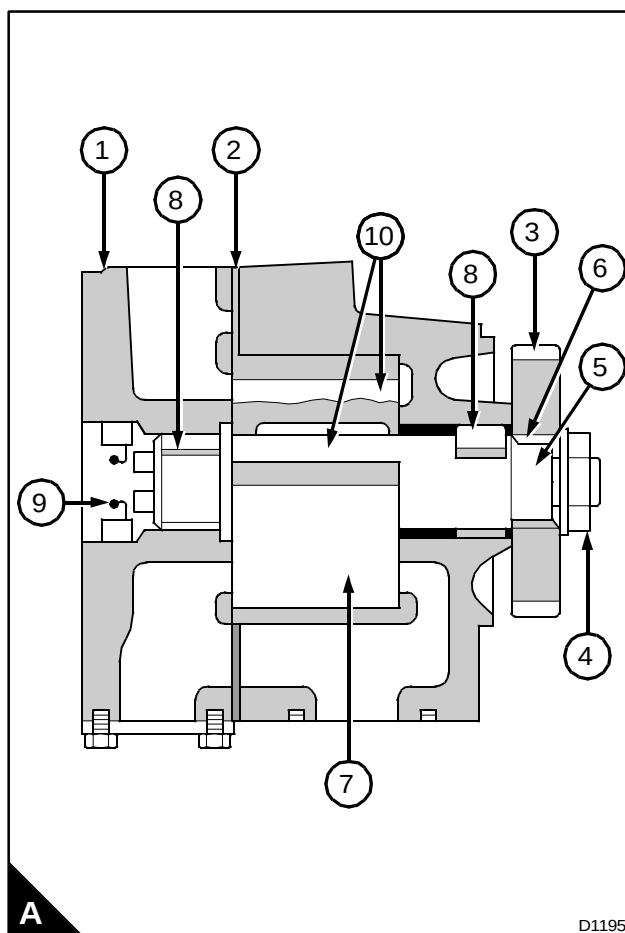


To dismantle

Operation 10-9

Note: only suitable trained people with the appropriate equipment should attempt to overhaul the oil pump. For further information contact your nearest Perkins Dealer/Distributor.

- 1 Remove the setscrews that hold the pump together.
- 2 Remove the pump cover (A1) and peel of the joint (A2).
- 3 Use the soft jaws of a vice grip to grip the oil pump gear (A3) and remove the nut (A4) and the washer (A5).
- 4 Pull the gear from the drive shaft of the oil pump.
- 5 Remove the drive key (A6).
- 6 Push the drive shaft complete with the inner rotor from the oil pump body.
- 7 Remove the outer rotor (A7) from the oil pump body.
- 8 Pull the inner rotor from the drive shaft and the parallel key.
- 9 Remove the bearing (A8) and the oil seal (A9) from the pump cover.



To assemble

Operation 10-10

Special Requirement

Description	Part Number
Powerpart Threadlock and nutlock	21820117

Note: All joint surfaces must be clean and free of all old joint material.

- 1 Use clean engine lubricating oil to lubricate the bearings, the inside area of the pump body, the inner (A10) and outer rotor (A7) and the drive shaft.
- 2 Fit the outer rotor into the oil pump body.
- 3 Fit the parallel key for the inner rotor onto the drive shaft.
- 4 Slide the inner rotor along the shaft locating it on the key and seat the inner rotor against the raised shoulder on the drive shaft.
- 5 Carefully fit the drive shaft and rotor into the body of the oil pump, force should not be necessary.
- 6 Fit a new joint to the face of the oil pump body.

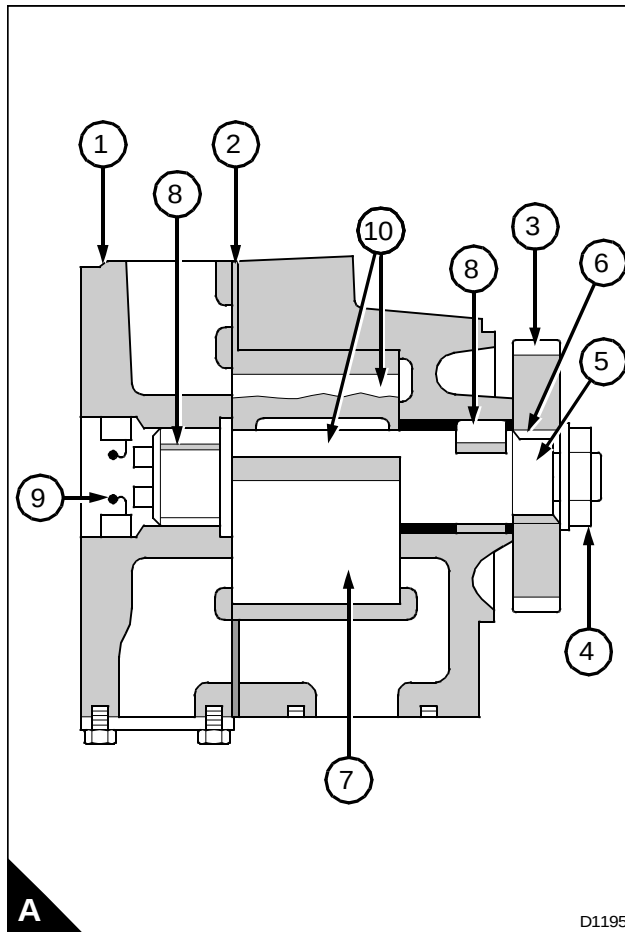
Note: This joint controls the end float.

Warning! Fit only genuine Perkins parts, failure to do so can damage the engine and may effect the warranty.

- 7 Align the oil pump cover (A1) to the bearings (A8). Align the dowel on the body to the cover and fit together.
- 8 Fit the two setscrews and retainer setscrew and hand tighten them evenly.
- 9 Torque the setscrews to 50 Nm (35 lbf ft) 5.1 kgf m.
- 10 Check that the oil pump drive shaft rotates freely.
- 11 Fit the relief valve, see Operation 10-12.

Continued

12 Fit the drive gear key into the shaft, push the gear onto the shaft and locate the key in the gear.



13 Apply threadlock sealant to the nut (A4).

14 Fit the heavy washer and screw on the nut and hand tighten.

15 Do not allow the gear (A3) to rotate. Tighten the retractor nut (A4) to 237 Nm (175 lbf ft) 24.1 kgf m. Ensure that the gear is not damaged during this operation.

16 Fit a new joint for the fuel lift pump.

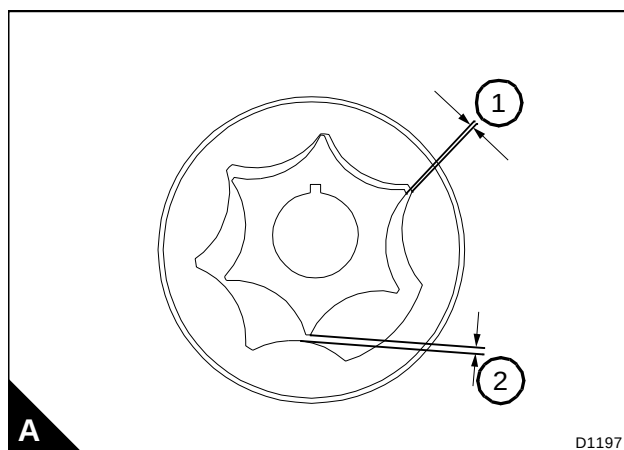
17 Fit fuel lift pump, see Chapter 11, Fuel system.

To inspect

Operation 10-11

Note: If any part is worn enough to have an effect on the performance of the oil pump, the complete pump must be renewed.

- 1 Dismantle the oil pump, see Operation 10-9.
- 2 Remove the outer rotor and clean thoroughly all the parts. Check for cracks and any other damage.
- 3 Check the inner rotor for damage or wear.
- 4 Check the oil pump shaft bearing for wear or damage.
- 5 Check the key, key way and the fuel pump drive dog for wear.
- 6 A final check on the dimensions should be done, see "Data and dimensions" on page 10.
- 7 Fit the inner rotor onto the key way and check that there is no movement in the rotation of the axis.
- 8 Fit the outer rotor and check the inner to outer rotor clearance (A1) 0.127mm (0.005 in).
- 9 Check the inner rotor to outer rotor clearance (A2) 0.178mm (0.007 in).
- 10 Assemble the oil pump, see Operation 10-10.



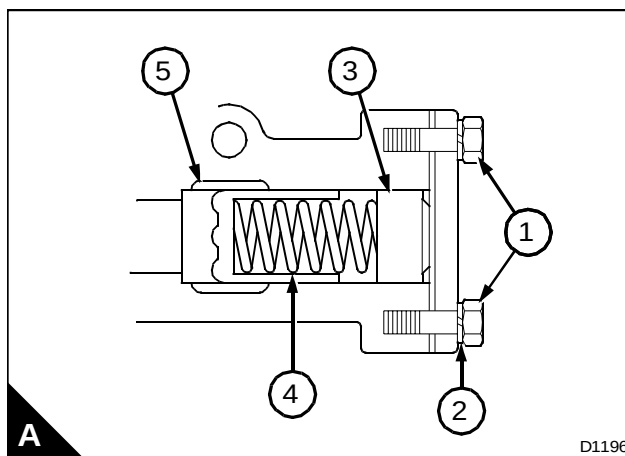
Relief Valve

To dismantle and to assemble

Operation 10-12

If necessary, the relief valve can be dismantled and assembled while it is fitted to the engine.

- 1 Remove the two setscrews (A1).
- 2 The cover (A2) will be removed by the spring pressure of the valve.
- 3 The spring retainer (A3), the spring (A4) and the plunger (A5) can be removed from the oil pump cover.
- 4 Ensure that all the components are cleaned and lubricated lightly with clean engine lubricating oil.
- 5 Fit the plunger (A5) into the bore of the relief valve.
- 6 Fit the spring (A4) and the spring retainer (A3) into the bore with the end of the spring fitted around the boss of the spring retainer.
- 7 Apply pressure to the spring and fit the joint cover and setscrews.
- 8 Torque the setscrews to 25 Nm (18 lbf ft) 2,5 kgf m.



To inspectOperation 10-13

Caution: Do not change the operation pressure of the relief valve by a method other than the installation of new components.

- 1 Check the spring for wear and other damage.
- 2 Check the load necessary to compress the spring to its fitted length, see chapter two.
- 3 Check the plunger for wear and other damage. Ensure that it slides easily into the bore of the oil pump body.
- 4 Check the body and the end plate for wear and other damage.
- 5 Renew worn or damaged components.

Fuel lift pump drive unit

To renew

Operation 10-14

Caution: Failure to follow the recommended "To fit" procedure may make you engine warranty invalid.

Notes:

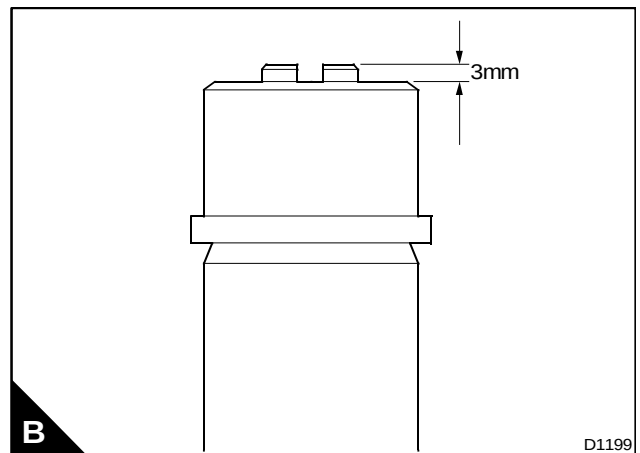
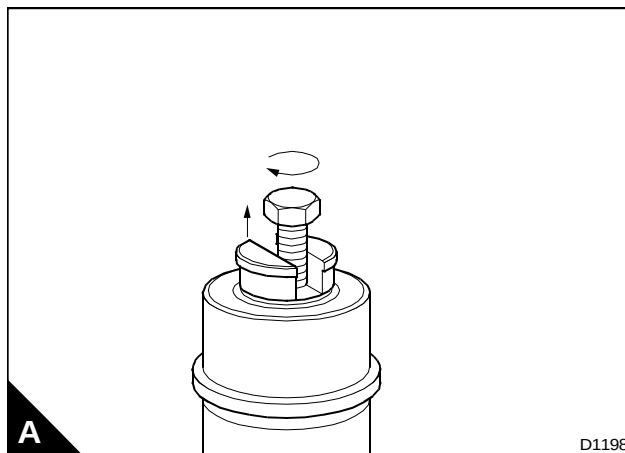
- The fuel pump drive unit can only be renewed when the oil pump is removed from the engine and dismantled.
- It is recommended that a Perkins Dealer/Distributor should renew a fuel lift pump drive unit.

To remove

- 1 Fit a M6 setscrew into the threaded hole and tighten until the drive unit is removed.

To fit

- 1 Immerse the new fuel lift drive unit in liquid nitrogen to decrease the diameter.
- 2 Carefully push the fuel lift drive dog into position.
- 3 The fuel lift drive unit must protrude by 3mm (0,12 in)



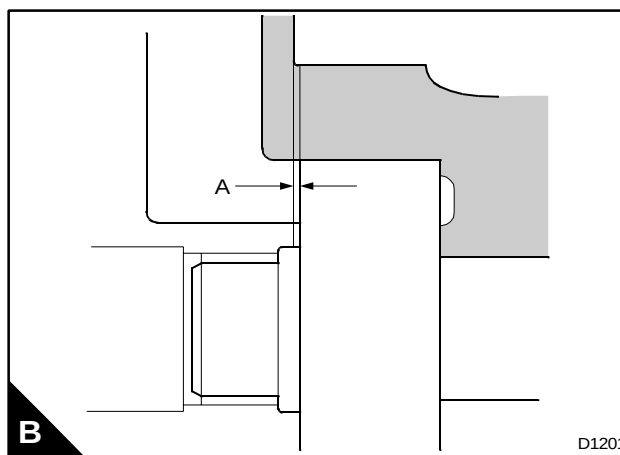
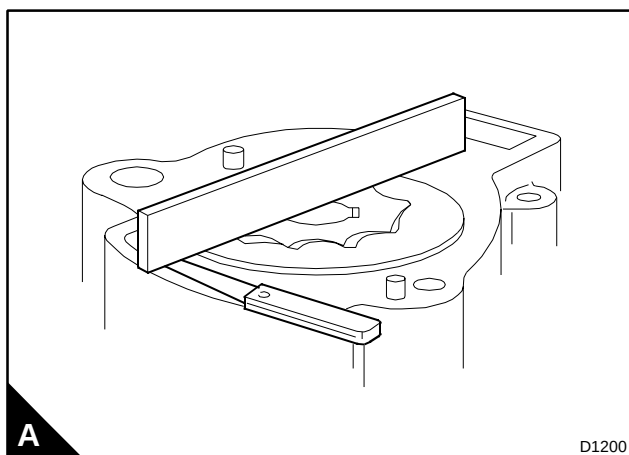
Rotor end float

To inspect

Operation 10-15

Note: If new rotors are fitted then the end float clearance must be checked.

- 1 Dismantle the oil pump body, see Operation 10-9.
- 2 Check that the end faces of the rotors are dry.
- 3 Fit the inner and outer rotor into the body of the oil pump without the drive shaft.
- 4 Place the oil pump in a vertical position.
- 5 Place a straight edge across the rotors and use a feeler gauge to measure the distance the rotor protrudes from the oil pump body face.
- 6 Measure the thickness of the oil pump cover joint. The joint must measure 0.229 mm (0.009 in) to 0.254 mm (0.011 in).
- 7 To calculate the rotor end float, take the thickness of the joint minus the approximate compression value, which is 0.05 mm (0.002 in) to 0.08 (0.003 in) to obtain the thickness of the joint after the oil pump cover is tightened. Then subtract how much the rotor protrudes from the oil pump body, and you are left with the rotor end float value.
- 8 The final rotor end float clearance should be between 0.08 mm (0.003 in) to 0.15 mm (0.006 in).
- 9 Assemble the oil pump body, see Operation 10-9.



Drive shaft bearings

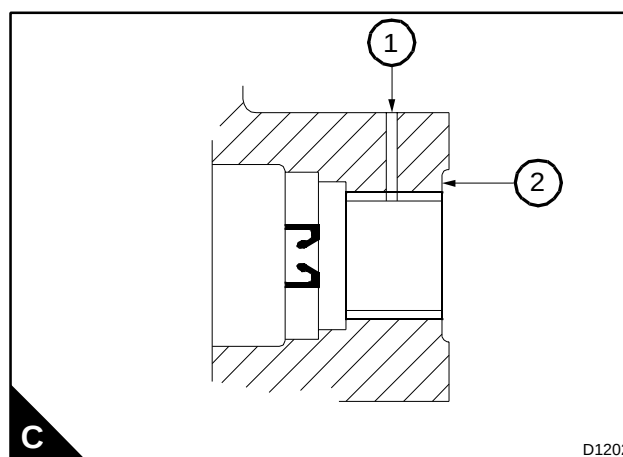
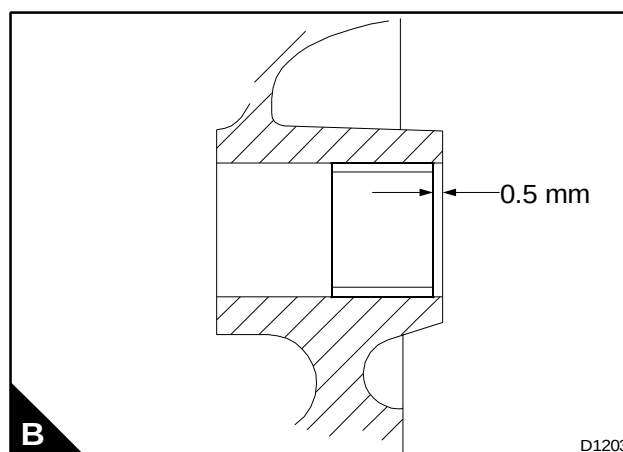
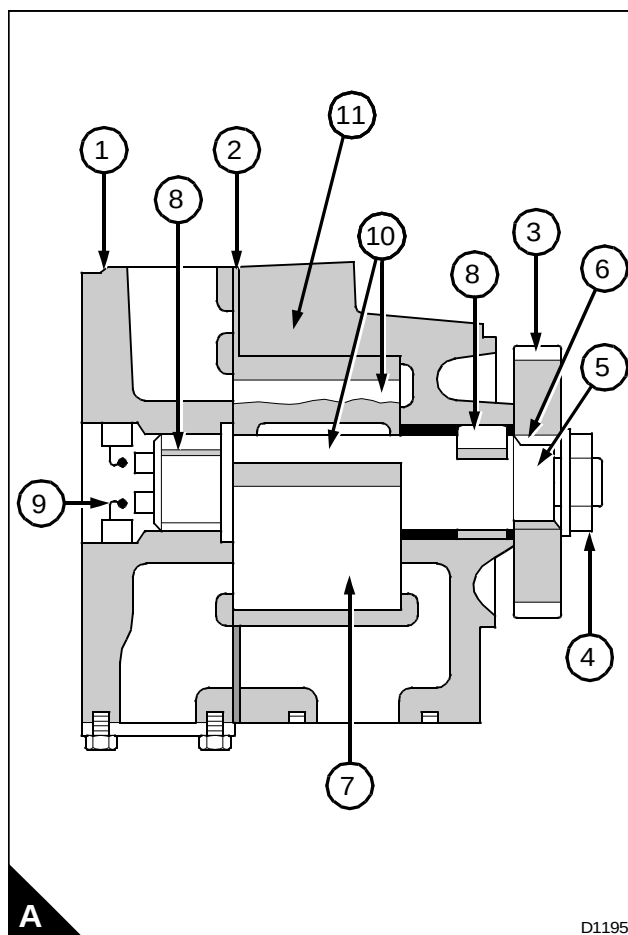
To remove and to fit

Operation 10-16

- 1 Dismantle the oil pump body, see Operation 10-9.
- 2 Use a suitable drift to drive the old bush from the oil pump body (A11).
- 3 Press the new bush to 0.5 mm (0.020 in) below the face of the oil pump body (B1).
- 4 Remove the second drive shaft bearing (A8):-
- 5 Use a suitable bearing extractor to remove the bush from the oil pump cover.
- 6 Use a suitable drift to drive the oil seal from its housing.
- 7 Press the new bush into the oil pump cover.
- 8 Align the oil hole in the housing (C1), with the oil hole in the bearing, and press bush until it is level with the oil pump cover face (C2).
- 9 Fit the new oil seal (A9).
- 10 Assemble the oil pump body, see Operation 10-10.

Notes:

- All components must be free from dirt and debris.
- Ensure that you do not damage the joint face surface.
- Always use clean engine lubricating oil to lubricate components.



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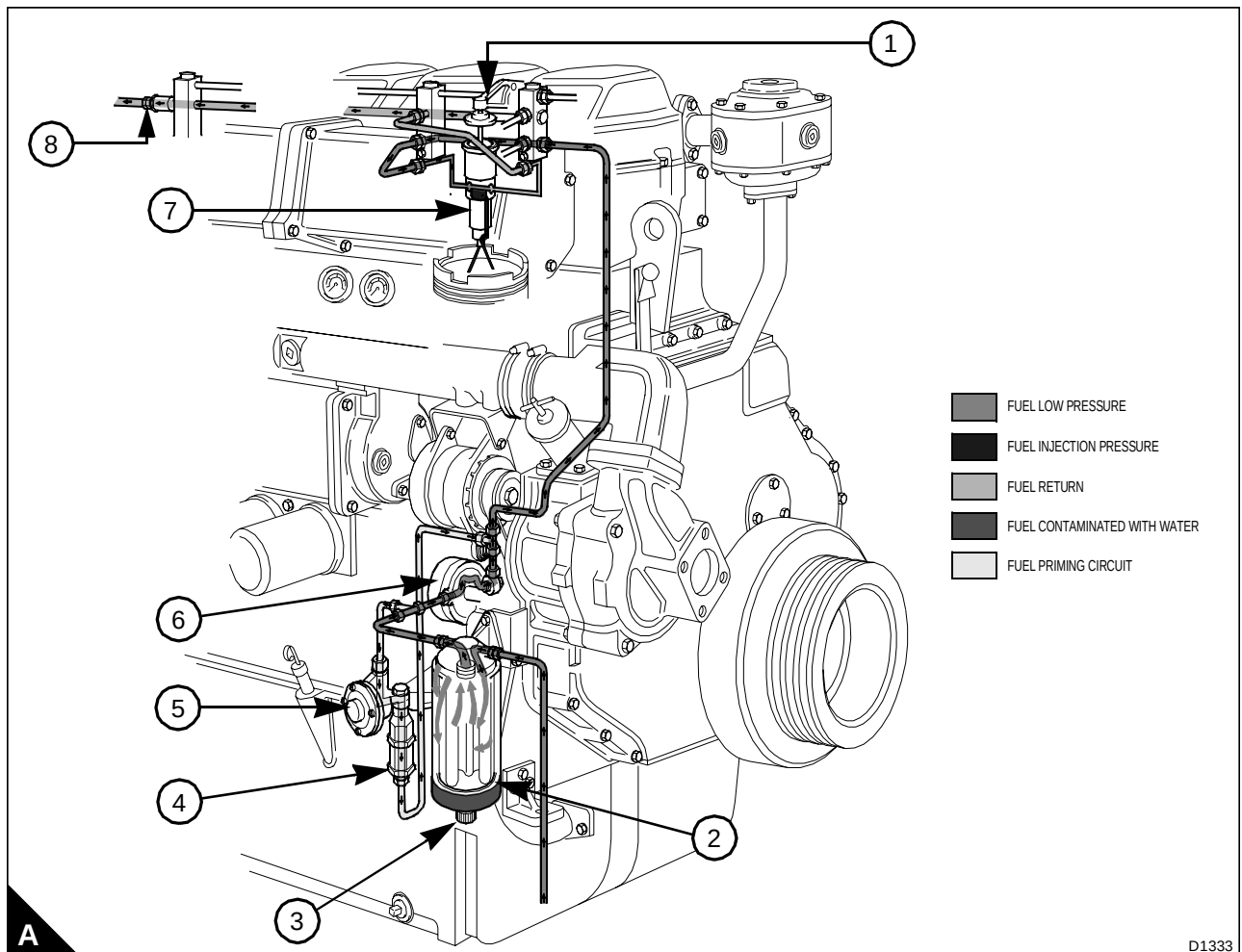
11

Fuel system

General description

The fuel system comprises of the following components:

Fuel reservoir, fuel filter (2), one way valve (4), fuel system priming pump (5), fuel lift pump (6) the fuel injector (7) and a one way pressure control valve (8). Each cylinder of the engine has an individual fuel injector unit attached to the cylinder head. Each unit performs the function of a fuel injection pump and a fuel injector. The operation of each fuel injector unit is controlled through the cam and rocker position.



The function of the fuel injector unit is to:

- raise the pressure of the fuel sufficiently to open the integral fuel injector nozzle valve and to spray a predetermined amount of atomised fuel into the combustion chamber.
- deliver an equal amount of fuel to each cylinder.
- inject the fuel at precisely the correct moment for the most efficient combustion.
- vary the amount of fuel injected in accordance with the requirements of load and speed.

Caution: The fuel injector mechanism can be adjusted, but must only be maintained and checked by personnel who have had the correct training.

Fuel filter

Warning! Discard the used canister and fuel oil in a safe place and in accordance with local regulations.

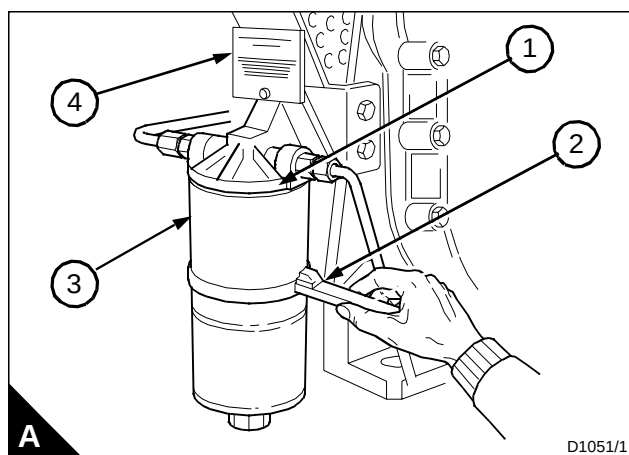
Caution: It is important that only genuine Perkins parts are used. The use of a canister that is not a genuine Perkins part may damage the fuel system and the warranty.

To remove and fit

Operation 11-1

To remove

- 1 Thoroughly clean the filter head (A1) and the canister (A3).
- 2 Put a suitable container under the fuel filter assembly.
- 3 Use a suitable strap wrench (A2) to remove the canister. Discard the canister.



To fit

Caution: The plate (A4) contains information on how to drain the fuel filter canister. It also has information on when to change the filter canister. Before the filter is changed refer to the maintenance schedule in the relevant Users Handbook.

- 1 Lubricate the top of the new canister seal with clean fuel oil.
- 2 Fit the new fuel filter canister and tighten it by hand only.
- 3 Prime the fuel system, refer to the relevant Users Handbook.
- 4 Remove the container.
- 5 Run the engine and check for leaks.

Fuel injector unit

To remove the fuel injector unit

Operation 11-2

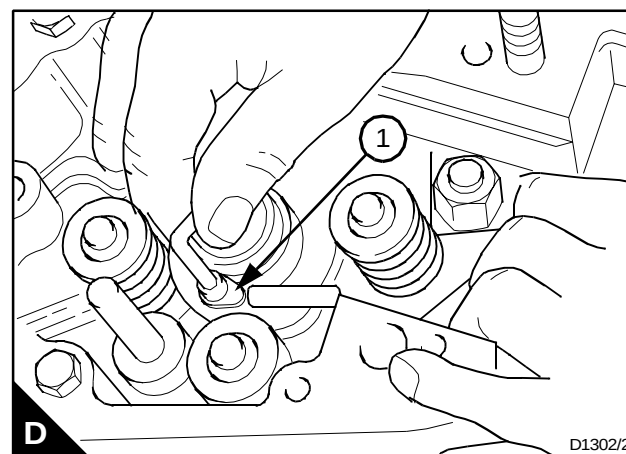
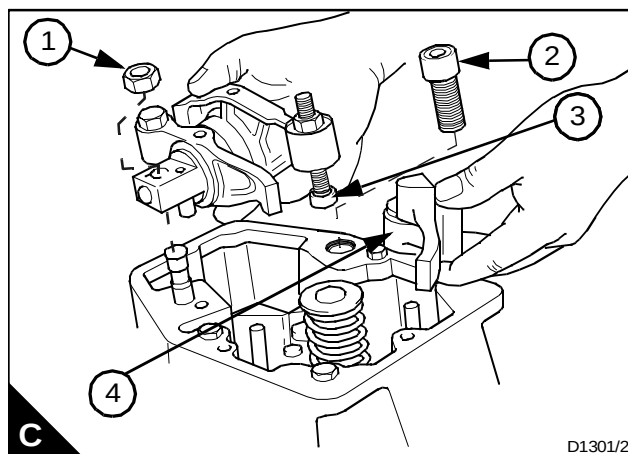
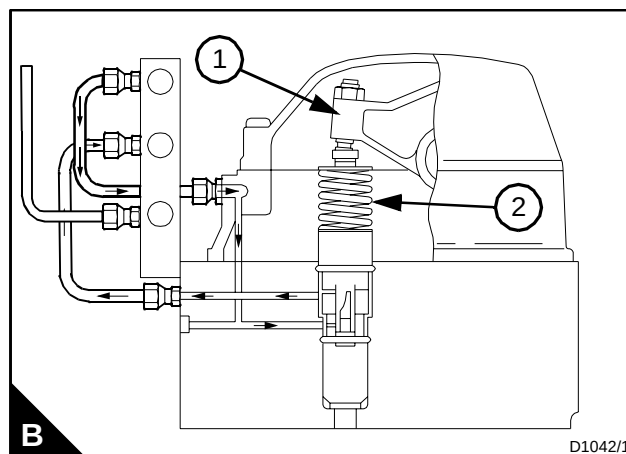
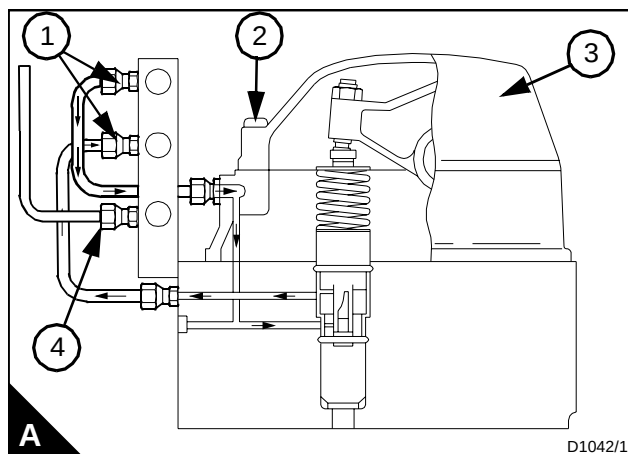
Special requirements

Special tools	
Description	Part number
Fuel injector unit puller	T6253/350

Warning! Wear eye protection during this operation.

To remove

- 1 Loosen the fuel feed and the fuel return pipe union nuts (A1) and let the fuel drain from the fuel rail into a suitable container. Remove the pipes.
- 2 Loosen the oil feed pipe union nut (A4) and drain the oil into a suitable container. Remove the pipe.
- 3 Remove the four slot head setscrews (A2) from the rocker box cover (A3) and remove the cover.
- 4 Observe the fuel injector rocker (B1), and rotate the engine until the fuel injector rocker (B1) has moved upwards and the fuel injector springs (B2) are fully extended.



- 5 Remove the nut (C1) and the cap screw (C2) from the rocker shaft assembly and remove.

Note: Ensure that the hardened cup (C3) located between the rocker arm and the fuel injector unit, does not fall inside engine.

- 6 Remove the three pushrods for the inlet, and the exhaust valves and the fuel injector.

Note: Mark all three pushrods rod and the inlet and exhaust valve rocker bridge pieces to ensure correct re assembly

- 7 Remove the inlet and exhaust rocker bridge pieces (C4)

8 Disconnect the governor mechanism (D1) from the pump control arm

Note: Do not drop the capscrew or collar into the assembly.

9 Remove the cap screw (E1) from the fuel injector clamp.

10 Fit the special tool T6253/350(F) and spacer to the fuel injector unit. Ensure that the two legs (F2) are put under the clamp (F3)

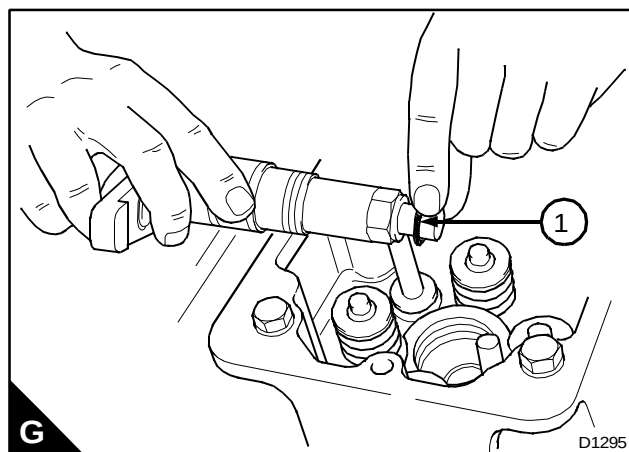
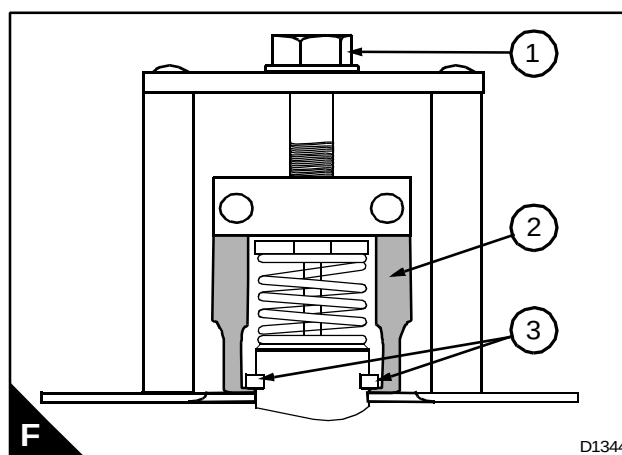
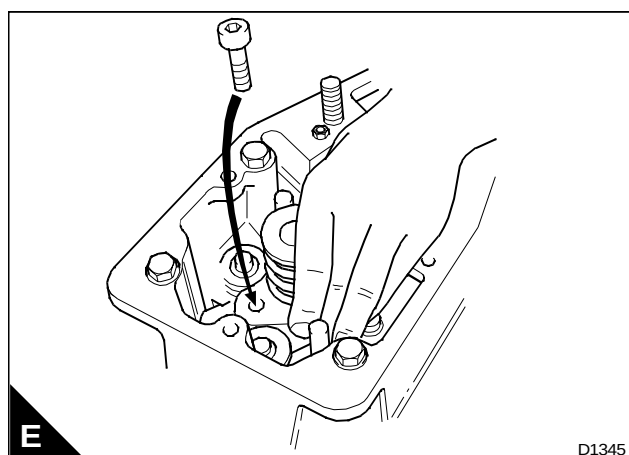
11 With a suitable spanner, turn the nut (F1) clockwise until the fuel injector is free of it's housing.

12 Remove the fuel injector from the cylinder head.

Note: The fuel injector should not be pulled upwards by the spring mechanism as this will only lift the plunger from the barrel.

13 Remove the copper washer (G1) from the fuel injector. If the washer is not attached to the fuel injector when extracted, then it must be removed from the fuel injector housing.

Note: When a fuel injector is removed, fuel will leak from the fuel gallery in the cylinder head into the cylinder bore. In order to prevent a hydro - static lock in the cylinder bore, rotate the engine to TDC and siphon off the excess fuel from the bore. When the engine is ready to be started, it must be rotated on the starter for 10 seconds with the governor lever set to the stop position.



To disassemble and to check a fuel injector unit

Operation 11-3

Special requirements

The fuel injector units should only be dismantled, serviced, tested and assembled if the correct test equipment, tools and dust free facilities are available.

Special tools			
Description	Part number	Description	Part number
Fuel injector clamp and fuel feed adaptor - 12mm (0.47 in)	T6253/146	Needle gauge	T6253/203
Service tool kit	T6253/202	Multiclean	T6253/204

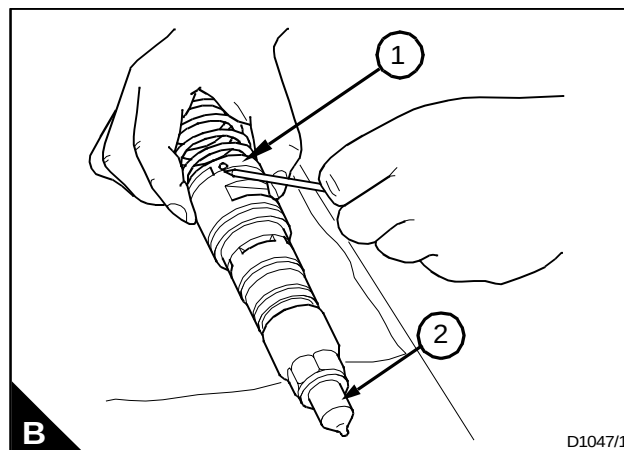
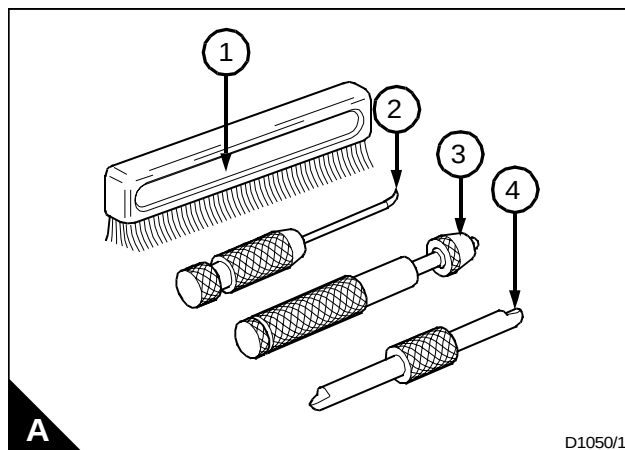
Warning! Do not rotate the engine on the starter without the rocker fitted, as damage to the camshaft and the pushrods may occur

Notes:

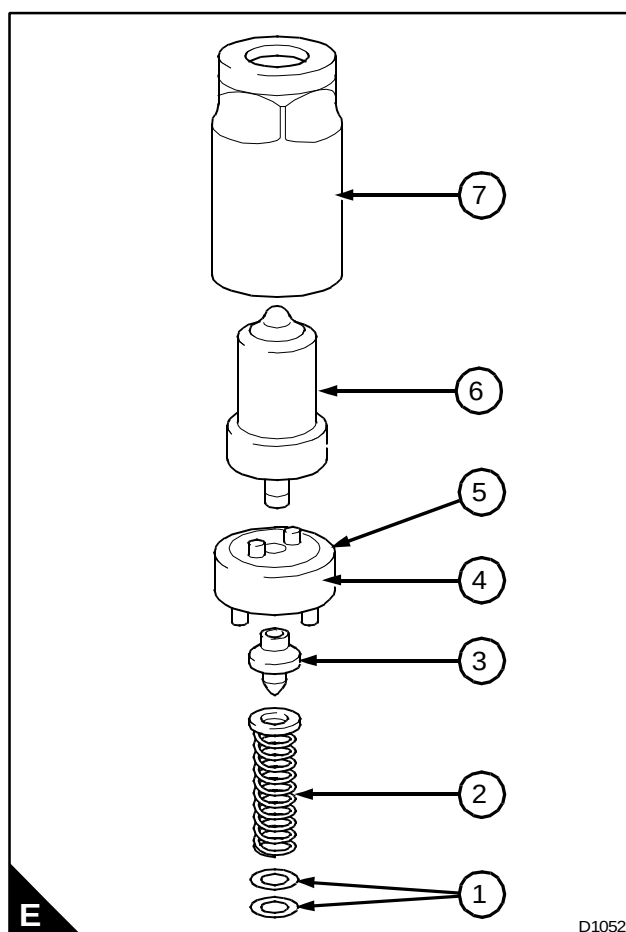
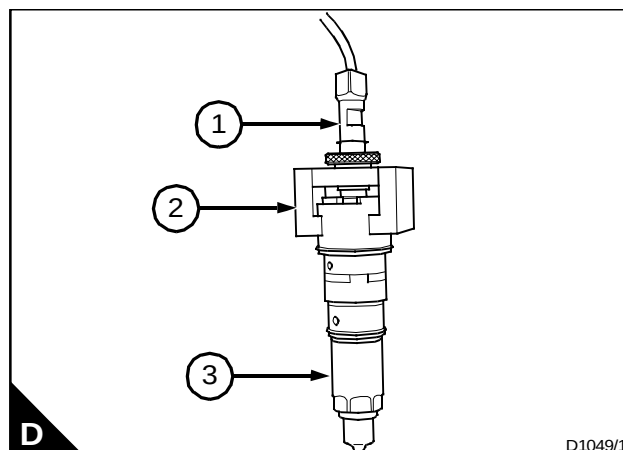
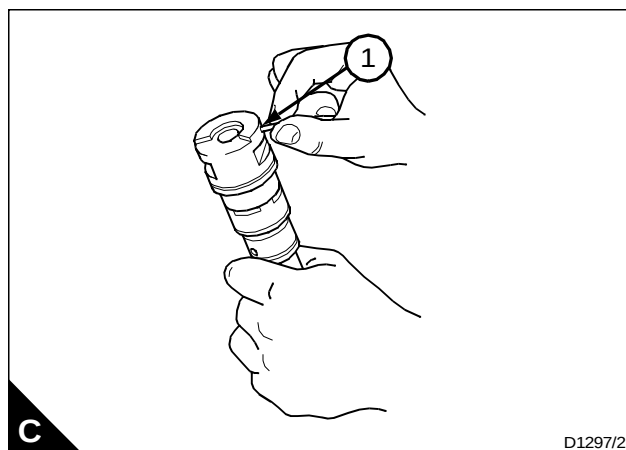
- The plunger spring assembly and element housing are a matched pair and their components cannot be interchanged. To eliminate the possibility of the plunger spring assembly being assembled to the wrong element housing, it is advisable to only work on one fuel injector unit at a time.
- The plunger spring assembly and element housing are non serviceable items. Exchange units are available from your local distributor if they are worn or excessively damaged.

To dismantle

- 1 If the fuel injector unit is in a dirty condition, seal off the spill ports and wash the body in clean fuel.
- 2 Remove the carbon deposits from the exterior of the fuel injector nozzle with a brass wire brush (A1) from Service tool kit.
- 3 Insert a screwdriver under the spring plate and lever it over the spring dowel (B1).
- 4 Remove the plunger spring assembly from the element housing.
- 5 Put the plunger spring assembly and the element housing into a bath of clean fuel or Calibration fluid B or C (Viscosity 38 Redwood at 100° F / 38° C).



Continued



6 Remove the timing pin (C1) from the element housing

Notes:

- If the fuel injector unit has been in service for some time, carbon deposits around the fuel injector nozzle and the element nut may cause the components to stick together. The fuel injector unit should be soaked in fuel or calibrating fluid to soften the carbon deposits and to prevent damage to the dowels (E5) in the transfer block as the nozzle nut E7) is unscrewed.
- A suitable releasing fluid may be used to break down the carbon quickly if there is not enough time to soak the fuel injector unit in clean calibrating fluid.

7 Put the fuel injector clamp (D2) into a vice and insert the element housing and the fuel injector nozzle into the clamp with the nozzle nut (D3) (E7) pointing upwards.

8 Use a suitable wrench and a 27mm socket, and unscrew the nozzle nut (D3) from the nozzle.

9 Remove the nozzle and needle (E6), transfer block (E4) and thrust cap (E3) and place all the components into the bath of clean fuel or calibrating fluid.

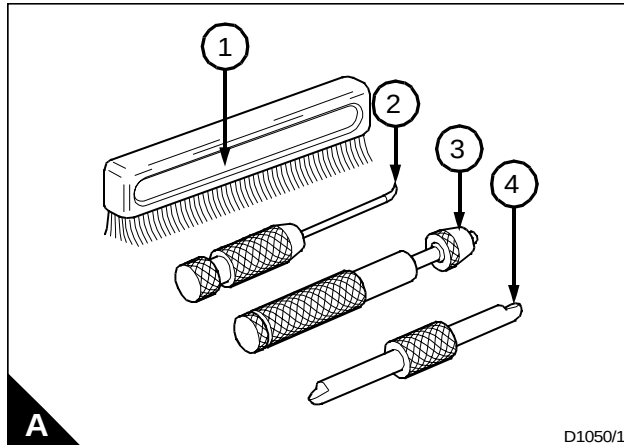
10 Release the fuel injector clamp from the vice and suspend the remaining components over bath. Invert the body to allow spring (E2) and the shims (E1) to be removed. Place with the other components in the bath.

