
Perkins 4.41 Series

Model LM

WORKSHOP MANUAL

**4 cylinder, naturally aspirated, diesel engine for
agricultural and industrial use**

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PACE

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
Safety precautions	4
Engine lift equipment	6
Viton seals	7
POWERPART recommended consumable products	8

2 Specifications

Basic engine data	11
Data and dimensions	12
Recommended torque settings	28
Compression test data	30

3 Cylinder head assembly

General description	31
----------------------------------	----

Rocker cover

Operation 3-1 To remove and to fit	32
--	----

Rocker assembly

Operation 3-2 To remove and to fit	33
Operation 3-3 To dismantle and to assemble	34
Operation 3-4 To inspect and to correct	34

Valve tip clearances

Operation 3-5 To check and to adjust	35
--	----

Valve springs

Operation 3-6 To change the valve springs (with cylinder head fitted)	36
---	----

Cylinder head assembly

Operation 3-7 To remove	38
Operation 3-8 To fit	40

Valves and valve springs

Operation 3-9 To remove	44
Operation 3-10 To fit	45
Operation 3-11 To inspect and to correct	46

Valve guides

Operation 3-12 To inspect	47
Operation 3-13 To remove	48
Operation 3-14 To fit	49

Cylinder head

Operation 3-15 To inspect and to correct	50
Operation 3-16 To correct a valve seat with a valve seat cutter	51
Operation 3-17 To fit valve seat inserts	52

4 Piston and connecting rod assemblies

General description	53
----------------------------------	----

Big end bearing

Operation 4-1 To remove	54
Operation 4-2 To fit	55
Operation 4-3 To inspect	55

Piston and connecting rod

Operation 4-4 To remove	56
Operation 4-5 To fit	57
Operation 4-6 To check the piston height above the cylinder block	59

Piston rings

Operation 4-7 To remove and to fit	60
--	----

Piston and connecting rod assembly

Operation 4-8 To dismantle	61
Operation 4-9 To assemble	62

Piston and piston rings

Operation 4-10 To inspect	63
---------------------------------	----

Connecting rod

Operation 4-11 To inspect	64
---------------------------------	----

Small end bush

Operation 4-12 To remove and to fit	64
---	----

5 Crankshaft assembly

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

Crankshaft pulley

Operation 5-1 To remove and to fit	66
--	----

Rear oil seal assembly

Operation 5-2 To remove and to fit	67
Operation 5-3 To renew the rear oil seal	68

Thrust washers

Operation 5-4 To check the crankshaft end-float	69
Operation 5-5 To remove	70
Operation 5-6 To fit	71

Main bearings

Operation 5-7 To remove (with the crankshaft in position)	72
Operation 5-8 To fit (with the crankshaft in position)	73
Operation 5-9 To inspect	73

Crankshaft

Operation 5-10 To remove	74
Operation 5-11 To fit	75
Operation 5-12 To inspect	77

Balancer unit

Operation 5-13 To remove	78
Operation 5-14 To fit	79
Operation 5-15 To dismantle	80
Operation 5-16 To assemble	82
Operation 5-17 To inspect	85
Operation 5-18 To remove and to fit the needle roller bearings for the drive shaft	86
Operation 5-19 To remove and to fit the bushes for the balance weights	87

6 Timing case and drive assembly

General description	89
-------------------------------------	----

Timing case cover

Operation 6-1 To remove	90
Operation 6-2 To fit	91

Front oil seal

Operation 6-3 To remove	92
Operation 6-4 To fit	93

Idler gear and hub

Operation 6-5 To remove	94
Operation 6-6 To fit	95

Fuel pump gear

Operation 6-7 To remove	96
Operation 6-8 To fit	97

Camshaft gear

Operation 6-9 To remove	98
Operation 6-10 To fit	99

Crankshaft gear

Operation 6-11 To remove	100
Operation 6-12 To fit	100

Timing case

Operation 6-13 To remove	101
Operation 6-14 To fit	102

Camshaft and tappets

Operation 6-15 To remove	104
Operation 6-16 To fit	105

7 Cylinder block assembly

General description	107
----------------------------------	-----

Cylinder block

Operation 7-1 To dismantle	107
Operation 7-2 To assemble	108
Operation 7-3 To inspect	109

Cylinder liner

Operation 7-4 To inspect	110
Operation 7-5 To recover a glazed liner	111
Operation 7-6 To remove	112
Operation 7-7 To fit a service liner	114

8 Engine timing

Lucas DPA fuel injection pumps

Operation 8-1 General description	117
Operation 8-2 To set number 1 piston to TDC on the compression stroke	118
Operation 8-3 Another method to set number 1 piston to TDC on the compression stroke. 119	
Operation 8-4 To check the valve timing	120
Operation 8-5 To check the timing of the fuel injection pump	121
Operation 8-6 To check the timing mark of the fuel injection pump	122
Operation 8-7 To check the engine timing mark	123

Stanadyne fuel injection pumps

Operation 8-8 General description	124
Operation 8-9 To set number 1 piston to TDC on the compression stroke	124
Operation 8-10 To check the valve timing	124
Operation 8-11 To check the timing of the fuel injection pump	125
Operation 8-12 To check the timing mark of the fuel injection pump	126
Operation 8-13 To check the engine timing mark	128

9 Aspiration system

Open engine breather	129
-----------------------------------	-----

10 Lubrication system

General description	131
Lubrication system flow diagram	132
Lubrication system flow diagram for the relief valve and balancer	133
Filter canister	
Operation 10-1 To renew	134
Filter head	
Operation 10-2 To remove and to fit	135
Sump	
Operation 10-3 To remove and to fit	136
Oil strainer and suction pipe	
Operation 10-4 To remove and to fit	137
Operation 10-5 To inspect and to correct	138
Lubricating oil pump	
Operation 10-6 To remove	139
Operation 10-7 To fit	140
Operation 10-8 To renew the shaft for the idler gear	141
Operation 10-9 To inspect	142
Relief valve	
Operation 10-10 To remove and to fit	143
Operation 10-11 To dismantle and to assemble	144
Operation 10-12 To inspect	144

11 Fuel system

General description	145
Fuel filter element	
Operation 11-1 Fuel filter element types	147
Operation 11-2 To renew the filter element of the separate element type	148
Operation 11-3 To renew the filter element of the canister type	149
Atomisers	
Operation 11-4 Atomiser fault	150
Operation 11-5 To remove and to fit	151
Fuel lift pump	
Operation 11-6 To remove and to fit	152

Operation 11-7 To dismantle	153
Operation 11-8 To assemble	154
Operation 11-9 To test	155

Lucas DPA fuel injection pump

Operation 11-10 To remove	156
Operation 11-11 To fit	157
Operation 11-12 To adjust	158
Operation 11-13 To eliminate air from the fuel system	159

Stanadyne fuel injection pump

Operation 11-14 To remove	161
Operation 11-15 To fit	162
Operation 11-16 To adjust	163
Operation 11-17 To eliminate air from the fuel system	164