11 Check that all the shims have been removed from the element housing.

To clean and to check

Cautions:

- *Metal polish or abrasive must not be used on the nozzle body and the needle valve damage will occur.*
- *The Special tool kit (A) is designed to enable quick and safe servicing of the nozzle assembly and must always be used. Use of other tools may cause serious damage the nozzle body and the needle valve.*



1 Ensure that all work surfaces are clean and that plenty of clean fuel is available.

Note: The nozzle body and needle valve are matched pairs and their components cannot be interchanged. It is recommended that only one nozzle assembly is dismantled at a time.

2 Wash and clean all parts of the element housing with clean fuel. Ensure that the nozzle clamp shoulder is free from carbon deposits. Remove any carbon with a scraper provided in the special tool kit

3 Check the mating surfaces of the nozzle body, the element housing and the transfer block. These surfaces must be clean, flat and smooth.

Note: If there are any indications that the surfaces are stained or damaged then they must be lightly lapped on a lapping plate. If the performance of the fuel injector unit has been below standard, the fuel injector should be tested as described in "To test and set the fuel injector" on page 144.

4 Soak the needle valve and nozzle body in clean fuel. Remove the needle from the nozzle body and check the guide surface. The surface must be bright, free from high spots, scratches and discoloured areas.

Note: If the needle valve is discoloured, has high spots, scratching any other damage then the complete fuel injector unit should be sent to an approved Perkins dealer for examination and reconditioning.

5 Use the needle gauge to check the needle lift in the nozzle body. This should be from 0.4 mm to 0.6mm. (0.016 in to 0.024 in). If the lift is greater than 0.75 mm (0.030 in), a new nozzle assembly must be fitted.

6 Check the nozzle body joint faces. The surface must be bright, free from high spots, scratches and discoloured areas.

7 Check that the needle valve slides smoothly in the bore of the nozzle body.

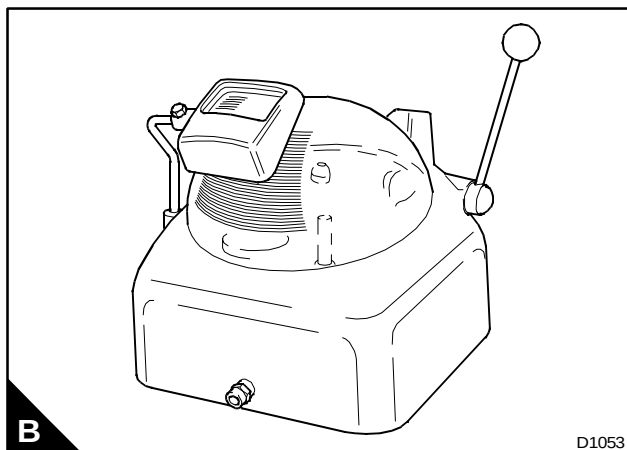
8 Clean out the fuel passages of the nozzle body with brass wire of suitable diameter.

9 Insert the fuel chamber scraper (A4) into the nozzle body until the nose locates in the fuel gallery. Press the scraper against the side of the gallery and rotate. Remove any carbon deposits.

10 Insert the seat scraper (A2) into the valve seat. Rotate and press the scraper into valve seat to remove any carbon.

11 Use a wire holder (A3) to Insert a 0.3 mm (0.0118 in.) diameter piece of wire into the spray holes in the end of the nozzle body. Rotate gently and prick out any carbon deposits. The wire should be fitted to the wire holder so that only 1.5 mm to 2.0 mm (0.059 in to 0.079 in) protrudes. This will ensure that the wire does not break in the spray hole.

Caution: Extreme care must be taken when cleaning the nozzle holes. It is impossible to remove the wire If it breaks in the hole. If the carbon deposits are extremely difficult to remove due to their hardness then the fuel injector unit should be returned to your nearest Perkins Dealer/Distributor for specialist cleaning.



Warning! When testing fuel injectors, care must be taken to prevent skin contact with the spray, since the operating pressure will cause the fluid to penetrate the skin. If this occurs get medical attention as soon as possible. The spray is also highly flammable

12 Use nozzle multi scan equipment (B) to thoroughly clean the carbon from inside of the nozzle body then blow clean. Wash the nozzle body in the opposite direction through the spray holes with clean fuel from the test pump.

13 Check under a strong light that the seats and spray holes are clean and free of all traces of carbon and other foreign matter.

To assemble the fuel injector unit

Operation 11-4

Special requirements

Special tools			
Description	Part number	Description	Part number
Fuel injector clamp and fuel feed adaptor - 12 mm (0.47 in)	T6253/146	Adaptor oil seal	T6253/146B
Nozzle 'Testmaster'	T6253/208		

To assemble

1 Thoroughly wash all the components in clean fuel oil.

Note: Do not wipe or dry with a cloth.

2 Reassemble the fuel injector. Ensure that the dowels in the transfer block location adaptor enter the nozzle body and element housing correctly.

3 Ensure that the fuel feed and fuel return holes are not obstructed

4 Secure the fuel injector clamp in a vice and place the fuel injector into the clamp.

5 Apply a light coating of grease to the nozzle body clamping shoulder. The grease will lubricate the clamping shoulder of the transfer block location adaptor and the nozzle body when the nozzle nut is tightened.

6 Tighten the nozzle nut hand tight. Use a suitable torque wrench and a long 27 mm socket to tighten the nozzle nut to 205 Nm (151 lbf ft) 20,9 kgf m.

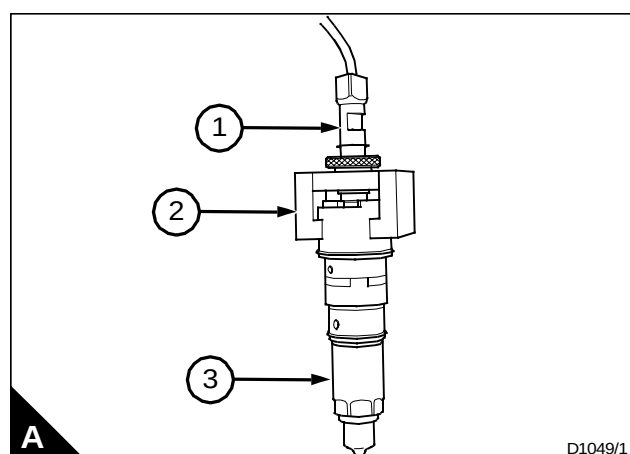
7 Check the performance of the fuel injector, see Operation 11-5.

8 Check the spray formation of the fuel injector. If it is below required standard check fault diagnostic test and renew the fuel injector if necessary.

9 If the nozzle opening pressure is not within the angle specified, then the shims may be added or removed from above the springs to increase or decrease the operating pressure.

Note: Shims are supplied in various thicknesses from 0.2794 mm (0,011 in) to 2.0322 mm (0.80 in). By careful selection, small adjustments can be made. e.g. An increase in shim thickness of 0.0508 mm (0.002in.) will give an approximate pressure increase of 517 kPa (75 lbf/in²) 5.273 kgf/cm².

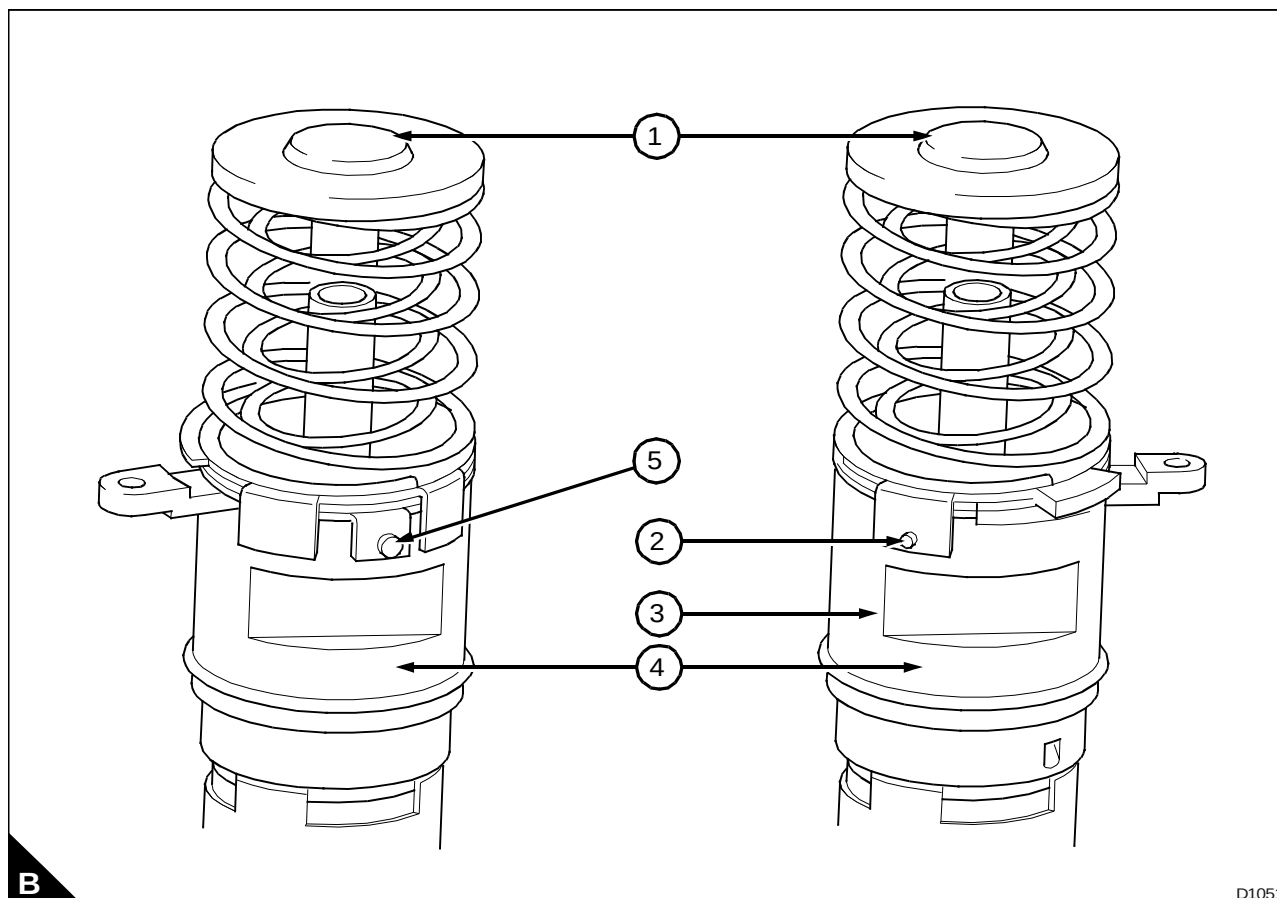
10 When the tests are completed satisfactorily, see Operation 11-5, remove the fuel injector from the fuel feed adaptor (A1) from and the fuel injector clamp (A2)



Continued

11 Assemble the spring plunger assembly (B1) to the element housing (B4). Ensure that the spring dowel (B2) and the timing pin (B5) engage with the spring plate locating collar.(B3).

Note: The fuel injector unit is now ready to be put back into the cylinder head.



Fuel fuel injector unit fault finding

Symptoms	Possible causes	
Operating pressure too high or too low	fuel injector wrongly set Damaged or worn fuel injector needle or nozzle Incorrect needle or nozzle seating angles, that result in incorrect sealing line or no angular difference Restricted needle lift There is an obstruction in the nozzle spray holes	Read just the shims to obtain the correct operating pressure. Renew the nozzle Renew the nozzle Renew nozzle assembly and / or thrust spindle or upper spring Clean the nozzle or renew the nozzle
Distorted nozzle spray formation	Nozzle dirty and coated with carbon Damaged or eccentric seats The joint faces between the transfer block, nozzle and the element housing are not aligned due to abrasion or the presence of foreign matter between the joints. Needle valve worn Spray holes eroded Needle valve damaged	Clean Renew the nozzle assembly Dismantle the fuel injector, clean and check all joint faces. Lap the faces to obtain a good and even contact or renew components Renew the nozzle assembly Renew the nozzle assembly Renew the nozzle assembly
Nozzle drips	Carbon on the valve seats Damaged or eccentric seats	Clean or replace the fuel injector unit Renew the nozzle assembly
Nozzle blueing	Faulty fitting, tightening or cooling	Renew the nozzle assembly. Check the cylinder head coolant passages for scale deposits.
Excessive leak-off (pressure drop time less than 8 seconds)	Needle valve worn 'O' ring on the fuel feed adaptor worn Foreign matter between face of the nozzle body and the transfer block or element housing	Renew the nozzle assembly Check and renew the 'O'rings Clean
Insufficient leak-off (Pressure drop time greater than 60 seconds)	Needle valve lacquered Needle valve damaged	Clean nozzle assembly Renew the nozzle assembly
Fuel system gassing, loss of injection to cylinder	Faulty sealing washer allowing combustion gasses to blow into fuel system Build up of carbon deposit on the bottom of fuel injector sleeve preventing the copper sealing washer sealing Nozzle needle sticking	Renew copper sealing washer Clean fuel injector sleeve, renew copper sealing washer and fuel injector 'O' rings Clean thoroughly after inspection and re test.

Note: Always test the fuel injector immediately after cleaning and assembly

To test and set the fuel injector

To test and set

Operation 11-5

Special requirements

Special tools			
Description	Part number	Description	Part number
Adaptor oil seal	T6253/146B	Nozzle 'Testmaster'	T6253/208
Fuel Injector clamp and fuel feed adaptor	T6253/146A		

Warning! When testing fuel injectors, care must be taken to prevent skin contact with the spray, since the operating pressure will cause the fluid to penetrate the skin. If this occurs get medical attention as soon as possible. The spray is also highly flammable

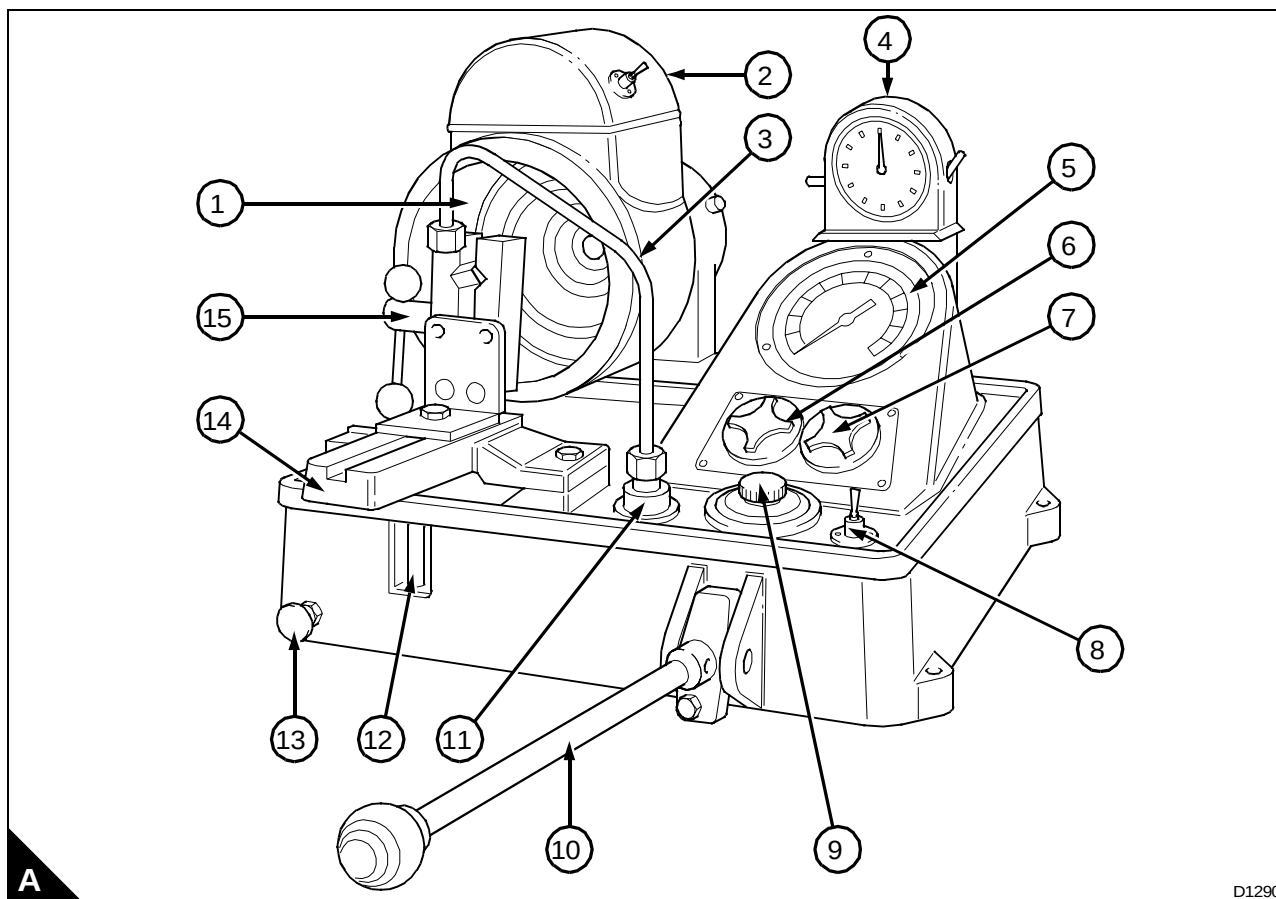
Notes:

- The recommended test oils are Calibration fluid B or C (Viscosity 38 Redwood at 100° F / 38° C) or equivalent fluids Do not use diesel fuel
- When testing an fuel injector only use the recommended special tools. This consists of an fuel injector clamp and fuel feed adaptor (B3 and B1). This is used in conjunction with a nozzle 'Testmaster' (A).

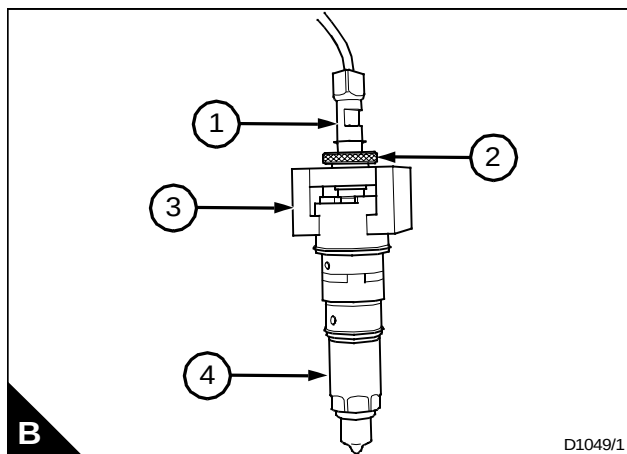
To prepare the fuel injector for testing

- 1 Ensure that the reservoir of the nozzle 'Testmaster' is filled to the correct level, with the correct Calibration fluid B or C (Viscosity 38 Redwood at 100° F / 38° C) fluid. This is approximately half way up the sight tube (A12)
- 2 Slot the fuel injector into the fuel injector clamp (B3) with the dowel uppermost.
- 3 Grease the oil seal on the fuel feed adaptor and push the adaptor through the clamp into the element housing. Lock in position with the knurled nut (B2)

Note: The oil seal on the fuel feed adaptor should be renewed after 10 to 15 tests



- 4 Place the fuel injector for testing loosely in the jaws of the quick action clamp (A15) and connect the high pressure pipe (A3) to the fuel feed adaptor (B1).
- 5 Adjust the clamp on the inclined support (A14) to position the fuel injector tip inside the spray chamber (A1).
- 6 Tighten the clamp and all the connections.



Notes:

- The fuel control valve (A6) when closed completely isolates the fuel injector from the hand pump. The degree of opening restricts the amount of test oil which can be delivered to the fuel injector.
- The gauge isolator (A7), when closed completely isolates the pressure gauge (A5) from the high pressure circuit. This eliminates the damping effect of the gauge and will prevent damage to it when testing atomisation and chatter.
- If pressure should become trapped in the gauge, release the gauge isolator a small amount to let the pressure fall slowly only fingertip pressure is required to operate this control and the fuel control valve.

- A tolerance of ± 5 bar is permissible when adjusting the fuel injector pressure setting with shims, see **Note** on page 141

Pressure setting

- 1 Close the gauge isolator
- 2 Open the control valve one full turn.
- 3 Switch on the extractor fan.
- 4 Operate the hand lever quickly until all air is expelled from the fuel injector
- 5 Close the fuel control valve and set the gauge pointer to 'ZERO', then open valve the minimum amount that allow the fuel injector to operate when pressing down hard on the hand lever. Note the reading on the scale.
- 6 Open the gauge isolator. Depress the hand lever and note the highest pressure on the gauge before the nozzle 'Pops' which indicates the needle valve opening. Adjust as necessary to 23400 kPa (3400 lbf/in²) by the adjustment of shim thickness as described in, **Note** on page 141.
- 7 With the gauge isolator open, raise the pressure to approximately 22063 kPa (3200 lbf/in²), then release the hand lever and allow the pressure to fall naturally. Check the rate at which the gauge needle drops from 20700 kPa (3000 lbf/in²) to 13800 kPa (2000 lbf/in²)

Note: For a nozzle in good condition, this time should be between 8 and 60 seconds with the test oil at a temperature of 20°C - 21° C, (68°F - 70°F).

Seat tightness test

Notes:

- When carrying out this test observe that no leakage occurs at the lapped pressure faces of the element housing, transfer block and nozzle body.
- Leakage may be external, when it is visible at the nozzle nut screw thread. It may be internal, however this cannot be distinguished from excessive leakage past the lapped part of the needle valve. If leakage past the pressure faces is suspected, do not over tighten the nozzle nut in an effort to cure the leakage. Remove the nozzle assembly and re-examine the pressure faces for signs of dirt or surface imperfections. Clean thoroughly, and if everything appears to be in order, replace the components and retest. If the pressure drop time is still low, this indicates excessive leakage past the lapped portion of the needle valve.
- Restricted back leakage, i.e the pressure drop takes longer than 60 seconds, is indicative of insufficient clearance between the nozzle bore and the needle valve. This could be caused by lacquering which may cause the needle valve to seize in its bore.
- These back leakage figures apply to the nozzle 'Testmaster' only.

This test comprises holding a pressure of 700kPa (100 lbf/in²), below the fuel injector release pressure of 23400 kPa (3400 lbf/in²) and observing the nozzle tip for leaks.

- 1 Switch off the extractor fan.
- 2 Open the fuel control valve.
- 3 Open the gauge isolator.
- 4 Depress the hand lever and check the fuel injector nozzle release pressure is set at 23400 kPa (3400 lbf/in²).
- 5 Wipe the nozzle tip dry.
- 6 Depress the hand lever and raise the pressure to 7 bar (6.8 atm) (100 lbf/in²) (700kPa) below the release pressure of 23400 kPa (3400 lbf/in²) and maintain for 10 seconds.
- 7 Allow the pressure to drop to 20700kPa (3000 lbf/in²) and check for seat leakage. The nozzle tip should be dry.

Note: Do not allow fuel to run down the fuel injector from the leak-off and give a false impression during the test.

Spray formation and chatter test

The nozzle must atomise the fuel completely to produce a regular spray pattern without a dribble or hosing. The spray from each nozzle hole should be the same shape.

- 1** Close the gauge isolator valve, if the valve is open, the nozzle will not function properly and the pressure gauge may be damaged.
- 2** Switch on the extractor fan
- 3** Set the fuel control valve to minimum flow rate.

Chatter test

With the gauge isolator closed, operate the hand lever at the slowest possible rate at which the nozzle can be made to discharge. Under these conditions, the nozzle must discharge with a sharp and crisp chattering action. It must be impossible to make the nozzle squirt or dribble by working the test pump at any speed.

Spray formation

With the gauge isolator valve closed, operate the hand lever at a speed of 90 - 100 strokes per minute and check that the spray from each hole is well atomised, of regular form and free from ragged edges. All the spray formations must be equal and correctly spaced.

Release Pressure

Open the gauge isolator valve, check that the fuel injector opens at the pressure of 225 - 235 atmospheres. Close the gauge isolator valve, operate the pump a few times to ensure that all the components have settled and finally, check the pressure again.

Pressure gauge

Before the fuel injector is removed from the test pump, close the gauge isolator valve to prevent damage to the pressure gauge which may result from a sudden drop in pressure. If the fuel injector is not being fitted immediately, blank off the inlet and leak-off drillings with masking tape and fit a protective cap over the nozzle assembly.

To fit a fuel injector

Operation 11-6

1 Fit new 'O' rings (A1) to the fuel injector, then apply petroleum jelly to assist in fitting into the cylinder head.

Note: Before the fuel injector is fitted, check that no dirt or foreign matter has been left in the cylinder head.

2 Check if the old copper washer has been removed from the cylinder head. If it has not been removed, use a piece of wire to remove it.

3 Check that the bush in the cylinder head is free from burrs and if necessary use a scraper to remove them.

Note: Ensure that no debris falls into the engine.

4 Fit the copper sealing washer (A2) and apply petroleum jelly to hold it in position.

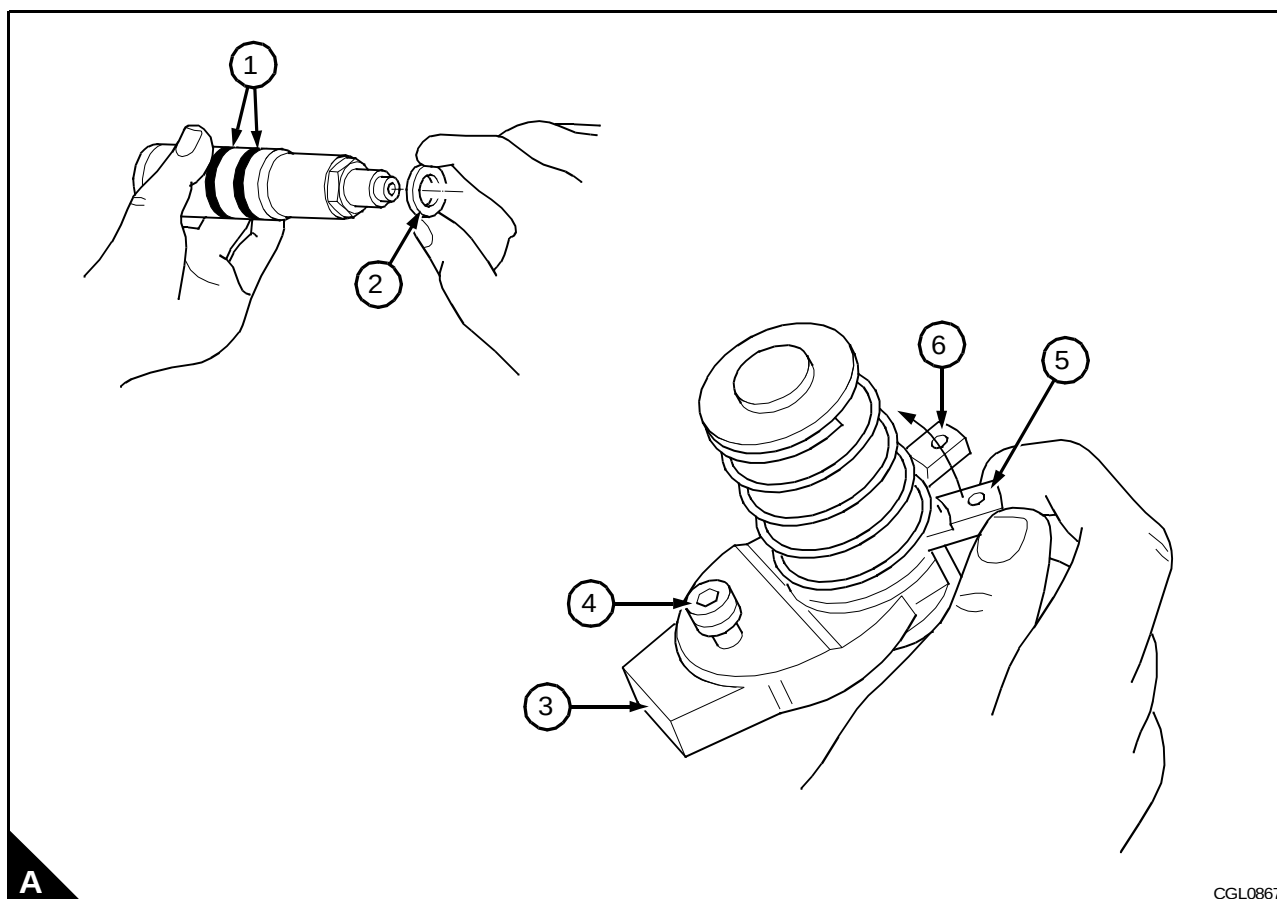
Note: The fuel injector washer thickness is $2\text{ mm} \pm 0.1$, ($0.079\text{ in} \pm 0.004$) and must be softened by annealing. Thickness other than this will cause leakage and binding of the governing mechanism due to the incorrect height of the fuel injector in the head.

5 Fit the fuel injector clamp (A3) to the fuel injector and lower the assembly into the cylinder head. Fit but do not tighten the retaining capscrew (A4). Push the fuel injector in a clockwise downward direction against the fuel injector clamp, then tighten the retaining capscrew to 95 Nm (70 lbf ft) 9,7 kgf m.

6 Push the fuel control arm (A5) in the anti-clockwise direction to the 'No Fuel position (A6).

7 Repeat this procedure for all the fuel injectors that need to be replaced.

8 Calibrate and time the fuel injector, see Operation 8-2.



Fuel Lift pump

To remove and to fit

Operation 11-7

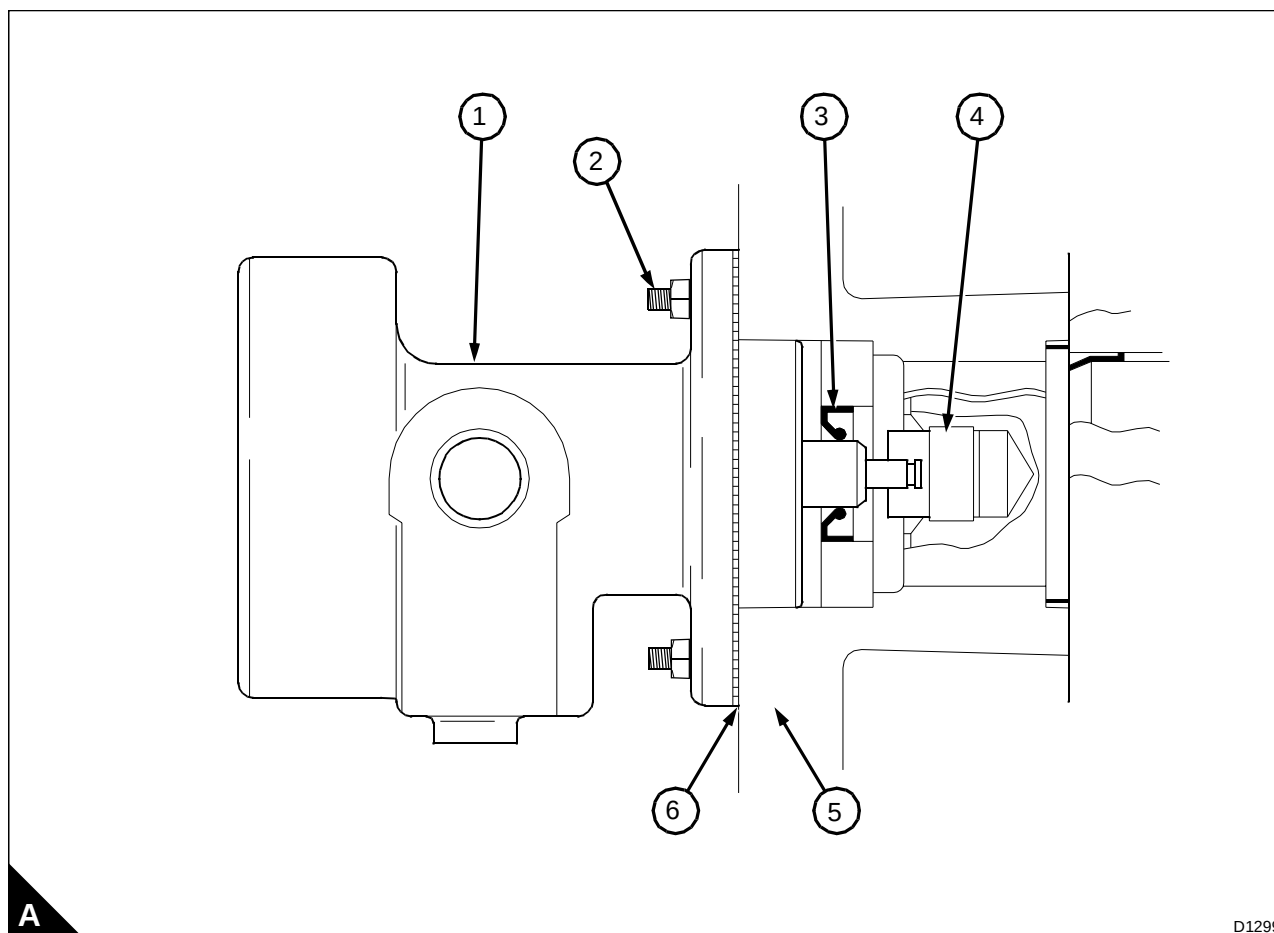
To remove

- 1 Disconnect the fuel pipes to and from the fuel lift pump.
- 2 Remove the two retainer nuts (A2) that hold the lift pump to the rear of the oil pump.
- 3 Remove the fuel lift pump (A1) from the oil pump (A5).
- 4 Plug the fuel pipes and cover the fuel lift pump flange mount on the oil pump to prevent the entry of dirt.

To fit

- 1 Clean the fuel lift pump flange mount of any old joint material.
- 2 Fit a new joint onto the flange mount and fit the fuel lift pump (A1), and carefully align the fuel lift pump shaft with the oil seal (A3) and the drive dog (A4).
- 3 Fit and tighten the retainer nuts (A2).
- 4 Torque the retainer nut (A2) to 25 Nm (18,4 lbf ft).
- 5 Remove the plugs from the fuel pipes and fit onto their connections.
- 6 Prime the fuel system, see User Handbook, How to prime the fuel system, page 16.

Note: If the fuel tank is positioned below the level of the fuel lift pump, ensure that all the connections are air tight and that the non-return valve operates freely.

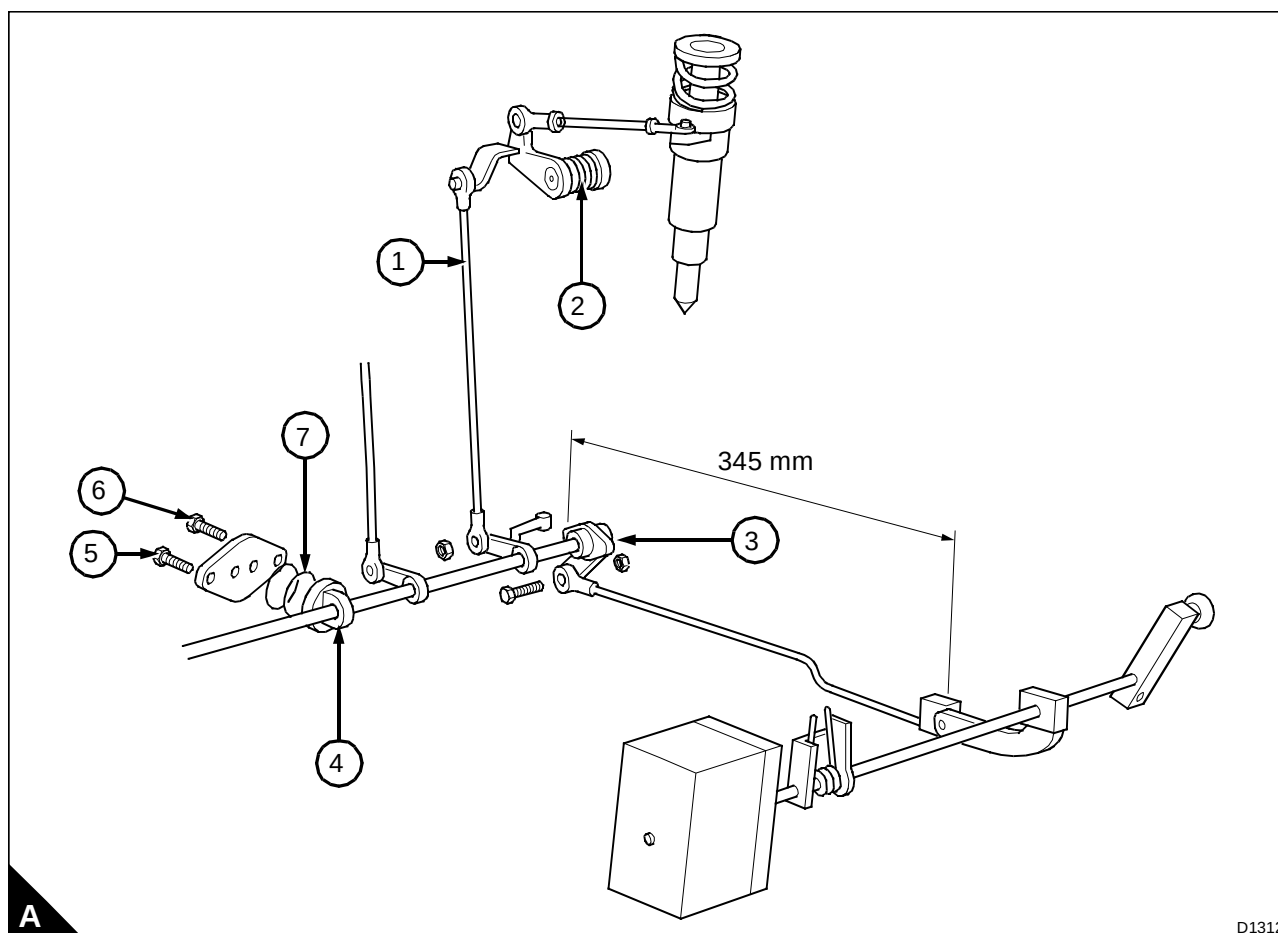


Fuel control shaft**To remove****Operation 11-8**

Note: Do not remove the control shaft assembly unless renewal of a component part is required.

- 1 Remove the gearcase, see Operation 6-1.
- 2 Remove the cam follower housing, see Operation 6-10.
- 3 Remove each individual connecting link (A1).
- 4 Remove the nuts and bolts (A3) that hold the control shaft front support bearing to the suspension plate.
- 5 Remove the setscrews (A6) that hold the control shaft support bearings to the cover plates.
- 6 Remove the setscrews (A5) that hold the cover plated to the crankcase.
- 7 Remove the O rings from the cover plate and discard the O rings.
- 8 Push the control shaft bearings (A4) from their housings.
- 9 Pull the control shaft through the hole in the back plate.

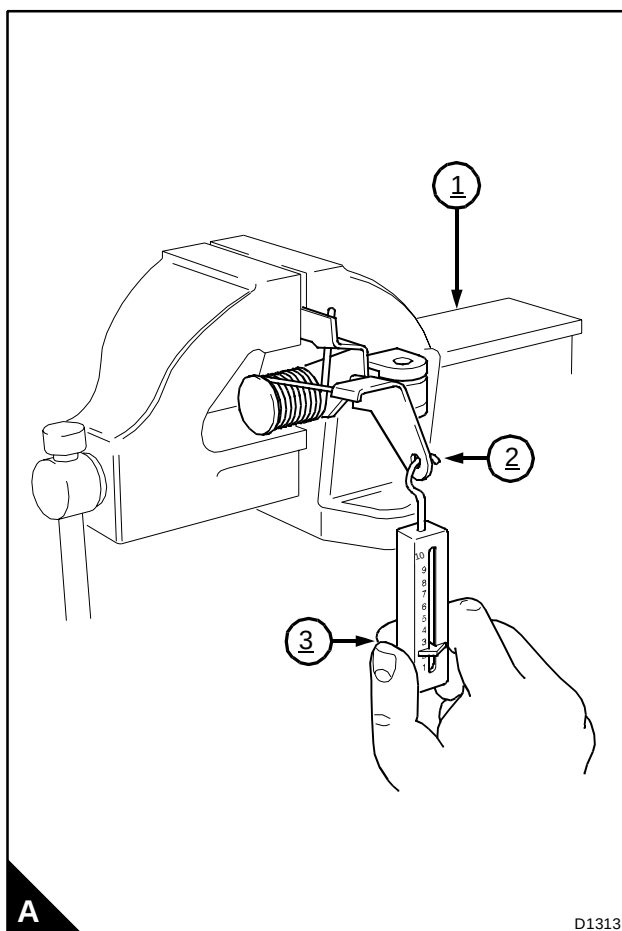
Note: Check at each stage of the removal in order to ascertain the reason for the tight spot on the control shaft.



To inspect

Operation 11-9

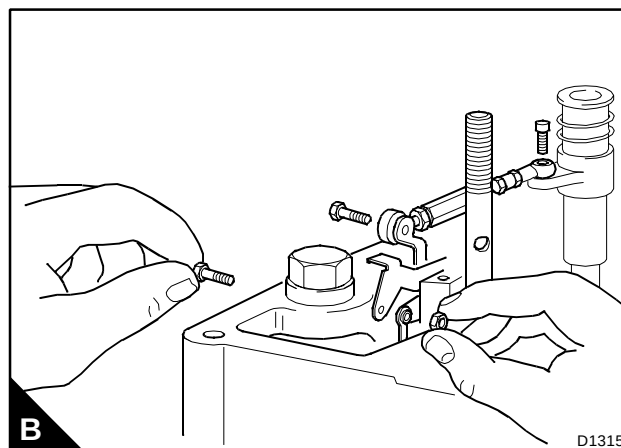
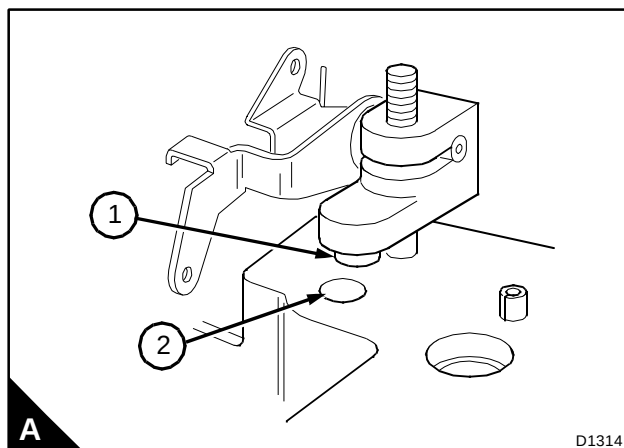
- Check the break back lever assemblies for smoothness of operation on their pins, fit new components if required.
 - Check the condition of the break back lever spring. See procedure below.
- 1 Place the break back lever in a vice (A1).
 - 2 Fit a spring balance into the input lever bolt hole (A2).
 - 3 Apply a minimum load of 0.9 kg (2 lb) to the spring balance(A3) to cause the break back lever to separate.
- Note:** If the load is less than 0.9 kg (2 lb) the break back lever assembly should be dismantled and a new spring fitted.
- Check that the connecting links (see page 151 (A1)) are not bent or damaged, fit new connecting links if required. Do not attempt to straighten the connecting links.



To fit

Operation 11-10

- 1 Lubricate the bearings with clean engine oil.
- 2 Fit the fuel control shaft with the aid of two engineers. One to support the fuel control shaft as it passed through the hole in the bacl plate and the second engineer to locate the fuel control shaft bearings in the crankcase.
- 3 Fit new O rings on the base of each fuel control shaft bearing.
- 4 Fit the cover plates and their capscrews.
- 5 Fit the setscrews that retain the cover plates to the crankcase.
- 6 Tighten the setscrews in stages, and check the free movement of the fuel control shaft continually.
- 7 Fit the fuel control shaft front support bearing and tighten the setscrews to the required torque of 8 Nm (6 lb ft).
- 8 Connect the fuel control shaft to the governor with the connecting links set at 345 mm (13,58 in) between the centres.
- 9 Fit the connecting links (see page 151 (A1)).
- 10 Fit the break back lever assembly to each cylinder head, and ensure that the location peg (A1) is correctly located in location hole (A2).
- 11 Fit the connecting links to the back back lever (B).



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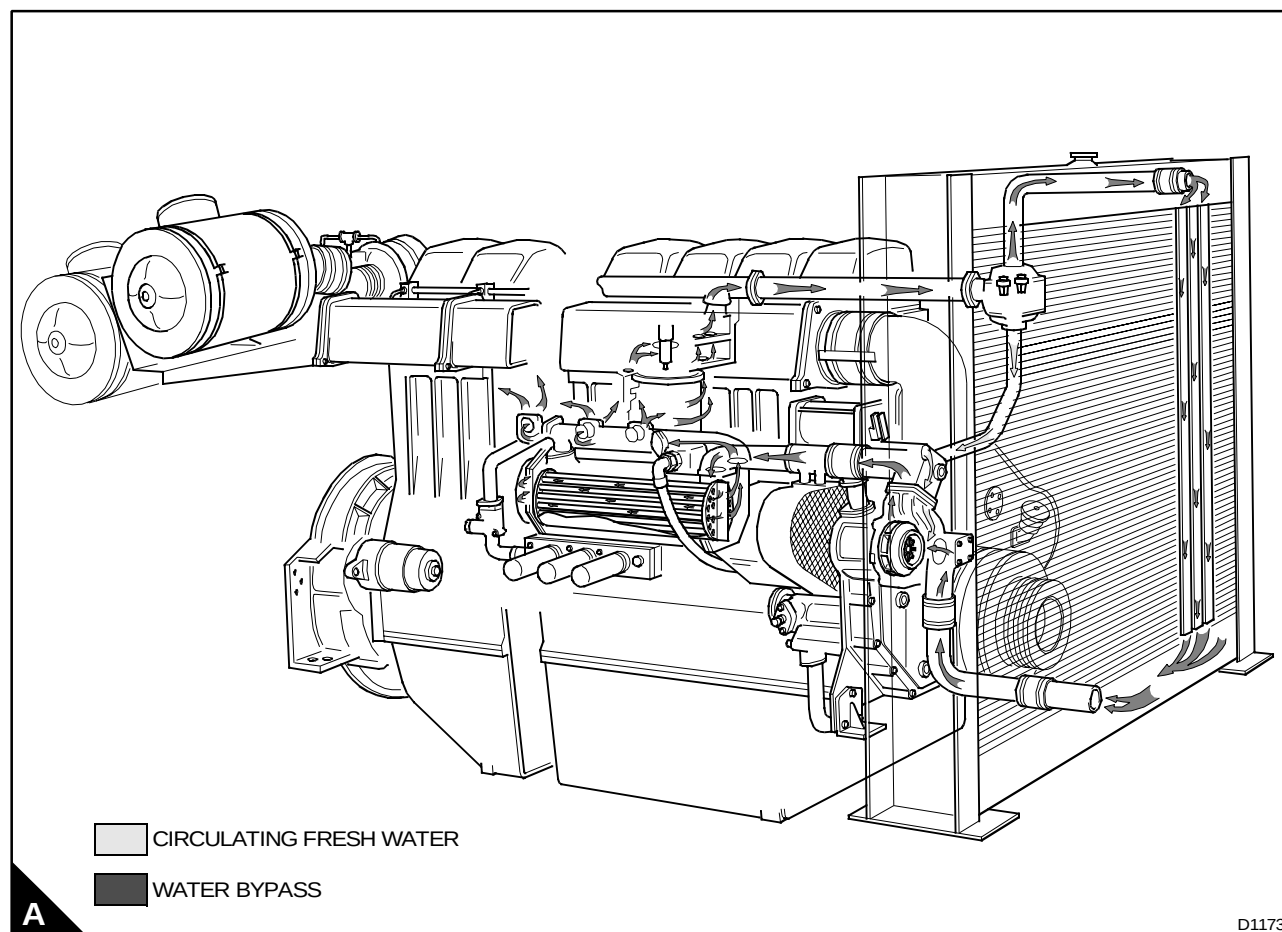
12

Cooling system

The coolant is circulated through the engine by a centrifugal coolant pump mounted on the front face of the timing cover and is driven by the engine gear train. The coolant from the coolant pump flows through the oil cooler before entering the crankcase coolant jacket. From the cooling jacket around the cylinders, the coolant flows upwards into the cylinder heads and the coolant rail to the thermostat housing. The thermostat housing is fitted with two thermostat elements, which determine the direction of the coolant flow dependant on the temperature. When cold, the flow is directed back via a by-pass pipe to the coolant pump suction to be re-circulate.

With the thermostat open the coolant is allowed to enter the radiator, and is cooled by air blowing over the single core cooling matrix. The hot air from the turbocharger is directed via a large diameter air pipes to the radiator/charge cooler, and after flowing through a single core radiator is directed through large bore pipes to the engine air intake manifold. The cooling of the charge air is achieved by installing an additional radiator between the normal coolant cooling radiator and the cooling fan. The radiator fan forces air through each matrix in series.

The oil cooler comprises of a tubestack enclosed within a cast body and sealed by "O" rings and joints to the port covers. The covers are secured by bolts, setscrews, and spring washers to the body. Oil is delivered from the lubricating oil pump via a flexible pipe into the inlet port and into cooler body circulating around the outside of the tubes. Coolant is delivered from the coolant pump and passes from the outlet pipe to the end cover inlet port. Then passes through the tubes, and makes one pass in both direction, and then exits from the outlet port to the water transfer pipe and into the water jacket.



Coolant pipework

To remove and fit the coolant pipework

Operation 12-1

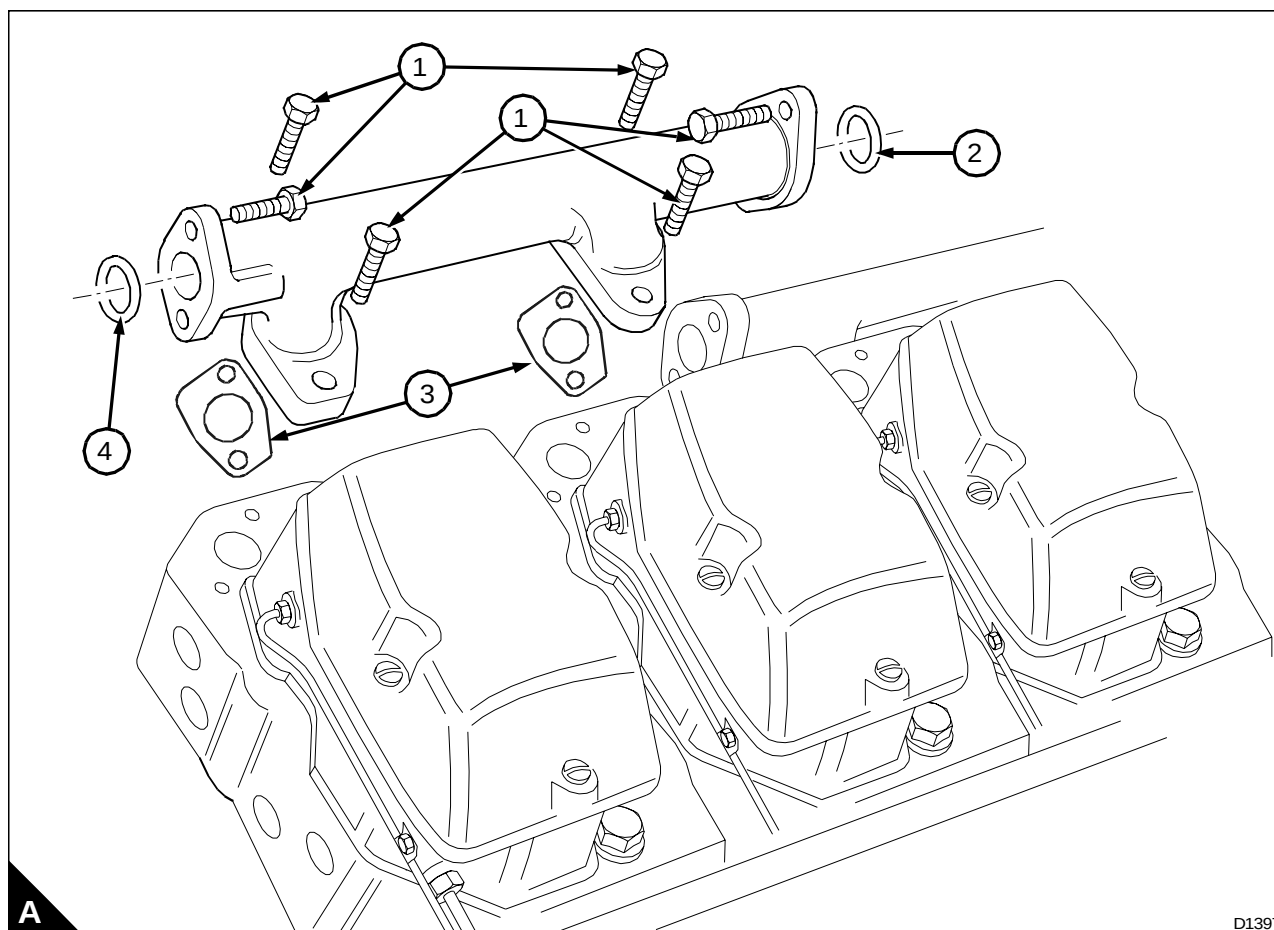
Note: The coolant pipework can be as individual sections or as a complete assembly

To remove

- 1 Drain the coolant level in the cooling system to below the coolant pipework.
- 2 Remove the setscrews (A1) and remove the coolant pipework.
- 3 Remove the "O" rings (A2, A4) and joints (A3) from the coolant pipework flanges and discard.

To fit

- 1 Ensure that all the mating faces of the coolant pipework flanges are clean.
- 2 Fit new "O" ring and joints to the flanges of the coolant pipework.
- 3 Fit the coolant pipework to the engine.
- 4 Fit the setscrews to the coolant pipework and gradually and evenly tighten to a torque of 50 Nm (36.9 lbf ft) 5,1 kgf m.
- 5 Fill the cooling system to the correct level, operate the engine for a few minutes then re-check the cooling system level, refill as required.

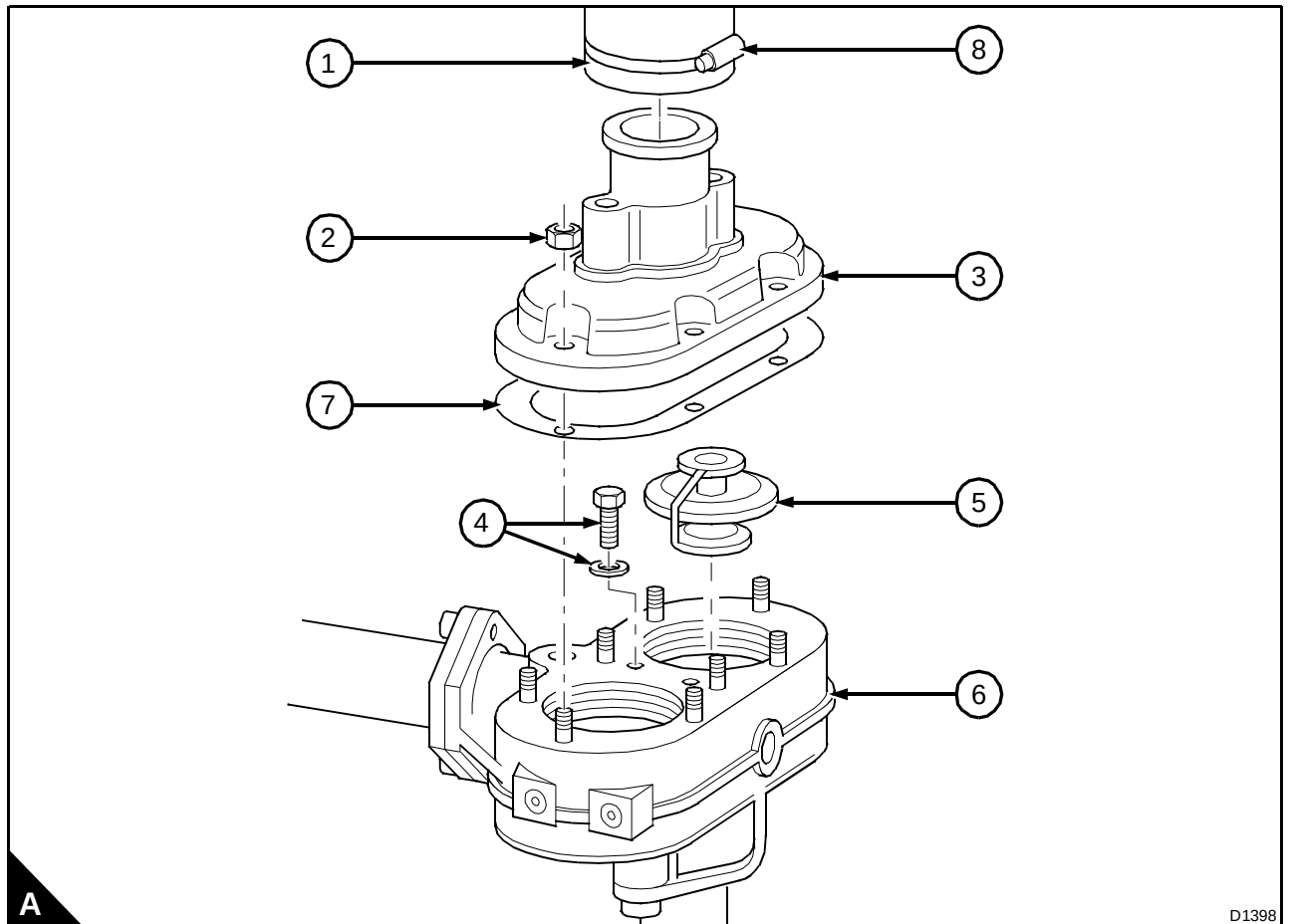


Thermostat

To remove the thermostat

Operation 12-2

- 1 Drain the coolant level in the cooling system to below the thermostat position.
- 2 Remove the outlet hose (A1).
- 3 Remove the retaining nuts (A2) and lift off the top cover (A3) and discard the cover joint.
- 4 Remove the clamping setscrews and washers (A4) then remove the thermostat elements (A5) from their location in the thermostat housing (A6).

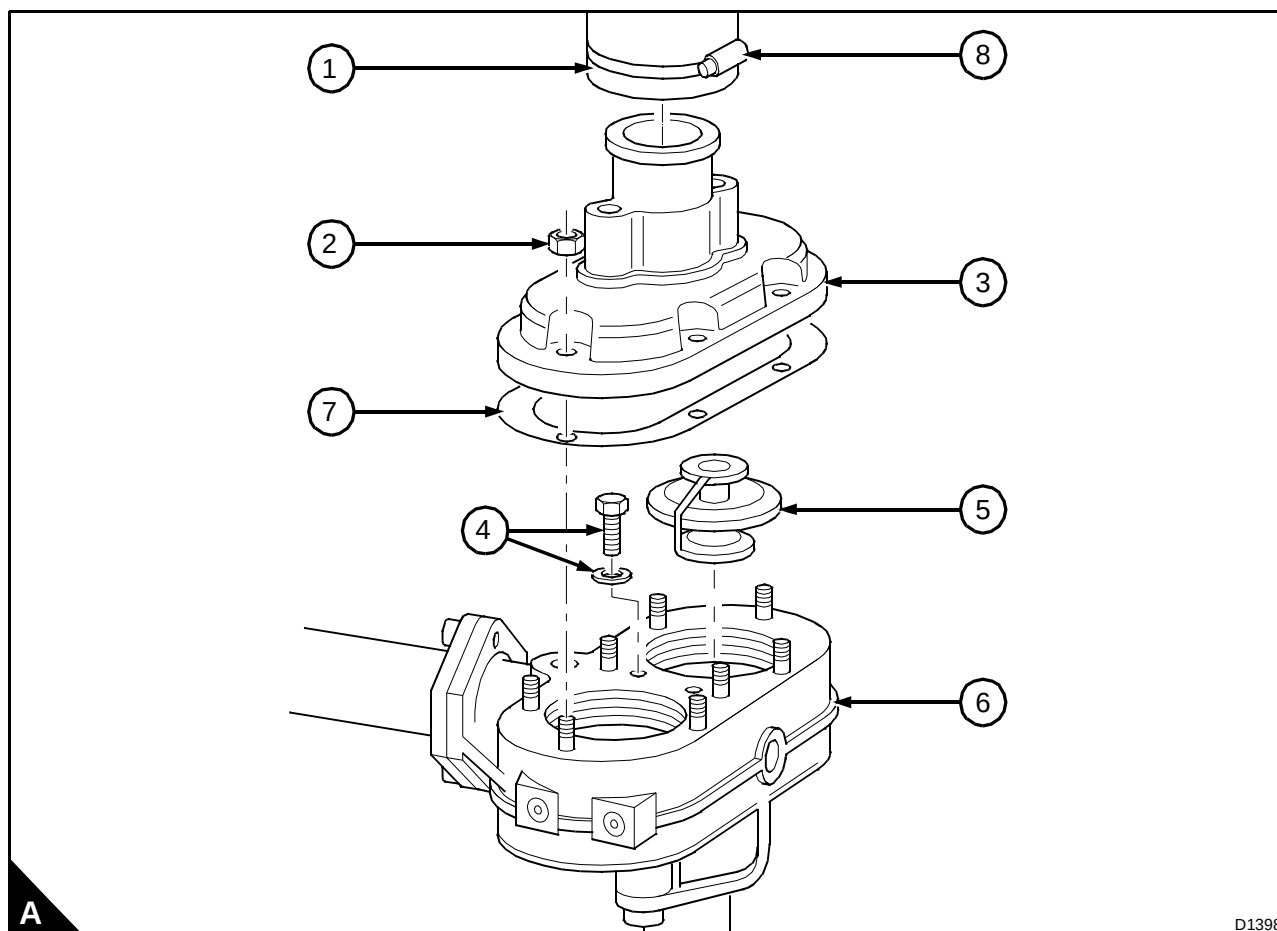


To fit the thermostat

Operation 12-3

Warning! Do not run the engine without the thermostats fitted.

- 1 Clean the mating faces of the thermostat housing, and cover.
- 2 Fit the thermostat elements (A5) into the housing, then fit the clamping bolts and washers (A4).
- 3 Fit a new joint (A7) to the housing, then fit the top cover (A3). Gradually and evenly torque all the retaining nuts to 50 Nm (36.9 lbf ft) 5,1 kgf m.
- 4 Fit the outlet hose (A1) and tighten the hose clip (A8).



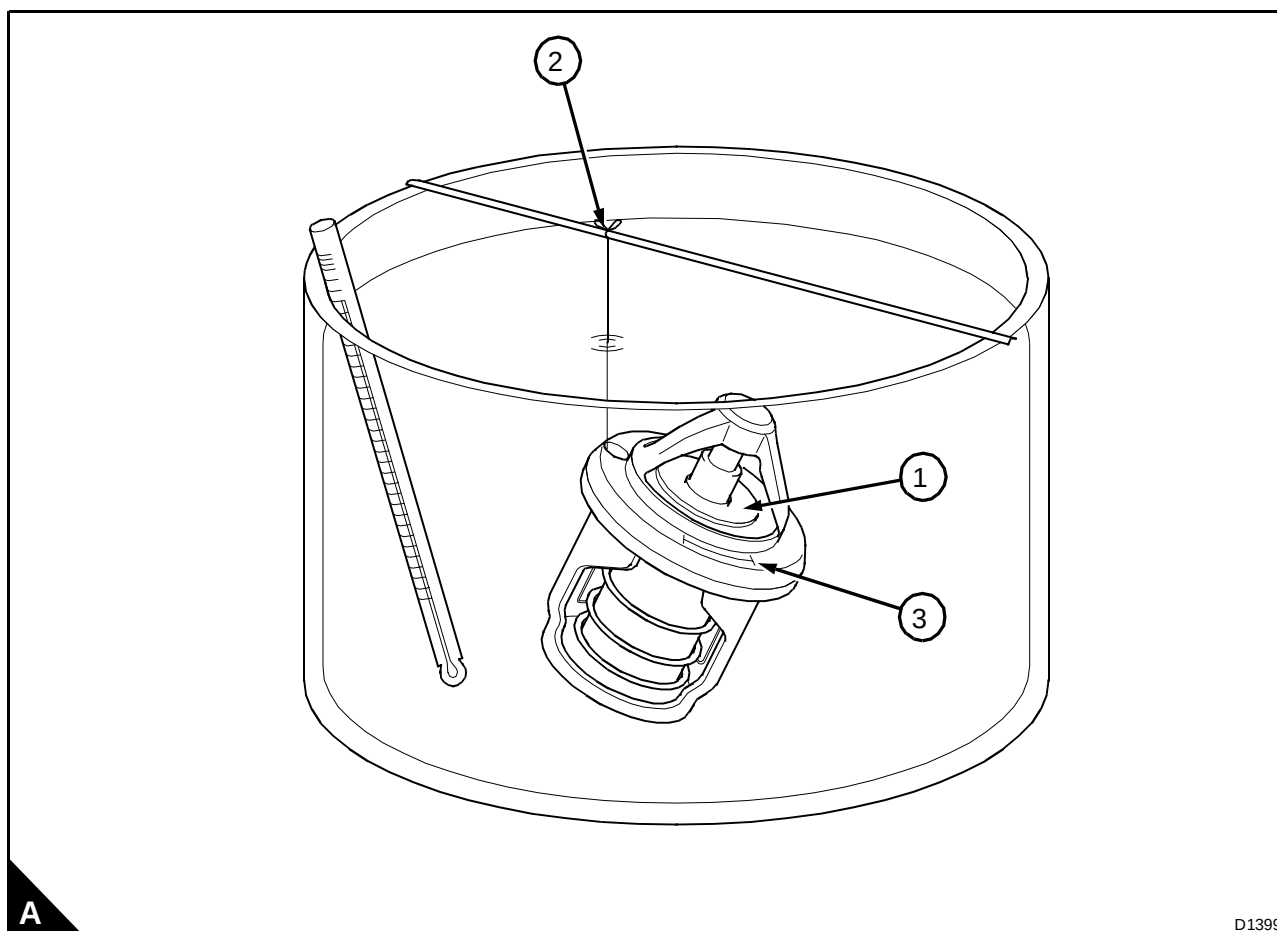
To test

Operation 12-4

Note: Visually inspect the thermostats for damage. If the valve (A1) is open at ambient temperature the thermostat must be renewed.

- 1 Hang the thermostat in a suitable container filled with coolant.
- 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. For the correct operating temperatures, refer to the Data and dimensions.

Caution: If the thermostat does not operate correctly, it must be renewed. do not try to adjust the settings.



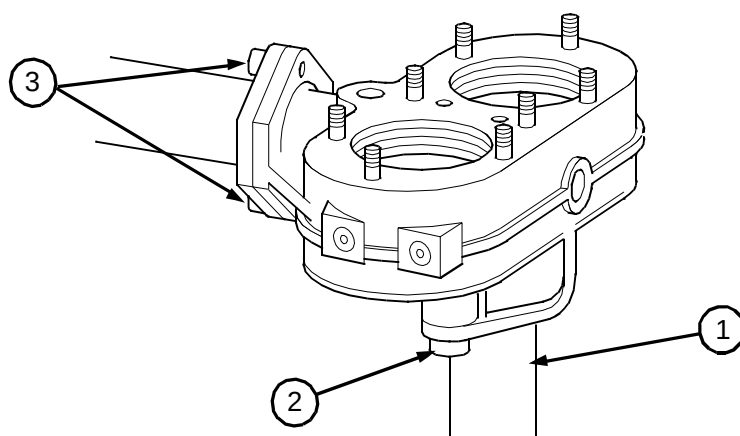
Thermostat housing

To remove and fit the thermostat housing

Operation 12-5

To remove

- 1 Remove the closed circuit breather, see Operation 9-11.
- 2 Remove the thermostats, see Operation 12-2.
- 3 Remove the two setscrews (A2) from the coolant bypass pipe flange (A1), remove the "O" ring from the flange and discard.
- 4 Remove the two setscrews (A3) from the coolant inlet pipe flange (A3), remove the "O" ring from the flange and discard.
- 5 Remove the thermostat housing.



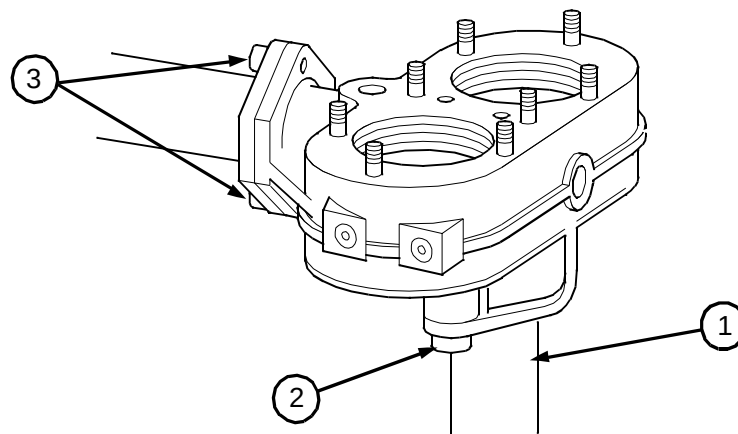
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Continued

To fit

- 1** Ensure that all the mating faces of the coolant bypass pipe flange, coolant inlet pipe flange (A3) and the thermostat housing are clean.
- 2** Fit a new "O" ring to the flange of the coolant inlet pipe flange, fit the flange of the coolant inlet pipe flange to thermostat housing then fit the two setscrews and gradually and evenly tighten to a torque of 50 Nm (36.9 lbf ft) 5,1 kgf m.
- 3** Fit a new "O" ring to the flange of the coolant bypass pipe, fit the flange of the coolant bypass pipe to thermostat housing then fit the two setscrews and gradually and evenly tighten to a torque of 50 Nm (36.9 lbf ft) 5,1 kgf m.
- 4** Fit the thermostats, see Operation 12-3.
- 5** Fit the closed circuit breather, see Operation 9-12.
- 6** Fill the cooling system to the correct level, then operate the engines for a few minutes then re-check the cooling system level, refill as required.

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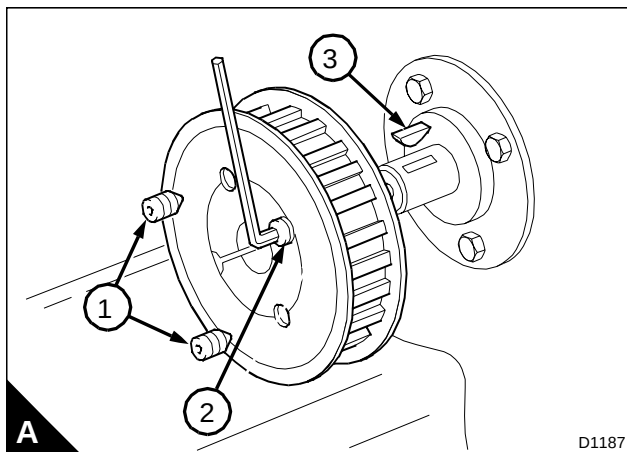
Coolant pump

To remove the coolant pump

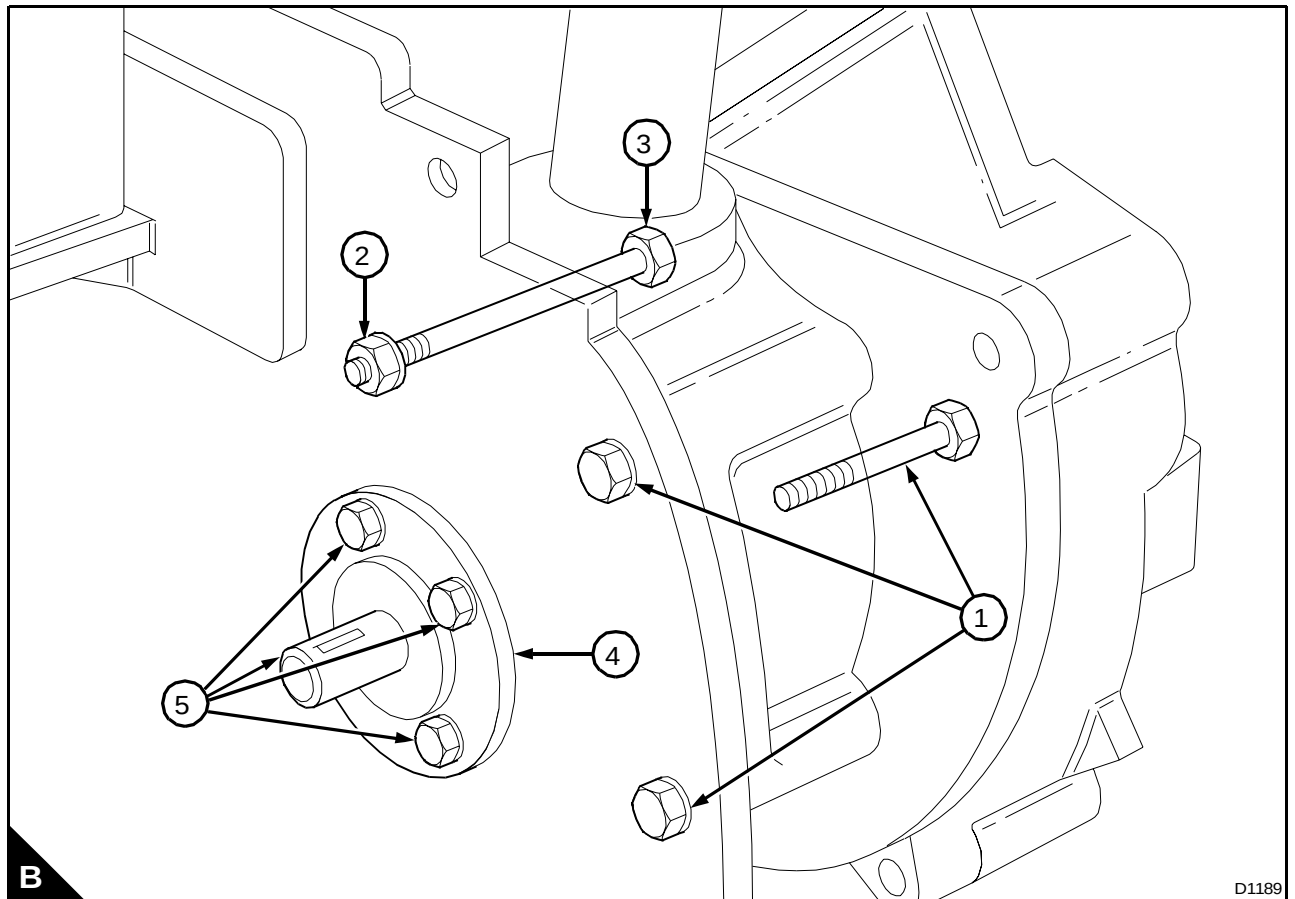
Operation 12-6

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

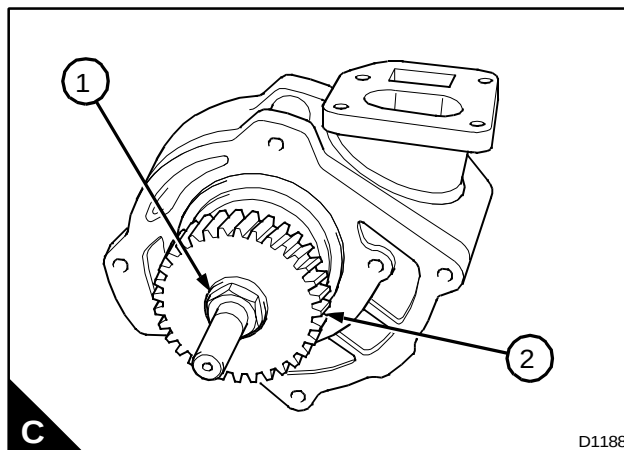
- 1 Remove the fan guards, see Operation 12-10.
- 2 Remove the fan, see Operation 12-11.
- 3 Drain the cooling system, then disconnect the hose at the inlet connection of the coolant pump.
- 4 Disconnect the hoses from the thermostat housing, to the oil cooler and the bypass pipe from the thermostat housing.
- 5 Remove the coolant elbow from the front of the coolant pump.
- 6 Remove the alternator, see Operation 14-3.
- 7 Remove the two locking screws from the hub of the Alternator drive pulley (A1).
- 8 Insert one screw into the extractor hole (A2) and tighten until the hub assembly is loose and can be pulled from the shaft.
- 9 Remove the drive key (A3) from the shaft.



- 10 Remove the 3 off setscrews (B1) from the coolant pump. Then remove the nut (B2) and bolt (B3).
- 11 Carefully remove the coolant pump from engine.



12 Place the coolant pump in a suitable vice, then remove the nut and washer (C1) from the drive shaft.



13 Use a suitable gear puller to remove the gear (C2) from the drive shaft.

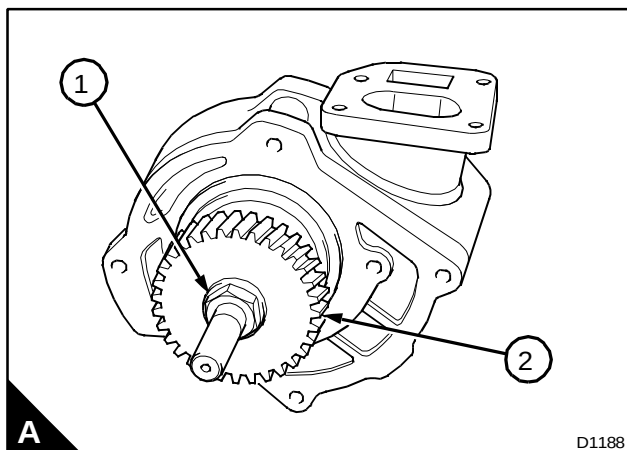
14 Remove the 4 off setscrews (B5) from the coolant pump shaft housing. Remove the housing and discard the bearing and joint.

To fit the coolant pump

Operation 12-7

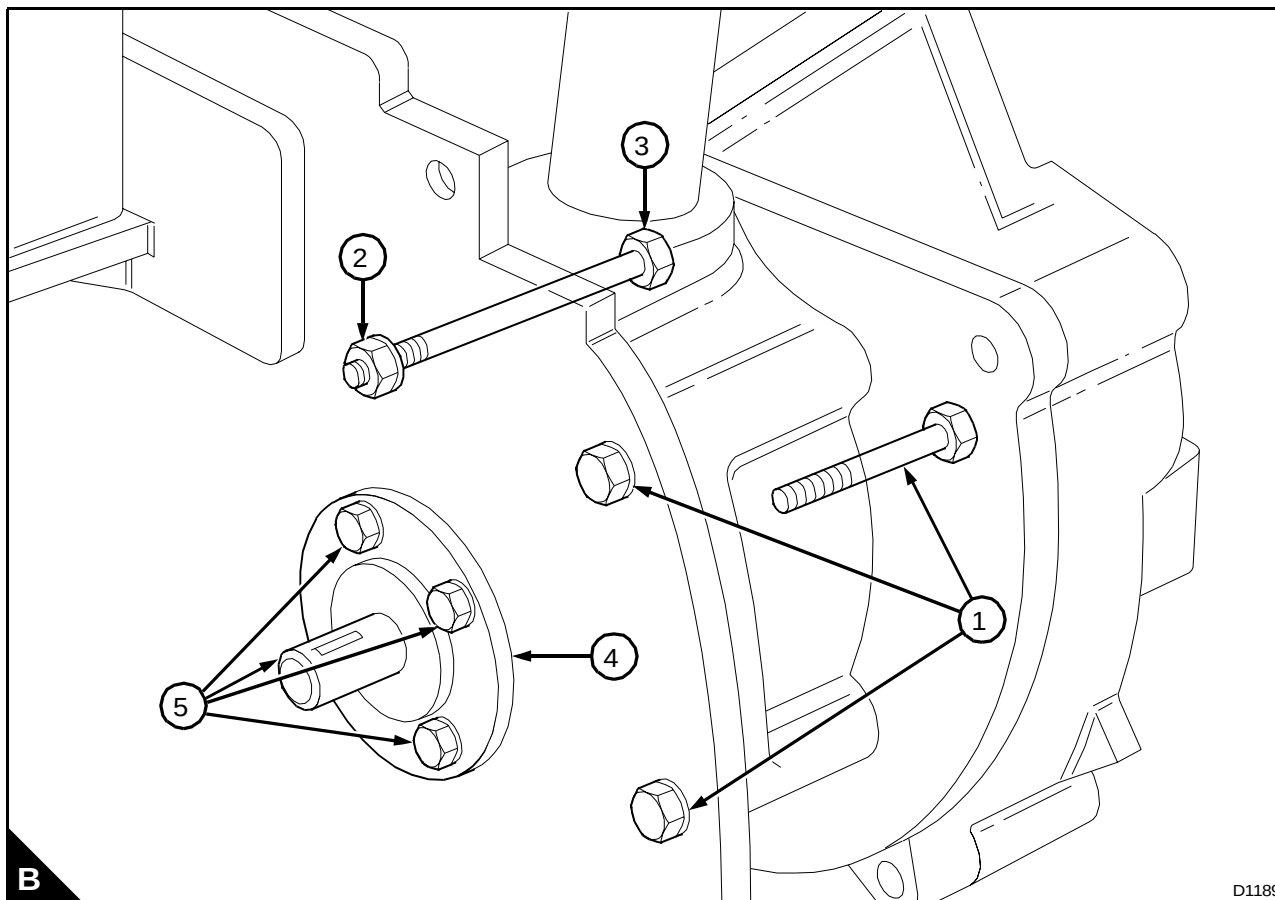
Note: Ensure that all joint faces are clean and free from the old joint materials.

- 1 Fit the gear to the drive shaft of the coolant pump, then fit the washer and nut. Torque the nut to 230 Nm (170 lbf ft) 23,4 kgf m.
- 2 Fit a new joint to the coolant pump and lubricate the drive gear with clean engine oil.



- 3 Fit the coolant pump, rotate the shaft to allow the drive gear to correctly mesh, then push the coolant pump to the timing case.

- 4 Fit the 3 off setscrews (B1), then fit the bolt (B3) and nut (B2). Gradually and evenly tighten all to a torque of 50 Nm (36.9 lbf ft) 5,1 kgf m.



Continued

- 5** Fit the bearing and oil seal into the coolant pump shaft housing.
- 6** Fit a new joint to the coolant pump shaft housing and install the 4 off setscrews (B5). Gradually and evenly tighten all to a torque of 25 Nm (18.4 lbf ft) 2,5 kgf m.
- 7** Fit the drive key for the alternator drive pulley into the coolant pump shaft.
- 8** Fit the alternator drive pulley and push onto the coolant pump shaft.
- 9** Fit the two locking screws onto the hub of the alternator drive pulley and tighten.
- 10** Fit the alternator, see Operation 14-6.
- 11** Fit a new joint to the coolant pump elbow. Fit the coolant elbow to the front of the coolant pump.
- 12** Fit the hoses to the oil cooler and to the coolant bypass pipe.
- 13** Fit the coolant inlet pipe to the coolant pump.
- 14** Fit the fan, see Operation 12-11.
- 15** Fit the fan guards, see Operation 12-10.

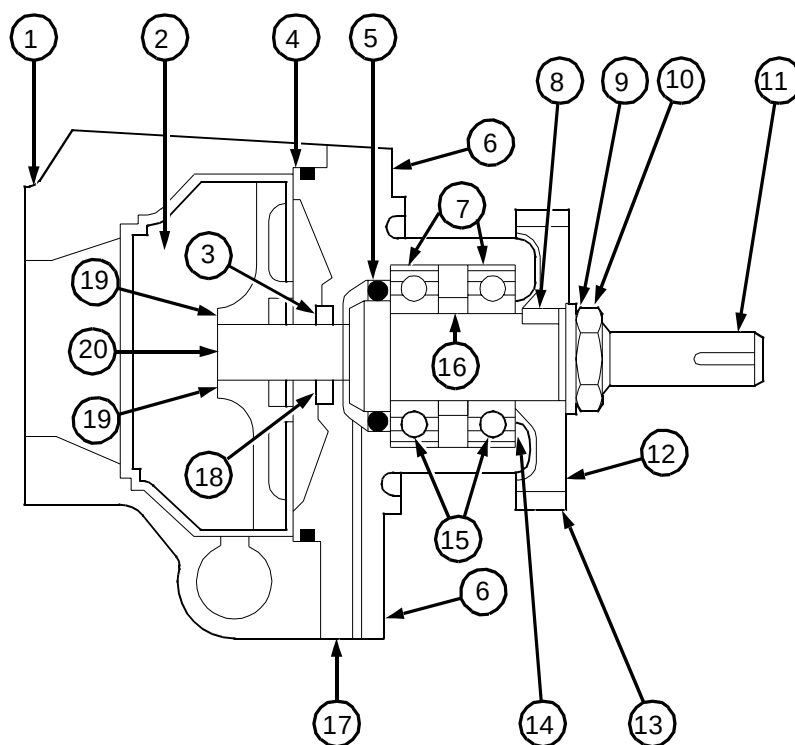
To disassemble the coolant pump

Operation 12-8

- 1 Remove the coolant pump, see Operation 12-6.
- 2 Lightly tap the coolant pump body with a soft faced hammer to break the interference fit with the bearing housing. Remove the "O" ring and discard.
- 3 Place the drive gear in to a vice with soft vice jaws. Remove nut (A10) and washer from the pump shaft (A11).

Note: Ensure that face (A6) is correctly supported and there is sufficient clearance to allow the shaft (A11) and bearing (A15) to be removed.

- 4 Remove drive gear and drive key from the coolant pump shaft.
- 5 Remove bearing retaining clip (A14).
- 6 Position the coolant pump on to face (A6) onto a suitable press.
- 7 Use a suitable mandrel between the press and coolant pump shaft at (A20). Press out the coolant pump shaft from the impeller (A2) and the housing (A17).
- 8 Remove the carbon seal assembly (A3) from the impeller and the ceramic counter face from the bearing housing, discard both items.
- 9 Remove the bearing retaining rings (A7) and discard.
- 10 Remove oil seal from the bearing housing and discard.
- 11 Remove the bearings (A15) and the distance piece (A16) from the shaft.



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To assemble the coolant pump

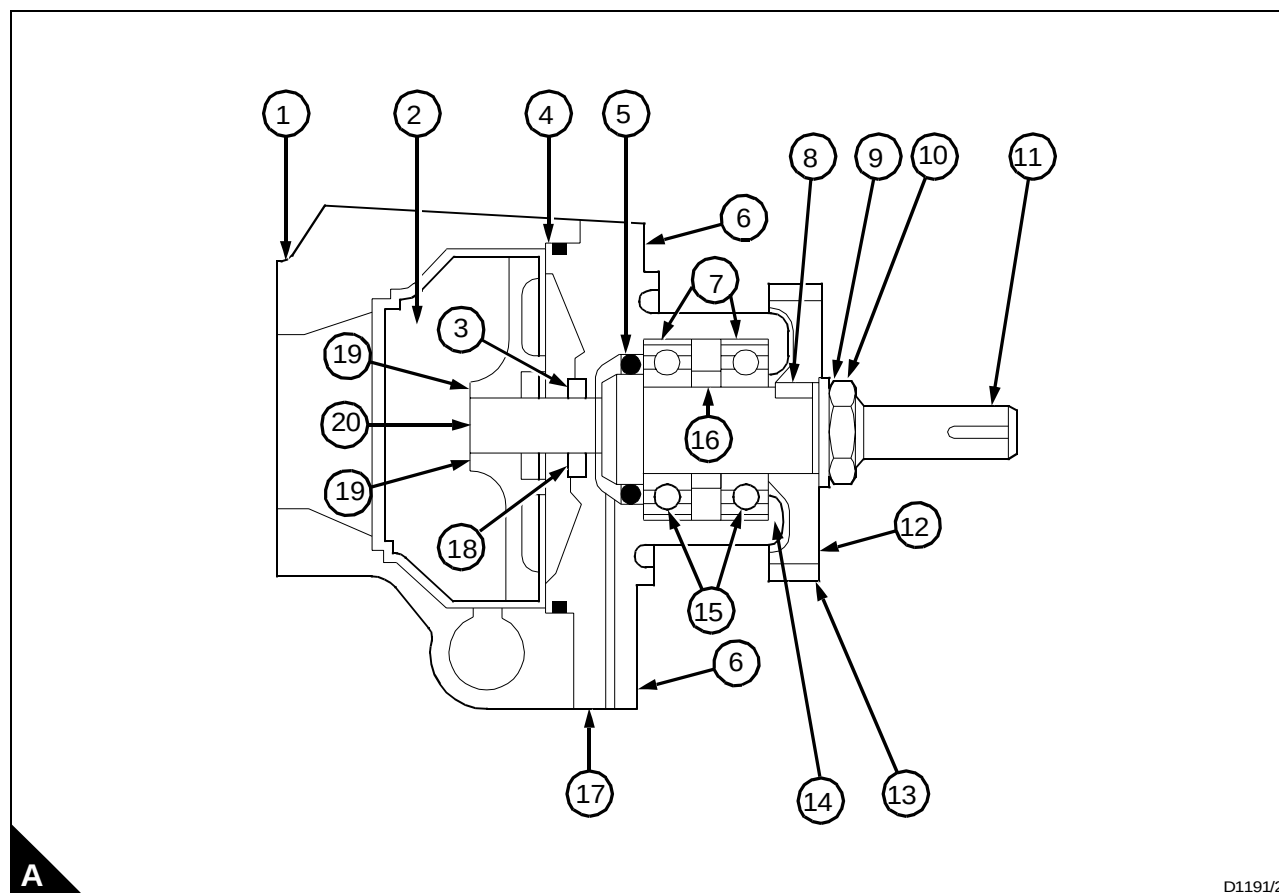
Operation 12-9

Special Requirement

Description	Part number
POWERPART Threadlock and nutlock	21820117 or 21820118

Caution: It is important that all of the components in the kit for the coolant pump are used.