12 Cooling system

General description	167
--------------------------------------	-----

Thermostats

Operation 12-1 To remove and to fit	168
Operation 12-2 To test	168

Coolant pump

Operation 12-3 To remove	169
Operation 12-4 To fit	170
Operation 12-5 To dismantle	171
Operation 12-6 To assemble	172

Fan

Operation 12-7 To remove and to fit	174
---	-----

Lubricating oil cooler

Operation 12-8 To remove and to fit (canister type)	175
---	-----

13 Flywheel and flywheel housing

General description	177
--------------------------------------	-----

Flywheel

Operation 13-1 To remove and to fit	178
---	-----

Ring gear

Operation 13-2 To remove and to fit	179
---	-----

Flywheel housing

Operation 13-3 To remove and to fit	180
--	-----

14 Electrical equipment

Alternators	181
---------------------------	-----

Operation 14-1 To check and to adjust drive belt tension	182
Operation 14-2 To remove and to fit the drive belt	183
Operation 14-3 To remove and to fit the alternator	184
Operation 14-4 To maintain the alternator	184

Alternator fault diagnosis	185
--	-----

Starter motors	187
------------------------------	-----

Operation 14-5 To remove and to fit	187
Operation 14-6 To test on the engine	188

Starting aid	189
----------------------------	-----

Operation 14-7 To remove and to fit a fuelled starting aid	189
Operation 14-8 To check the fuelled starting aid	190

15 Auxiliary equipment

Power take-off adaptors (adaptor for a hydraulic pump)

Operation 15-1 To remove and to fit	191
Operation 15-2 To dismantle	192
Operation 15-3 To assemble	193

Exhauster

Operation 15-4 To remove and to fit	194
--	-----

16 Special tools

List of special tools	195
-------------------------------------	-----

1

General information

Introduction

This Workshop Manual has been designed to provide assistance in the service and overhaul of Perkins 4.41 engine. For overhaul procedures the assumption is made that the engine is removed from the application.

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.

The details of some operations will be different according to the type of fuel injection pump which is fitted. The specific pump type used can be found by reference to the manufacturer's identification plate on the pump body but, generally, the type of pump fitted is as shown below:

- Lucas - DPA
- Stanadyne - DB2.

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

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.

Data and dimensions are included in Chapter 2, Specifications.

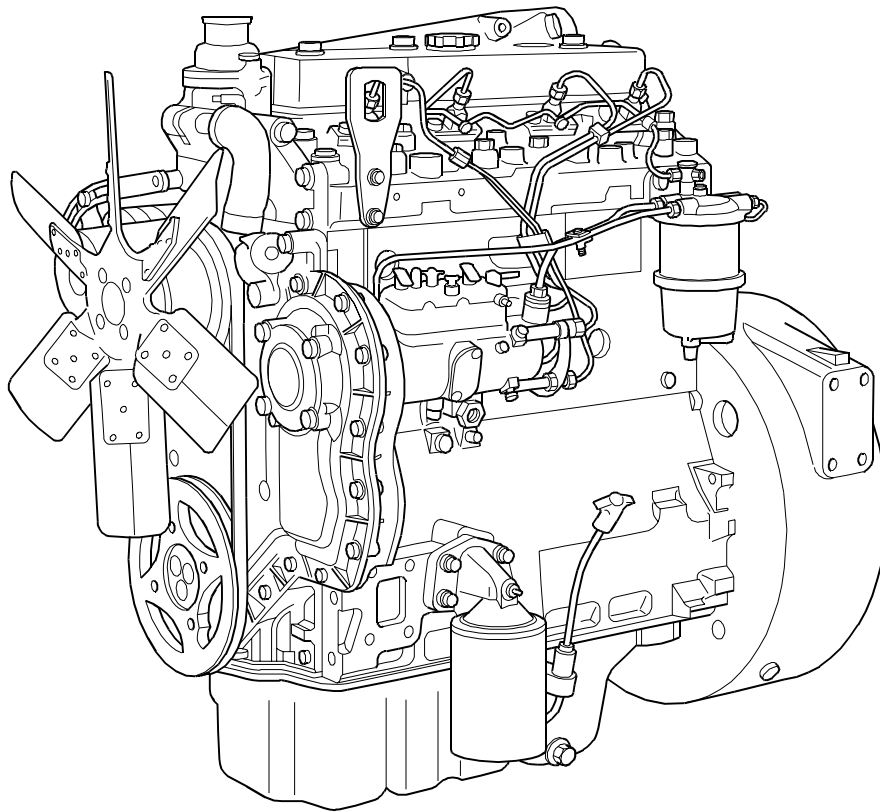
Read and remember the "Safety precautions" on page 4. They are given for your protection and must be used at all times.

Danger is indicated in the text by two methods:

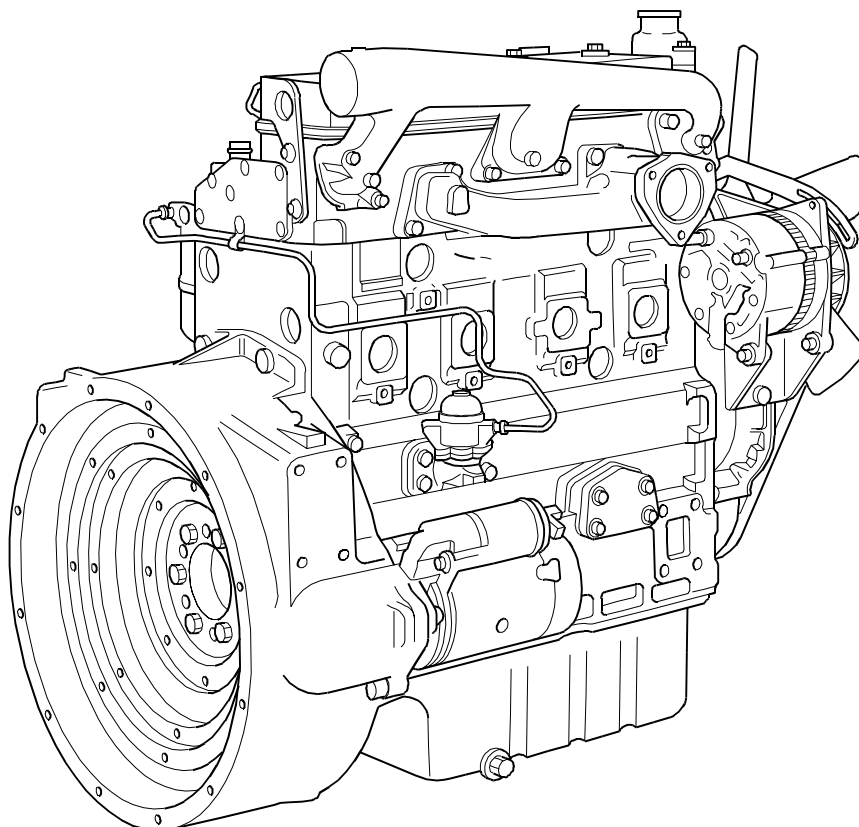
Warning! *This indicates that there is a possible danger to the person.*

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 views

L0002



L0003

Engine identification

The Perkins 4.41 engine has been designed for agricultural, industrial and generator set applications.

In this Workshop Manual, the engine type is indicated by code letters. These are the first two letters of the engine number as indicated below:

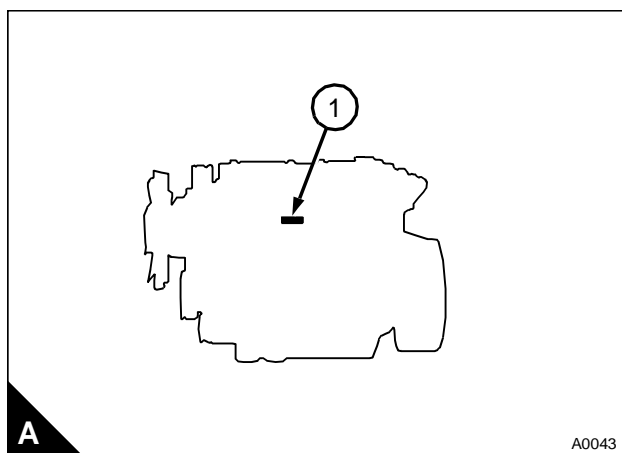
Code letters	Engine type
LM	Four cylinder, naturally aspirated

The engine number is stamped on a label which is fastened to the left side (A1) of the cylinder block. An example of an engine number is:

LM 50190 U 123450 A

Further information about the engine number system can be found in the relevant user's handbook.

Note: If you need parts, service or information for your engine, you must give the complete engine number to your Perkins distributor.



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 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.
- 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.
- 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.
- Disconnect the battery terminals before a repair is made to the electrical system.
- Only one person must control the engine.
- Ensure that the engine is operated only from the control panel or from the operators 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.
- 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 a safe place 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.

Continued

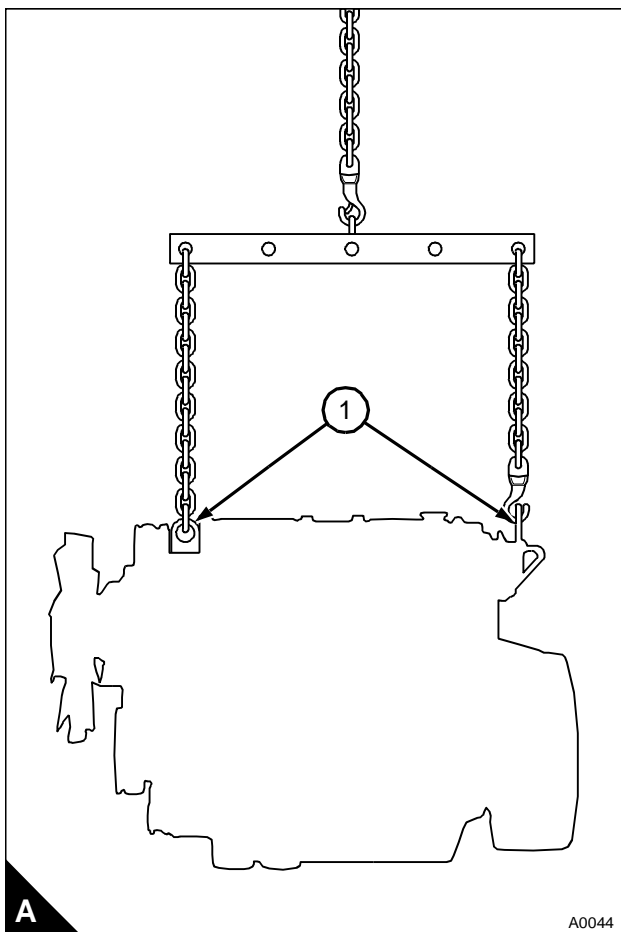
- The combustible material of some components of the engine (for example certain seals) can become extremely dangerous if it is burned. Never allow this burnt material to come into contact with the skin or with the eyes. Refer to "Viton seals" on page 7.
- Read and use the instructions relevant to lift equipment, see "Engine lift equipment" on page 6.
- 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.
- Do not allow compressed air to contact your skin. If compressed air enters your skin, obtain medical help immediately.
- Do not clean an engine while it runs. If cold cleaning fluids are applied to a hot engine, certain components on the engine may be damaged.
- Fit only genuine Perkins parts.

Engine lift equipment

The maximum weight of the engine without coolant, lubricant or a gearbox fitted will vary for different applications. It is recommended that lift equipment of 500 Kg (1100 lbs) minimum capacity is used.

Before the engine is lifted:

- Always use engine lift equipment of the approved type and of the correct capacity to lift the engine. It is recommended that lift equipment of the type shown in (A) is used to provide a vertical lift, directly above the engine lift brackets (A1). Never use a single lift bracket to raise an engine.
- Check the engine lift brackets for damage and that they are secure before the engine is lifted. The torque for the setscrews for the engine lift brackets is 44 Nm (33 lbf ft) 4,5 kgf m.
- To prevent damage to the rocker cover, ensure that there is clearance between the hooks and the rocker cover.
- Use lift equipment or obtain assistance to lift heavy engine components such as the cylinder block, the cylinder head, the balancer unit, the flywheel housing, the crankshaft and the flywheel.



Viton seals

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

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

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 15-60 minutes. **Obtain immediate medical attention.**

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 Antifreeze

Protects the cooling system against frost and corrosion. Part number 1 litre 21825166 or 5 litres 21825167.

POWERPART Chisel

Allows easy removal of old gaskets and joints. Currently Loctite chisel. Part number 21825163.

POWERPART Compound

To seal the outer diameter of seals. Currently Loctite Forma Gasket No 2. Part number 1861147.

POWERPART Easy Flush

Cleans the cooling system. Part number 2182501

POWERPART Gasket eliminator

Improves flange sealing when a gasket is not used. It provides a seal with temperature resistance that is flexible in positions where vibration and pressure occur. Currently Loctite 515. Part number 21826040.

POWERPART Jointing compound

Universal jointing compound which seals joints. Currently Hylomar. Part number 1861155 or 1861117.

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 Liquid gasket

To seal flat faces of components where no joint is used. Especially suitable for aluminium components. Currently Loctite 518. Part number 21820518

POWERPART Nutlock

To retain and seal threaded fasteners and cup plugs where easy removal is necessary. Currently Loctite 242e. Part number 21820242

POWERPART Platelock

For tight fitted metal surfaces. Suitable for metal plated surfaces and stainless steel, Currently Loctite 243. Part number 21826039.

POWERPART Repel

Dries damp equipment and gives protection against corrosion. Passes through dirt and corrosion to lubricate and to assist removal of components. Currently Loctite repel. Part number 21825164.

Continued

POWERPART Retainer (oil tolerant)

To retain components which have a transition fit. Currently Loctite 603. Part number 21820603.

POWERPART Retainer (high strength)

To retain components which have an interference fit. Currently Loctite 638. Part number 21820638

POWERPART Silicone adhesive

An RTV silicone adhesive for application where low-pressure tests occur before the adhesive sets. Used to prevent leakage where movement of the joint occurs. Currently Loctite 5900. Part number 21826038.