- 1 Clean all components of the coolant pump with a suitable cleaning solvent. Check the impeller, bearing housing, pump body, and all bores and counter faces are free from cracks, corrosion and any other damage.
- 2 Press bearings (A15) and the distance piece (A16) on to the pump shaft. Ensure that the inner bearing is located against the shaft shoulder.
- 3 Fit the oil seal (A5) in to the bearing housing (A17) with the open side facing the bearing side (A15), lubricate the sealing lip of the seal with clean engine oil.
- 4 Fit the bearing retaining rings (A7) in to the bearing housing, then insert the shaft/bearing assembly.
- 5 Fit the circlips (A14) into the bearing housing.
- 6 Fit drive key into the coolant pump shaft.
- 7 Fit the drive gear (A13) and the washer (A9) to the shaft, and apply threadlock and nutlock sealant to the nut (A10), and loosely fit the nut (A10).
- 8 Place the drive gear in to a vice with soft vice jaws. Tighten the nut (A10) to a torque of 230 Nm (175 lbf ft) 23,4 kgf m.
- 9 The rubber casing of the ceramic counter face (A18) must be lubricated with a suitable 4% Cyclam lubricant solution in demineralised water.



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10 Fit the lubricated ceramic counter face into the recess using special tool, then wait 10 minutes to ensure that the Cyclam lubricant solution has evaporated and the rubber casing is sealed to the housing.

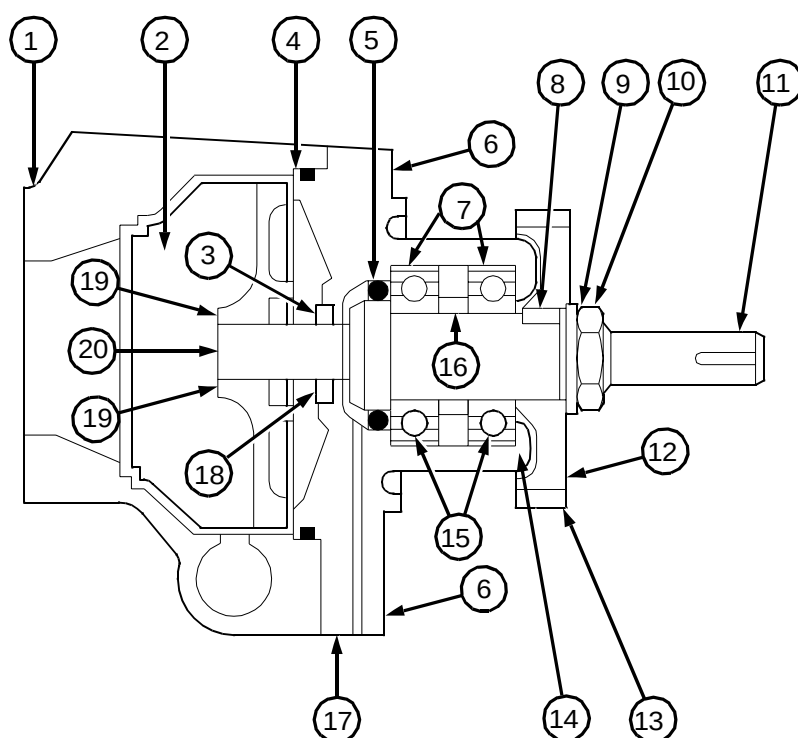
11 The rubber faced internal bore of the carbon seal (A3) must be lubricated with 4% of a suitable Cyclam lubricant solution in demineralised water.

12 Locate the lubricated carbon seal onto shaft, ensuring that it is concentric with the shaft. Using special tool push the carbon seal to the ceramic counter face until both faces mate, keep pressure on the tool for 10 minutes to allow the Cyclam lubricant solution to evaporate.

13 Locate the bearing housing assembly on a suitable press bed so that face (A12) will take the pressure of assembly.

14 Locate the impeller (A2) squarely onto the shaft and using the suitable press push the impeller until it is flush with the end of the shaft. Check that the assembly is free to rotate and that the impeller is concentric to the bearing housing.

15 Lubricate a new "O" ring with a suitable Cyclam lubricant solution and fit to the bearing housing, check that the impeller clears the pump body.



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Fan Guards

To remove and fit**Operation 12-10**

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

To remove

- 1 Remove the setscrews that secure the guards to the engine and to the radiator.
- 2 Remove the fan guards.

To fit

- 1 Fit the fan guards.
- 2 Fit the setscrews that secure the guards to the engine and to the radiator.

Fan

To remove and fit**Operation 12-11**

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

To remove

- 1 Remove the fan guards, see Operation 12-10.
- 2 Remove the six M12 setscrews from the fan and remove the fan from the fan drive pulley.

To fit

- 1 Fit the fan and the six setscrews to the fan drive pulley, then torque the setscrews gradually and evenly to a of 85 Nm (62.7 lbf ft) 8,6 kgf m.
- 2 Fit the fan guards, see Operation 12-10.

Fan drive belts

To check the fan drive belts

Operation 12-12

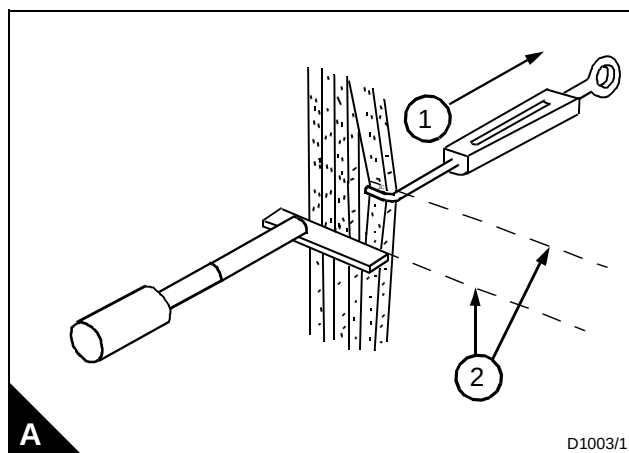
Cautions:

- The maximum force of 49 N (11.02 lbf) 5 kgf must be used on a new fan belt for the first twenty four hours.
- Do not fit one fan belt, always fit the fan belts in a set.

1 Remove the fan guards, see Operation 12-10.

2 Apply a force of 31 to 49 N (6.97 - 11.02 lbf) 3,16 - 5 kgf to each of the fan belts separately (A1). Apply this force to the longest free length of the belt between the crankshaft pulley and the fan pulley.

Note: The correct deflection of the fan belt (A2) is 4,2 mm (0.165 in).



To adjust the fan drive belts

Operation 12-13

1 Remove the fan guards, see Operation 12-10.

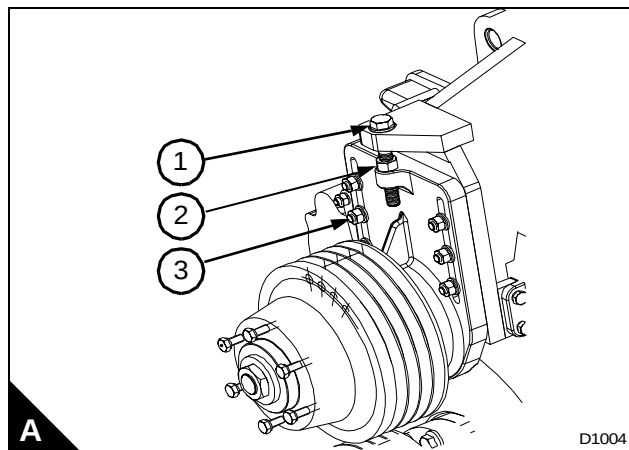
2 Loosen the 6 nuts (A3) and loosen the lock nut (A2).

3 To increase the tension of the fan belt rotate the adjusting screw (A1) clockwise. To loosen the tension of the fan belt rotate the adjusting screw anti-clockwise.

4 When all the belts are at the correct tension, tighten the 6 nuts (A3) to 85 Nm (62.7 lbf ft) 8,6 kgf m and tighten the locking nut (A2).

5 Check that the fan belt tension is correct on each belt.

6 Fit the fan guards, see Operation 12-10.

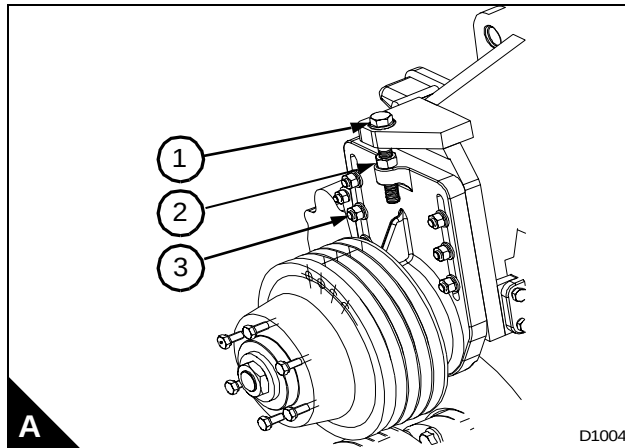


To remove and fit the drive belts

Operation 12-14

To remove

- 1 Remove the fan guards, see Operation 12-10.
- 2 Remove the fan, see Operation 12-11.
- 3 Loosen the 6 nuts (A3) and loosen the lock nut (A2).
- 4 Rotate the adjusting screw anti-clockwise (A1), until the drive belts can be removed from the fan drive pulley.
- 5 Remove the drive belts.

**To fit**

Caution: Do not fit one fan belt, always fit the fan belts in a set.

- 1 Fit the drive belts to the fan drive pulley.
- 2 Adjust the fan drive belts to the correct tension, see Operation 12-13.
- 3 Fit the fan guards, see Operation 12-10

Fan drive

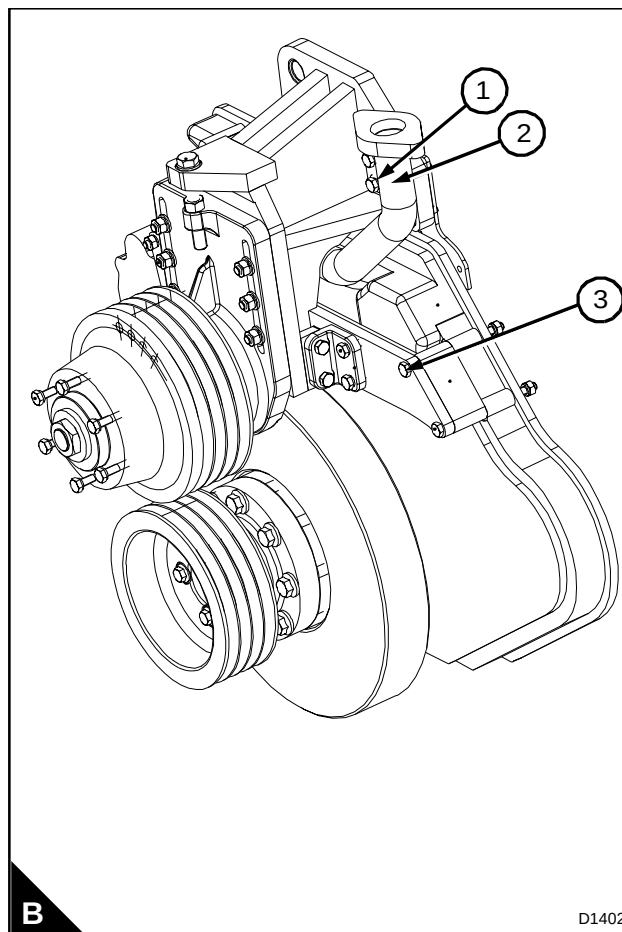
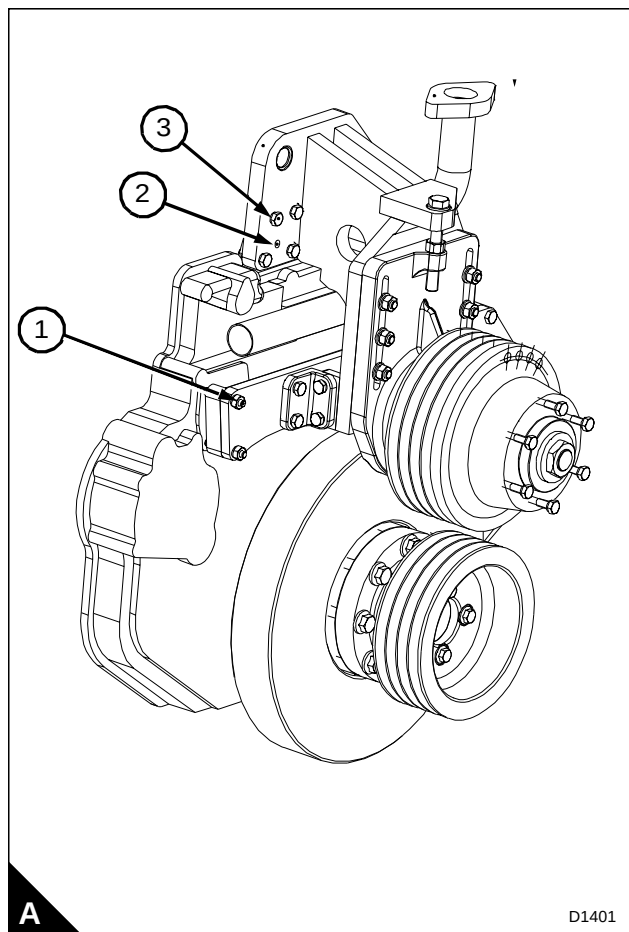
To remove and fit

Operation 12-15

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

To remove

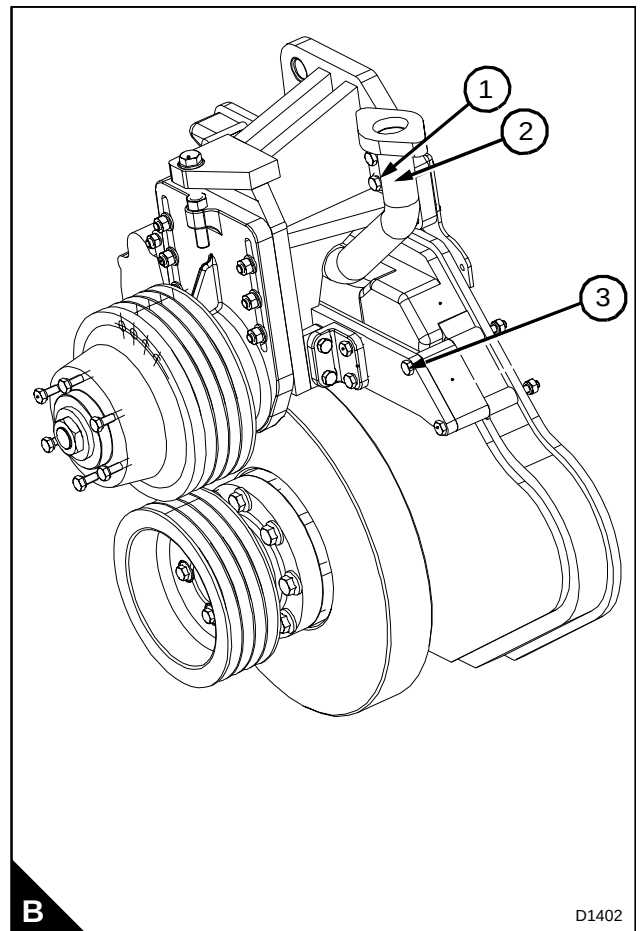
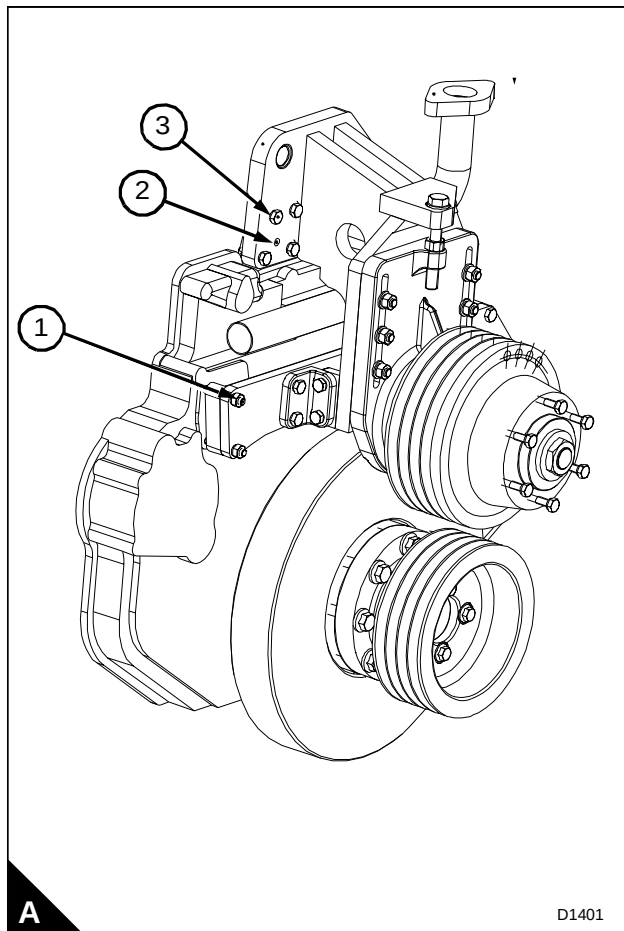
- 1 Remove the fan guards, see Operation 12-10.
- 2 Remove the fan, see Operation 12-11.
- 3 Remove the fan drive belts, see Operation 12-14.
- 4 Remove the stop solenoid, see Operation 12-11
- 5 Remove the four setscrews (A3) and the four setscrews (B1) that secure the fan drive to the engine.
- 6 Remove the two setscrews (A1) and the two setscrews (B3) and the spacers from the support brackets of the fan drive.
- 7 Remove the fan drive from the dowels (A2) and (B2).



Continued

To fit

- 1 Fit the fan drive to the dowels (A2) and (B2) and the fit the setscrews (A3 and B1).
- 2 Gradually and evenly torque the setscrews to 50 Nm (36.9 lbf ft) 5,1 kgf m.
- 3 Fit the spacers and setscrews (A1 and B3), gradually and evenly torque the setscrews to 50 Nm (36.9 lbf ft) 5,1 kgf m.
- 4 Fit the fan drive belts, see Operation 12-14.
- 5 Fit the fan, see Operation 12-11.
- 6 Fit the stop solenoid, see Operation 12-11.
- 7 Fit the fan guards, see Operation 12-10.

*Continued*

Lubricating oil cooler

To remove

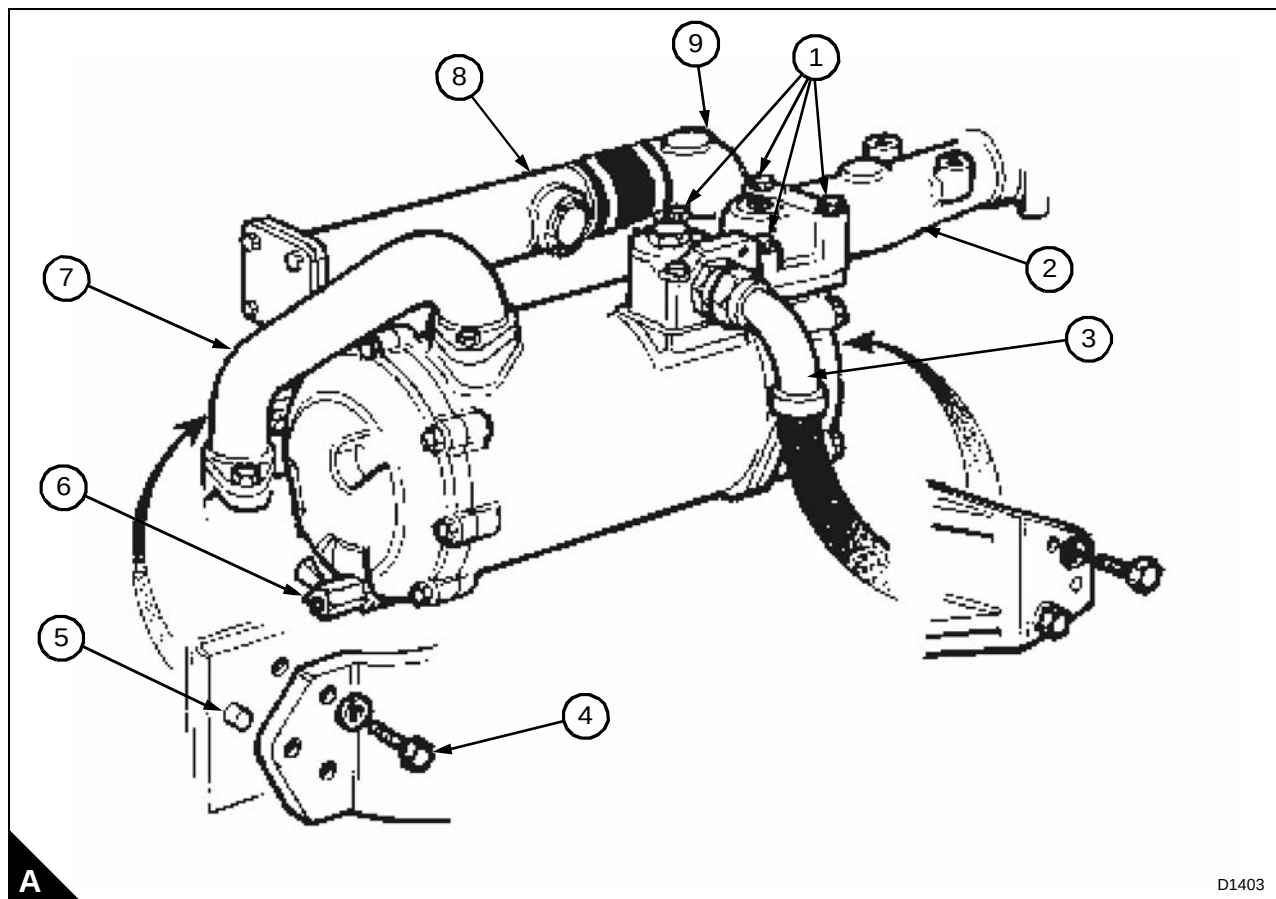
Operation 12-16

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

- 1 Drain the engine cooling system.
- 2 Drain the coolant from the oil cooler by opening the drain tap (A6).
- 3 Remove the flexible oil feed pipe (A3).
- 4 Remove the oil outlet pipe (A7).
- 5 Loosen the hose clips on the outlet elbow to the (A2) hose.
- 6 Remove the four setscrews (A1) from coolant feed pipe (A2).
- 7 Loosen the hose clips on the outlet elbow from the oil cooler to the coolant pipe (A8).
- 8 Remove the four setscrews from the coolant outlet elbow (A9).
- 9 Remove the four setscrews (A4) that secure the oil cooler mounting brackets to the crankcase.
- 10 Remove the oil cooler off its locating dowels (A5) and lift away from the engine.

Notes:

- Discard all 'O' rings and joints when they are removed and fit new 'O' rings and joints in their place.
- Be prepared for the oil and coolant spillage from the oil cooler body.

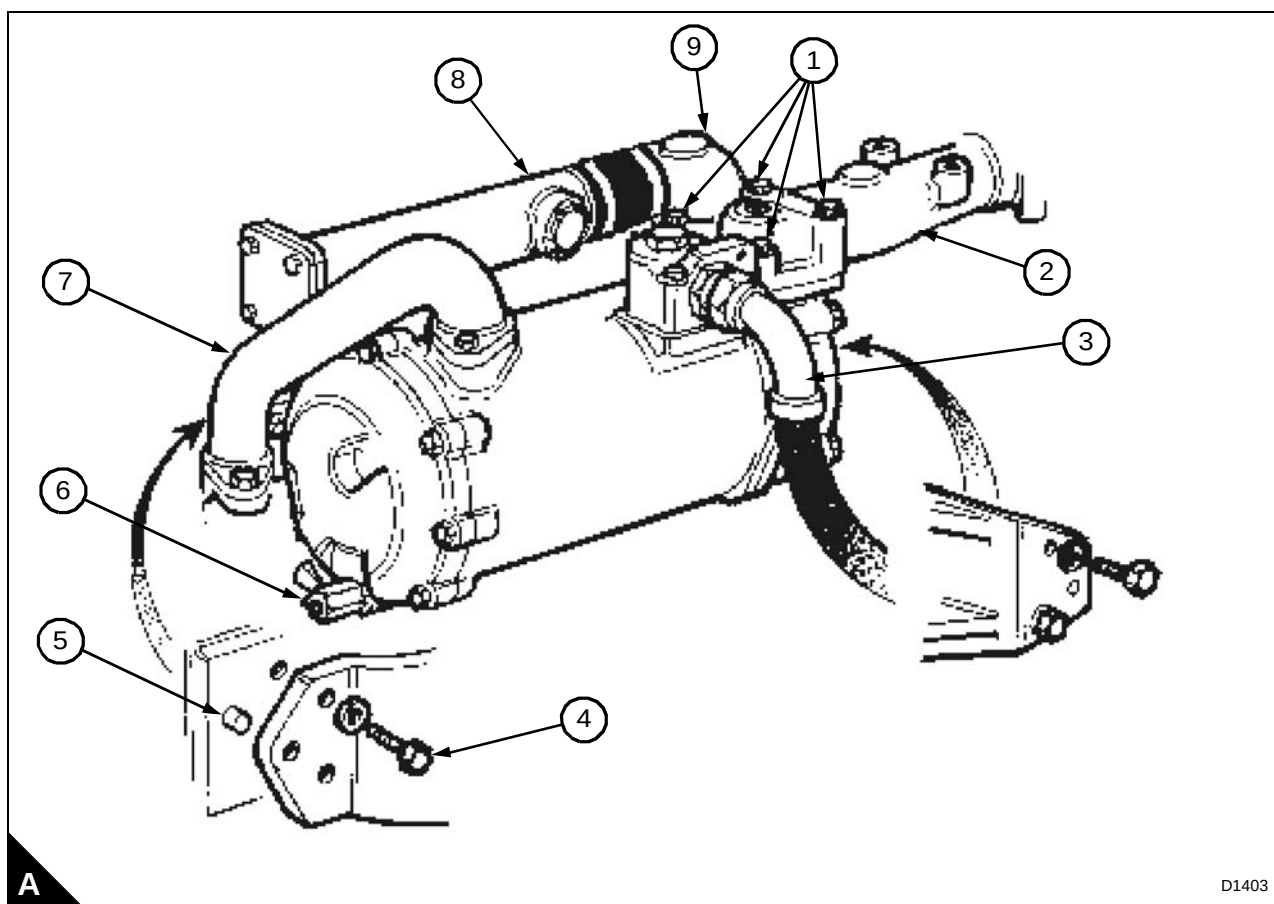


To fit

Operation 12-17

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

- 1 Lift the oil cooler into position, setting it on the locating dowels. Push against the cooler body against the crankcase holding it in position while the mounting setscrews (A4) are fitted and tightened to a torque of 50 Nm (36 lbf ft) 5,1 kgf m.
- 2 Fit the flexible oil feed pipe (A3) and tighten to a torque of 50 Nm (36 lbf ft) 5,1 kgf m.
- 3 Fit a new "O" ring to the oil outlet pipe (A7) and fit the pipe to the oil cooler. Fit the setscrews and tighten to a torque of 50 Nm (36 lbf ft) 5,1 kgf m.
- 4 Fit new joints to the coolant outlet elbow (A9) and fit to the oil cooler. Fit new 'O' ring in (A2) and fit four setscrews and gradually and evenly tighten to a torque of 50 Nm (36 lbf ft) 5,1 kgf m.
- 5 Refill the cooling system, refer to the Users Handbook.
- 6 Prime the lubricating system, refer to the Users Handbook.



To disassemble and clean the oil cooler tube stack

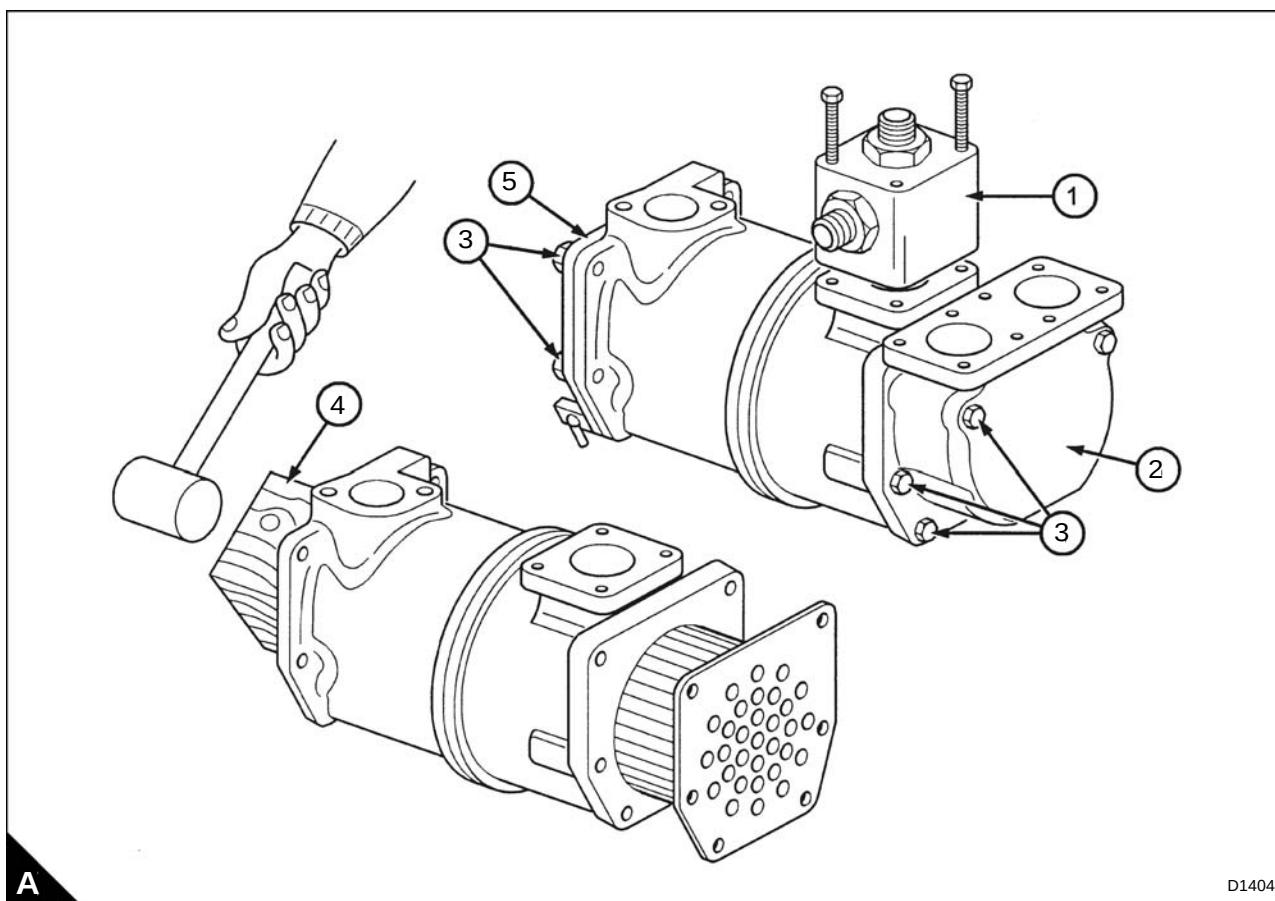
Operation 12-18

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

- 1 Remove the oil cooler from the crankcase, see Operation 12-16.
- 2 Remove the setscrews (A3) and remove the end covers (A2) and (A5). A light tap with a soft mallet may be needed to free the covers.
- 3 Remove the setscrews from the oil inlet body (A1), remove the oil inlet body and the 'O' ring. Discard the 'O' ring.
- 4 Using a block of wood (A4) to protect the face of the tube stack, carefully knock the tube stack out of the oil cooler body.
- 5 Discard the tube stack 'O' ring and remove any joint material.
- 6 Check the coolant side of the tube stack for lime scale contamination.
- 7 Check the lubricating oil side of the tube stack for oil contamination.

Note: If the tube stack is in a serviceable condition it can be cleaned using industrial detergent and an lime scale solvent. The manufacturers instructions on the use of these substances must be strictly adhered to.

Caution: If lime scale or oil contamination is still present after cleaning, the tube stack must be replaced as a reduced ability to transfer heat can lead to engine failure.

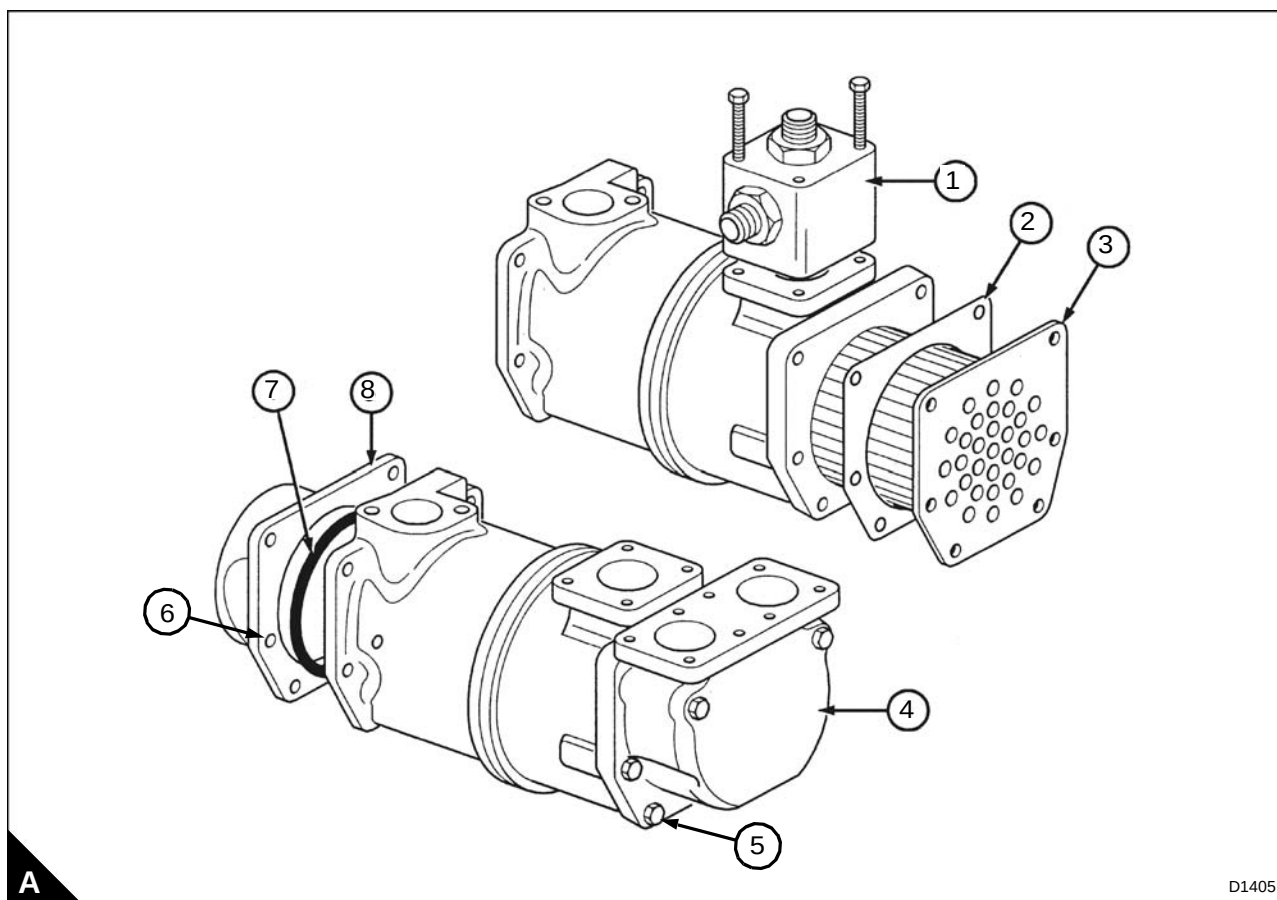


To assemble the oil cooler tube stack

Operation 12-19

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

- 1 Fit a new joint (A2) between tube stack and oil cooler body, then carefully insert the tube stack (A3) into the oil cooler body.
- 2 Fit a new joint fit the end cover (A4) and tighten the setscrews (A5) gradually and evenly to 50 Nm (36 lbf ft) 5,1 kgf m.
- 3 Fit a new 'O' ring (A7) to the tube stack then fit the end cover (A8) and tighten the setscrews (A5) gradually and evenly to 50 Nm (36 lbf ft) 5,1 kgf m.
- 4 Fit a new O ring to the oil inlet body (A1) and tighten the setscrews (A5) gradually and evenly to 50 Nm (36 lbf ft) 5,1 kgf m.
- 5 Fit the oil cooler from the crankcase, see Operation 12-17



To pressure test the oil cooler

Operation 12-20

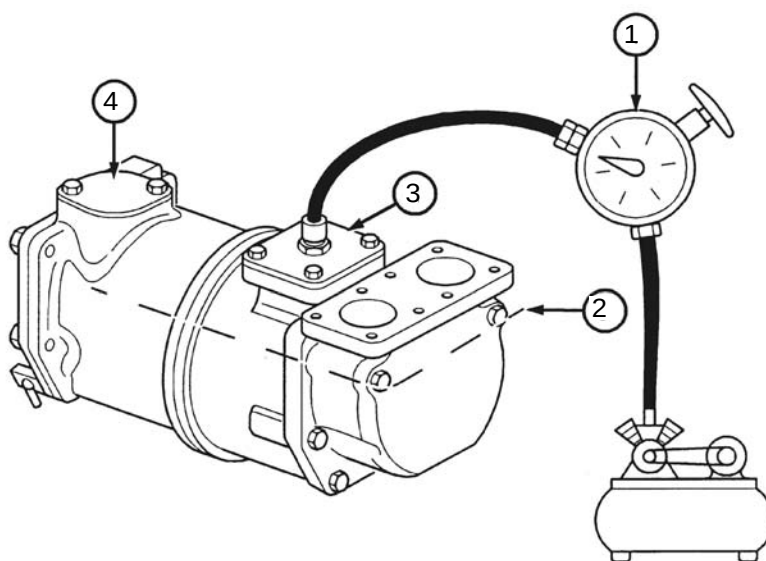
1 Use suitable pre-fabricated blanking plate (A4) and a pre-fabricated blanking plate with an suitable air pipe connection (A3).

Warning! Ensure the blanking plate fabrication is able to withstand the required pressure.

2 Fill the coolant side of the oil cooler with clean water to the level indicated (A2).

3 Fit new joints to the blanking plates and then fit the blanking plates.

4 Connect compressed air to the pre-fabricated blanking (A3) using a pressure gauge regulator (A1). Set the pressure at 3 bar (50 psi). The pressure should hold for 3 minutes.



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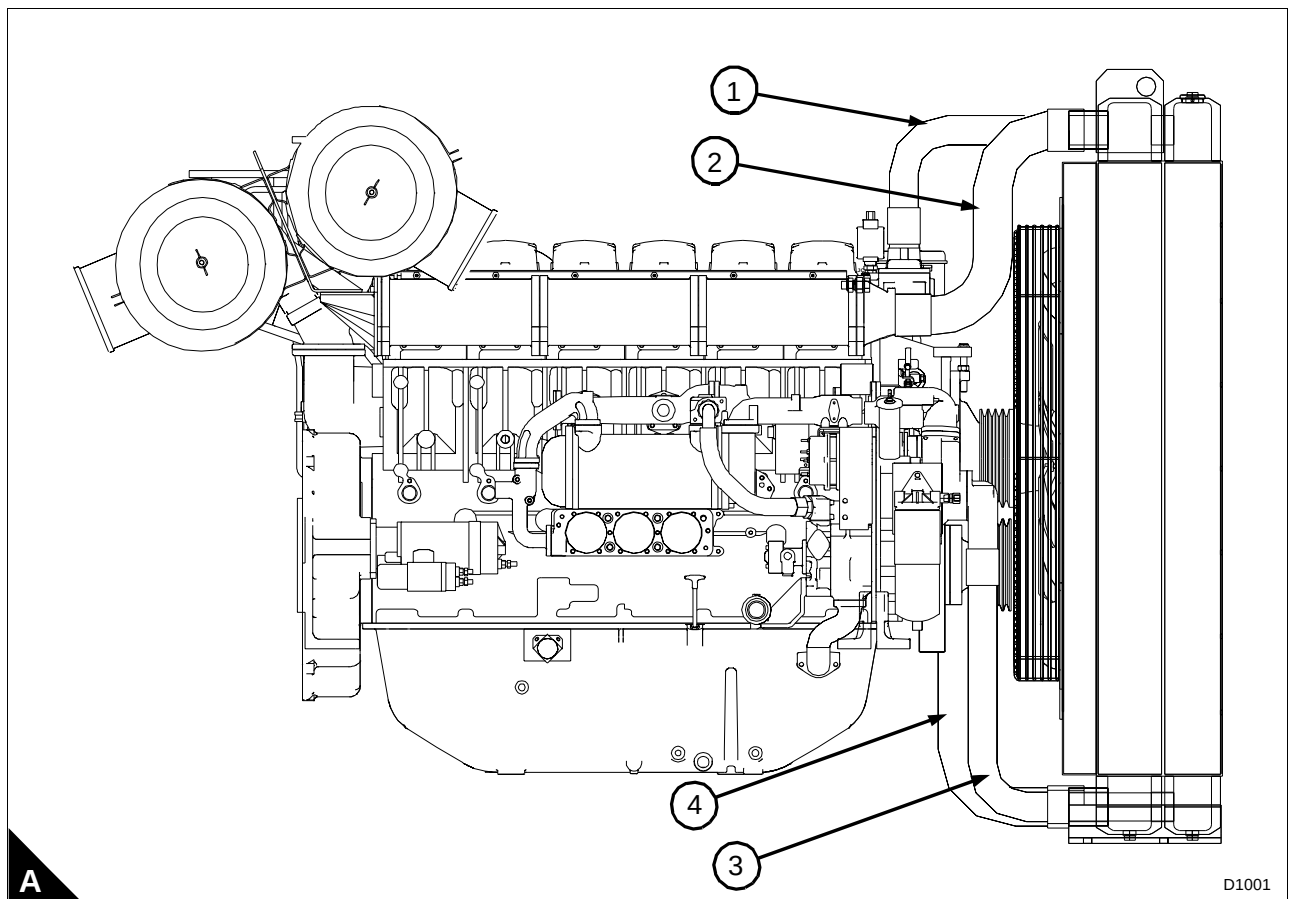
Radiator

To remove

Operation 12-21

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

- 1 Remove the fan guards, see Operation 12-10.
- 2 Drain the cooling system.
- 3 Loosen the hose clip from the radiator pipe (A1). Remove the hose from the radiator pipe (A1).
- 4 Loosen the hose clips and straps from the two radiator pipes (A2). Remove the hoses from the two radiator pipes (A2).
- 5 Loosen the hose clip from the radiator pipe (A3). Remove the hose from the radiator pipe (A3).
- 6 Loosen the hose clips and straps from the two radiator pipes (A4). Remove the hoses from the two radiator pipes (A4).
- 7 Remove the four setscrews that secure the radiator to the engine frame.
- 8 Remove the radiator from the engine frame.