POWERPART Silicone rubber sealant

Silicone rubber sealant which prevents leakage through gaps. Currently Hylosil Part number 1861108.

POWERPART Studlock

To permanently retain large fasteners and studs. Currently Loctite 270. Part number 21820270.

POWERPART Threadlock

To retain small fasteners where easy removal is necessary. Currently Loctite 222e. Part number 21820222.

POWERPART Threadlock (hydraulic/pneumatic)

To retain and seal pipe connections with fine threads. Especially suitable for hydraulic and pneumatic systems. Currently Loctite 542. Part number 21820542

POWERPART Threadlock (pipe)

To retain and seal pipe connections with coarse threads. Pressure systems can be used immediately. Currently Loctite 575. Part number 21820575.

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2

Specifications

Basic engine data

Number of cylinders.	4
Cylinder arrangement..	In-line
Cycle	Four stroke
Direction of rotation	Clockwise from the front
Induction system..	Naturally aspirated
Combustion system	Direct injection
Nominal bore	101 mm (3.98 in)
Stroke	127 mm (5.000 in)
Compression ratio	15.3:1
Cubic capacity	407 litres (248 in ³)
Firing order	1, 3, 4, 2
Valve tip clearance (cold):	
- Inlet	0,20 mm (0.008 in)
- Exhaust	0,45 mm (0.018 in)
Lubricating oil pressure ⁽¹⁾207 kpa (30 lbf/in ²) 2,1 kgf/cm ²

(1) Minimum at maximum engine speed and normal engine temperature.

Data and dimensions

Note: This information is given as a guide for personnel engaged on engine overhauls. The dimensions which are shown are those which are mainly used in the factory. The information applies to all engines, unless an engine type code is shown.

Cylinder head

Angle of valve seat:

Exhaust... .. 46° (88° included angle)

Inlet 46° (88° included angle)

Diameter of parent bore for valve guide. 15,87/15,89 mm (0.6247/0.6257 in)

Leak test pressure 200 kPa (29 lbf/in²) 2,04 kgf/cm²

Head thickness 102,79/103,59 mm (4.047/4.078 in)

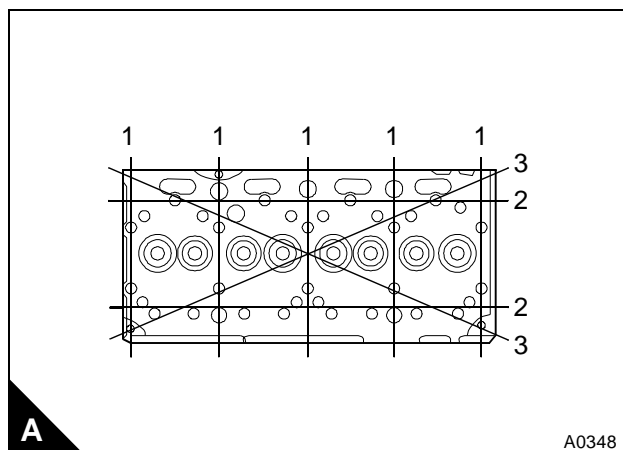
Minimum permissible thickness after head face has been machined 102,48 mm (4.035 in)

Maximum permissible distortion of cylinder head

A1... .. 0,08 mm (0.003 in)

A2... .. 0,15 mm (0.006 in)

A3... .. 0,15 mm (0.006 in)



Inlet and exhaust valves

Inlet valves

Diameter of valve stem	9,46/9,49 mm (0.3725/0.3735 in)
Clearance in valve guide	0,02/0,10 mm (0.0008/0.0039 in)
Maximum clearance in valve guide	0,13 mm (0.005 in)
Diameter of valve head	44,86/45,11 mm (1.766/1.776 in)
Angle of valve face	45°
Seal arrangement	Rubber seal fitted to valve guide
Depth of valve head below the face of cylinder head:	
Production limits	1,27/1,60 mm (0.050/0.063 in)
Service limit	1,85 mm (0.073 in)

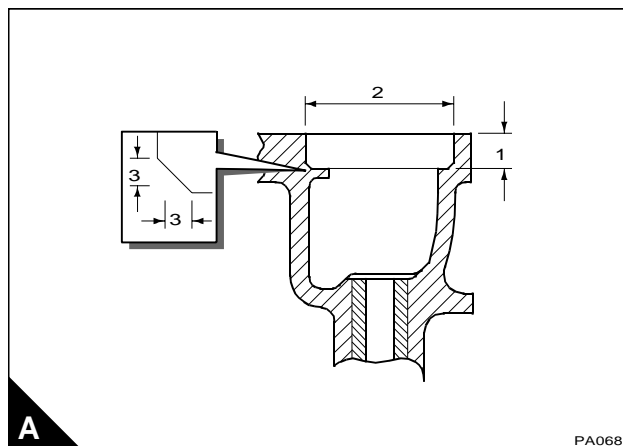
Exhaust valves

Diameter of valve stem	9,43/9,46 mm (0.371/0.372 in)
Clearance in valve guide	0,05/0,13 mm (0.002/0.005 in)
Maximum clearance in valve guide	0,15 mm (0.006 in)
Diameter of valve head	37,26/37,52 mm (1.467/1.477 in)
Angle of valve face	45°
Seal arrangement	Rubber seal fitted to valve guide
Depth of valve head below face of cylinder head:	
Production limits	1,28/1,60 mm (0.050/0.063 in)
Service limit	1,85 mm (0.073 in)

Valve seat inserts

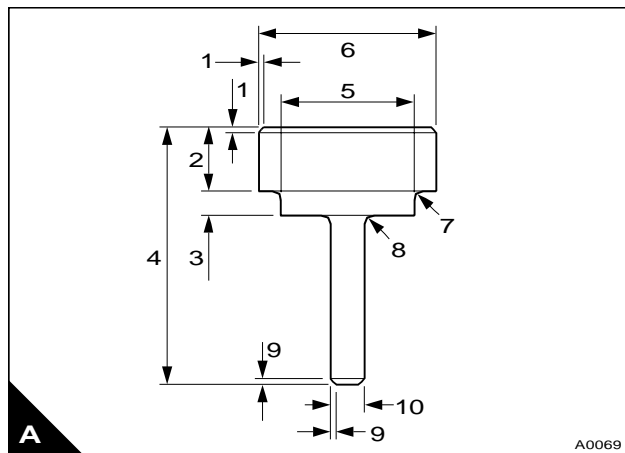
Dimensions of recesses for valve seat inserts

Measurement	Inlet	Exhaust
A1	7,19/7,32 mm (0.283/0.288 in)	9,52/9,65 mm (0.375/0.380 in)
A2	51,22/51,24 mm (2.0165/2.0175 in)	42,62/42,65 mm (1.6780/1.6790 in)
A3	Chamfer 0,38 mm (0.015 in) maximum	Chamfer 0,38 mm (0.015 in) maximum