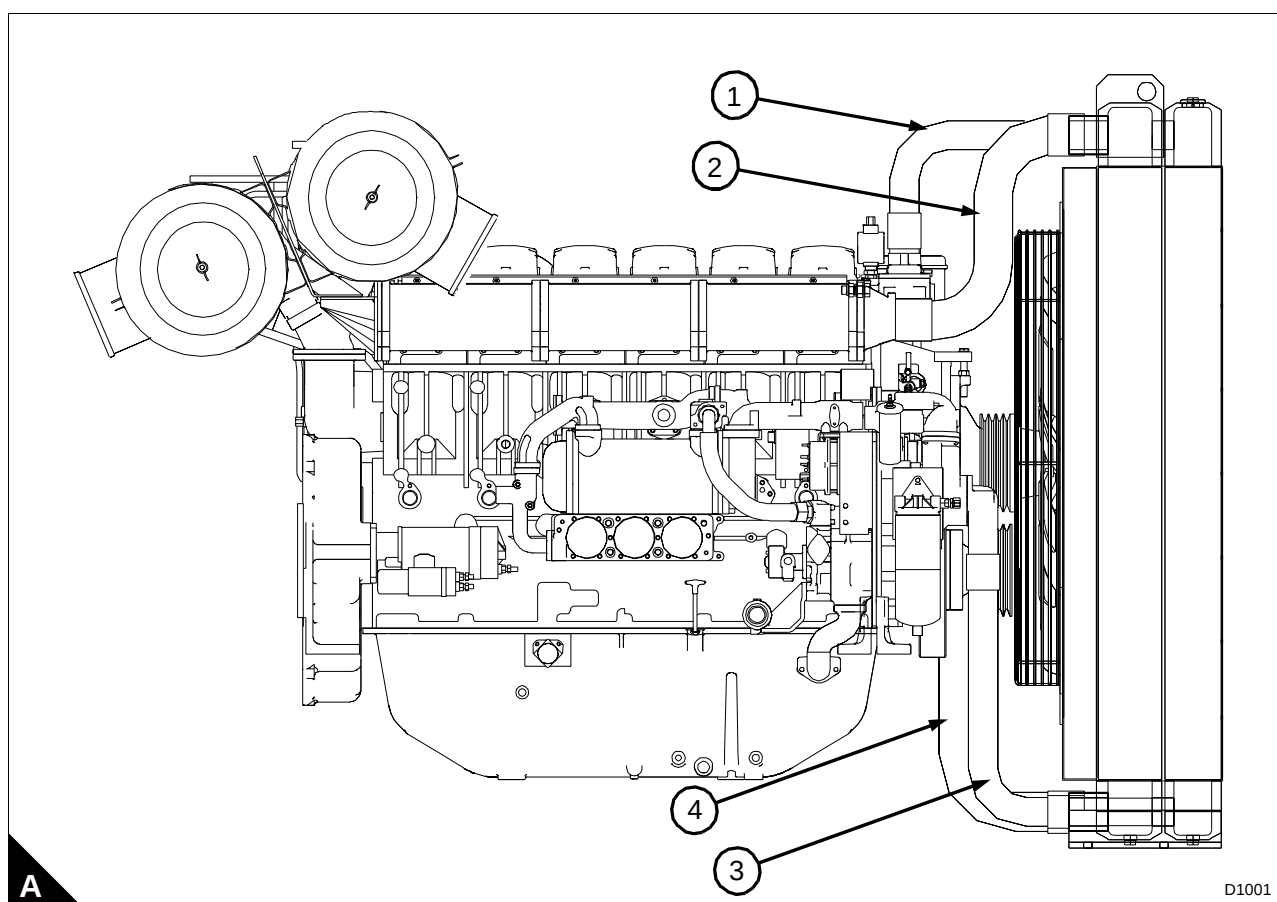


To fit

Operation 12-22

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

- 1 Fit the radiator from the engine frame. Tighten the four setscrews that secure the radiator to the engine frame. To torque for these setecrews is 400 Nm (295 lbf ft) 40,7 kgf m.
- 2 Fit the hoses to the two radiator pipes (A4). Fit and tighten the hose clips and straps to the two radiator pipes (A4).
- 3 Fit the hose to the radiator pipe (A3). Fit and tighten the hose clip to the radiator pipe (A3).
- 4 Fit the hoses to the two radiator pipes (A2). Fit and tighten the hose clips and straps to the two radiator pipes (A2).
- 5 Fit the hose to the radiator pipe (A1). Fit and tighten the hose clip to the radiator pipe (A1).
- 6 Fit the fan guards, see Operation 12-10.
- 7 Fill the cooling system. Refer to the relevant User's Handbook.



13

Flywheel and housing

General description

The cast iron flywheel is fitted with a hardened starter ring. The starter rings have 190 teeth. The flywheel housing is made of cast iron.

Flywheel

To remove and to fit the flywheel

Operation 13-1

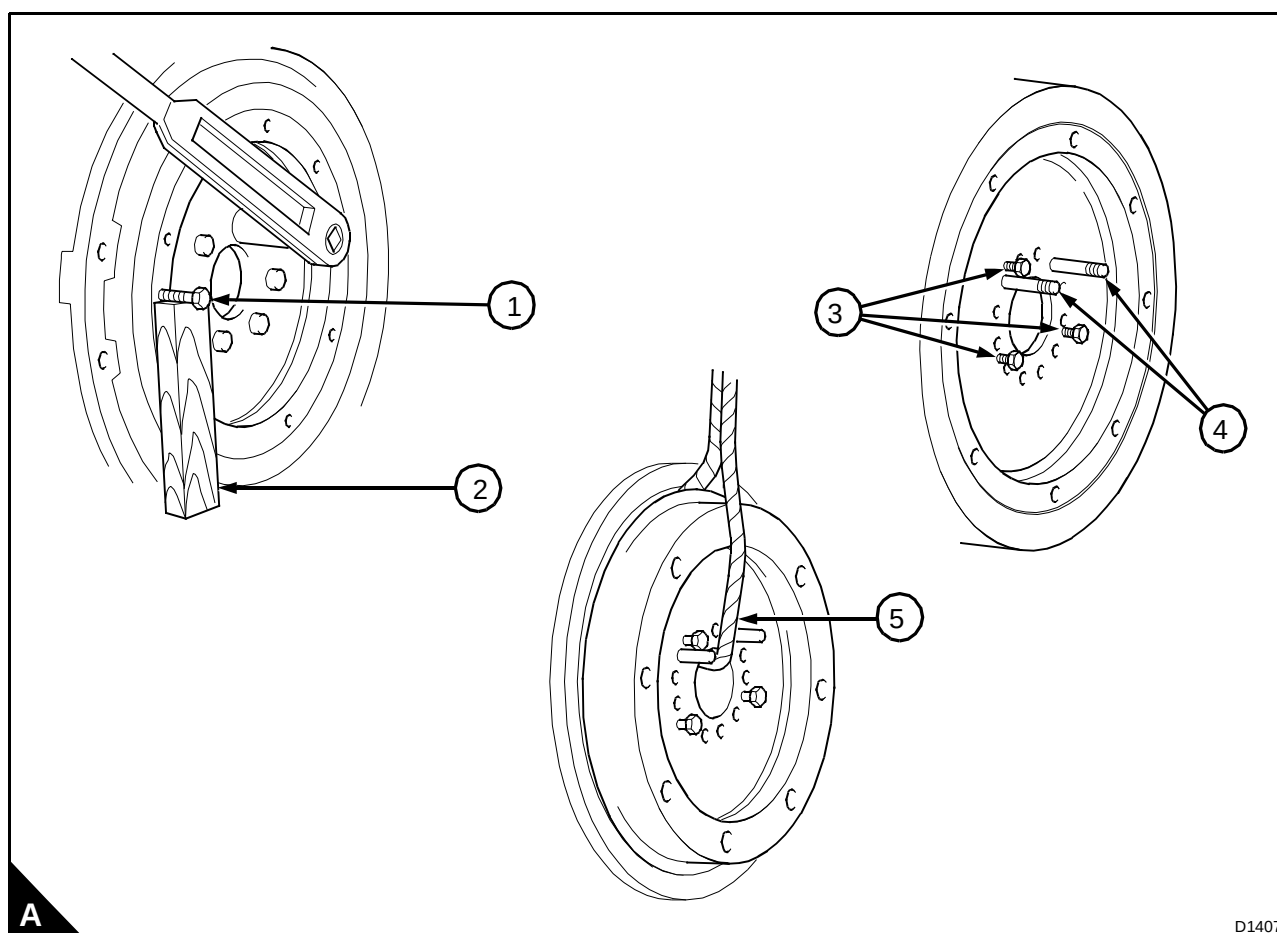
Special requirements

Special tools	
Description	Part number
Flywheel guide studs	T6253-157

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

To remove

- 1 Lock the flywheel in position by fitting a setscrew (A1) into the flywheel face then set a piece of wood (A2) between the head of the setscrew and the floor.
- 2 Remove two opposite fasteners from the flywheel. Fit the two guide studs (A4) to ensure that the flywheel can be removed and fitted safely.



- 3 Remove the remainder of the fasteners.
- 4 Fit three M12 x 100mm setscrews (A3) into the extractor holes in the flywheel, then tighten the setscrews in a diagonal pattern to push the flywheel off the crankshaft onto the guide studs until there is sufficient clearance to thread a rope sling through the flywheel (A5).
- 5 Take the weight of the flywheel with the hoist then slide the flywheel along the guide studs and lift clear of the engine
- 6 Check the flywheel and ring gear for damage and renew, if necessary.
- 7 Check the area around the fixing holes of the flywheel for cracks. If cracks are found, the flywheel must be renewed.

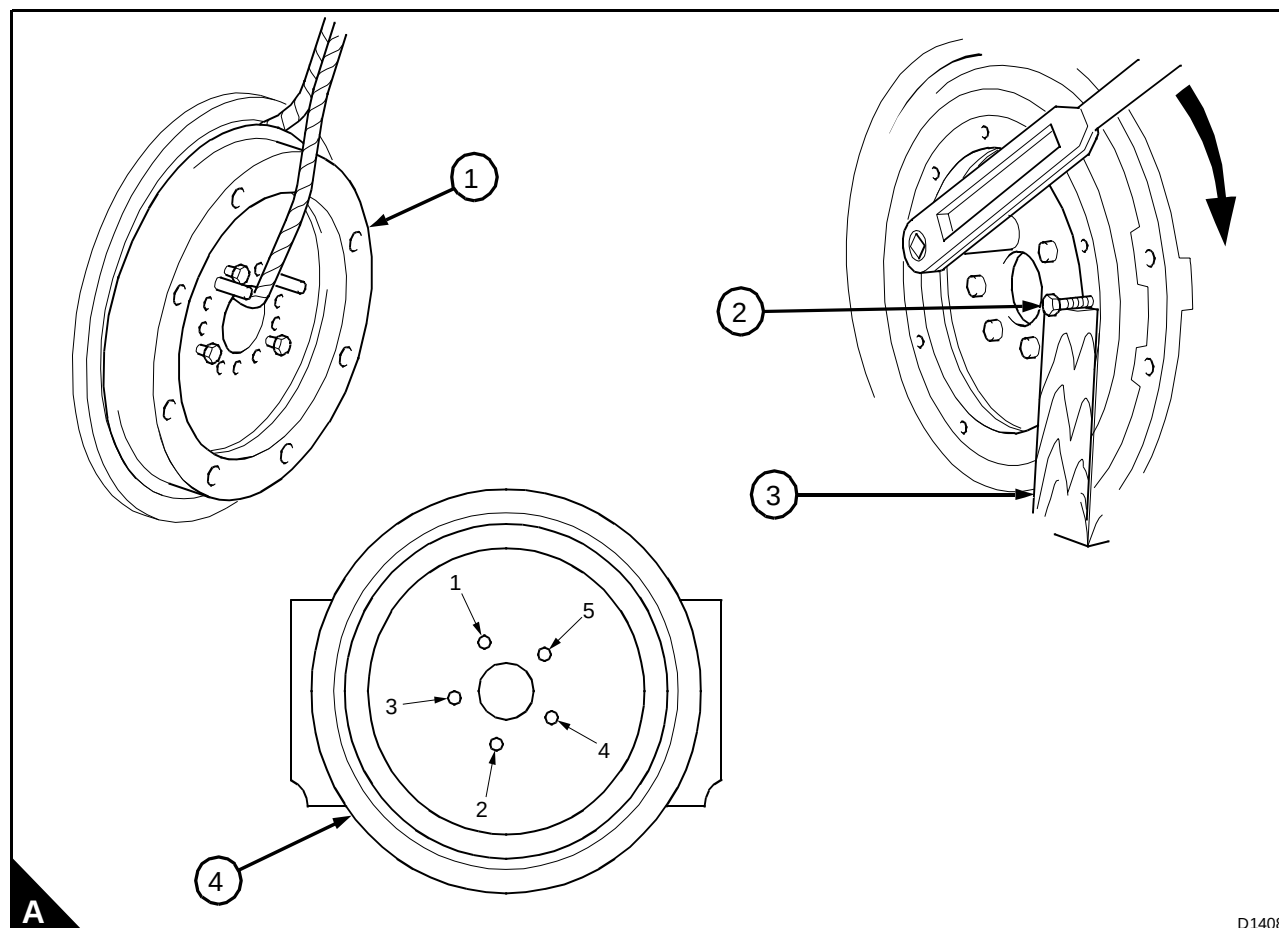
To fit

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

- 1 Ensure that both the crankshaft palm, and the flywheel mounting face, are clean and free from damage.
- 2 Fit the flywheel guide studs into the crankshaft, then using a rope sling and hoist lift the flywheel onto the guide studs. Push the flywheel (A1) along the guide studs and remove the rope sling.
- 3 Lubricate the threads and the underside of the heads of the fasteners with clean engine oil, then fit them hand tight, pulling the flywheel onto the crankshaft. Remove the guide studs
- 4 Lock the flywheel into position by fitting a setscrew (A2) into the flywheel face, then set a piece of wood (A3) between the head of the setscrew and the floor.
- 5 Torque the fasteners the following procedure (See table below) and sequence (see graphic A).

M16 Bolts	
Stage	Torque
1	Hand tighten
2	135 Nm (100 lbf ft)
3	337 Nm (249 lbf ft)

- 6 Check the run out of the flywheel face. The maximum permissible run out of the flywheel face is 0,13 mm (0.005 in).



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Gear ring

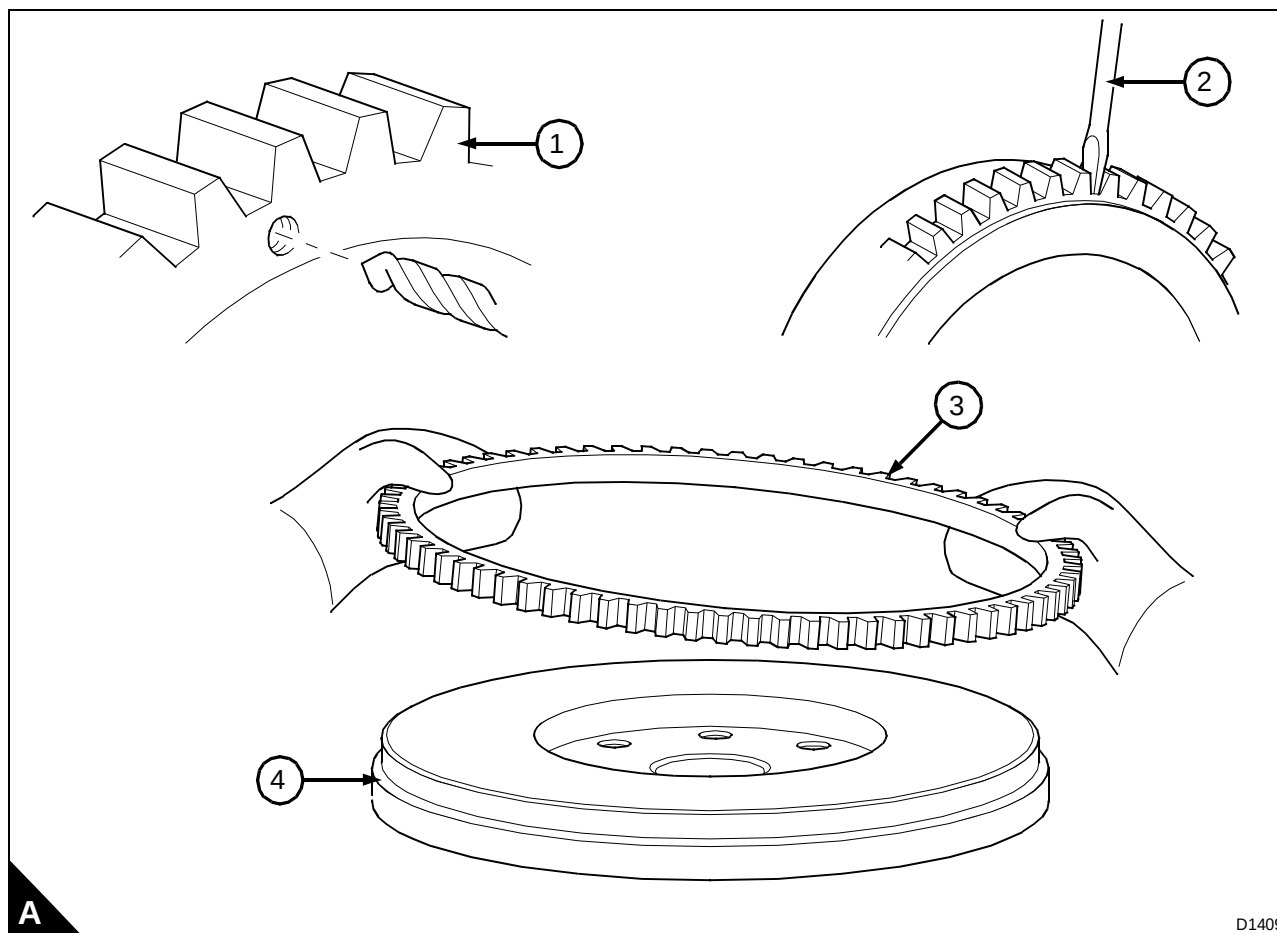
To remove and to fit the gear ring

Operation 13-2

Warning! Wear eye protection and suitable protective clothing during this operation.

To remove

1 Inspect the starter ring gear for wear. If replacement is necessary, drill a hole through the ring gear (A3) at the base of a tooth (A1) then using a hammer and chisel (A2) split the ring gear and remove the gear ring from the flywheel.



To fit

Note: The ring gear (A3) must be fitted with the chamfered teeth facing upwards towards the pinion on the starter motor.

- 1 The ring gear is heated onto the flywheel. When a new gear is to be fitted, ensure that it is not heated to more than 250 °C (480 °F).
- 2 Check that the gear ring is correctly fitted to the shoulder (A4) of the flywheel.

Flywheel Housing

To remove and to fit the flywheel housing

Operation 13-3

Special requirements

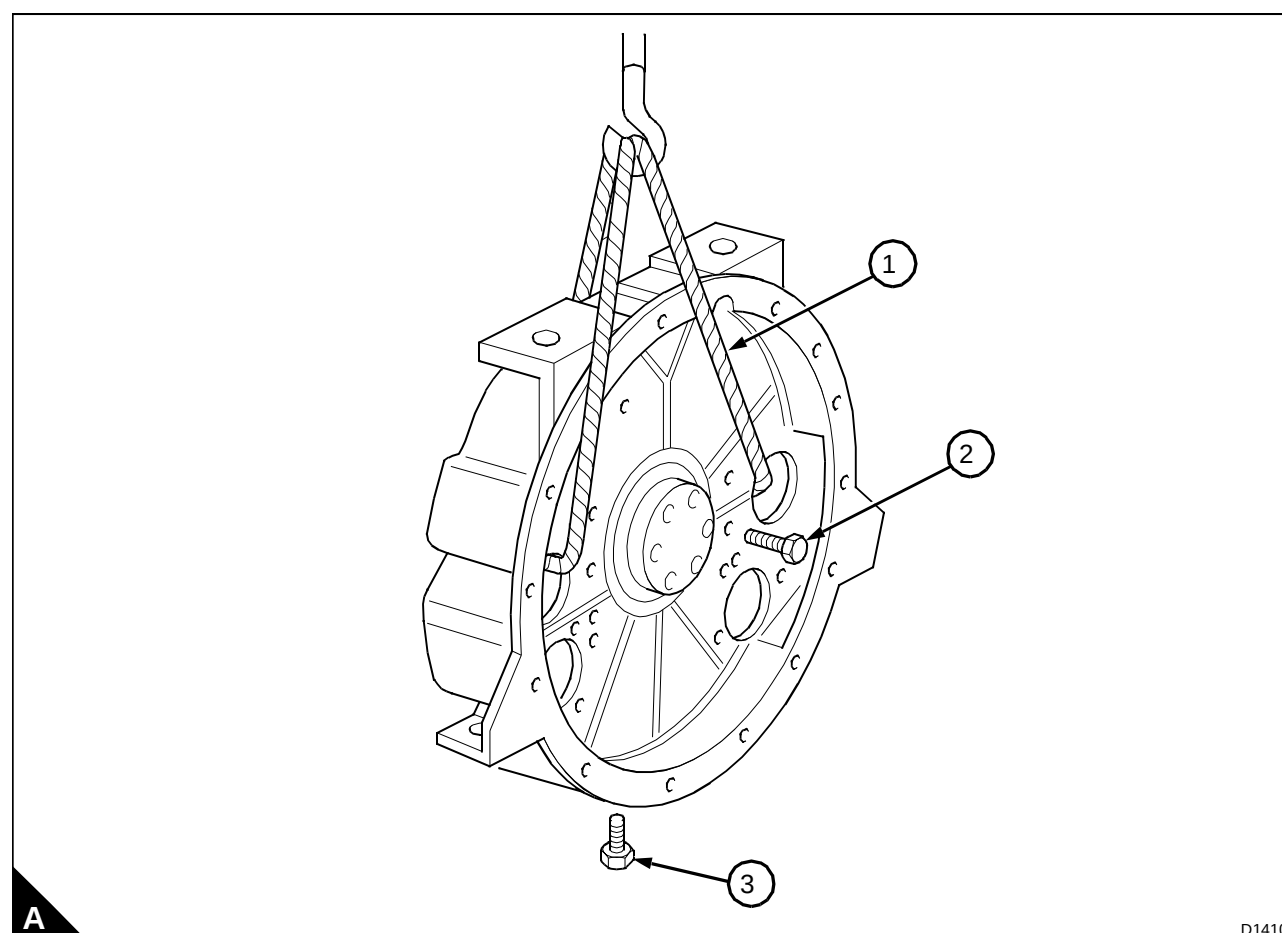
Consumable products	
Description	Part number
POWERPART Gasket and flange sealant	21820518

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

Note: This procedure relates to an engine that has been removed from its installation.

To remove

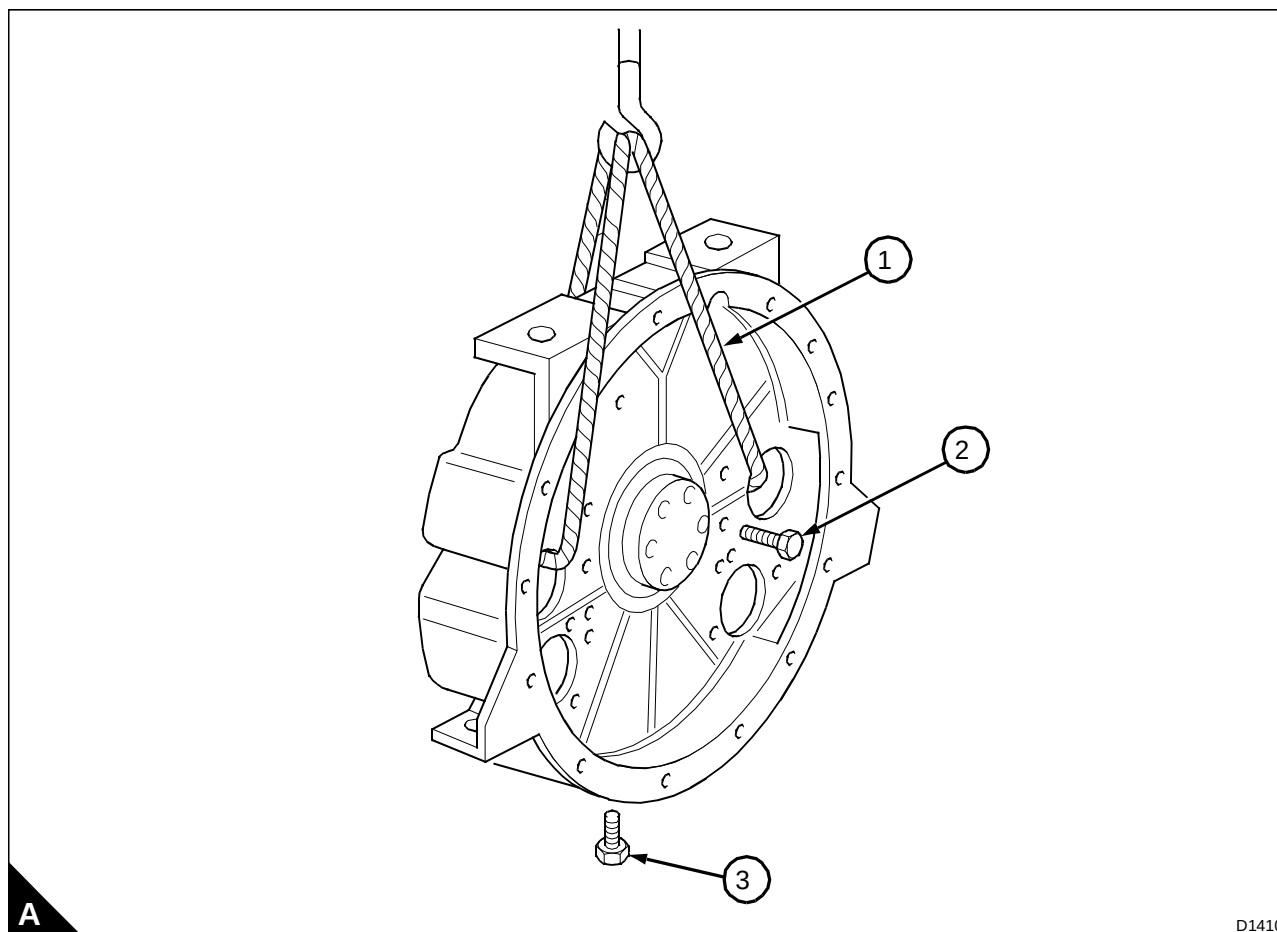
- 1 Remove the flywheel, see Operation 13-1.
- 2 Remove the setscrews (A3) that secure the sump to the flywheel housing.
- 3 Use a rope sling passed through the starter motor mounting (A1), take the weight of the housing with a hoist.
- 4 Remove the setscrews (A2) and carefully move the flywheel housing from the crankcase dowels.
- 5 Remove the flywheel housing oil seal, see Operation 13-4.



To fit

Warning! Always use lift equipment of the approved type and of the correct capacity to lift heavy engine components. Never work alone when you operate lift equipment.

- 1 Lightly coat the flywheel housing mating surfaces with POWERPART gasket and flange sealant.
- 2 Fit the flywheel housing onto its locating dowels in the crankcase. Fit the setscrews (A2) hand tight, ensuring that the housing is pulled evenly to the crankcase. Torque the setscrews gradually and evenly to 50 Nm (35 lbf ft) 5,1 kgf m.
- 3 Fit the four setscrews (A3) that secure the sump to the flywheel housing and gradually and evenly torque to 50 Nm (35 lbf ft) 5,1 kgf m.
- 4 Fit the flywheel, see Operation 13-1.



Flywheel housing oil seal

To remove and to fit the flywheel housing oil seal

Operation 13-4

Special requirements

Special tools	
Description	Part number
Oil seal fitting tool	T6253/140

Warning! Wear eye protection and suitable protective clothing during this operation.

To remove

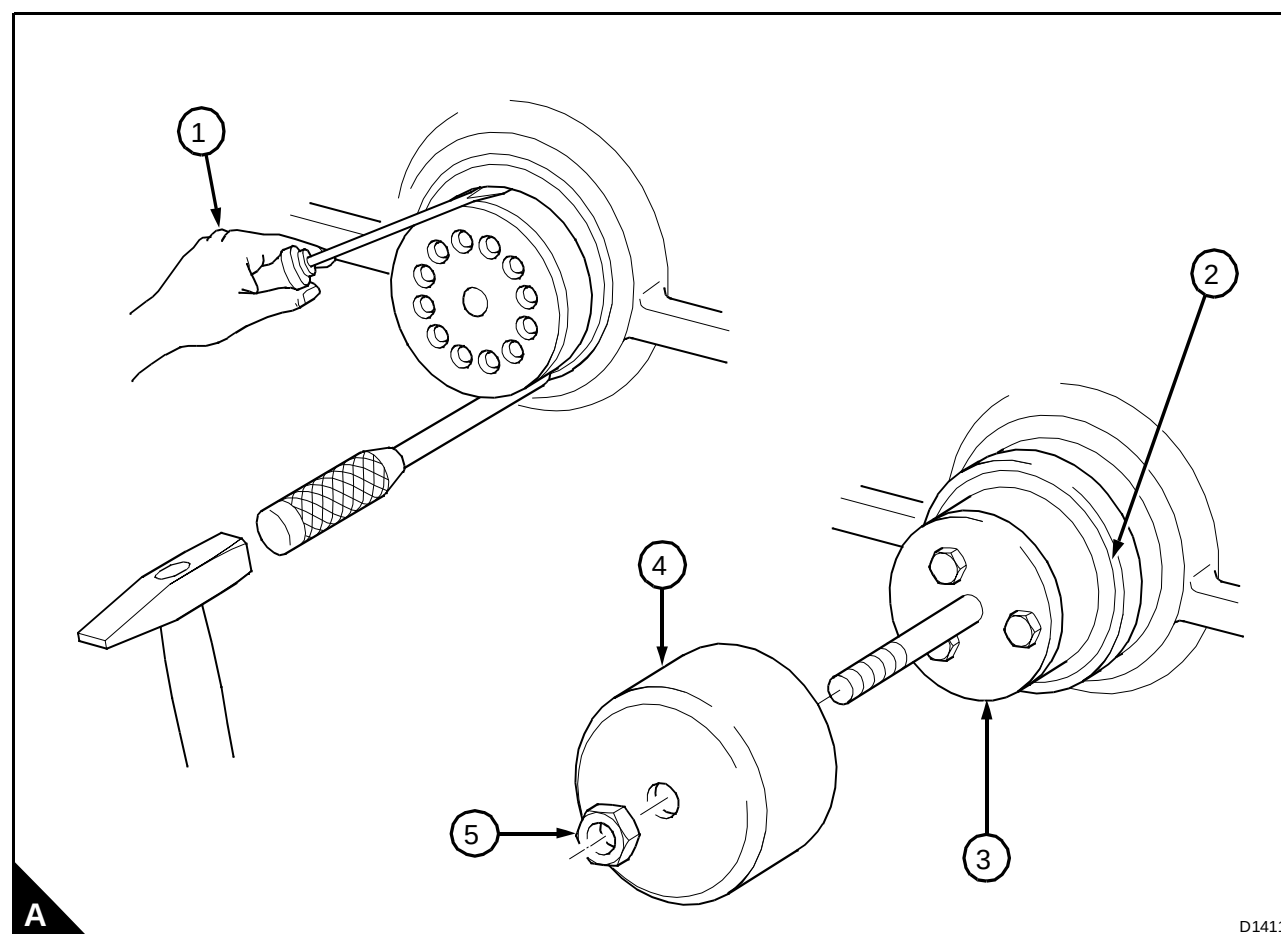
- 1 Remove the flywheel, see Operation 13-1.

Note: Ensure that you do not damage the crankshaft oil seal contact diameter.

- 2 Use a hammer and round flat headed punch, carefully knock the outer casing of the oil seal in the flywheel housing. The seal will distort and step out of the housing.
- 3 Carefully insert a screwdriver between the seal and housing (A1) then lever out the seal.

To fit

- 1 Fit the oil seal guide (A3) to the crankshaft.
- 2 Lubricate the oil seal (A2) and carefully push the oil seal on to the crankshaft up to the flywheel housing.
- 3 Fit the outer sleeve (A4) up to the seal, then fit and tighten the nut (A5) forcing the seal into the gearcase.
- 4 Remove the oil seal fitting tool.



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14

Electrical equipment

General description

Warnings!

- *The starter system is a insulated return system. Check the polarity of the batteries before you disconnect or connect the batteries.*
- *Only personnel with the correct training and the correct service tools should make a repair or adjustment to the electrical systems.*

Cautions:

- *Do not disconnect the battery while the engine is in operation. This will cause a voltage surge in the alternator charge system which will immediately cause damage to the diodes or to the transistors.*
- *Do not disconnect an electrical wire before the engine is stopped and all electrical switches are in the "off" position.*
- *Do not cause a short circuit by the connection of electrical wires to the wrong terminals. The correct electrical wire must be connected to the correct terminal. A short circuit or wrong connection, which gives reverse polarity, will immediately cause permanent damage to the diodes and to the transistors.*
- *Do not connect a battery into the system until it has been checked for the correct polarity and voltage.*
- *Do not check for current flow with a spark contact as damage can be caused to the transistors.*

Alternator

General description

The alternator is driven by a toothed belt that is shaft driven from the coolant pump gear.

The alternator system is 24 volts. The alternator has a output of 30 (amps) at a stabilized output of 28 volts.

To check the drive belts

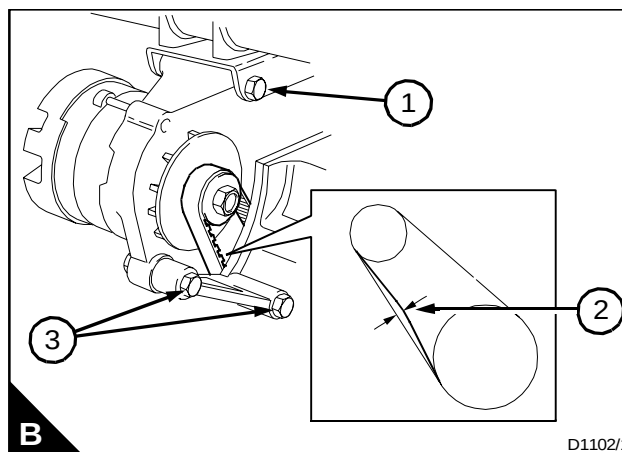
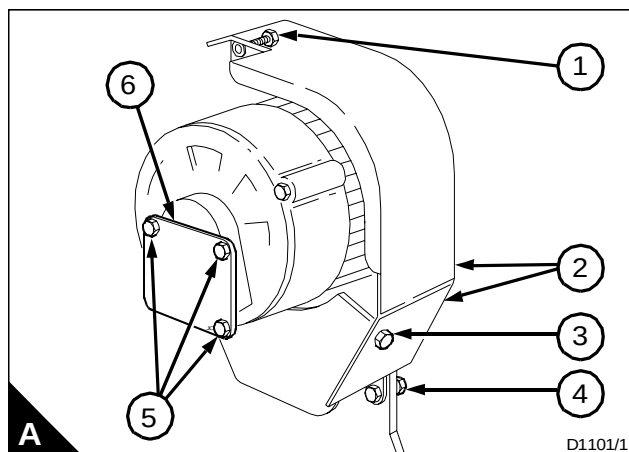
Operation 14-1

Warning! Disconnect the batteries and any other power that can start the engine.

Caution: Do not disconnect the batteries while the engine is running.

Note: The alternator guard is a 3 piece item.

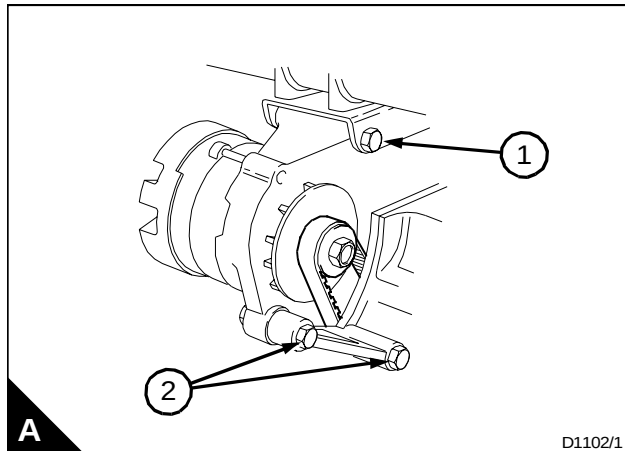
- 1 Remove the three bolts (A5) from the plate (A6) and remove the plate.
- 2 Remove the bolt (A3).
- 3 Remove the top bolt (A1) and the bottom bolt (A4) and remove the two parts of the guard (A2).
- 4 To check the belt tension, apply 15,6 N (3.5 lbf) 1,5 kgf of pressure midway between the two pulleys (B2). The correct deflection of the belt is 1,5 mm (0.0625 in).
- 5 Adjust the belt if necessary, see Operation 14-2.
- 6 Fit the guard assembly and tighten all the bolts securely.
- 7 Connect the power supply to the starter motor.



To adjust the drive belt tension

Operation 14-2

- 1 Remove the guard assembly from the alternator.
- 2 Loosen the pivot bolt (A1) and loosen the link adjuster bolts (A3).

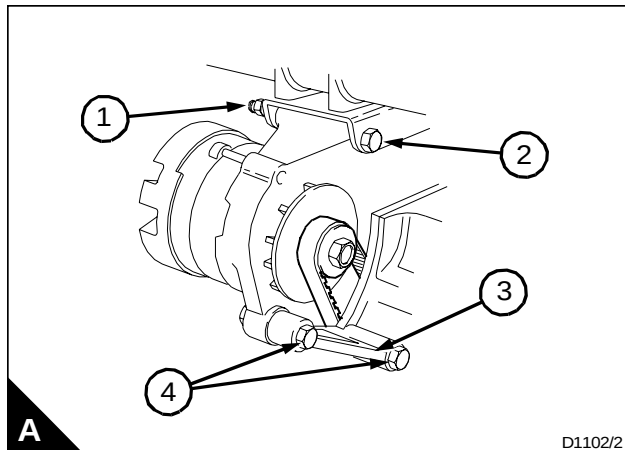


- 3 Adjust the alternator belt to the required tension, see Operation 14-1.
- 4 Tighten the bolts (A1) and (A2) securely.
- 5 Check the belt tension again to ensure that it is correct, see Operation 14-1.
- 6 Fit the guard and tighten all the bolts securely.
- 7 Connect the power supply to the starter motor.

To remove the alternator

Operation 14-3

- 1 Disconnect the connections to the rear of the alternator. Mark the connection to help assembly
- 2 Loosen the pivot bolt nut (A1).



- 3 Remove the two setscrews (A4) and remove the link adjuster (A3).
- 4 Support the alternator. Remove the pivot bolt (A2) and remove the drive belt from the alternator pulley.

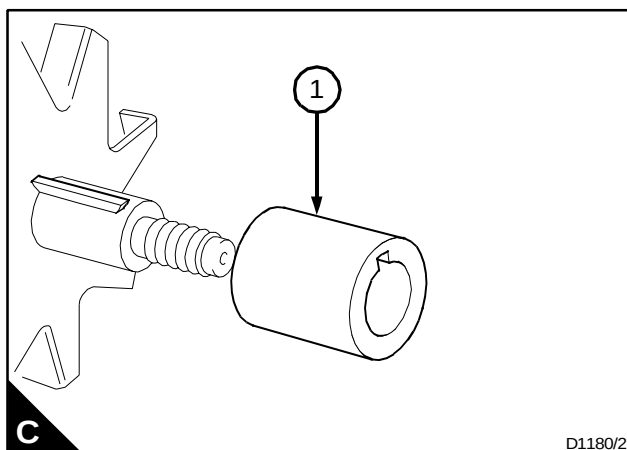
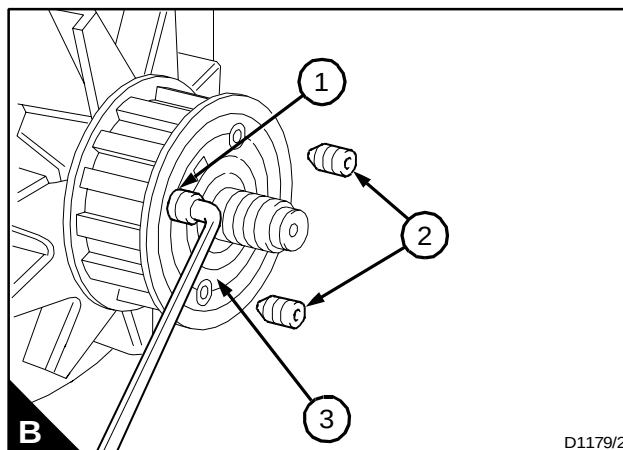
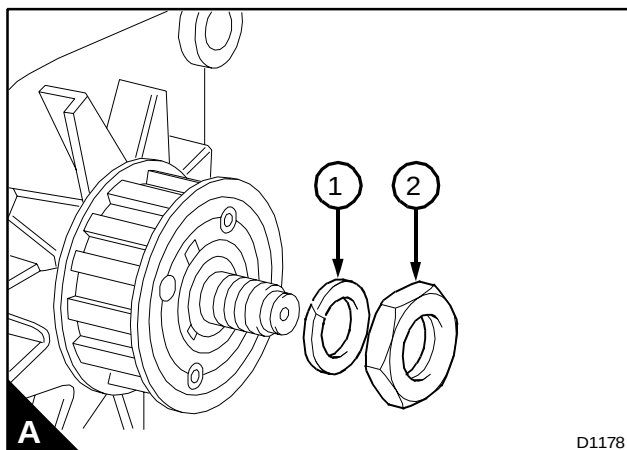
Remove the alternator drive pulley

Operation 14-4

1 Remove the nut (A2) and washer (A1) from the alternator pulley.

2 Remove the two locking screws (B2). Fit one of the lock screws into the hole (B1). Tighten the lock screw until the pulley (B3) is released.

Note: The pulley is fitted on to a inner hub (C1).

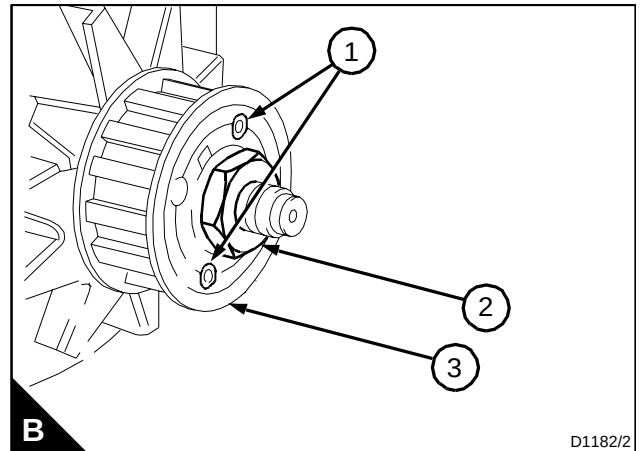
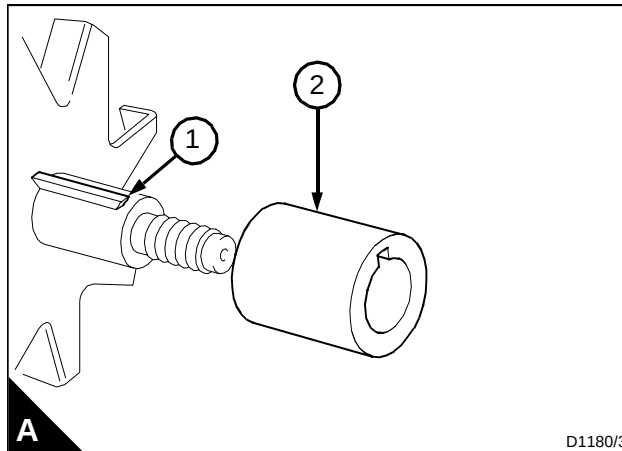


3 Remove the inner hub (C2) from the shaft (C1) of the alternator.

To fit the alternator drive pulley

Operation 14-5

- 1 Align the hub (A2) to the key (A1) in the alternator shaft. Fit the hub.
- 2 Fit the washer and the nut (B2). Tighten the nut to 75 Nm (55 lbf ft) 7,64 kgf m.



- 3 Fit the toothed pulley on to the inner hub (A2).
- 4 Fit the two locking screws (B1) and tighten them evenly to 20 Nm (15 lbf ft) 2 kgf m.
- 5 Use small hammer action on the pulley face and check the locking screw torque again.
- 6 Ensure that the pulley rotates freely.

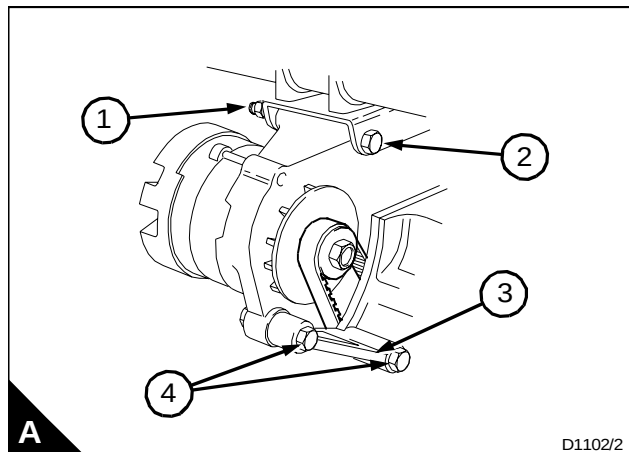
Caution: The locking screw torque must be checked after a few hours of engine operation.

To fit the alternator

Operation 14-6

Caution: Check the alignment of the alternator pulley to the drive pulley.

- 1 Support the alternator and fit the drive belt on to the pulley.
- 2 Align the top pivot hole of the alternator to the support bracket and fit the bolt (A2). Loosely fit the nut (A1).