Valve seat insert tool

Measurement	Inlet	Exhaust
A1	1,59 mm (0.063 in)	1,59 mm (0.063 in)
A2	19,05 mm (0.750 in)	19,05 mm (0.750 in)
A3	6,35 mm (0.250 in)	7,92 mm (0.312 in)
A4	76,20 mm (3.00 in)	76,20 mm (3.00 in)
A5	37,26/37,28 mm (1.467/1.468 in)	32,58/32,84 mm (1.283/1.293 in)
A6	51,00/51,23 mm (2.008/2.017 in)	42,39/42,62 mm (1,669/1.678 in)
A7	0,79 mm (0.031 in)	0,79 mm (0.031 in)
A8	1,59 mm (0.063 in)	1,59 mm (0.063 in)
A9	1,59 mm (0.063 in)	1,59 mm (0.063 in)
A10	9,45/9,47 mm (0.372/0.373 in)	9,45/9,47 mm (0.372/0.373 in)



Valve guides and valve springs

Valve guides

Inside diameter 9,51/9,56 mm (0.3744/0.3764 in)
 Outside diameter 15,90/15,91 mm (0.6260/0.6265 in)
 Interference fit of valve guide in cylinder head... .. 0,03/0,07 mm (0.0012/0.0027 in)

Length:

Inlet 57,94 mm (2.281 in)
 Exhaust.. ... 61,10 mm (2.406 in)
 Protrusion from bottom of recess for valve spring 15,10 mm (0.594 in)

Single valve springs

Fitted length 40,0 mm (1.57 in)
 Load at fitted length 312/344 N (70.1/77.3 lbf) 31,8/35,1 kgf
 Number of active coils 4.5
 Number of damper coils. 0
 Direction of coils. Left hand

Tappets, rocker shaft, rocker levers and bushes

Tappets

Diameter of tappet stem. 18,99/19,01 mm (0.7475/0.7485 in)
 Diameter of tappet bore in cylinder block... .. 19,05/19,08 mm (0.7500/0.7512 in)
 Clearance of tappet in cylinder block. 0,04/0,09 mm (0.0015/0.0037 in)

Rocker shaft

Outside diameter 19,01/19,04 mm (0.7485/0.7495 in)

Rocker levers and bushes

Maximum permissible clearance between rocker lever bush and rocker shaft.. ... 0,13 mm (0.005 in)

Pistons and connecting rods

Pistons

Type.	"Toroidal" combustion bowl, controlled expansion
Diameter of bore for gudgeon pin	34,928/34,934 mm (1.3751/1.3754 in)
Height of piston above top face of cylinder block	0,14/0,36 mm (0.005/0.014 in)
Width of groove for top ring	2,54/2,56 mm (0.1000/0.1007 in)
Width of groove for second ring.....	2,54/2,56 mm (0.1000/0.1007 in)
Width of groove for third ring	5,04/5,06 mm (0.1984/0.1992 in)

Piston rings

Top compression ring	Barrel face, molybdenum insert, internal top step
Second compression ring	Taper face, cast iron
Oil scraper ring	Coil spring loaded, chromium faced
Width of top ring	2,46/2,49 mm (0.097/0.098 in)
Width of second ring	2,48/2,49 mm (0.097/0.098 in)
Width of third ring	4,98/4,99 mm (0.1960/0.1964 in)
Clearance of top ring in groove	0,05/0,10 mm (0.002/0.004 in)
Clearance of second ring in groove	0,05/0,08 mm (0.002/0.003 in)
Clearance of third ring in groove	0,05/0,08 mm (0.002/0.003 in)
Gap of top ring	0,41/0,86 mm (0.016/0.034 in)
Gap of second ring	0,40/0,86 mm (0.016/0.034 in)
Gap of third ring.....	0,40/0,86 mm (0.016/0.034 in)

Connecting rods

Type.	'H' section, square shape small end
Location of cap to connecting rod	Serrations
Diameter of parent bore for big end.	67,21/67,22 mm (2.6460/2.6465 in)
Diameter of parent bore for small end	38,89/38,92 mm (1.531/1.532 in)
Length between centres	219,05/219,10 mm (8.624/8.626 in)

Connecting rod bearings

Type:	Steel back, aluminium/tin bearing material
Width:	31,62/31,88 mm (1.245/1.255 in)
Thickness at centre of bearings:.....	1,835/1,842 mm (0.0723/0.0725 in)
Bearing clearance:.....	0,035/0,081 mm (0.0014/0.0032 in)
Available undersize bearings.....	-0,25 mm (-0.010 in); -0,51 mm (-0.020 in); -0,76 mm (-0.030 in)

Gudgeon pins

Type.	Fully floating
Outside diameter	34,920/34,925 mm (1.3748/1.3750 in)
Clearance fit in piston boss	0,003/0,014 mm (0.0001/0.0006 in)

Small end bushes

Type.	Steel back, lead-bronze or lead-bronze tin bearing material
Outside diameter	38,94/39,03 mm (1.535/1.536 in)
Inside diameter (reamed)	34,94/34,96 mm (1.3758/1.3765 in)
Clearance between bush in small end and gudgeon pin.	0,020/0,043 mm (0.0008/0.0017 in)

Crankshaft

Diameter of main journals..	76,16/76,18 mm (2.998/2.999 in)
Maximum wear and ovality on journals and crank pins .	0,04 mm (0.0016 in)
Width of front journal..	36,93/37,69 mm (1.454/1.484 in)
Width of centre journal...	44,15/44,22 mm (1.738/1.741 in)
Width of all other journals ..	39,24/39,35 mm (1.545/1.549 in)
Diameter of crank pins...	63,47/63,49 mm (2.499/2.500 in)
Width of crank pins ..	40,35/40,42 mm (1.589/1.591 in)
Diameter of flange..	133,27/133,37 mm (5.247/5.251 in)
Depth of recess for spigot bearing.	20,22/20,98 mm (0.796/0.826 in)
Bore of recess for spigot bearing...	46,96/46,99 mm (1.849/1.850 in)
Crankshaft end-float...	0,05/0,38 mm (0.002/0.015 in)
Maximum permissible end-float .	..0,51 mm (0.020 in)
Fillet radii of journals and crank pins..	3,68/3,96 mm (0.145/0.156 in)
Undersize journals and crank pins.-0,25 mm (-0.010 in); -0,51 mm (-0.020 in); -0,76 mm (-0.030 in)
Crankshaft heat treatment .	Induction hardened

Crankshaft overhaul

Notes:

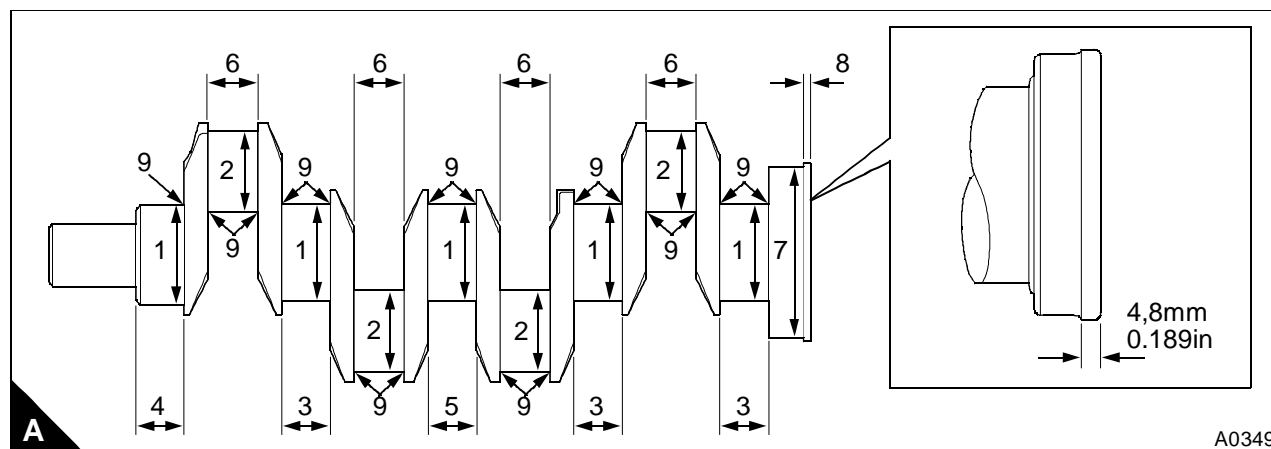
- Induction hardened crankshafts need not be hardened after they have been machined undersize.
- Check the crankshaft for cracks before and after it is ground. Demagnetise the crankshaft after it has been checked for cracks.
- After the crankshaft has been machined remove any sharp corners from the lubricating oil holes.
- Surface finish and fillet radii must be maintained.

The finished sizes for crankshaft journals (A) which have been ground undersize are given in the table below:

Item	0,25 mm (0.010 in)	0,51 mm (0.020 in)	0,76 mm (0.030 in)
1	75,905/75.926 mm (2.9884/2.9892 in)	75,651/75,672 mm (2.9784/2.9792 in)	75,397/75,418 mm (2.9684/2.9692 in)
2	63,216/63,236 mm (2.4888/2.4896 in)	62,962/62,982 mm (2.4788/2.4796 in)	62,708/62,728 mm (2.4688/2.4696 in)
3	39,47 mm (1.554) maximum	-	-
4	37,82 mm (1.489 in) maximum	-	-
5	44,68 mm (1.759 in) maximum	-	-
6	40,55 mm (1.596 in) maximum	-	-
7	133,17 mm (5.243 in) minimum	-	-
8	Do not machine this diameter	-	-
9	3,68/3,96 mm (0.145/0.156 in)	-	-

Surface finish for journals, crank pins and fillet radii must be 0,4 microns (16 micro inches).

Surface finish for seal area of crankshaft palm must be 0,4/1,1 microns (16/43 micro inches).



Continued

With the crankshaft on mountings at the front and rear journals, the maximum run-out (total indicator reading) at the journals must not be more than shown below:

Journal	Crankshaft
1	Mounting
2	0,08 mm (0.003 in)
3	0,15 mm (0.006 in)
4	0,08 mm (0.003 in)
5	Mounting

Run-out must not be opposite. The difference in run-out between one journal and the next must not be more than 0,10 mm (0.004 in).

Run-out on the crankshaft pulley diameter, rear oil seal diameter and the rear flange diameter must not be more than 0,05 mm (0.002 in) total indicator reading.

Crankshaft bearings and thrust washers

Main bearings

Type (All bearings) .. Steel back, 20% tin-aluminium bearing material

Bearing width

Centre bearing .. 36,32/36,70 mm (1.430/1.445 in)

All other bearings .. 31,62/31,88 mm (1.245/1.255 in)

Bearing thickness at centre

All bearings .. 2,083/2,089 mm (0.0820/0.0823 in)

Bearing clearance

All bearings .. 0,057/0,117 mm (0.0022/0.0046 in)

Available undersize bearings .. -0,25 mm (-0.010 in); -0,51 mm (-0.020 in); -0,76 mm (-0.030 in)

Crankshaft thrust washers

Type .. Steel back, lead bronze bearing material

Position .. Each side of centre main bearing

Thickness:

Standard .. 2,26/2,31 mm (0.089/0.091 in)

Oversize .. 2,45/2,50 mm (0.096/0.098 in)

Balancer unit

Diameter of drive shaft for front bearing .. 28,562/28,575 mm (1.1245/1.1250 in)

Diameter of drive shaft for rear bearing .. 23,787/23,800 mm (0.9365/0.9370 in)

Number of teeth on gear of drive shaft .. 21

Backlash from gear of drive shaft to idler gear .. 0,17/0,29 mm (0.007/0.011 in)

End-float of drive shaft .. 0,13/0,30 mm (0.005/0.012 in)

Diameter of bore for front bearing of drive shaft .. 34,912/34,937 mm (1.3745/1.3755 in)

Diameter of bore for rear bearing of drive shaft .. 29,972/29,993 mm (1.1800/1.1808 in)

Diameter of bore for idler gear .. 47,64/47,65 mm (1.8755/1.8760 in)

Diameter of hub of idler gear .. 38,09/38,10 mm (1.4996/1.5000 in)

End-float of idler gear .. 0,07/0,23 mm (0.003/0.009 in)

Thickness of thrust washer for idler gear .. 4,14/4,29 mm (0.163/0.169 in)

Number of teeth on idler gear .. 37

Inside diameter of bushes in balancer frame and end cover (fitted) .. 38,133/38,174 mm (1.5013/1.5029 in)

Diameter of spigots for balance weights .. 38,054/38,069 mm (1.4982/1.4988 in)

Fit of spigot in bush .. 0,064/0,120 mm (0.0025/0.0047 in)

End-float of balance weights .. 0,19/0,40 mm (0.007/0.016 in)

Backlash of gears on balance weights .. 0,10/0,27 mm (0.004/0.011 in)

Backlash of drive gear to spline on balance weight .. 0,05/0,20 mm (0.002/0.008 in)

Number of teeth on drive gear .. 24

Number of teeth on spline on balance weight .. 16

Timing case and drive assembly

Camshaft

Diameter of number 1 journal	50,71/50,74 mm (1.9965/1.9975 in)
Diameter of number 2 journal	50,46/50,48 mm (1.9865/1.9875 in)
Diameter of number 3 journal:	49,95/49,98 mm (1.9665/1.9675 in)

Cam lift:

Inlet	7,62/7,69 mm (0.2999/0.3029 in)
Exhaust..	7,71/7,79 mm (0.3036/0.3066 in)
Maximum permissible ovality and wear on journals...	0,05 mm (0.021 in)

End-float:

Production limits.	0,10/0,41 mm (0.004/0.016 in)
Service limit	0,53 mm (0.021 in)
Width of spigot for thrust washer	5,64/5,89 mm (0.222/0.232 in)

Camshaft thrust washer

Type	360°
Depth of recess in cylinder block for thrust washer	5,46/5,54 mm (0.215/0.218 in)
Thickness of thrust washer	5,49/5,54 mm (0.216/0.218 in)
Relationship of thrust washer to front face of cylinder block..	-0,05/+0,08 mm (-0.002/+0.003 in)