- 3 Align the adjuster bracket (A3) and fit the two setscrew (A4).
- 4 Connect the connections at the rear of the alternator.
- 5 To adjust the belt, see Operation 14-2.

To maintain

Operation 14-7

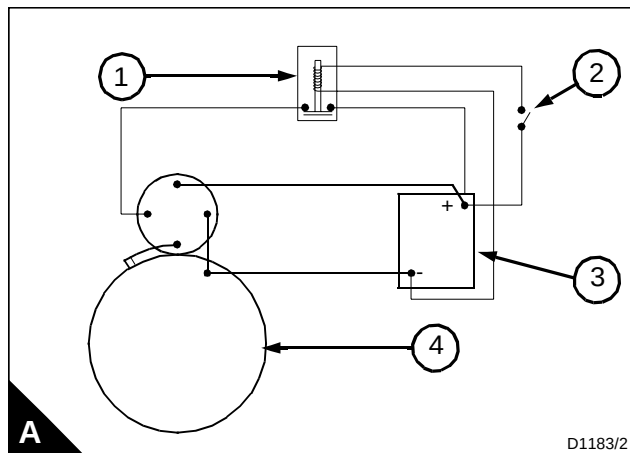
- 1 Ensure that the drive belt is not worn and that the belt tension is correct, see Operation 14-1.
- 2 Keep the alternator clean. To clean the alternator, use a material that is damp with a special fluid used for this purpose. Ensure that the fluid does not enter the cover of the alternator.
- 3 Ensure that air can pass easily over the casing to keep it cool.

Starter motor

General description

The starter motor for the 4006-23 litre engine requires a 24 volt supply.

The starter motor is operated when the starter relay is energised. The starter motor turns and the solenoid is engaged.



- 1 Relay
- 2 Starter switch
- 3 Battery
- 4 Starter motor.

To remove

Operation 14-8

Warning! Always disconnect the battery terminals before the removal of any component of the electrical system.

Caution: Do not loosen the bottom terminal nut on the starter motor connections. Ensure that the nut can not rotate when the top nut is removed in order to remove the cables.

- 1 Disconnect the power supply.
- 2 Disconnect the starter motor cables and mark the connection.
- 3 Remove the fasteners and remove the starter motor.

To Fit

Operation 14-9

- 1 Align the starter motor to the housing. Fit the starter motor and fit the fasteners.
- 2 Tighten the three fasteners to 95 Nm (70 lbf ft) 9,68 kgf m.
- 3 Fit the cables. Ensure that the lower nut on the connection terminal can not rotate. Tighten the connection securely.
- 4 Connect the power supply.

The air starter motor system

General description

Cautions:

- *Do not operate the air starter motor above a pressure of 1034 kpa (150 lb in²).*
- *Do not operate the air starter motor below a pressure of 480 kpa (69,6 lb in²).*

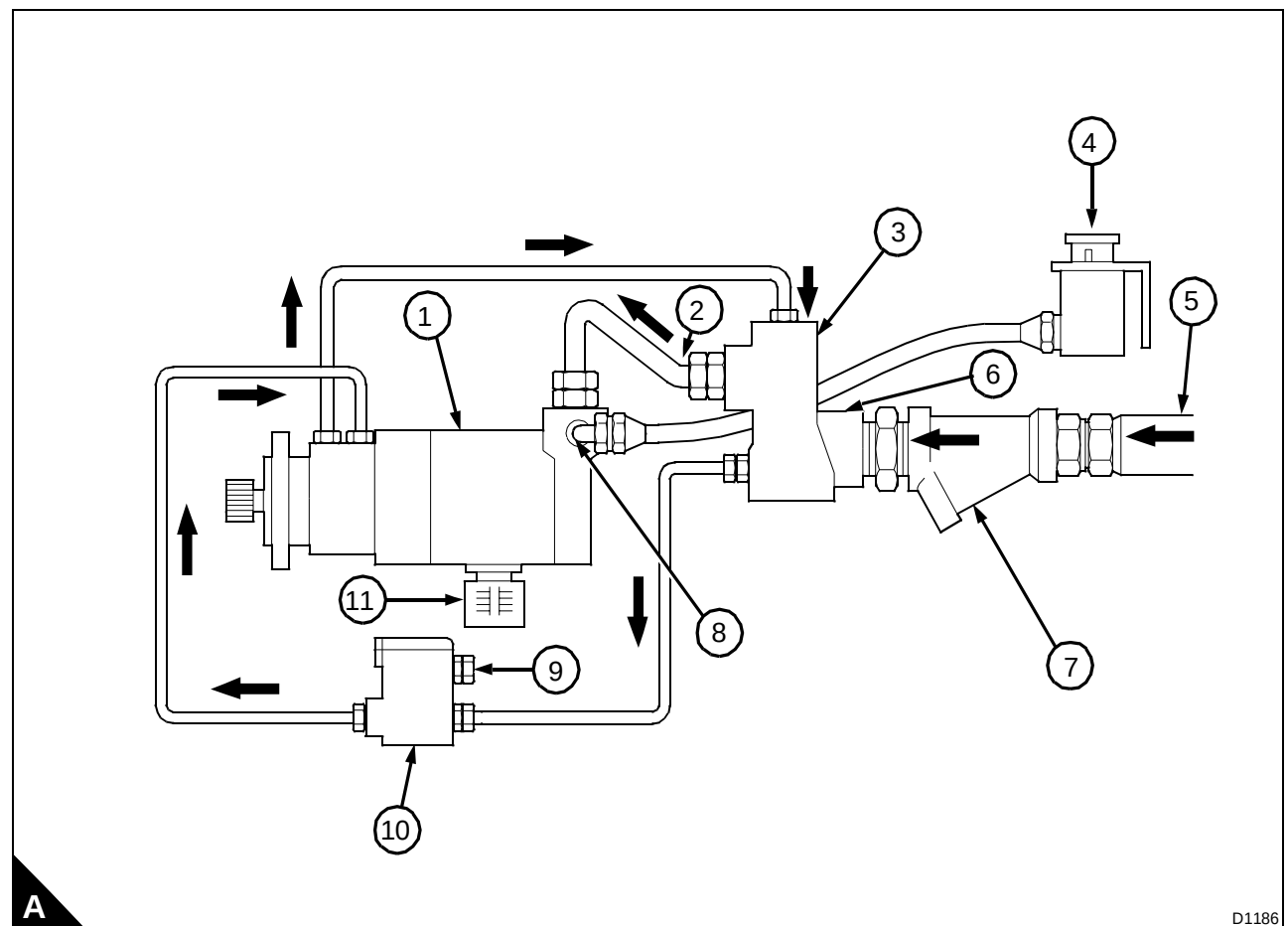
This system requires compressed air at the service line pressure of 1034 kpa (150 lb in²) to operate the starter motor. The main line pressure of 1172 kpa (170 lb in²) is required at the reservoir.

The system can be designed for remote or automatic operation.

The system has a self contained lubrication reservoir. This supplies measured amount of lubrication oil to the air starter motor.

The starter system

A1	The air starter motor
A2	Relay outlet
A3	Relay valve
A4	Oil reservoir
A5	Service line pressure
A6	Relay valve inlet
A7	Strainer
A8	Oil lubricator
A9	Conduit connection
A10	24 Volt three way solenoid valve
A11	Exhaust port

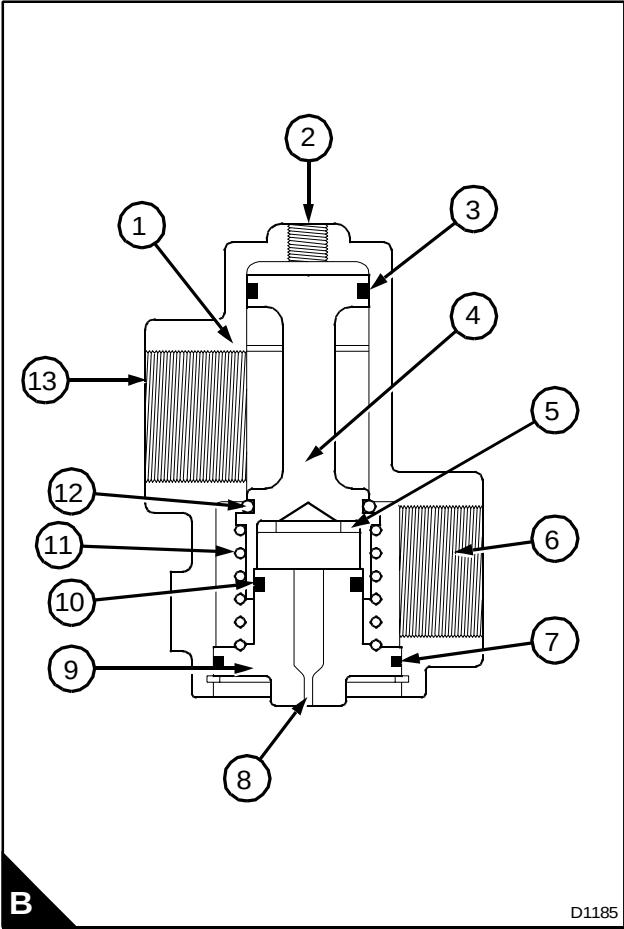


Caution: The lubrication oil supply line pressure must not exceed 34 kpa (5/lb in²).

Notes:

- The lubrication oil for the air starter motor requires a non-detergent SAE 10 oil for above 0 °C (32 °F) and for temperatures below 0 °C (32 °F) use diesel fuel. The reservoir capacity is 0.5 litres (0.19 gal)
- The in-line strainer (A7) may be serviced. The service interval will depend on the frequency of use of the air start system and the quality of the compressed air.
- Item (A10) is a three way air control valve that is operated by a 24 volt system

Relay valve



B1	Valve housing
B2	Relay valve inlet
B3	Piston seal
B4	Piston
B5	Piston stop
B6	Inlet
B7	Large end cap seal
B8	Vent
B9	End cap
B10	Small end cap seal
B11	Piston return spring
B12	Piston seat
B13	Outlet

To remove

Operation 14-10

- 1 Disconnect the compressed air supply.
 - 2 Disconnect the air starter motor hose and mark the connection.
 - 3 Remove the fasteners and remove the starter motor.
-

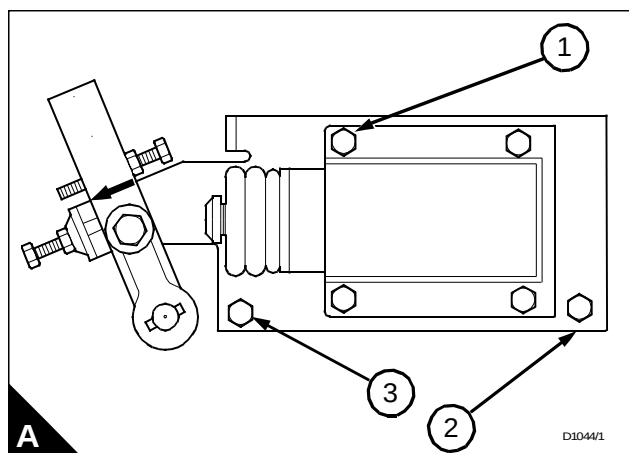
To fit

Operation 14-11

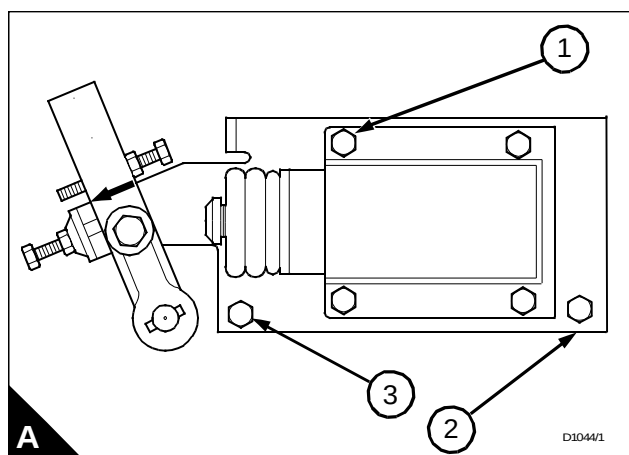
- 1 Align the starter motor to the housing. Fit the starter motor and fit the fasteners.
- 2 Tighten the three fasteners to 95 Nm (70 lbf ft) 9,68 kgf m.
- 3 Fit all the connections to the starter motor. Tighten the connections securely.
- 4 Connect the compressed air supply and check for leaks.

Stop solenoid**To remove****Operation 14-12**

- 1 Disconnect the electrical connection to the stop solenoid.
- 2 Remove the 4 bolts (A1) and remove the stop solenoid from the mounting plate (A2)
- 3 If necessary remove the setscrews (A3) and remove the mounting plate.

**To fit****Operation 14-13**

- 1 If removed align the mounting plate and fit the setscrews (A3). Tighten the setscrews (A3) to 50 Nm (36.8 lbf ft) 5 kgf m.
- 2 Align the stop solenoid to the mounting plate and fit the bolts (A1). Ensure that the stop solenoid is aligned correctly and tighten the bolts to 25 Nm (18.4 lbf ft) 2,5 kgf m.
- 3 Connect the electrical connections.



Digital Electronic Governor

Introduction

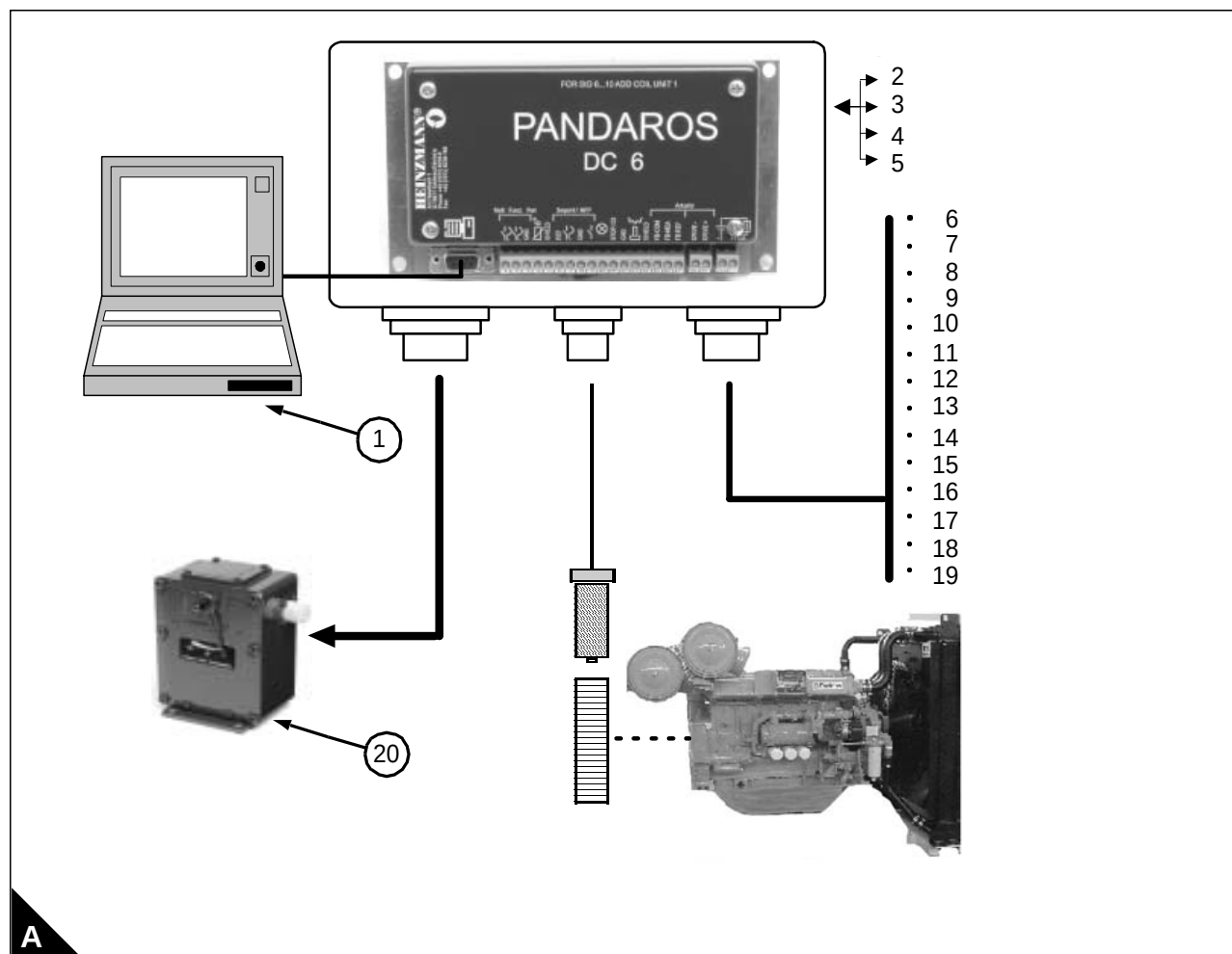
The 4006-23 engine is fitted with a Heinzmann Pandaros digital speed governor for improved performance and functionality. This document gives an overview of the governor system and details of customer interface requirements.

The control system consists of the control unit, the actuator, the setpoint adjusters, the sensors, and the connection cables. The actuator is connected to the engine fuel injector linkage to control the amount of fuel injected.

The control unit is engine mounted within an IP55 enclosure.

Outline of System

Caution: Adjustments to this control unit may only be made by authorised Perkins representative, equipped with the necessary programmer. There are no user adjustments inside the box.



Continued

- (A1) Laptop computer
- (A20) Actuator

Governor status	
(A2)	Run status
(A3)	CAN Communication
(A4)	DC- Desk displays
(A5)	Governor errors

Accessories	
(A6)	Stop/Run
(A7)	Synchronising
(A8)	Load sharing
(A9)	Voltage matching
(A10)	Reactive load share
(A11)	Speed ramp
(A12)	Load ramp
(A13)	Soft load transfer
(A14)	Isochronous ramp
(A15)	Power factor set
(A16)	Mains parallel
(A17)	Island parallel
(A18)	Group synchronising
(A19)	Digital power control

Description of System

The electronic control unit is the heart of the system. At the core of the control unit is a powerful 16 bit microprocessor. The actual controller programme on which the processor operates is permanently stored in a FLASH-EPROM. The control unit compares the actual engine speed as measured by a magnetic pick-up on the flywheel with the desired speed and drives the actuator and hence the fuel input to the engine so that the actual engine speed matches the desired engine speed.

Engine boost pressure is measured and used to control fuelling for optimum performance and minimum smoke.

Additional inputs are available for engine temperature measurement, to give fuelling control against engine temperature and for connection of additional automatic load sharing and synchronising equipment.

A PC programme with special interface cable is used for initial setting of the governor parameters and system optimization and fault finding.

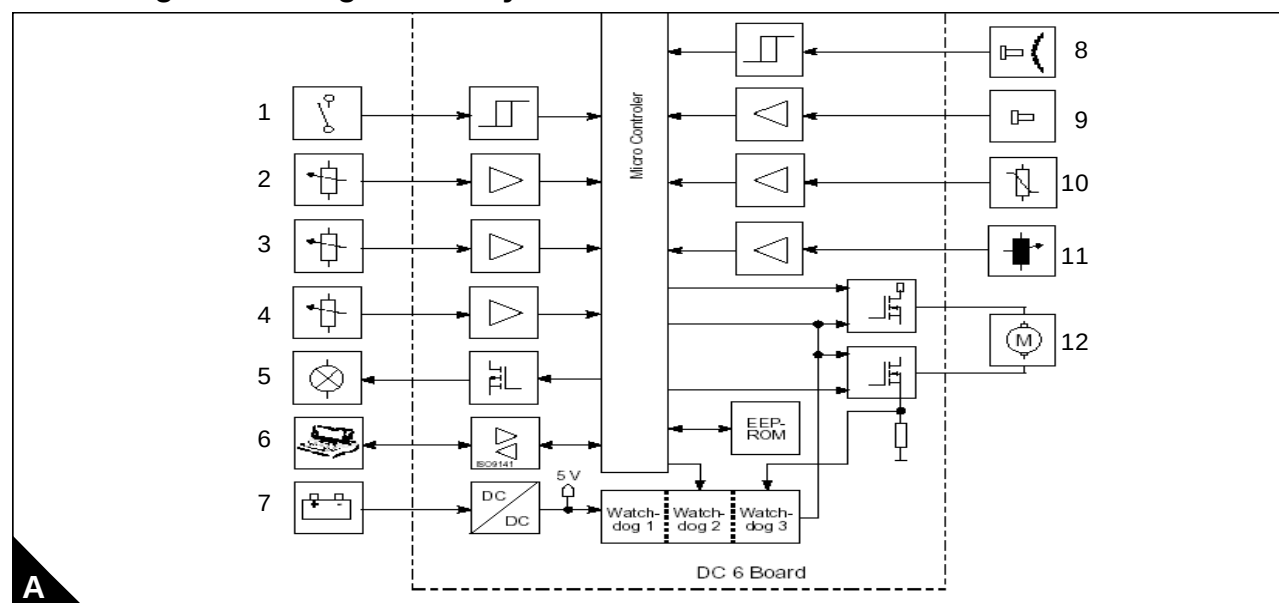
A CAN bus is available for connection to digital load sharing and synchronising equipment and future monitoring of the system.

If a sensor or the actuator is at fault, an alarm is issued and there will be an engine shutdown. Internal errors get detected also and they will be stored as all other failures. All failures can be read out with an external PC or laptop computer.

To epitomize the dynamics for every operating point, the PID parameters are corrected in dependence of speed, temperature and load by means of stability maps. Proportional, Integral and Derivative gain values can be modified from the service tool.

Note: An external overspeed protection device must always be used in addition to the internal overspeed.

Block diagram of the governor system



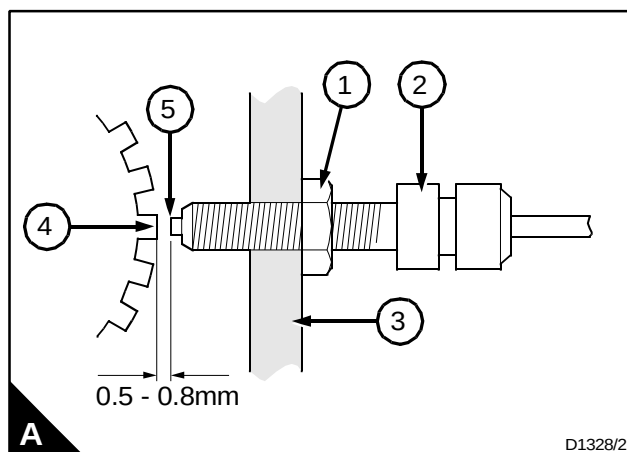
Governor system	
(A1)	Switch inputs
(A2)	Analogue setpoint adjuster
(A3)	Analogue synchronizer
(A4)	Analogue load measuring unit
(A5)	Failure lamp
(A6)	Interface RS 232
(A7)	24 V Power supply
(A8)	Speed sensor
(A9)	Pressure sensor
(A10)	Temperature sensor
(A11)	Actuator position sensing
(A12)	Actuator drive

Magnetic pick-up

To clean the magnetic pick-up

Operation 14-14

- 1 Loosen the locknuts (A1) and remove the magnetic pick-up (A2) from the flywheel housing (A3).
- 2 Clean the magnetic tip (A5).



- 3 Fit the magnetic pick-up (A2) into the flywheel housing. Turn the magnetic pick-up by hand until contact is made with the gear tooth (A4). Rotate the magnetic pick-up half a turn away from the gear tooth. The clearance between the tooth gear and the magnetic pick-up must be 0.5 to 0.8 mm (.0196 to .0314 in).
- 4 Tighten the lock nut (A1). Do not allow the magnetic pick-up to rotate.

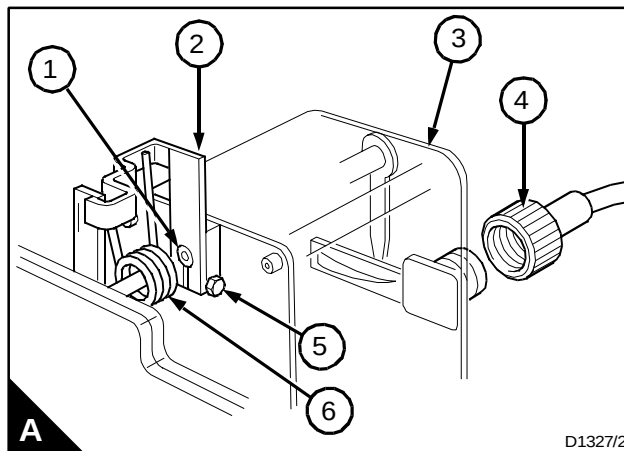
To remove the actuator

Operation 14-15

Warnings!

- *Disconnect the batteries and any other power that can start the engine.*
- *Check that the actuator will position the fuel injectors in the no fuel position. At the actuator position 10, the fuel injector controls arm must be in the no fuel position.*
- *When the actuator is removed care must be taken because the spring (A6) is under tension and will be released.*

- 1 Disconnect the batteries.
- 2 Remove the connection (A4).
- 3 Remove the 4 setscrews that secure the actuator (A3). Remove the actuator and disconnect the spring (A6).
- 4 If a new actuator is to be fitted, loosen the setscrew (A5) and remove the lever (A2) from the shaft (A1).

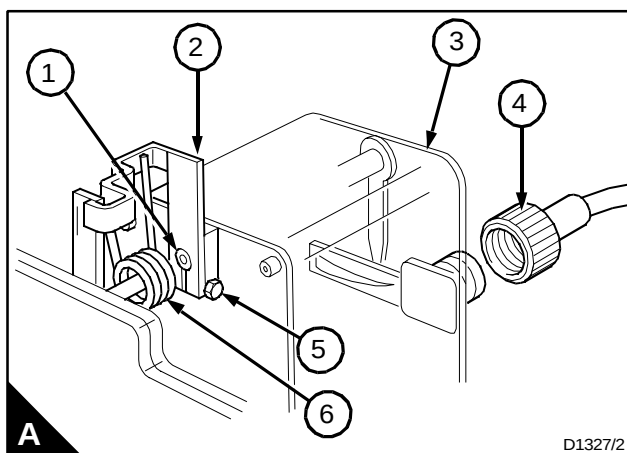


To fit

Operation 14-16

Warning! Check that the actuator will position the fuel injectors in the no fuel position. At the actuator position 10, the fuel injector control arm must be in the no fuel position.

- 1 Align the actuator shaft (A1) to lever (A2). Check that shaft is in the correct position to fit the lever and tighten the setscrew (A5) securely.
- 2 Install the spring (A6) and fit the actuator (A3) and tighten the 4 setscrews securely.
- 3 Ensure that the fuel injector control arm is in the no fuel position.
- 4 Fit the connection (A4).
- 5 Connect the batteries.
- 6 Check the feedback voltage, see "Feedback Setting" on page 212.



Specification of Governor system

Supply voltage 24 V DC

Min. voltage 9 V DC

Max. voltage 33 V DC

Max. ripple voltage max. 10% @ 100 Hz

Current consumption max. 11 A for max. 60 Seconds

Permissible voltage dip at maximum current consumption max. 10% at control unit

Fuse protection of governor 15 A

Current consumption of whole governor:

- In steady state condition approx. 1 A
- On change of load approx. 3 - 4 A
- Max. current approx. 4.5 A
- In current limitation approx. 2.5 A

EMC Directives: 89/33/EEG, 95/54/EEG

ISO 11452-2: Frequency band F2, 60 V/m

Functional status B

ISO 7637-2: Frequency band F2, 60 V/m

Functional status B

ISO 7637-3: Frequency band F2, 60 V/m

Functional status B

VDE 0879-3: Severity Level 4

CE: EN 50081-2, EN 50082-2

All inputs and outputs are protected against reverse-voltage and short circuit to battery plus and minus.

Analogue inputs may be set to 0-5volts, 4-20mA or +/- 3volts in software

Digital input engine stop $U_0 < 2 \text{ V}$, $U_1 > 6.0 \text{ V}$,

Digital output failure lamp $I_{\text{sink}} < 0.3 \text{ A}$

To remove the digital control box

Operation 14-17

- 1 Remove the 3 cables connected to the digital control box.
- 2 Remove the 4 nuts and remove the digital control box complete with the 4 rubber mountings.

To Fit the digital control box

Operation 14-18

- 1 Ensure that the 4 rubber mountings are not damaged. Renew if necessary.
- 2 Align the 4 rubber mountings the back plate and fit.
- 3 Fit the 4 nuts and tighten securely.
- 4 Connect the 3 cables to the digital control box.

Feedback Setting

To adjust

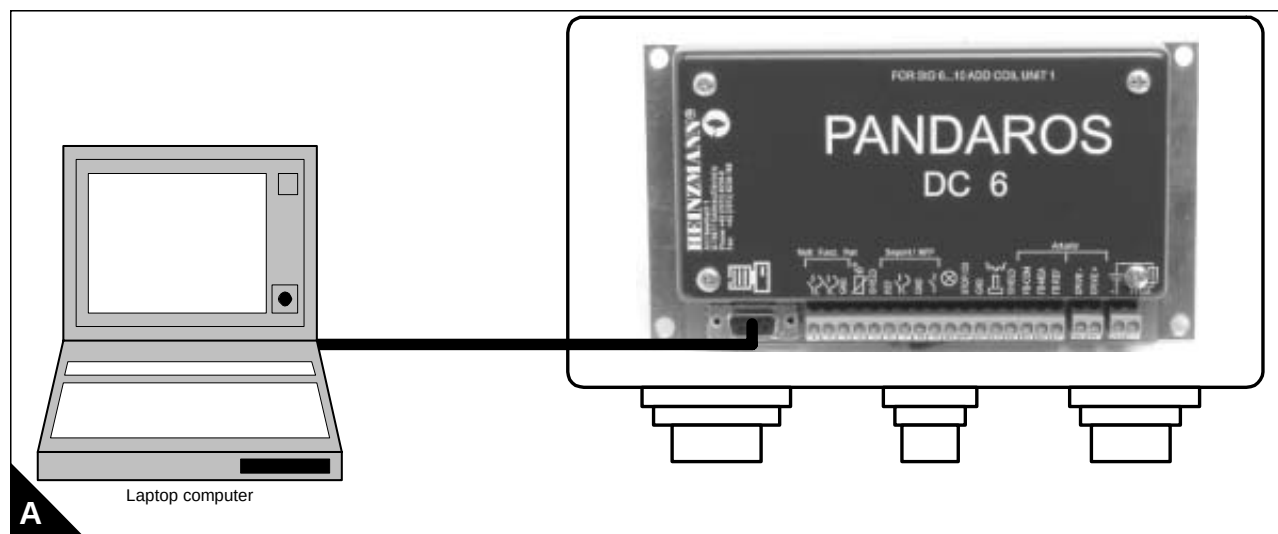
Operation 14-19

For the governor to operate correctly, it is necessary for the control box to establish the feedback parameters which correspond to 0% and 100% actuator position. Whenever an actuator has been replaced, it is necessary to carry out a feedback calibration procedure.

The Pandaros Packager service tool software can automatically carry out a calibration procedure to establish these parameters.

Note: To properly execute automatic calibration the actuator must operate smoothly and be able to easily move from 0 to 100% (left and right stop). It is therefore necessary for the actuator to be disconnected from the engine linkage.

- 1 Connect PC to governor box (A).



- 2 Power up governor.

With the control box to actuator cable connected, apply 24 volts DC to the plus and minus cables from the governor box.

- 3 Start the Pandaros Packager service tool.

For information on the use of the Pandaros Packager, refer to the Service Tool Manual.

- 4 Select 'Start communication'. The service tool will then load the data from the governor.

Continued

5 From the 'Adjustment – Actuator/Power Supply' screen, click on the 'Automatic adjust' Start button.

The screenshot shows a software interface with three tabs: 'Configuration', 'Adjustment', and 'Display'. The 'Adjustment' tab is active. Inside, there's a section titled 'Actuator + Power Supply'. Under 'Actuator', there are two rows: 'ServoCurrentSetpoint' with a value of '0.0' and unit 'A', and 'Feedback' with a value of '65472' and unit 'Digits'. Below these is an 'AutomaticAdjust' section with a 'Start' button. Under 'Power Supply', there are two rows: 'PowerSupply' with a value of '25.37' and unit 'V', and '5V_Ref' with a value of '5.01' and unit 'V'. At the bottom of the screen, there are three buttons: 'Speed Governor', 'Engine/Generator', and 'Actuator/Power Supply' (which is highlighted with a dashed border).

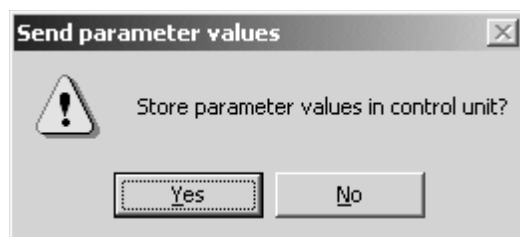
6 The system will go through its automatic calibration procedure and when complete, the box shown below appears giving details of the values established.

7 Click the OK button to accept the settings.

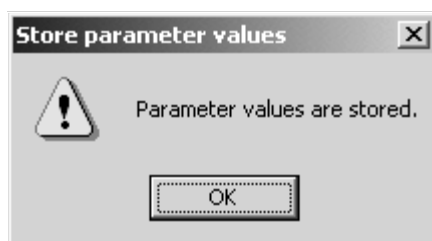
The screenshot shows a dialog box titled 'Results Actuator adjust'. It contains two sections. The first section, 'Reference Values', has two rows: 'Low Reference Value' with a value of '10051' and 'High Reference Value' with a value of '60741'. The second section, 'Error Limits', has two rows: 'Low Error Limit' with a value of '2000' and 'High Error Limit' with a value of '64000'. At the bottom right of the dialog, there are two buttons: 'Reload' and 'OK' (which is highlighted with a dashed border).

Continued

8 You will then be asked if the parameter values should be stored in the control unit. Click Yes.



9 A message box appears saying that the parameters have been stored.



10 Click on OK, turn off the 24 volt power supply and disconnect the PC cable.

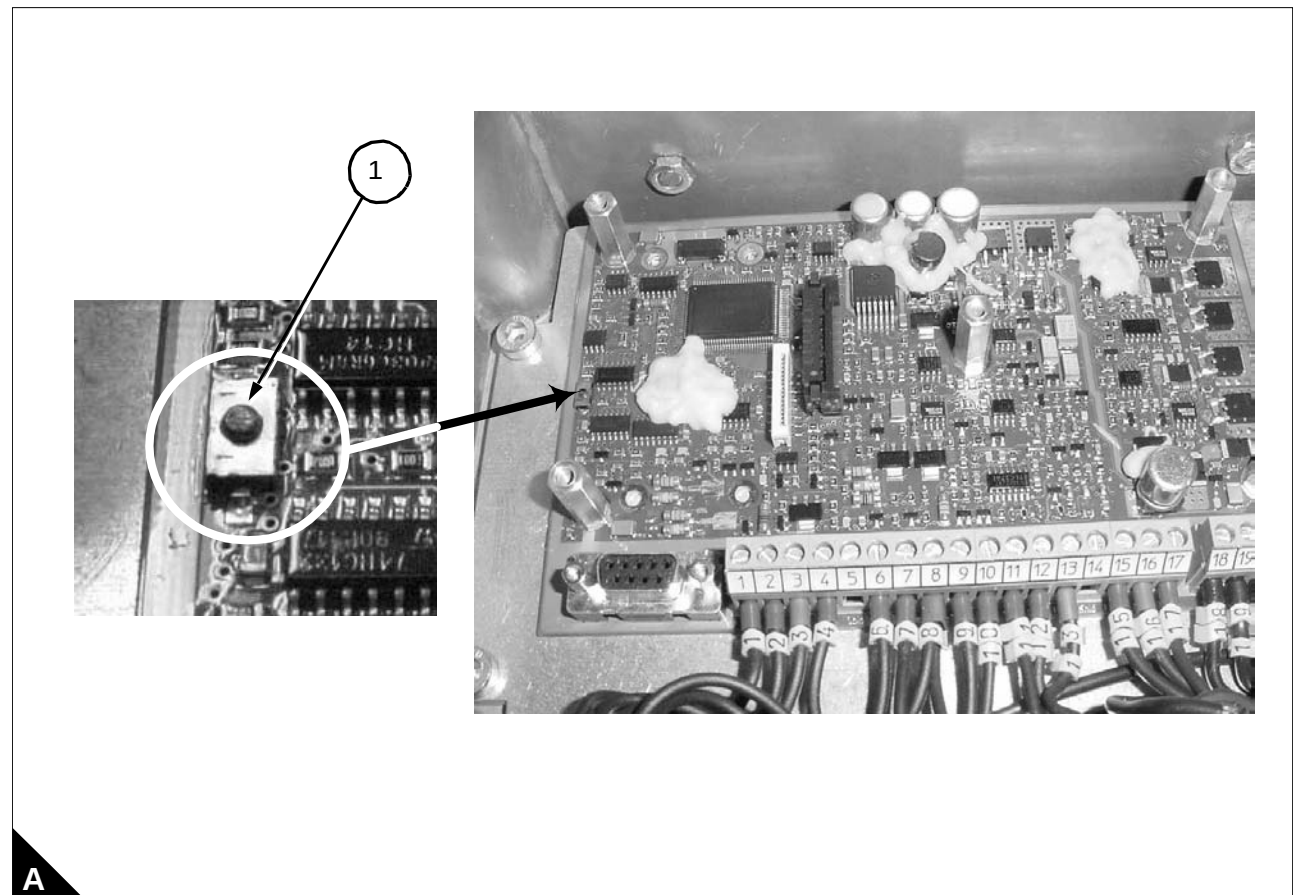
11 The actuator can now be fitted to the engine and the linkage connected.

Feedback setting without service tool

If an actuator has to be replaced and the Service Tool is not available, feedback setting can be accomplished as follows:

- 1 Remove the lid of the IP55 governor box and the lid of the Pandaros box inside.
- 2 Connect the cable from the control box to the actuator and apply 24 volts to the governor.
- 3 Locate the feedback setting push button as shown below (A1).

Note: Later control boxes have a different printed circuit board layout.



- 4 Ensure that the actuator output shaft is disconnected from the engine linkage and is free to move from 0% to 100%.
- 5 Press the button and the system will automatically calibrate the feedback.
- 6 Remove the 24 V supply, replace the covers and fit the actuator to the engine.

Configuration

As dispatched from the factory, the engine will be configured in accordance with the Customers requirements determined from the Sales Order Process. The factory configurations are:

Speed

1500 Rev/Min, 1800 Rev/Min or switchable 1500/1800 Rev/Min.

Droop/Isochronous

The default configuration will be isochronous operation. If the engine has been requested to run in droop, the desired percentage droop will also have been set.

External Speed Control Input

Single generator fixed speed

The default configuration is for an engine to operate in single generator mode i.e. not paralleled with any other generator. This mode has no provision for external speed control, speed will be fixed at 1500 or 1800.

Single generator variable speed

This mode allows the synchronizer input to be used with an external 5K potentiometer for manual speed setting control.

Caution: In this configuration, an external speed setting control *MUST* be connected to enable the engine to run.

Parallel generator, Heinzmann LSU/Sync

This provides for connection to standard Heinzmann analogue load sharing and synchronizing units and the connections for this are designated:

- A3 Common connection
- B3 Synchronizer input
- E3 Load sharer input

Caution: In this configuration, the necessary load sharing/synchronizing inputs *MUST* be connected to allow the engine to run.

Parallel generator other load sharing and synchronising units

This configuration will be determined from discussion with the genset builder and is available to special order only if agreed by Perkins. The inputs may be +/- 3 volt, for speed/load control or 4-20mA for speed/load control.

Note: Any other configuration changes require the use of the Service Tool and special communications cable. Refer to, "Changing the governor configuration" on page 217 and Service Tool manual for information on other configurable parameters.

Changing the governor configuration

To adjust

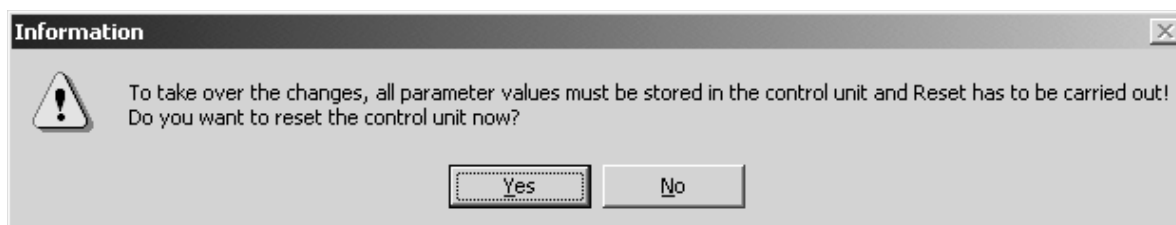
Operation 14-20

In order to change the engine governor configuration, it is necessary to use the Pandaros packager Service Tool and special communications cable. The communications connector is accessible inside the governor box. A security 'Dongle' is also supplied which must be plugged into the PC parallel port before the software will work.

The various parameter settings for the above engine modes are detailed .

Notes:

- Some settings detailed below are only available with the Pandaros Packager version 2.03 together with Pandaros system software version 14.1.01 which is included as standard from Pandaros controller serial number 04 07 1372-6 onwards. If an update to an earlier control unit is required, please contact Perkins Application Department.
- After changing some parameters, it is necessary to 'Store parameters in governor' and then power the governor down and power up again or with later Pandaros Packager version, click Yes in the window as shown below, to reset the control unit, before the changes take effect.



The service tool configuration screen is shown below.

Configuration			Adjustment			Display																		
Engine Configuration																								
SpeedMin1	1450	1/min	SpeedMin2	1750	1/min	Generator Mode ☒ Single generator fixed speed ☐ Parallel generator variable speed with droop ☐ Parallel generator																		
SpeedMax1	1550	1/min	SpeedMax2	1850	1/min																			
SpeedFix1	1500	1/min	SpeedFix2	1800	1/min																			
Droop1	8.0	%	Droop2	2.0	%																			
Droop1RelLow	47.0	%	Droop2RelLow	10.0	%																			
Droop1RelHigh	81.0	%	Droop2RelHigh	90.0	%																			
Droop1SpeedRef	1500	1/min	Droop2SpeedRef	1800	1/min																			
Overspeed	1650	1/min																						
☒ LockedSwitchOn ☒ SpeedFix1Locked ☐ SpeedFix2Locked			Common Alarm ☐ WarnFlashOn ☐ ResetOn						Engine Stop ☒ Switch ☐ Close ☐ Impulse ☒ Open															
☐ SpeedRampOn <table border="1"> <tr> <td>SpeedRampUp</td> <td>SpeedRamp1</td> <td>SpeedRamp2</td> <td>SpeedRamp3</td> </tr> <tr> <td></td> <td>100.0</td> <td>100.0</td> <td>100.0</td> </tr> <tr> <td>SpeedRampDown</td> <td>100.0</td> <td>100.0</td> <td>100.0</td> </tr> <tr> <td>SpeedSwitchToRamp</td> <td></td> <td>4000</td> <td>4000</td> </tr> </table>			SpeedRampUp	SpeedRamp1	SpeedRamp2				SpeedRamp3		100.0	100.0	100.0	SpeedRampDown	100.0	100.0	100.0	SpeedSwitchToRamp		4000	4000	☐ Sectional Ramp ☒ Fixed Ramp		
SpeedRampUp	SpeedRamp1	SpeedRamp2	SpeedRamp3																					
	100.0	100.0	100.0																					
SpeedRampDown	100.0	100.0	100.0																					
SpeedSwitchToRamp		4000	4000																					
Engine																								

Single generator fixed speed

If the **Generator Mode** option button 'Single generator fixed speed' is selected, the engine will run in isochronous mode at a fixed speed of 1500 or 1800 rev/min or be switchable between these speeds.

For single speed 1500 rev/min operation, parameter **SpeedFix1** is used to set the engine speed.

For single speed 1800 rev/min operation, parameter number **SpeedFix2** is used to set the engine speed.

For switchable 1500/1800 rev/min operation, parameter **SpeedFix1** is used to set 1500 rev/min and parameter **SpeedFix2** is used to set 1800 rev/min.

Caution: *There may be hardware changes between 1500 rev/min and 1800 rev/min engines so these parameters must not be changed without reference to the factory. Any unauthorised changes will result in the engine warranty being void.*

If the box **LockedSwitchOn** is ticked, the engine will be single speed, the speed being selected by the SpeedFix1Locked or SpeedFix2Locked option buttons.

If the box **LockedSwitchOn** is not ticked the engine is switchable speed from an external switch. When the engine speed of 1500 or 1800 is selected, various parameters such as overspeed settings are automatically adjusted to suit the selected engine running speed. The current overspeed setting is displayed on the screen but cannot be changed.

Single/Parallel Generator (Non Heinzmann Load Sharing)

To adjust

Operation 14-21

This function allows the engine to run at either 1500 or 1800 rpm **isochronously**, at whatever the SpeedFix1 or SpeedFix2 is set at.

Configuration			Adjustment			Display		
Engine Configuration								
SpeedMin1	1400	1/min	SpeedMin2	1750	1/min	Generator Mode ☐ Single generator fixed speed ☒ <u>Single/Parallel generator (Other)</u> ☐ Single/Parallel generator (Other) with droop ☐ Parallel generator (Heinzmann LMG/SyG) ☐ Parallel generator (Heinzmann Theseus) ☐ Parallel generator variable speed in droop range		
SpeedMax1	1600	1/min	SpeedMax2	1850	1/min			
SpeedFix1	1500	1/min	SpeedFix2	1800	1/min			
Droop1	4.0	%	Droop2	4.0	%			
Droop1RefLow	10.0	%	Droop2RefLow	10.0	%			
Droop1RefHigh	90.0	%	Droop2RefHigh	90.0	%			
Droop1SpeedRef	1500	1/min	Droop2SpeedRef	1800	1/min			
Overspeed	1650	1/min						
☒ LockedSwitchOn ☒ SpeedFix1Locked ☐ SpeedFix2Locked			☐ CommonAlarm ☐ WarnFlashOn ☐ ResetOn		Engine Stop ☐ Switch ☒ Close ☒ Impulse ☐ Open			
☐ SpeedRampOn SpeedRamp1 SpeedRamp2 SpeedRamp3 SpeedRampUp SpeedRampDown SpeedSwitchToRamp 100.0 100.0 4000 100.0 100.0 4000 100.0 100.0 4000					☐ Sectional Ramp ☒ Fixed Ramp			
Engine			Load Control			Synchronizer		

The speed of the engine will be adjusted by the Load Control input:

- 0-5 volts or
- 0-10 volts or
- 4-20mA.

The load control input will adjust the SpeedFix1 / 2 by +/- Load Control factor % i.e., SpeedFix1500 rpm will change by +/- 50 rpm for a LoadControl Factor of 10% with a LoadControlReference of 50% and an input LoadControl voltage 0 – 5 volts.

For details of setting the LoadControlFactor and LoadControlReference see section 'Other Settings'.

The governing will be isochronous only.

Single/Parallel Generator with Droop

To adjust

Operation 14-22

This function will allow the engine to run at either 1500 or 1800 rpm or whatever the SpeedFix1 or SpeedFix2 is set at.

Configuration			Adjustment			Display																	
Engine Configuration																							
SpeedMin1	1400	1/min	SpeedMin2	1750	1/min	Generator Mode ☐ Single generator fixed speed ☐ Single/Parallel generator (Other) ☒ Single/Parallel generator (Other) with droop ☐ Parallel generator (Heinzmann LMG/SyG) ☐ Parallel generator (Heinzmann Theseus) ☐ Parallel generator variable speed in droop range																	
SpeedMax1	1600	1/min	SpeedMax2	1850	1/min																		
SpeedFix1	1500	1/min	SpeedFix2	1800	1/min																		
Droop1	4.0	%	Droop2	4.0	%																		
Droop1RefLow	10.0	%	Droop2RefLow	10.0	%																		
Droop1RefHigh	90.0	%	Droop2RefHigh	90.0	%																		
Droop1SpeedRef	1500	1/min	Droop2SpeedRef	1800	1/min																		
Overspeed	1650	1/min																					
☒ LockedSwitchOn ☒ SpeedFix1Locked ☐ SpeedFix2Locked			CommonAlarm ☐ WarnFlashOn ☐ ResetOn			Engine Stop ☐ Switch ☒ Close ☒ Impulse ☐ Open																	
☐ SpeedRampOn <table border="1"> <tr> <td>SpeedRampUp</td> <td>100.0</td> <td>SpeedRamp2</td> <td>100.0</td> <td>SpeedRamp3</td> <td>100.0</td> </tr> <tr> <td>SpeedRampDown</td> <td>100.0</td> <td>SpeedRamp2</td> <td>100.0</td> <td>SpeedRamp3</td> <td>100.0</td> </tr> <tr> <td>SpeedSwitchToRamp</td> <td></td> <td>4000</td> <td></td> <td>4000</td> <td></td> </tr> </table>			SpeedRampUp	100.0	SpeedRamp2	100.0	SpeedRamp3	100.0	SpeedRampDown	100.0	SpeedRamp2	100.0	SpeedRamp3	100.0	SpeedSwitchToRamp		4000		4000		☐ Sectional Ramp ☒ Fixed Ramp		
SpeedRampUp	100.0	SpeedRamp2	100.0	SpeedRamp3	100.0																		
SpeedRampDown	100.0	SpeedRamp2	100.0	SpeedRamp3	100.0																		
SpeedSwitchToRamp		4000		4000																			
Engine			Load Control			Synchronizer																	

The governing will be in Droop set by the droop 1 or 2.

The speed of the engine at no load is set by SpeedFix 1 / 2 for any droop value Set.

No external speed control is available.

Parallel Generator Heinzmann (SyG02/LMG10-01)

To adjust

Operation 14-23

This function allows the engine to run at either 1500 or 1800 rpm or whatever the SpeedFix1 or SpeedFix2 is set at.

Configuration			Adjustment			Display		
Engine Configuration								
SpeedMin1	1400	1/min	SpeedMin2	1750	1/min	Generator Mode ☐ Single generator fixed speed ☐ Single/Parallel generator (Other) ☐ Single/Parallel generator (Other) with droop ☒ Parallel generator (Heinzmann LMG/SyG) ☐ Parallel generator (Heinzmann Theseus) ☐ Parallel generator variable speed in droop range		
SpeedMax1	1600	1/min	SpeedMax2	1850	1/min			
SpeedFix1	1500	1/min	SpeedFix2	1800	1/min			
Droop1	4.0	%	Droop2	4.0	%			
Droop1RefLow	10.0	%	Droop2RefLow	10.0	%			
Droop1RefHigh	90.0	%	Droop2RefHigh	90.0	%			
Droop1SpeedRef	1500	1/min	Droop2SpeedRef	1800	1/min			
Overspeed	1650	1/min						
☒ LockedSwitchOn ☒ SpeedFix1Locked ☐ SpeedFix2Locked			CommonAlarm ☐ WarnFlashOn ☐ ResetOn			Engine Stop ☐ Switch ☒ Close ☒ Impulse ☐ Open		
☐ SpeedRampOn SpeedRampUp: 100.0 SpeedRamp2: 100.0 SpeedRamp3: 100.0 SpeedRampDown: 100.0 SpeedRamp2: 100.0 SpeedRamp3: 100.0 SpeedSwitchToRamp: 4000 4000						☐ Sectional Ramp ☒ Fixed Ramp		
Engine			Load Control			Synchronizer		

The speed of the engine will be adjusted by Heinzmann analogue LMG10-01 and SyG02 inputs.

The inputs will adjust the SpeedFix1/2 by +/- Load Control or Synchroniser factor % i.e., SpeedFix1500 rpm will change by the value of the LoadControl or Synchronising Factor with a LoadControl or synchroniser Reference % value to suit LMG10-01 and SyG02.

The LoadControlFactor and LoadControlReference settings are made automatically and no further settings are required.

The governing will be isochronous only.

Parallel Generator Heinzmann Digital Theseus

To adjust

Operation 14-24

This configuration will allow the Heinzmann Digital Theseus to run with the Pandaros governor at any fixed synchronous speed.

Configuration			Adjustment			Display					
Engine Configuration											
SpeedMin1	1400	1/min	SpeedMin2	1750	1/min	Generator Mode ☐ Single generator fixed speed ☐ Single/Parallel generator (Other) ☐ Single/Parallel generator (Other) with droop ☐ Parallel generator (Heinzmann LMG/SyG) ☒ Parallel generator (Heinzmann Theseus) ☐ Parallel generator variable speed in droop range					
SpeedMax1	1600	1/min	SpeedMax2	1850	1/min						
SpeedFix1	1500	1/min	SpeedFix2	1800	1/min						
Droop1	4.0	%	Droop2	4.0	%						
Droop1RefLow	10.0	%	Droop2RefLow	10.0	%						
Droop1RefHigh	90.0	%	Droop2RefHigh	90.0	%						
Droop1SpeedRef	1500	1/min	Droop2SpeedRef	1800	1/min						
Overspeed	1650	1/min									
☒ LockedSwitchOn ☒ SpeedFix1Locked ☐ SpeedFix2Locked			CommonAlarm ☐ WarnFlashOn ☐ ResetOn						Engine Stop ☐ Switch ☒ Close ☒ Impulse ☐ Open		
☐ SpeedRampOn SpeedRampUp: SpeedRamp1 100.0, SpeedRamp2 100.0, SpeedRamp3 100.0 SpeedRampDown: 100.0, 100.0, 100.0 SpeedSwitchToRamp: 4000, 4000			☐ Sectional Ramp ☒ Fixed Ramp						Theseus Start Delay: 0.0 s Node Number: 1 CAN ☒ Baudrate ☐ Segment CAN-Baudrate ☒ 125 kBaud ☐ 250 kBaud ☐ 500 kBaud ☐ 1 MBaud		
Engine											

For setting information please refer to Theseus manual.

Parallel Generator Variable Speed in Droop Range

To adjust

Operation 14-25

This function allows the engine to run at either 1500 or 1800 rpm in droop at whatever the SpeedFix1 or SpeedFix2 is set at.

Configuration			Adjustment			Display		
Engine Configuration								
SpeedMin1	1400	1/min	SpeedMin2	1750	1/min	Generator Mode ☐ Single generator fixed speed ☐ Single/Parallel generator (Other) ☐ Single/Parallel generator (Other) with droop ☐ Parallel generator (Heinzmann LMG/SyG) ☐ Parallel generator (Heinzmann Theseus) ☒ Parallel generator variable speed in droop range		
SpeedMax1	1600	1/min	SpeedMax2	1850	1/min			
SpeedFix1	1500	1/min	SpeedFix2	1800	1/min			
Droop1	4.0	%	Droop2	4.0	%			
Droop1RefLow	10.0	%	Droop2RefLow	10.0	%			
Droop1RefHigh	90.0	%	Droop2RefHigh	90.0	%			
Droop1SpeedRef	1500	1/min	Droop2SpeedRef	1800	1/min			
Overspeed	1650	1/min						
☒ LockedSwitchOn ☒ SpeedFix1Locked ☐ SpeedFix2Locked			CommonAlarm ☐ WarnFlashOn ☐ ResetOn			Engine Stop ☐ Switch ☒ Impulse ☐ Close ☐ Open		
☐ SpeedRampOn SpeedRamp1 SpeedRamp2 SpeedRamp3 SpeedRampUp SpeedRampDown SpeedSwitchToRamp 100.0 100.0 4000 100.0 100.0 4000 100.0 100.0 4000			☐ Sectional Ramp ☒ Fixed Ramp					
Engine			Load Control					

The speed of the engine can be adjusted by the Load Control input:

- 0 – 5 volts or
- 0 – 10 volts or
- 4 – 20mA.

The load control input will adjust the SpeedFix1/2 by +/- Load Control factor % i.e., SpeedFix1500 rpm will change by +/- 50 rpm for a LoadControl Factor of 10% with a LoadControlReference of 50% and an input LoadControl voltage 0 – 5 volts.

For details of setting the LoadControlFactor and LoadControlReference see section 'Other Settings'.

At no load and an input voltage of 2.5 volts the rated speed will be SpeedFix 1 or 2.

The governing will be in droop only.

Adjusting the Droop valve will not change the speed at no load.

Other settings

Load Control Settings

Operation 14-26

Configuration			Adjustment	Display
Load Control Configuration				
☒ Use AnalogIn1				
AnalogIn1_Value	0.020	V	ADC1 Type ☒ 0...5 V ☐ 0...10 V ☐ 4...20 mA	
AnalogIn1_RefLow	0.000	V		
AnalogIn1_RefHigh	5.000	V		
AnalogIn1_ErrorLow	0.000	V		
AnalogIn1_ErrorHigh	5.000	V		
AnalogIn1_Filter	8		LoadInput Error ☒ Reset ☐ Hold	
LoadInput	0.4	%		
SubstLoadInput	20.0	%	LoadInput ValueByError ☐ Last ☒ Subst	
Engine			Load Control	

- **ADC 1_Type**

This parameter enables selection of the type of input required to analogue input 1. The settings are:

- 0 to 5 volt input
- 0 to 10 volt input
- 4 to 20 mA input

- **AnalogIn1_RefLow**

This sets the lowest value the analogue input 1 will accept as a valid input.

- **AnalogIn1_RefHigh**

This sets the highest value the analogue input 1 will accept as a valid input.

- **AnalogIn1_ErrorLow**

This sets the low value at which the analogue 1 input signal will give an error, e.g. if *AnalogueIn1_RefLo* was set at 0.5 volt, *AnalogIn1_ErrorLo* could be set at 0.3 volt. This enables detection of an open circuit or faulty input signal.

- **AnalogIn1_ErrorHigh**

This sets the high value at which the analogue 1 input signal will give an error, e.g. if *AnalogueIn1_RefHi* was set at 4.5 volt, *AnalogIn1_ErrorHi* could be set at 4.7 volt. This enables detection of a faulty input signal.

- **LoadControlFactor and LoadControlReference**

If using analogue input 1, these two parameters set the range of the external speed control and the reference% for nominal speed i.e. if 1500 rev/min is the nominal running speed and speed variation of +/- 5% speed variation is required, set *LoadControlFactor* at **10%** and *LoadControlReference* at **50%**

Synchroniser settings

Configuration			Adjustment	Display
Synchronizer Configuration				
☒ Use AnalogIn2				
AnalogIn2_Value	4.467	V	ADC2 Type ☒ 0...5V ☐ 0...10V ☐ 4...20 mA	
AnalogIn2_RefLow	0.000	V		
AnalogIn2_RefHigh	5.000	V		
AnalogIn2_ErrorLow	0.000	V		
AnalogIn2_ErrorHigh	5.000	V		
AnalogIn2_Filter	8			
SyncInput	89.4	%	SyncInput Error ☒ Reset ☐ Hold	SyncInput ValueByError ☒ Last ☐ Subst
SubstSyncInput	0.0	%		
SynchronFactor	40.0	%		
SynchronReference	50.00	%		
Engine			Load Control	Synchronizer

- **ADC2 type**

This parameter enables selection of the type of analogue input 2. The settings are:

- 0 to 5 volt input
- 0 to 10 volt input
- 4 to 20 mA input

For external speed control from a 5K potentiometer, select 0 to 5 volt.

The other available adjustments are:

- **AnalogIn2_RefLo**

This sets the lowest value the analogue input 2 will accept as a valid input.

- **AnalogIn2_RefHigh**

This sets the highest value the analogue input will accept as a valid input. F

- **AnalogIn2_ErrorLow**

This sets the low value at which the analogue 2 input signal will give an error, e.g. if *AnalogIn2_RefLo* was set at 0.5 volt, *AnalogIn2_ErrorLo* could be set at 0.3 volt. This enables detection of an open circuit or faulty input signal.

- **AnalogIn2_ErrorHigh**

This sets the high value at which the analogue 2 input signal will give an error, e.g. if *AnalogIn2_RefHi* was set at 4.5 volt, *AnalogIn2_ErrorHi* could be set at 4.7 volt. This enables detection of a faulty input signal.

- **SynchronFactor / SynchronReference**

If using analogue input 2, these two parameters set the range of the external speed control and the reference % for nominal speed i.e. if 1500 rev/min is the nominal running speed and speed variation of +/- 5% speed variation is required, set *SynchronFactor* at **10%** and *SynchronReference* at **50%**

Droop setting

For manual parallel operation in Droop mode this setting allows the engine to run in Droop similar to a mechanical speed governor, i.e, when set to Droop mode the engine will run at rated speed plus Droop %. E.g, 1500 rpm at 4% droop will run at 1560 rpm at no load and 1500 rpm at full load. When operating in droop mode, the following parameters must be set :

- **Droop**

Set to required percentage droop – there are separate droop settings for 1500 and 1800 rev/min, the 1800 rev/min settings being labelled Droop2.

- **DroopRefLo**

To set this parameter, with the governor powered up and the engine running at no load, read parameter **ActPos** from the Speed Governor – Adjustment tab as shown below and enter this value into parameter **DroopRefLo**.

- **DroopRefHi**

To set this parameter, with the governor powered up and the engine running at full load, read parameter **ActPos** and enter this value into parameter **DroopRefHi**.

- **DroopSpeedRef**

Set this parameter to the nominal running speed of the engine i.e. 1500 or 1800 rev/min.

Engine Stop

- **Switch or Impulse**

If this is set to switch, engine stop is active only as long as the stop command is coming in else if this is set to Impulse, engine stop is active by a single switching pulse until the engine stops.

- **Close or Open**

If this is set to Open then opening the stop switch will stop the engine. If this is set to Close then closing the stop switch will stop the engine.

Common alarm

If the WarnFlashOn box is ticked, the external warning light will flash otherwise it will be steadily illuminated.

The ResetOn box is not used in this application.

PID parameters

To adjust

Operation 14-27

The engine is supplied with default governor PID (Proportional, Integral and Derivative) gain parameters which will give stable operation with the majority of engine-alternator combinations. If any instability occurs with a particular engine-alternator combination, it will be necessary to change the governor PID values as described below.

The PID parameters are available on the **Adjustment – Speed Governor** tab.

Configuration	Adjustment	Display
Adjustment Speed Governor		
PID Gain: 20.0 % Stability: 4.0 % Derivative: 30.0 % ☐ SpeedSetpPCOn SpeedSetpPC: 0 1/min ☐ SpeedGradientDT1On DT1: 10.0 % ☐ StaticCorrOn StaticCorrFactor: 100.0 % StaticCorrRange: 20 1/min		
Actuator Position ActPos: 2.1 % ActPosSetpoint: 3.0 % ActPosAtZeroFuel: 0.0 % FuelQuantity: 0.0 % Speed Speed: 0.0 1/min SpeedSetp: 0 1/min SpeedSetpRamp: 450 1/min SpeedSetpSelect: 1500 1/min DroopOffset: 0 1/min GenSetOffset: 0 1/min Overspeed: 1650 1/min Switch Functions SwitchEngineStop: 0 SwitchDroop20r1: 0 SwitchSpeedRange20r1: 0 SwitchSpeedFix1: 1 SwitchSpeedFix2: 0 SwitchSpeedLimit20r1: 0 SwitchBoostLimit20r1: 0 SwitchPIDMap20r1: 0		
PID Map PID_CorrFactor: 100.0 % PID Map: Open		
Speed Governor Engine/Generator Actuator/Power Supply		

To set these parameters, the engine is started and run up to the working point for which the adjustment is to be made. As a rule, this working point will be at rated speed and off-load. For optimization of the PID parameters, proceed by the following steps:

- 1 Increase the P-factor **Gain** until the engine tends to become unstable. Then, decrease the P-factor again until the speed oscillations disappear or are reduced to a moderate level.
- 2 Increase the I-factor **Stability** until the engine passes over to long-waved speed oscillations.
- 3 Increase the D-factor **Derivative** until the speed oscillations disappear. If the oscillations can not be eliminated by the D-factor, the I-factor will have to be reduced.

With these values set, disturb engine speed for a short moment (e.g., by shortly operating the engine stop switch) and observe the transient response. Continue to modify the PID parameters until the transient response is satisfactory.

PID Maps

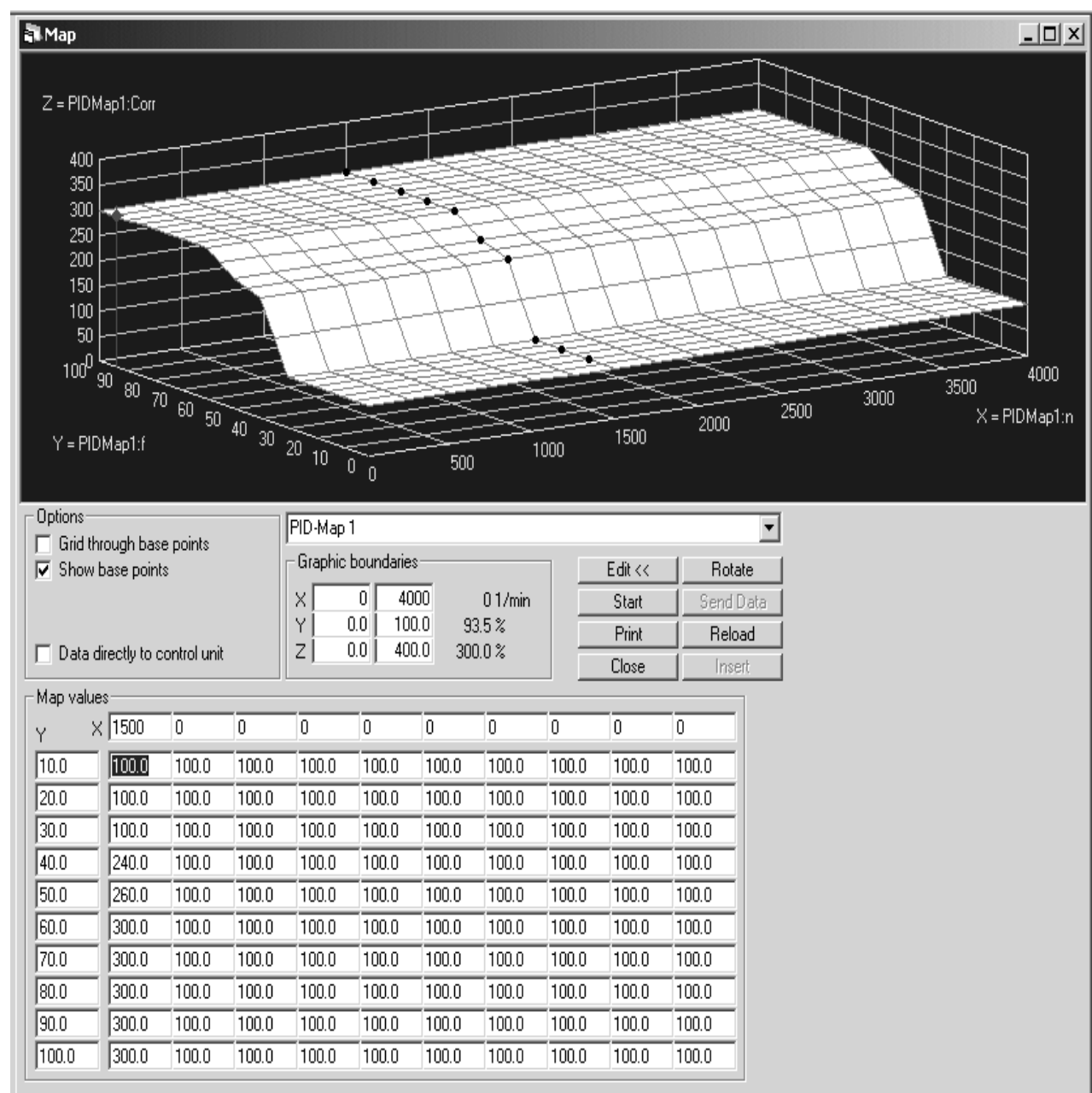
To adjust

Operation 14-28

Since the PID values which give optimum performance are different for various load values (In general, gains may be greater with increasing load), The governor gains are mapped, gain vs load. These maps are created during the engine development process but can be changed using the service tool.

There are two sets of PID maps, one for speed determined by parameter **SpeedFix1** and one for speed determined by parameter **SpeedFix2**.

To adjust the maps if required, on the Adjustment – **Speed** governor screen, click the PID Map '**Open**' button and then click the '**Edit**' button on the map screen. For fixed speed engines, only the first column is used. If necessary, change the gain entry against the actuator position (Y axis) where the instability is occurring. The values are percentages, i.e. 100 represents 100% and does not change the basic PID values.



Speed Ramps

Speed ramps are not normally used in generating set applications but for pump sets, for example, it may be desired to have a slow ramp in speed from idle to full speed.

To do this, the control provides ramps to retard acceleration. The delay rate of increasing or decreasing the set value can be adjusted separately in either direction. Furthermore, it is possible to decide on the type of speed ramp by means of the parameter.

- **FixedRamp** = Fixed speed ramp
- **Sectional Ramp** = Sectional speed ramp.

The ramp functions are activated by ticking the **SpeedRampOn** box on the **Configuration – Engine** tab.

Fixed Speed Ramp

To use the fixed speed ramp, select the Fixed Ramp option button. With the fixed speed ramp, the rate by which the setpoint is delayed will be the same across the entire speed range. The ramp rates for ramping upward and downward can be separately set by means of the parameters under **SpeedRamp1**.

- **SpeedRampUp**. Ramp rate for upward ramp.
- **SpeedRampDown**. Ramp rate for downward ramp.

The unit of these parameters is speed increase resp. speed decrease per second (revolutions per minute per second = rpmps). If ramping is desired in one direction only, the maximum value (4000 rpmps) is to be entered for the other direction.

The speed setpoint as delayed by the ramp can be viewed by the parameter **SpeedSetpRamp**. The parameter **SpeedSetpSelect** represents the speed setpoint that the ramp is supposed to arrive at.

Programming Example.

Speed is supposed to rise from 1,000 rpm to 1,500 rpm in the course of 20 seconds. This is equivalent to an increase of speed of 500 rpm within 20 seconds or of 25 rpm per second. Deceleration is to work without ramp.

Number	Parameter	Value	Unit
	SpeedRampUp	25	rpmps
	SpeedRampDown	4000	rpmps

Activation:

- **SpeedRampOn**
ticked.
- **FixedRamp**
selected.

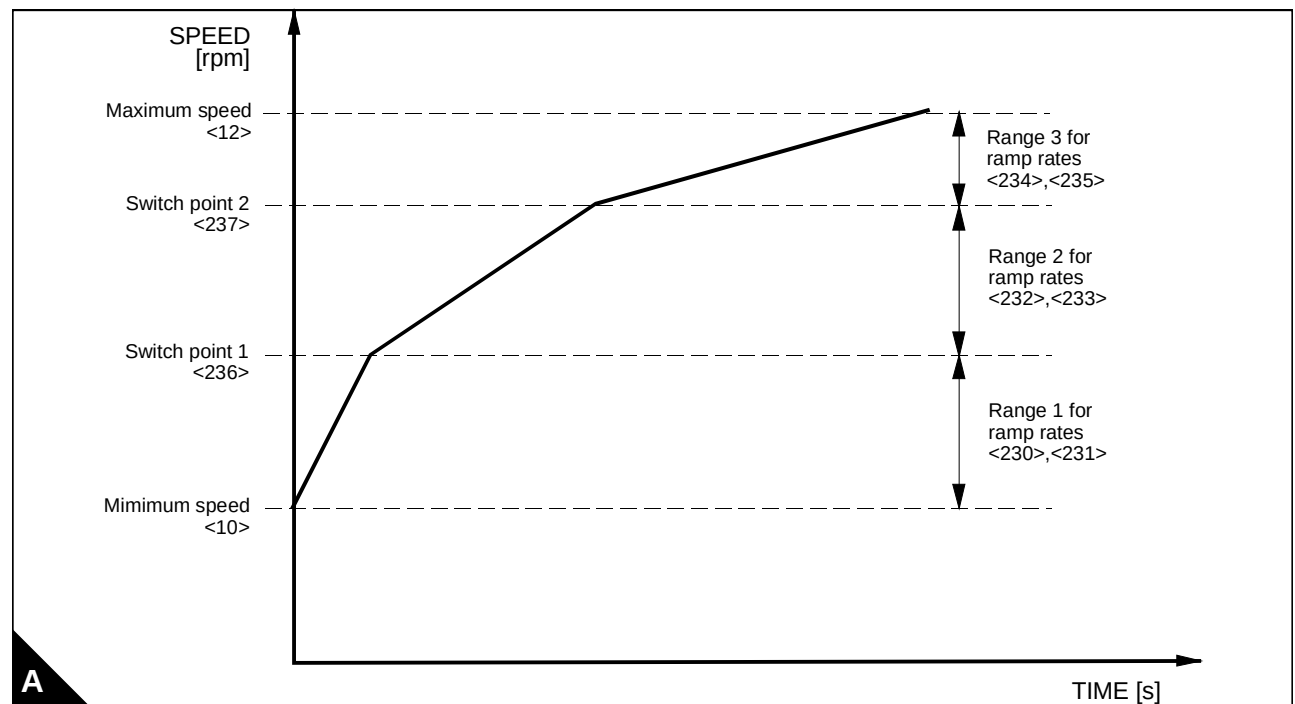
Sectional Speed Ramp

To adjust

Operation 14-29

For certain applications, it is desirable that the ramping rate is not the same for the entire speed range. To achieve this, the control offers the option to split the whole speed range up into 3 sections and to set the ramping rate for each respective section separately. This also means that the ramping rate will depend on the current setpoint value **2031 SpeedSetp**.

Speed Profile of Sectional Speed Ramp



Note: The kink points where the ramping rate is to change are determined by these parameters:

- **SpeedRamp2 - SpeedSwitchToRamp**
Change of rate from section 1 to section 2.
- **SpeedRamp3 - SpeedSwitchToRamp**
Change of rate from section 2 to section 3.

Continued

The different ramping rates by which the setpoint is to be delayed within the respective sections are set by means of the following parameters:

- **SpeedRamp1 - SpeedRampUp**

Ramp rate for ramping upward in section 1.

- **SpeedRamp1 - SpeedRampDown**

Ramp rate for ramping downward in section 1.

- **SpeedRamp2 - SpeedRampUp**

Ramp rate for ramping upward in section 2.

- **SpeedRamp2 - SpeedRampDown**

Ramp rate for ramping downward in section 2.

- **SpeedRamp3 - SpeedRampUp**

Ramp rate for ramping upward in section 3.

- **SpeedRamp - SpeedRampDown**

Ramp rate for ramping downward in section 3.

The unit of these parameters is again given by speed increase or speed decrease per second. The ramps are enabled through the parameter **SpeedRampOn** box, selection of the sectional speed ramp is made by selecting **Sectional Ramp** option button.

Note: When only two ramp sections are to be provided the switch point 2 represented by parameter SpeedRamp3 must be set to maximum speed value.

The speed setpoint as delayed by the ramp can be viewed by the parameter **SpeedSetpRamp**. The parameter **SpeedSetpSelect** represents the speed setpoint that the ramp is supposed to arrive at.

Programming Example:

The upward ramping rate between minimum speed and 800 rpm is supposed to be 100 rpmps, and speed reduction is to be performed as fast as possible. The upward ramping rate between 800 rpm and 1200 rpm is to be 50 rpmps, the downward ramping rate 40 rpmps. Between 1200 rpm and maximum speed both the upward and downward rates shall be 20 rpmps.

Parameter	Value	Unit
SpeedRamp1 - SpeedRampUp	100	rpmps
SpeedRamp1 - SpeedRampDown	4000	rpmps
SpeedRamp2 - SpeedRampUp	50	rpmps
SpeedRamp2 - SpeedRampDown	40	rpmps
SpeedRamp3 - SpeedRampUp	20	rpmps
SpeedRamp3 - SpeedRampDown	20	rpmps
SpeedRamp2 - SpeedSwitchToRamp	800	rpm
SpeedRamp3 - SpeedSwitchToRamp	1200	rpm

Activation:

- **SpeedRampOn**

ticked

- **Sectional Ramp**

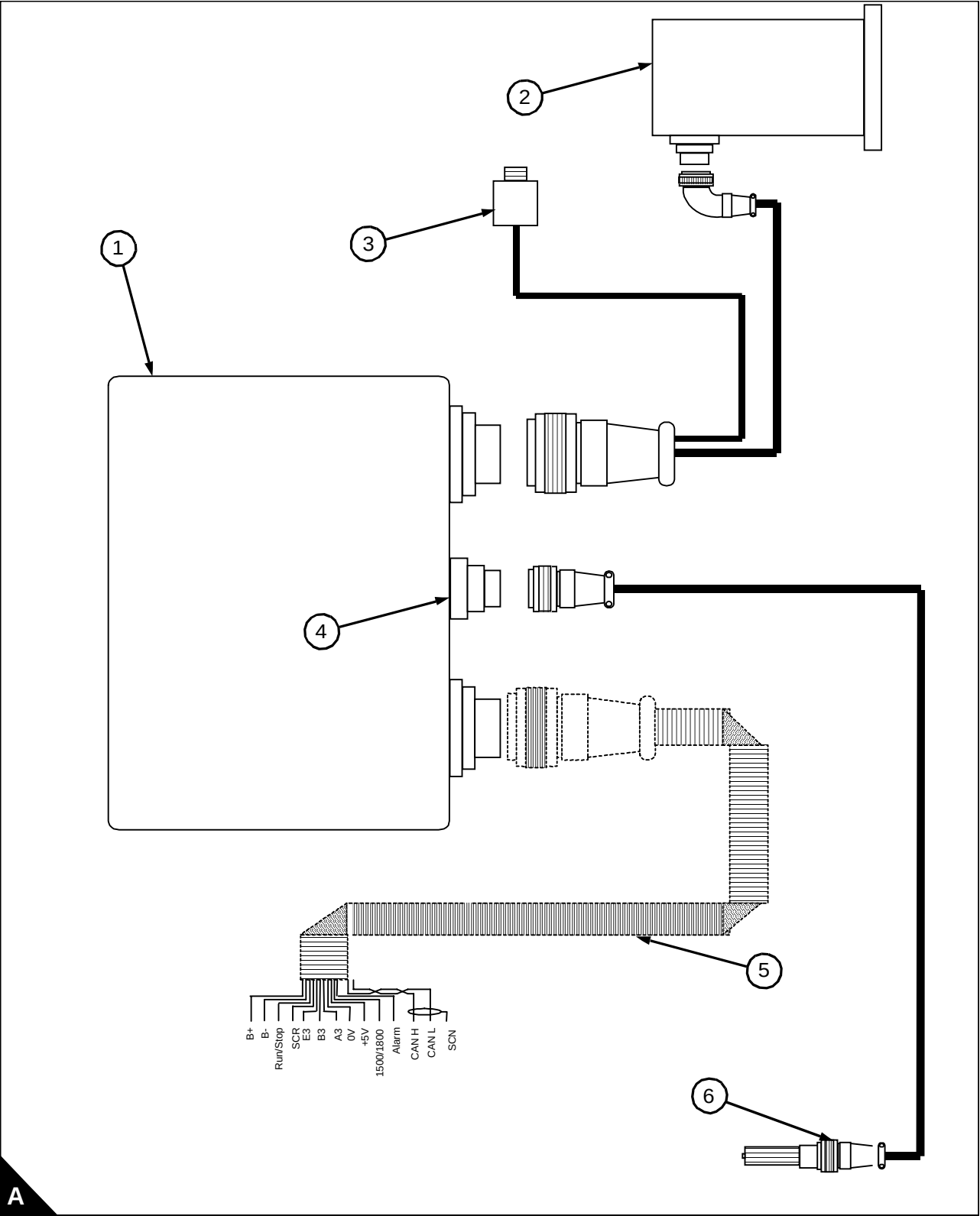
selected.

System Wiring

The cables between the control box, actuator, boost pressure sensor and speed pick-up are provided and fitted by Perkins.

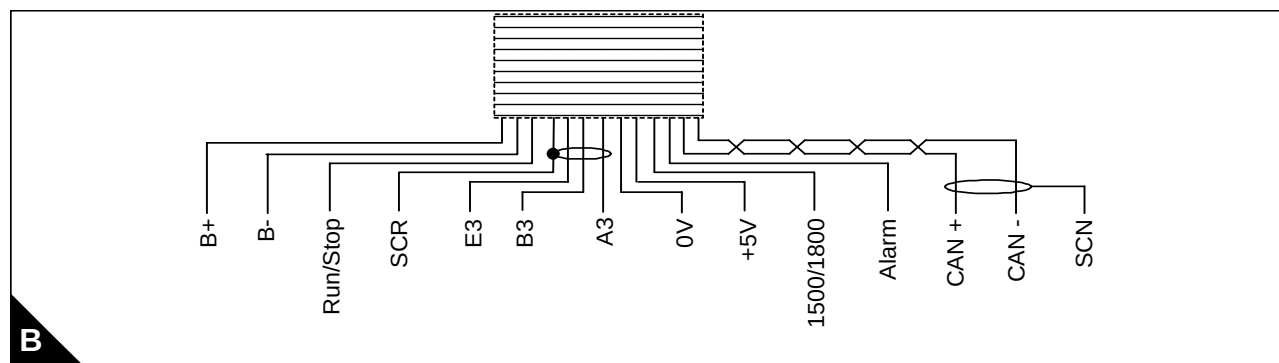
A 4 metre long cable with connector at the control box end is available as an optional extra for external connections to the unit. This cable may also be supplied by the OEM.

Continued



A1	Digital governor control box
A2	Governor actuator
A3	Boost pressure sensor
A4	2 pin connection
A5	4 metre length optional cable harness for customer connections
A6	Magnetic pick up

External Connections – Perkins supplied cable



B+ The 24 volt battery positive supply to governor. A 15 amp fuse or circuit breaker must be fitted in this circuit for overcurrent/short circuit protection.

B- The 24 volt battery negative supply to the governor.

Run/Stop A switch connected from this wire to + 24V will enable the engine to run when closed and will stop the engine when open. This is the preferred method of normal stop. If this is not required, link the Run/Stop wire to + 24V.

A3 Common for synchronizer/load sharer input.

B3 Synchronizer input. This may be used for speed control signal from an analogue synchronizer or other external speed control depending on the configuration as described above. For fixed speed engines, no connection is required.

E3 Load sharer input. This is for connection to a Heinzmann analogue load sharing unit. For fixed speed engines, no connection is required.

0V & 5V This is a 5 volt supply for an external speed setting potentiometer for single generator variable speed configuration. For fixed speed engines, no connection is required.

1500/1800 A switch connected from this wire to + 24V will enable the engine to be switched between 1500 Rev/Min and 1800 Rev/Min speeds when switchable 1500/1800 Rev/Min running is configured. For single speed engines, no connection is required. Switchable 1500 /1800 Rev/Min engines will default to 1500 Rev/Min if no connection is made.

Alarm This is a digital output to indicate a fault on the governor system. Connect a lamp or relay between this connection and + 24V for indication of fault condition. It is necessary to use the service tool to establish the reason for the fault indication.

SCR This is the cable screen which is connected to the metalwork of the connector at the control box end for EMC requirements.

CAN+, CAN- CAN bus connections for digital load sharing/synchronizing (where fitted).

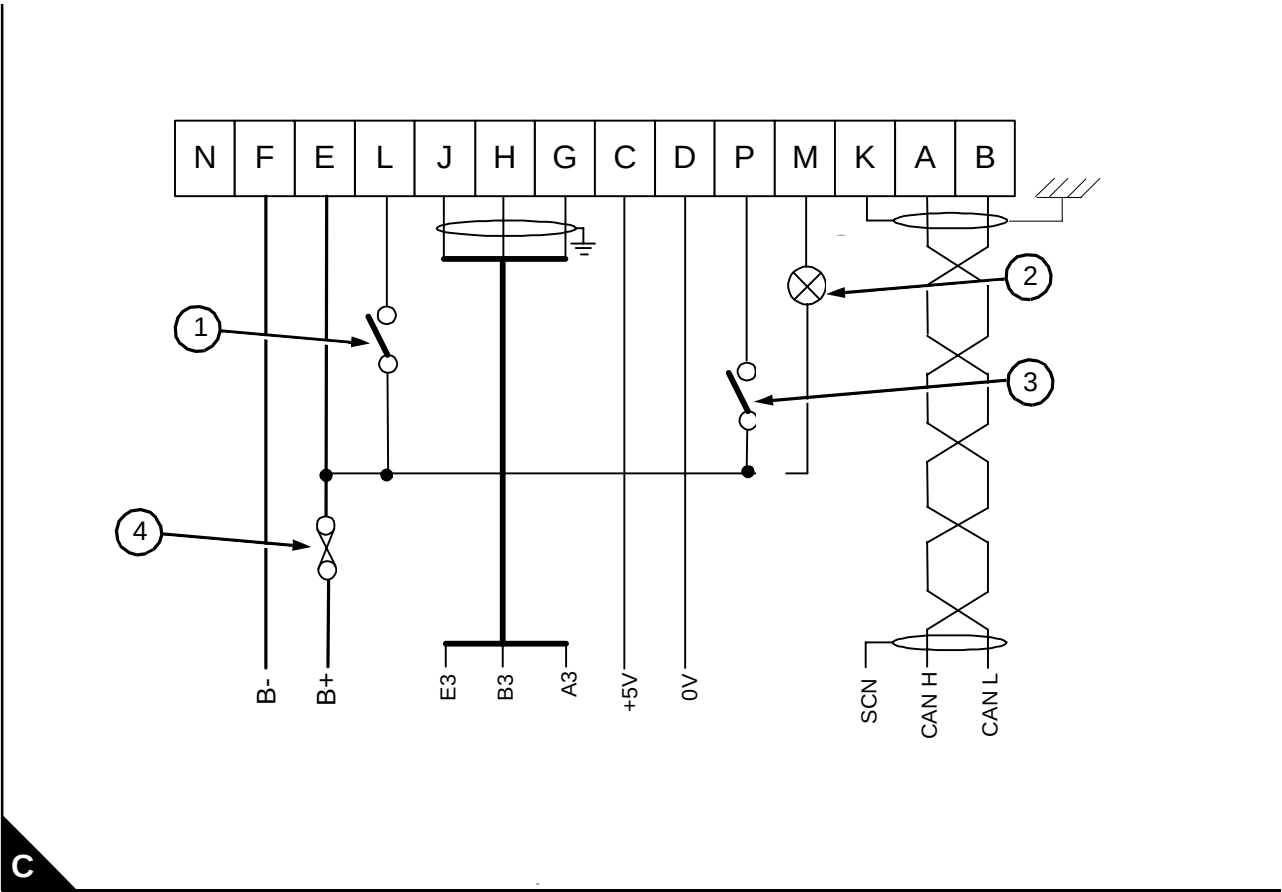
External connections – Control box connector

For description of external connections, see "External Connections – Perkins supplied cable" on page 233.

14 Pin OEM Connector													
N	F	E	L	J	H	G	C	D	P	M	K	A	B
	B-	B+	Run/Stop	E3	B3	A3	+5V	0V	1500/1800	Alarm	SCN	Can H	Can L

External Connection Details

14 Pin OEM connection.



- CAN Connections for digital load sharing/synchronising if required.
- For connection option for external speed control, see "Alternative Connections for Speed Setting Inputs" on page 235.

C 1	Stop/Start switch (link if not fitted)
C 2	Alarm lamp
C 3	1500/1800 switch
C 4	15A fuse

Cable Sizes

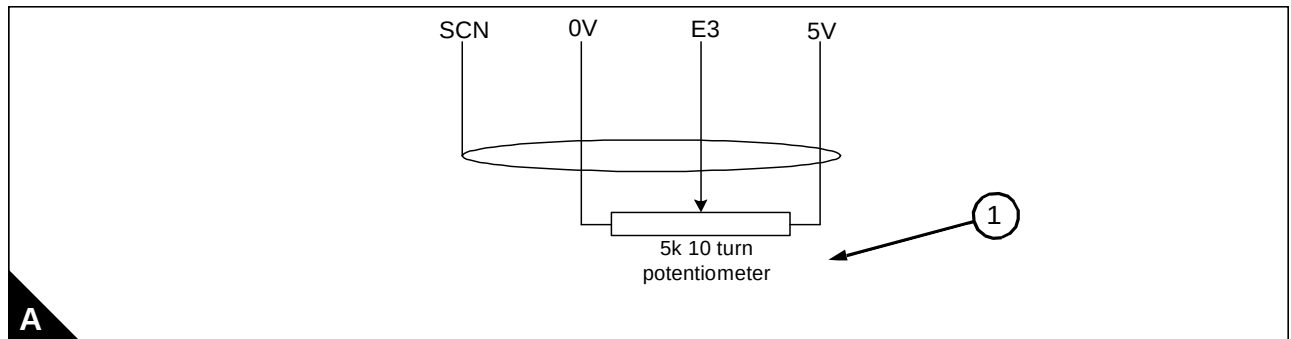
Battery supply cables must be 1.5 mm² minimum up to a maximum length of 7 metres. All other cables 0.5 mm² minimum.