Camshaft gear

Number of teeth	56
Diameter of bore	34,93/34,95 mm (1.3750/1.3760 in)
Outside diameter of hub of camshaft.	34,90/34,92 mm (1.3741/1.3747 in)
Clearance fit of gear on hub	0,008/0,048 mm (0.0003/0.0019 in)

Fuel pump gear

Number of teeth	56
-----------------	----

Crankshaft gear

Number of teeth	28
Diameter of bore	47,625/47,650 mm (1.8750/1.8760 in)
Diameter of hub for gear on crankshaft	47,625/47,645 mm (1.8750/1.8758 in)
Transition fit of gear on crankshaft.	-0,020/+0,048 mm (-0.0008/+0.0010 in)

Idler gear and hub

Number of teeth	63
Diameter of bore of gear	57,14/57,18 mm (2.2495/2.2512 in)
Width of gear and split bush assembly (fitted in position)..	30,66/31,16 mm (1.207/1.227 in)
Inside diameter of flanged bushes (fitted in position).	50,78/50,80 mm (1.999/2.000 in)
Outside diameter of hub.	50,70/50,74 mm (1.9960/1.9975 in)
Clearance of bushes on hub..	0,04/0,10 mm (0.0016/0.0039 in)

End float of gear:

Production limits (cast iron gears)..	0,10/0,20 mm (0.004/0.008 in)
Production limits (steel gears)	0,24/0,33 mm (0.009/1.299 in)
Service limit	0,38 mm (0.015 in)
Backlash for all gears.	0,08 mm (0.003 in) minimum

Cylinder block assembly

Cylinder block

Height between top and bottom faces	441,12/441,33 mm (17.367/17.375 in)
Diameter of parent bore for cylinder liner	104,25/104,28 mm (4.104/4.106 in)
Depth of recess for flange of cylinder liner	3,81/3,91 mm (0.150/0.154 in)
Diameter of recess for flange of cylinder liner	107,82/107,95 mm (4.245/4.250 in)
Diameter of parent bore for main bearing	80,416/80,442 mm (3.1660/3.1670 in)

Camshaft bore diameter

Four cylinder engines:

Number 1 (for bush)	55,56/55,59 mm (2.188/2.189 in)
Number 2	50,55/50,60 mm (1.990/1.992 in)
Number 3	50,04/50,09 mm (1.970/1.972 in)
Bore of bush for number 1 camshaft journal	50,79/50,85 mm (2.000/2.002 in)

Cylinder liners

Type:

Production	Dry, interference fit, flanged
Service	Dry, transition fit, flanged
Outside diameter of production liner	104,25/104,28 mm (4.105/4.106 in)
Interference fit of production liner	0,03/0,08 mm (0.001/0.003 in)
Inside diameter of production liner (finished)	101,054/101,079 mm (3.978/3.979 in)
Transition fit of service liner	+/- 0,03 mm (+/- 0.001 in)
Inside diameter of service liner (fitted)	101,092/101,117 mm (3.980/3.981 in)
Thickness of flange	3,81/3,86 mm (0.150/0.152 in)
Relative position of top of liner flange to top face of cylinder block	0,10 mm (0.004 in) above/ 0,10 mm (0.004 in) below

Engine timing

Static timing - CAV fuel injection pump

The engine check angle must be used with special tool MS.67B and with the engine set with number 1 piston at top dead centre (TDC) on the compression stroke. The pump is checked with the pump set at the start of injection for number 1 cylinder.

The code letters are included in the setting code stamped on the data plate of the fuel injection pump. Some fuel pumps may have the setting code stamped on a modification plate which is fastened to the flange of the pump. If a modification plate is fitted, use the code letters stamped on this plate. A typical setting code is 2643D00AD/2/2420; in this example the code letters are "AD".

Fuel pump code letters	Engine check angle (degrees)	Pump mark angle (degrees)
AD	280.5	291
BD	280.5	293
CD	280.5	287
FD	286	296

Static timing - Stanadyne fuel injection pump

The engine check angle must be used with special tool MS.67B and with the engine set with the piston of the number 1 cylinder at top dead centre (TDC) on the compression stroke. The pump is checked with the pump set at the start of injection for the number one cylinder.

Fuel pump code letters	Engine check angle (degrees)	Pump mark angle (degrees)
DD	286	297

Lubrication system

Lubricating oil pump

Type... .. Differential rotor, gear driven

Number of lobes. Inner rotor 6, outer rotor 7

Clearance of outer rotor to body:

Without balancer unit. 0,15/0,34 mm (0.006/0.013 in)

With balancer unit 0,31/0,45 mm (0.012/0.017 in)

Clearance of inner rotor to outer rotor 0,04/0,13 mm (0.0015/0.0050 in)

End-float of rotor assembly 0,03/0,10 mm (0.001/0.004 in)

Idler gear for lubricating oil pump

End float. 0,03/0,33 mm (0.001/0.013 in)

Inside diameter of bush (fitted) 22,23/22,26 mm (0.875/0.866 in)

Outside diameter of idler shaft... .. 22,19/22,21 mm (0.873/0.874 in)

Clearance of bush of idler gear on shaft 0,020/0,066 mm (0.0008/0.0026 in)

Oil pressure relief valve (standard)

Diameter of bore for plunger 18,24/18,27 mm (0.718/0.719 in)

Outside diameter of plunger... .. 18,16/18,18 mm (0.715/0.716 in)

Clearance of plunger in bore.. 0,06/0,11 mm (0.002/0.004 in)

Length of spring (fitted) 59,8 mm (2.4 in)

Load on spring (fitted) 15,9/23,1 N (3.6/5.2 lbf) 1,6/2,4 kgf

Pressure to open valve 340/395 kPa (49/57 lbf/in²) 3,4/4,0 kgf/cm²

Continued

Oil pressure relief valve (with balancer)

Diameter of bore for plunger 16,00/16,03 mm (0.630/0.631 in)
 Outside diameter of plunger 15,95/15,98 mm (0.628/0.629 in)
 Clearance of plunger in bore 0,02/0,08 mm (0.0008/0.003 in)
 Length of spring (fitted) 42,7 mm (1.7 in)

Load on spring (fitted):

Engines without piston cooling jets.. ... 24/30 N (5.4/6.7 lbf) 2,4/3,1 kgf

Pressure to open valve:

Engines without piston cooling jets.. ... 414 kPa (60 lbf/in²) 4,2 kgf/cm²

Oil filter

Type. Full flow, screw-on type canister

Pressure to open by-pass valve in filter... .. 55/83 kPa (8/12 lbf/in²) 0,6/0,8 kgf/cm²

Pressure to open by-pass valve in oil cooler 172 kPa (25 lbf/in²) 1,8 kgf/cm²

Fuel system**CAV fuel injection pump**

Type. DPA

Direction of rotation from drive end Clockwise

Outlet for number 1 cylinder Letter "W"

Stanadyne fuel injection pump

Type. Stanadyne DB2

Outlet for number 1 cylinder 8 o'clock position as seen from the rear of the pump

Direction of rotation from drive end Clockwise

Fuel system Self-vent

Fuel lift pump

Type. A.C.Delco, type XD

Method of drive Eccentric on camshaft of engine

Static pressure (no delivery) 42/70 kPa (6/10 lbf/in²) 0,4/0,7 kgf/cm²

Test pressure (75% of minimum static pressure) 31 kPa (4.5 lbf/in²) 0,32 kgf/cm²

Atomiser service settings

CAV fuel injection pump

Code	Holder	Nozzle	Set and reset procedure		
			atm	(lbf/in ²)	MPa
HD	LRB67015	JB6801012	260	3822	26,4
HL	LRB67014	JB6801014	230	3381	23,3
HU	LRB67014	JB6801014	220	3234	22,3
HZ	LRB67014	JB6801014	220	3234	22,3
JS	2645A302	2645A608	220	3234	22,3

Stanadyne fuel injection pump

Code	Holder	Nozzle	Set and reset procedure		
			atm	(lbf/in ²)	MPa
NP	2645L304	2645L613	220	3234	22,3

Note: The code letters are stamped on the side of the atomiser body just below the connection for the nut of the high pressure pipe.