Alternative Connections for Speed Setting Inputs

Variable speed generator, isochronous or droop

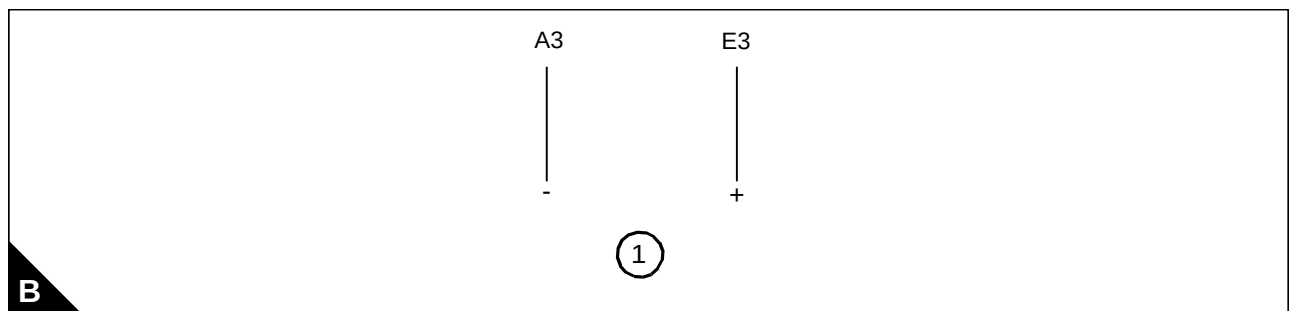
Potentiometer control

Connect 0V and 5V to the potentiometer and the slider of the potentiometer to E3.



(A1)	5K 10 Turn potentiometer
------	--------------------------

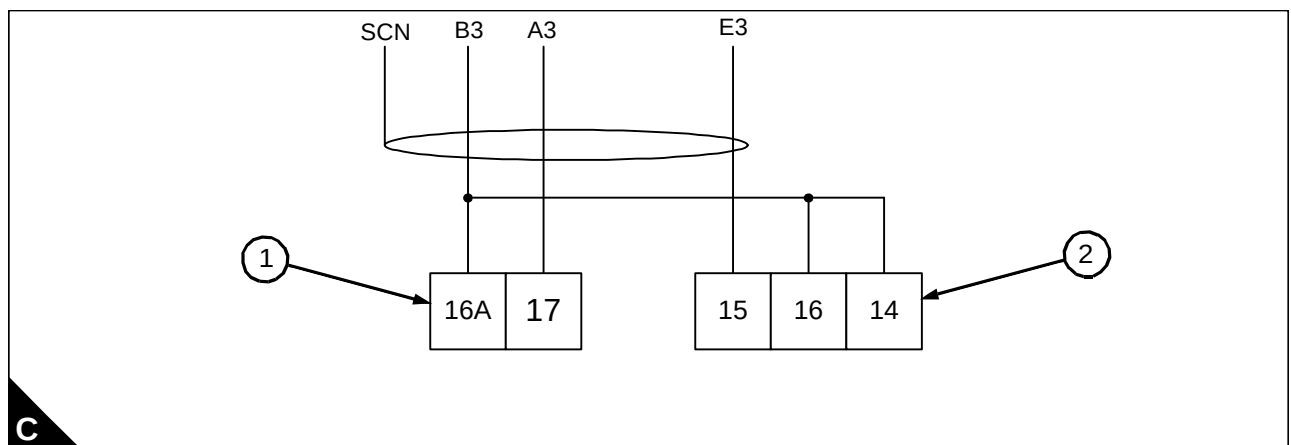
External voltage control



(B1)	To external speed setting voltage/current
------	---

Parallel generator, Heinzmann LSU/Sync

Connect A3, B3 and E3 wires as shown.

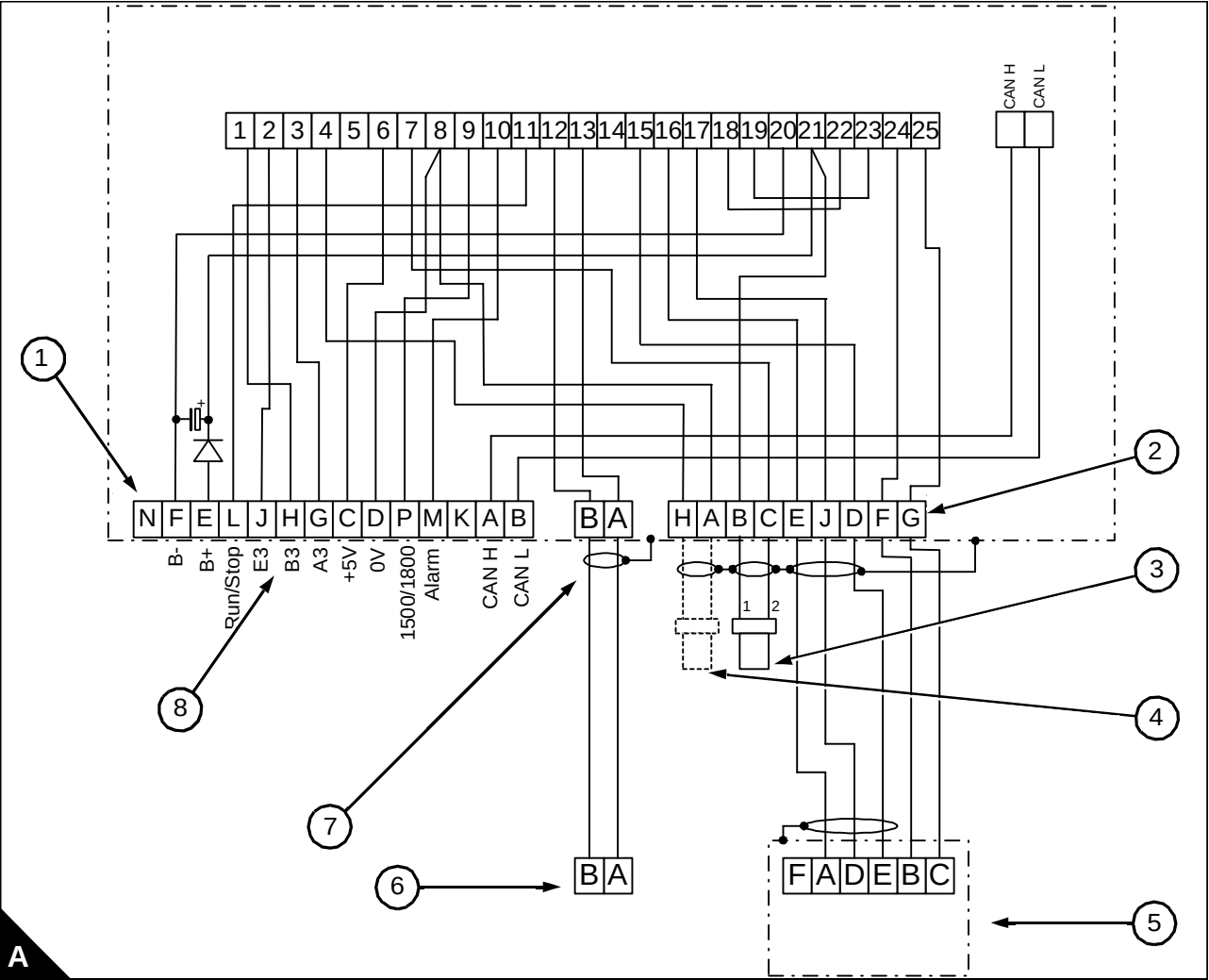


(C1)	Synchronizer SYG02
(C2)	Load measure unit LMG 03-S2

For equivalent connections on the analogue Theseus unit see Heinzmann literature.

Wiring detail, digital control box in IP enclosure – production engines

Pandaros box



A1	14 pin connection
A2	10 pin connection
A3	Boost sensor
A4	Temperature sensor
A5	Heinzmann actuator
A6	Pick-up
A7	2 pin connection
A8	OEM connection

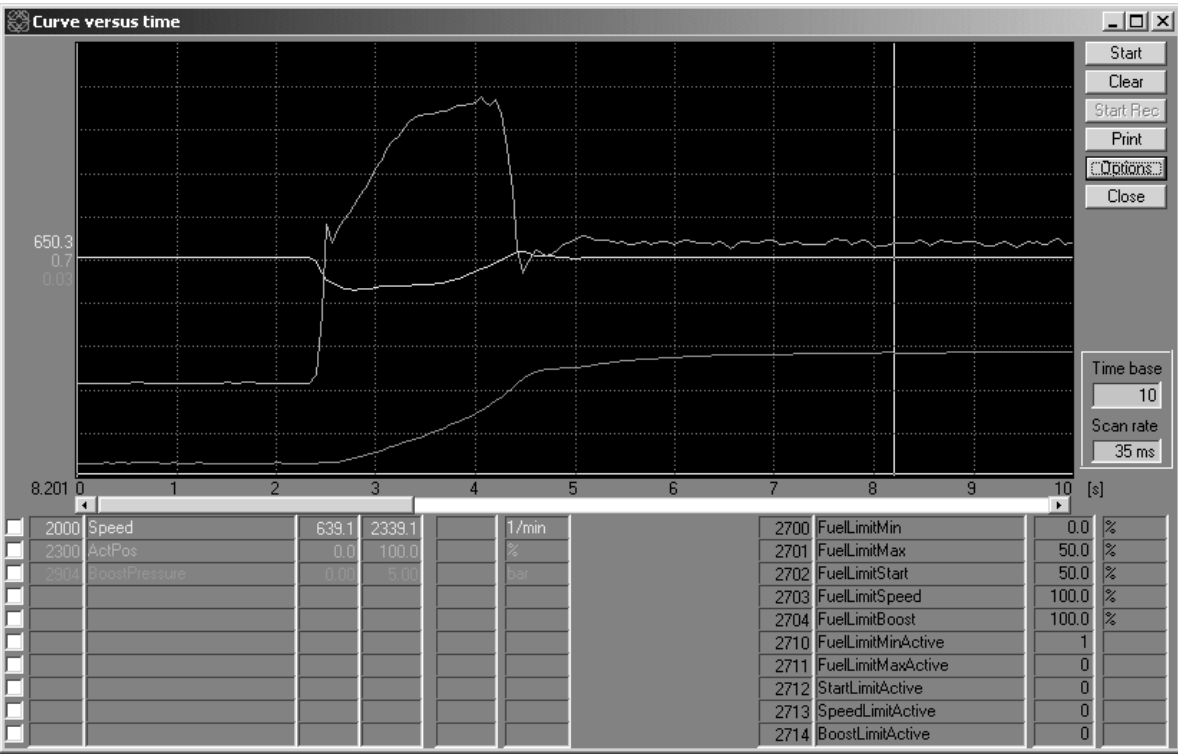
Fault Tracing

Note: The faults detailed below only relate to governor system problems, not engine mechanical problems.

Fault Guide	
Governor does not open when cranking engine	No signal from magnetic pick-up. Excessive pick-up gap > 0.5 to 0.8 mm. No signal from magnetic pick-up. Excessive pick-up gap > 0.5 to 0.8 mm. Check resistance (Approx. 52 ohm) at control unit A2/B2 plug. Check pick-up voltage at cranking speed (Approx. 1.5V AC) at control unit A2/B2 plug. Wiring fault or magnetic pick-up defective. No DC voltage at control unit. Check fuse in supply line. Check wiring. Supply voltage inadequate or polarity reversed. Shut down switch in Stop position. Stop solenoid not energised. Control box error exists – look for error lamp on (If fitted). Power governor down to clear error and re-try. Use service tool to investigate error. Actuator blocked or linkage incorrectly adjusted. Actuator defective. Check resistance at actuator terminals B/C (Approx. 2 ohm). New control box not programmed. Control unit defective.
Governor moves to maximum position when power supply is switched on	Wiring fault. Faults in pick-up cable. Check shielding. Control unit defective.
Engine goes to overspeed after start-up	Speed setting parameters in control box wrong. Excessive pick-up gap: only a proportion of teeth counted. Intermittent pick-up cable fault. Engine linkage or fuel injector jammed. Actuator feedback voltage incorrectly adjusted. Actuator or control box defective.
Governor not stable	Faults in pick-up cable. Check shielding. Faults in external speed setting control. Check wiring and shielding. Load fluctuations. Inadequate supply voltage. Poor electrical contact. Play or friction in linkage. Governor gains incorrectly set.
Speed droops under load	Governor is set up for droop operation. Actuator is at maximum fuelling position – engine is overloaded. Stability is incorrectly adjusted. Fault in control unit.
Engine will not pull load	Low boost pressure. Boost pressure sensor or wiring faulty. Use service tool to investigate boost pressure fault.

Continued

The Service Tool can be used to assist in fault finding. The various adjustment and display screens allow parameters such as speed, actuator position, boost pressure etc. to be viewed and the real time graphic facility can be used to get a visual impression of parameter changes during transients. If necessary, the data captured can be stored to a file for further evaluation. This function is available under the main menu 'Graphic – Curve Versus Time.



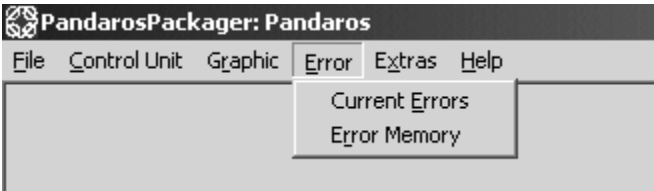
Error Codes

The control box continuously monitors the system and if a fault is detected, The control box registers the fault, turns the alarm lamp on (If fitted) and, if the fault warrants it, stops the engine. The following table lists the fault codes:

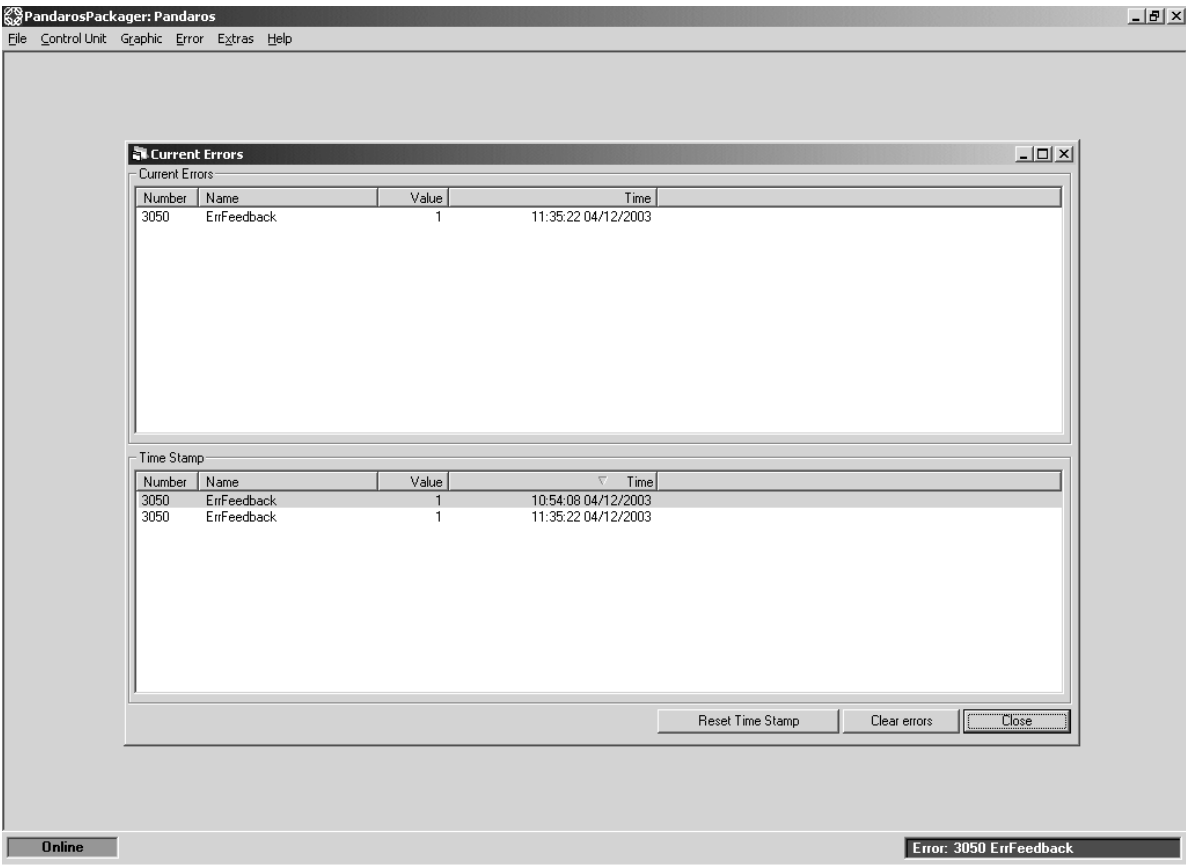
Code	Name	Value	Description
3000	Configuration Error	0	Configuration file error
3001	Err Pick Up	0	Speed sensor error
3004	ErrOverSpeed	0	Engine overspeed
3007	ErrLoadInput	0	Load sharer input error
3008	ErrSynclInput	0	Synchronizer input error
3009	ErrBoostPressure	0	Boost pressure sensor error
3012	ErrCoolantTemp	0	Not used
3032	ErrCoolantTempWarn	0	Not used
3050	ErrFeedback	0	Actuator feedback signal error
3053	ErrActuatorDiff	0	Too great a difference between set value and actual value of actuator
3056	ErrFeedbackRef	0	Error on reference value of actuator feedback
3059	ErrFeedbackAdjust	0	Error during auto calibration of actuator
3076	ErrParamStore	0	Error on storing parameters
3077	ErrProgramTest	0	Error on programming checksum
3078	ErrRAMTest	0	Error during RAM test
3080	ErrDisplay	0	Not used
3081	Err5V_Ref	0	Error on 5 volt reference
3085	ErrVoltage	0	Error on voltage supply
3090	ErrData	0	Error on data block
3092	ErrConfiguration	0	Configuration error
3093	ErrStack	0	Error of internal parameter management
3094	ErrIntern	0	Internal software fault
3101	SErrPickUp	0	Sentinel for Speed sensor error
3104	SErrOverSpeed	0	Sentinel for Engine overspeed
3107	SErrLoadInput	0	Sentinel for Load sharer input error
3108	SErrSynclInput	0	Sentinel for Synchronizer input error
3109	SErrBoostPressure	0	Sentinel for Boost pressure sensor error
3112	SErrCoolantTemp	0	Not used
3132	SErrCoolantTempWarn	0	Not used
3150	SErrFeedback	1	Sentinel for Actuator feedback signal error
3153	SErrActuatorDiff	0	Sentinel for Too great a difference between set value and actual value of actuator
3156	SErrFeedbackRef	0	Sentinel for Error on reference value of actuator feedback
3159	SErrFeedbackAdjust	0	Sentinel for Error during auto calibration of actuator
3176	SErrParamStore	0	Sentinel for Error on storing parameters
3177	SErrProgramTest	0	Sentinel for Error on programming checksum
3178	SErrRAMTest	0	Error during RAM test
3180	SErrDisplay	0	Not used
3181	SErr5V_Ref	0	Sentinel for Error on 5 volt reference
3185	SErrVoltage	0	Sentinel for Error on voltage supply
3190	SErrData	0	Sentinel for Error on data block
3192	SErrConfiguration	0	Sentinel for Configuration error
3193	SErrStack	0	Sentinel for Error of internal parameter management
3194	SErrIntern	0	Sentinel for Internal software fault
3195	SExceptionNumber	0	Sentinel for Exception number
3196	SExceptionAddrLow	0000Hex	Sentinel for Software fault
3197	SExceptionAddrHigh	0000Hex	Sentinel for Software fault
3198	SExceptionFlag	0000Hex	Sentinel for Software fault

Continued

The current errors are displayed by selecting Error – Current Errors from the top menu of Pandaros Package.



The current error screen is then displayed.



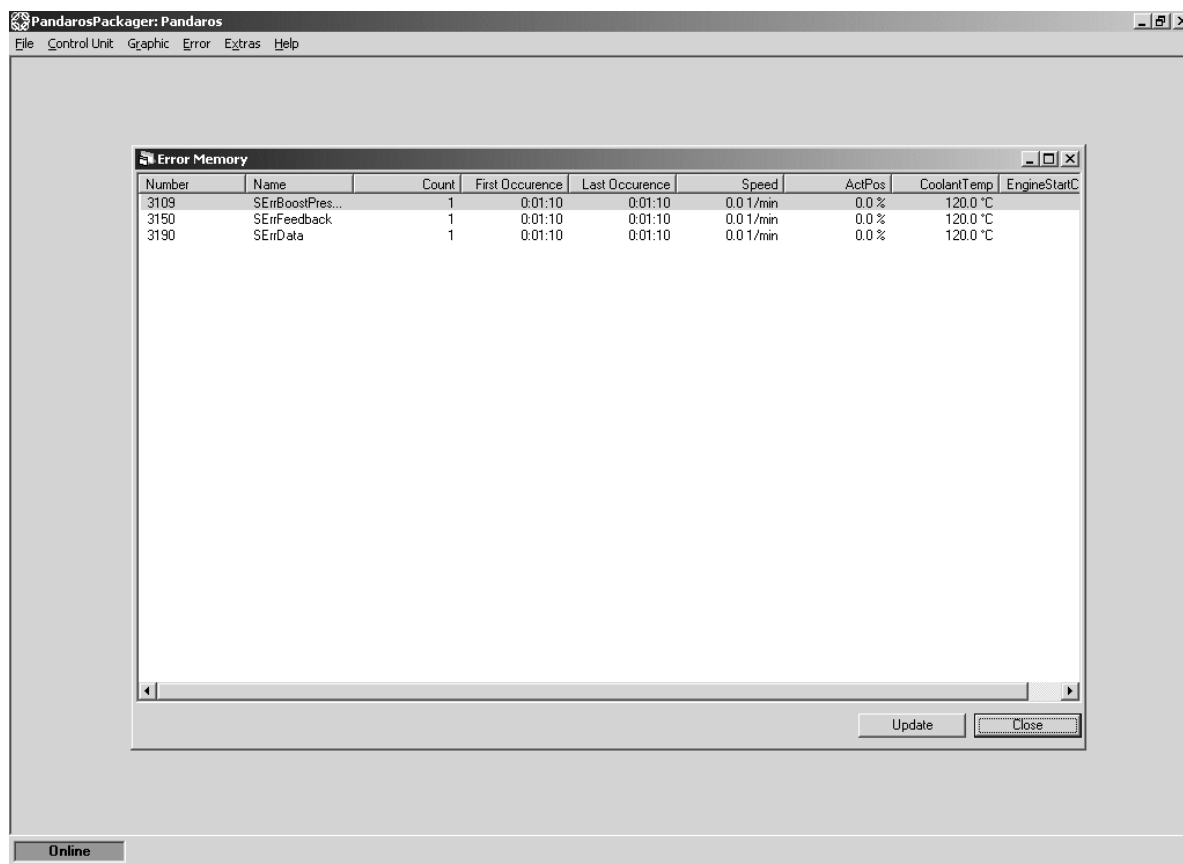
Providing that the current errors have been physically cleared, the current error screen can be cleared using the clear errors button.

To clean the time stamp screen, click the reset time stamp button.

Continued

- **Error memory**

Although the current errors can be cleared, a history of errors is stored in the Error Memory. These can be displayed but cannot be cleared.



Low oil High water temperature switch

General description

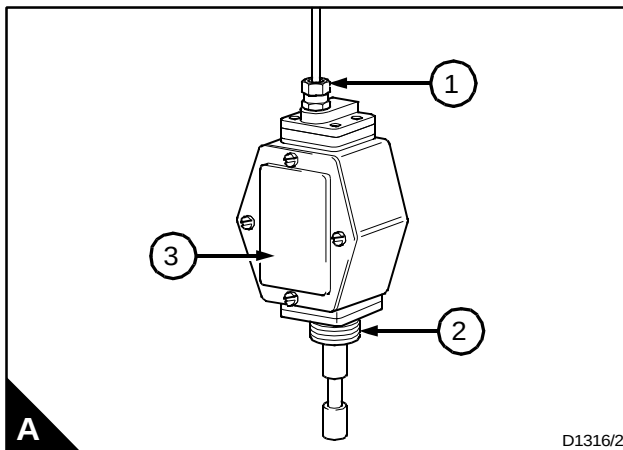
Warning! The switch settings are factory set do not adjust, it could be dangerous to personnel and may affect the warranty.

The switch controls two operations. High water temperature and low lubricating oil pressure. The switch is connected to the engine stop solenoid and then activated by the high water temperature or low lubricating oil pressure will operate the stop solenoid.

To remove

Operation 14-30

- 1 Remove the nut (A1).

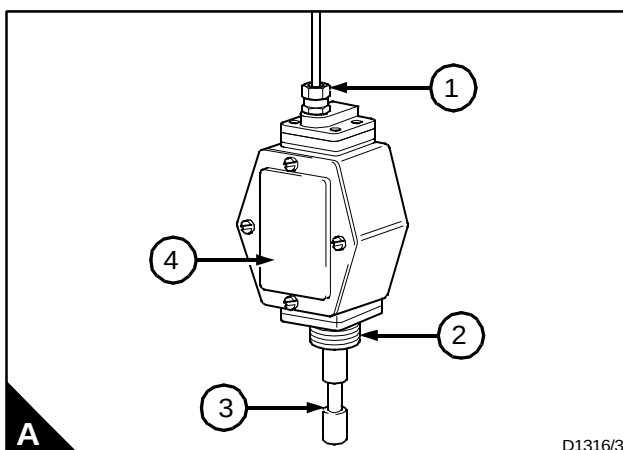


- 2 Loosen the gland nut from the threads (A2).
- 3 Remove the switch (A3) from the engine.

To fit

Operation 14-31

- 1 Fit probe (A3) into the gland nut housing.
- 2 Tighten the gland nut on to the threads (A2).
- 3 Fit the nut (A1) and tighten securely.

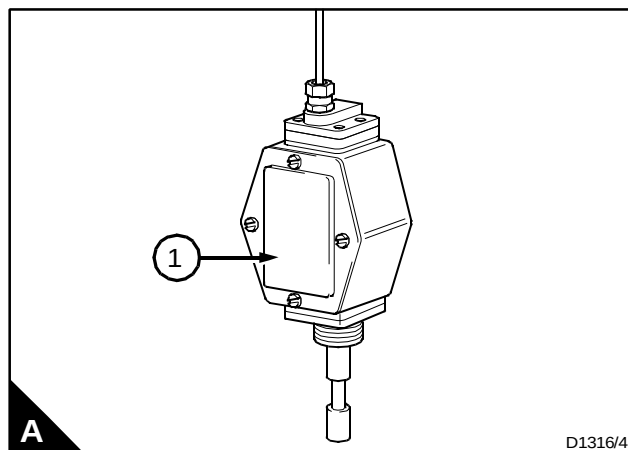


Switch connections

To remove and fit

Operation 14-32

1 Remove the cover (A1).



2

Pressure terminal connections	
1	Common
3	Mof = Make on fall
2	Bof = Break on fall

3

Temperature terminal connections	
6	Mor = Make on rise
5	Bor = Break on rise
4	Common

Note: The earth connection is next to the number 6 connection.

4 Fit the cover (A1).

Switch setting

Low oil pressure		
Alarm	Shutdown	
2,06 bar (30 lb/in²)	1,93 bar (28 lb/in²)	

High coolant temperature		
Thermostat	Alarm	Shutdown
71°	91°	96°
85°	96°	101°

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15

Auxiliary equipment

Ren Valve

General description

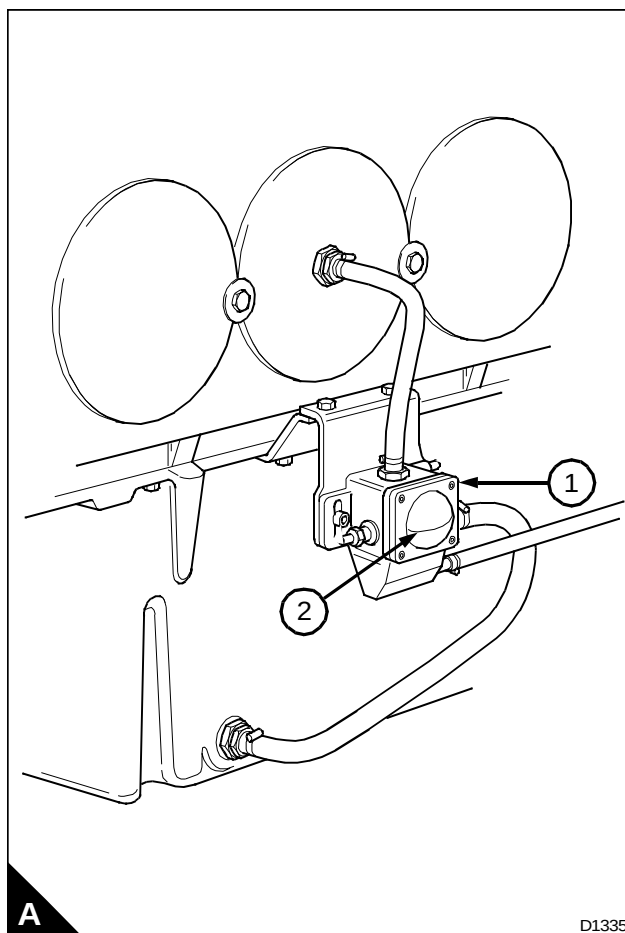
To allow an engine to operate for long periods, a Ren valve (A1) may be fitted (by an OEM) to keep the oil in the sump at the required level automatically.

To maintain this oil level in the sump a make-up tank is installed near to the engine and the Ren Valve. The make-up tank will supply the surplus oil as if and when required to maintain a constant oil level in the sump.

The centre window (A2) in the Ren valve corresponds with the oil level in the sump, which is the correct level of oil.

Notes:

- The oil level in the sump should be checked on the dipstick before start up.
- The position of the make-up tank should be above the Ren valve to ensure a gravity feed.



To remove

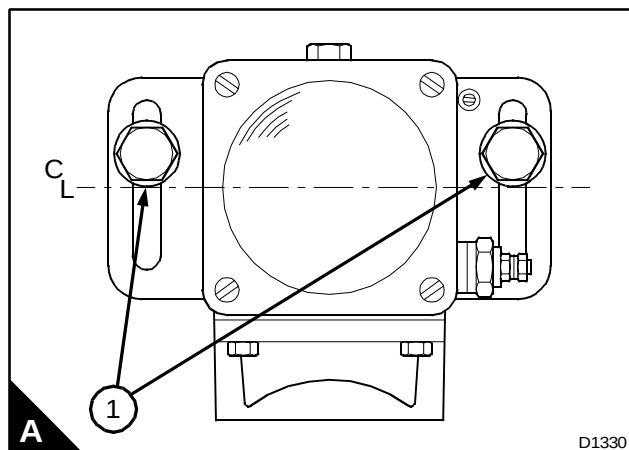
Operation 15-1

1 Remove the drain plug to drain the lubricating oil system and if your engine operates from a make-up tank, make sure it has been turned off before draining.

2 Remove all flexible pipe clip connections on the Ren valve.

Note: Take care not to spill any access oil left in the pipes.

3 Remove the setscrews (A1) from the mounting bracket and then remove the Ren valve.



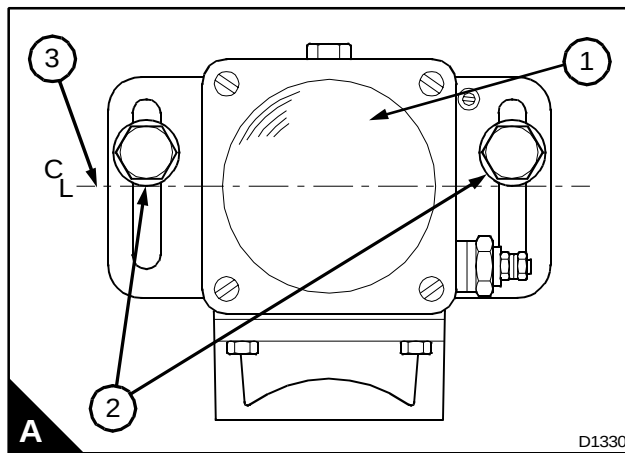
To fit

Operation 15-2

- 1 Fit the Ren valve onto the mounting bracket and screw into position.
- 2 Connect all the flexible pipes to the Ren valve.
- 3 Fit the oil drain plug back into the correct position.
- 4 Slowly fill the oil sump to the maximum with the correct type lubricating oil.
- 5 Start the engine and run on a light load for a few minutes.
- 6 Check the oil level in the glass (A1), if required adjust the height of the Ren valve by the two setscrews (A2).
- 7 Move the Ren valve up and down on the two slotted holes (A2) until the oil level indicated on the glass is half way up the glass (A3).

Note: This must be done when the engine operates

- 8 Stop the engine.
- 9 If your engine uses a make-up tank, turn the oil supply back on.
- 10 Check for oil leaks.



Immersion heater

General description

Warning! Do not run the engine while the immersion heater is switched on

For an easier start under cold climatic conditions, a 2kW immersion heaters is fitted (A3) and piped into the engine coolant system, between the suction pipe, from the radiator to the engines coolant system and the engines oil cooler.

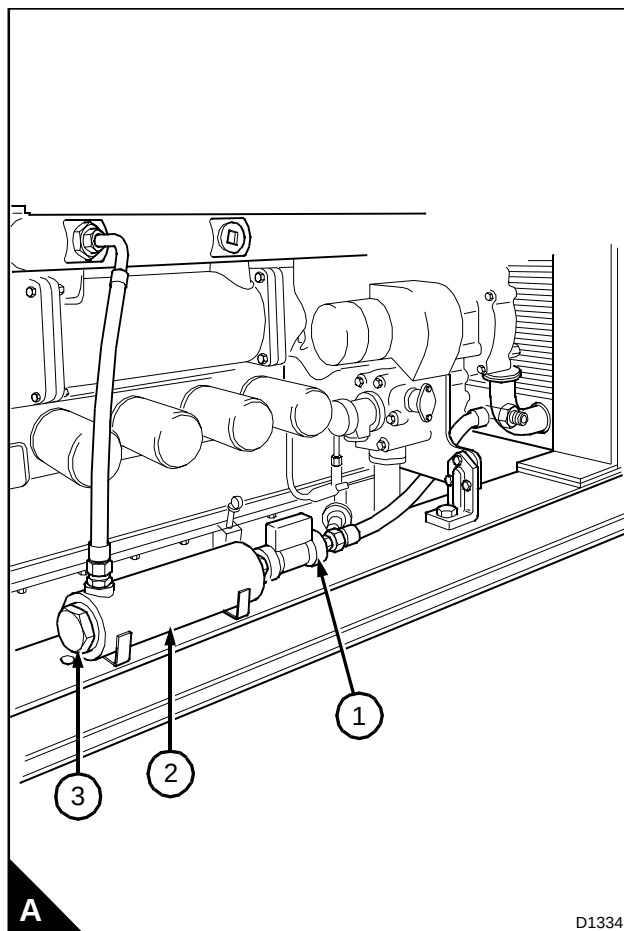
When the heater is switched on, water flows from the suction pipe, through rubber diaphragm check valves into the tank (A2) over the element and onto the engine oil cooler.

The immersion heater is controlled by a thermostat (A1) and can be found near to each tank heater. When the water temperature has reached 37.8°C (100°F), the thermostat automatically cuts off the electrical supply to the immersion heater.

When the temperature of the immersion heater drops to 26.7°C (80°F), the immersion heater will automatically switched on again.

Notes:

- In the event of failure the immersion heater is non serviceable and a new unit must be fitted.
- While the engine operates, the electrical supply to the immersion heater must be isolated.



To remove

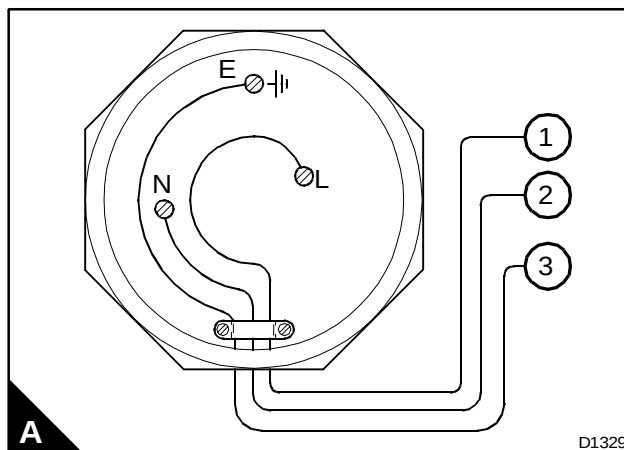
Operation 15-3

Warning! The supply for the immersion heater is 230/250v AC.

- 1 Remove the radiator filler cap
 - 2 Drain the engine cooling system through the radiator drain plug, found at the bottom of the radiator.
 - 3 If fitted, remove the immersion heater drain plug and allow to drain.
 - 4 Remove two screws from the terminal box cover and remove the cover.
 - 5 Disconnect the cables to the immersion heater (A1,A2,A3).
 - 6 Remove the heater element by turning it anti clockwise.
 - 7 Remove the tank end cover and inspect the O ring in the flap valve and check that it operates freely.
- The immersion heater is wired up as follows: -

Key (See graphic below)

- 1 Connect Line
- 2 Connect Neutral
- 3 Connect Earth



To fit

Operation 15-4

- 1 Ensure that the tank end cover is clean and that no joint material remains on the face.
- 2 Renew the joint on the tank end cover.
- 3 Screw the immersion heater into the tank.
- 4 Connect all cables in the heater body, refer to Operation 15-3
- 5 Fit the drain plug in the immersion heater (if fitted) and the radiator.
- 6 Slowly fill the coolant system until coolant flows from the highest point in the coolant system to eliminate all air locks.
- 7 Fit the radiator cap filler
- 8 Start engine and run at a light load for a few minutes and then stop engine.
- 9 Check for coolant leaks and coolant levels and adjust accordingly.
- 10 Switch ON immersion heater.

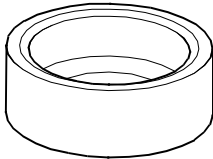
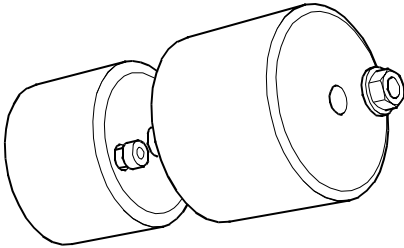
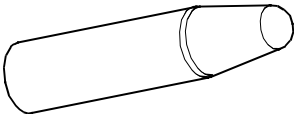
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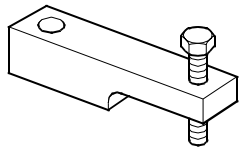
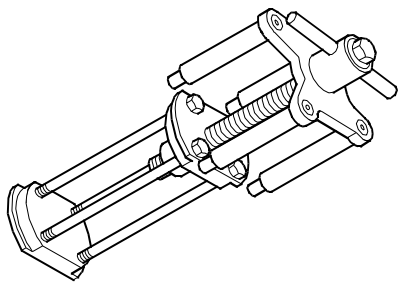
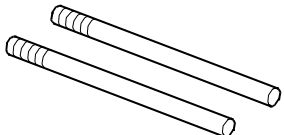
Special tools

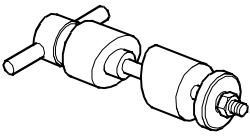
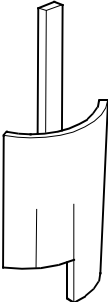
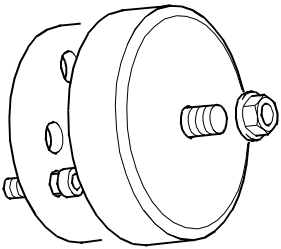
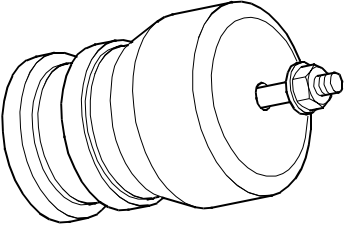
These tools are available through your nearest Perkins Dealer/Distributor. If you cannot obtain the correct tool locally contact:

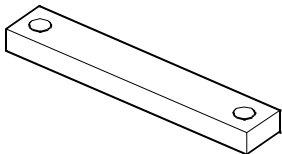
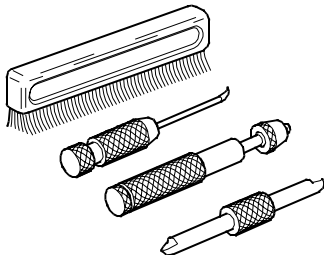
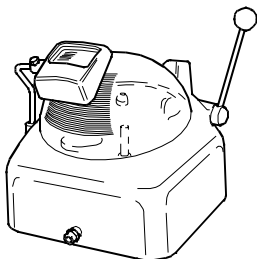
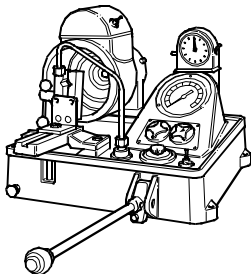
The Perkins Service Department, Peterborough, PE1 5NA, England, UK. Tel 01733 583000, Fax 01733 582240.

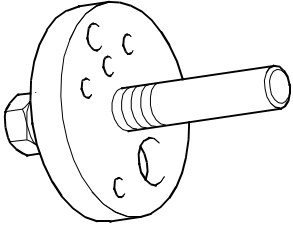
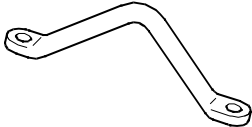
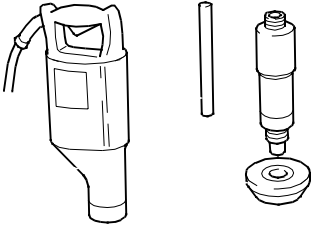
List of special tools

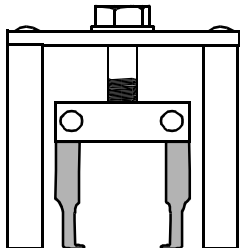
Part number	Description	Illustration
T6253/139	Piston slip ring	
T6253/141	Gearcase oil seal fitting tool	
T6253/142	Camshaft guide tube	
T6253/146	Fuel injector clamp and fuel feed adaptor	
T6253/146A	Fuel injector clamp and fuel feed adaptor	

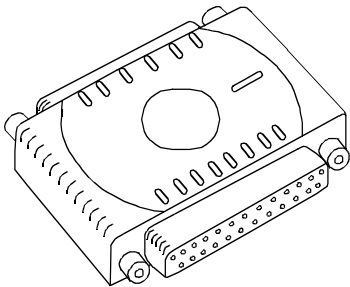
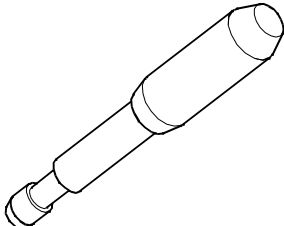
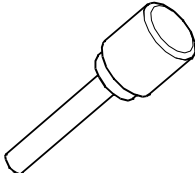
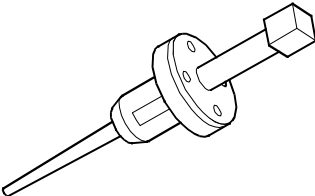
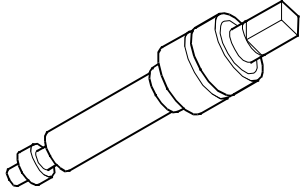
Part number	Description	Illustration
T6253/146B	Adaptor oil seal	
T6253/147	Fuel injector clamp tool	
T6253/152	Liner extractor	
T6253/156	Bush swaging tool	
T6253/157	flywheel guide studs	

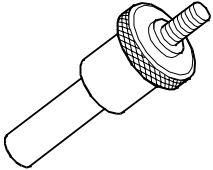
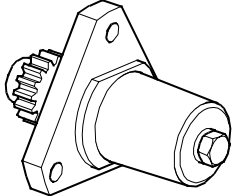
Part number	Description	Illustration
T6253/159	Small end bush extractor and inserter	
T6253/177	Calibration tool	
T6253/140	Flywheel housing oil seal fitting tool	
T6253/197	Spacer tool for breakback lever	
T6253/199	Camshaft bearing removal and fitting tool	

Part number	Description	Illustration
T6253/200	Liner clamp	
T6253/202	Service tool kit	
T6253/203	Needle gauge	
T6253/204	Multi clean	
T6253/208	Nozzle testmaster	

Part number	Description	Illustration
T6253/209	Crankshaft pulley adaptor extractor	
T6253/212	Piston removal and installation tool	
T6253/237	Cylinder head lifting tool	
T6253/238	Circlip pliers	
T6253/240	Valve seat grinding equipment	

Part number	Description	Illustration
T6253/256	Piston ring tool	
T6253/243	Valve spring compressor	
T6253/307	Valve guide removal tool	
T6253/350	Fuel injector removal	
T85001/33	Gear space tool	

Part number	Description	Illustration
680/199	Dongle	 A rectangular electronic device with a circular cutout in the center and a multi-pin connector on one side.
T85002/2	Injector bush inserting tool	 A long, thin cylindrical tool with a wider, flanged end.
T85002/4	Valve seat fitting tool	 A short, thick cylindrical tool with a wider, flanged end.
T85002/6	Bush expanding tool lower	 A tool with a long, thin shaft and a wider, flanged end with a central hole.
T85002/7	Facing cutter	 A tool with a long, thin shaft and a wider, flanged end with a central hole.

Part number	Description	Illustration
T85002/14	Depth gauge	
T85002/58	Bush expanding tool	
T85090/2	Valve guide fitting tool	
T9142/21	Drift	
SE253	Engine cranking device	

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