Coolant pump

Type... .. Centrifugal, belt driven
 Outside diameter of shaft for pulley 24,587/24,600 mm (0.9679/0.9685 in)
 Inside diameter of bore of pulley 24,628/24,648 mm (0.9696/0.9704 in)
 Clearance fit of pulley on shaft... .. 0,03/0,06 mm (0.001/0.002 in)
 Diameter of bore of impeller... .. 15,872/15,893 mm (0.6248/0.6257 in)
 Outside diameter of shaft for impeller 15,9055/15,9182 mm (0.6263/0.6267 in)
 Interference fit of impeller on shaft. 0,01/0,04 mm (0.0004/0.0016 in)
 Impeller to body clearance. 0,69/0,89 mm (0.027/0.035 in)
 Diameter of bearing62,000 mm (2.440 in)
 Diameter of bore for bearing..62,019/62,000 mm (2.441/24.000 in)
 Interference fit of bearing in pump body 0,01/0,04 mm (0.0004/0.0016 in)

Thermostat

Type... ..Single, wax element, by-pass blanking

Nominal temperature stamped on thermostat by-pass valve	"Start to open" temperature	"Fully open" temperature	Minimum valve lift, fully open
82 °C (170 °F)	77/85 °C (170/185 °F)	92/98 °C (198/208 °F)	9 mm (0.35 in)
71 °C (160 °F)	67/75 °C (153/167 °F)	85/88 °C (185/190 °F)	9 mm (0.35 in)

Flywheel and flywheel housing

Limits for flywheel housing run-out and alignment (total indicator reading)

Diameter of housing flange bore		Maximum limit (total indicator reading)	
mm	in	mm	in
362	14.25	0,23	0.009
410	16.14	0,25	0.010
448	17.63	0,28	0.011
511	20.11	0,30	0,012
584	22.99	0,36	0.014
648	25.51	0,41	0.016
787	30.98	0,48	0.019

Alternators

Note: The information which follows is general and can change with specific applications.

Make and type Magneti Marelli A127, Bosch
Rating:

Magneti Marelli: A127 12V/55A or 12V/65A
Bosch:.. . . . 12V/55A or 24V/55A
Rotation Clockwise from drive end

Starter motors

Note: The information which follows is general and can change with specific applications.

Make and type Magneti Marelli M127, Magneti Marelli 2M113, Bosch JF
Voltage:

Magneti Marelli M127 12V
Magneti Marelli 2M113 12V
Bosch JF.. . . . 12V
Bosch JF.. . . . 24V
Number of teeth on pinion 10

Maximum starter cable resistance at 200 °C (680 °F):

12V 0,0017 ohms
24V 0,0034 ohms

Starting aid

Note: The information which follows is general and can change with specific applications.

Type. Electrically operated heater, with a fuel supply
Voltage 12V (dropping resistor used on 24V system)
Flow rate of fuel through starting aid 3,5/5,9 ml/min

Recommended torque settings

The torque tensions below apply to components lubricated lightly with clean engine oil before they are fitted.

Description	Thread size	Torque		
		Nm	lbf ft	kgf m
Cylinder head assembly				
Setscrews, cylinder head	$\frac{1}{2}$ UNF	See Operation 3-8		
Fasteners, rocker shaft brackets:				
- Aluminium brackets	M12	40	30	4,1
- Sintered steel brackets	M12	75	55	7,6
Cap nuts, rocker cover	M12	20	15	2,1
Setscrews, inlet manifold to cylinder head	M10	44	33	4,5
Nuts, exhaust manifold to cylinder head	M10	44	33	4,5
Setscrews, engine lift bracket	M10	44	33	4,5
Piston and connecting rod assembly				
Nuts, connecting rods	$\frac{1}{2}$ UNF	125	92	12,7
Crankshaft assembly				
Setscrews, main bearings	$\frac{5}{8}$ UNF	250	185	26,0
Setscrews, crankshaft pulley	$\frac{7}{16}$ UNF	115	85	11,8
Torxscrew, rear oil seal housing to cylinder block	M8	22	16	2,2
Cap screws, bridge piece to cylinder block	M6	16	12	1,6
Cap screws, rear oil seal housing to bridge piece	M6	13	10	1,3
Torxscrew, rear oil seal housing to bridge piece	M8	18	13	1,9
Setscrew, idler gear hub of balancer unit	M12	93	68	9,5
Nut, drive gear of balance weight	$\frac{1}{2}$ UNF	82	60	8,4
Setscrews, rear cover of balancer frame	M10	54	40	5,5
Setscrews, oil transfer plate (balancer unit)	M10	30	22	3,1
Setscrews, oil pump to balancer frame	M8	27	20	2,8
Setscrews, balancer to cylinder block	M10	54	40	5,5
Timing case and drive assembly				
Setscrews, timing case to cylinder block	M8	22	16	2,2
Setscrews, timing case to cylinder block	M10	44	33	4,5
Bolt, hub of idler gear	M10	44	33	4,5
Setscrew, camshaft gear	M12	78	58	8,0
Setscrews, timing case cover to timing case and block	M8	22	16	2,2
Cylinder block				
Setscrews, fitted instead of piston cooling jets	$\frac{3}{8}$ UNF	27	20	2,8
Aspiration system				
Setscrew, breather pipe to head	M8	22	16	2,8
Fuel system				
Nuts, high-pressure fuel pipes	M12	22	16	2,2
Setscrews, atomiser	M8	22	16	1,2
Setscrews, fuel lift pump	M8	22	16	2,2
Screw, for gear of fuel injection pump	$\frac{3}{8}$ UNF	27	20	2,8
Nuts for flange of fuel injection pump	M8	22	16	2,2

Description	Thread size	Torque		
		Nm	lbf ft	kgf m
Lubrication system				
Plug, lubricating oil sump	$\frac{3}{4}$ UNF	34	25	3,5
Setscrews, oil pump to front bearing cap	M8	22	16	2,2
Setscrews, cover for oil pump	M8	22	16	2,2
Fasteners, lubricating oil sump	M8	22	16	2,2
Cooling system				
Setscrews, fan drive housing to timing case	M10	44	33	4,5
Setscrews, fan drive pulley to hub	M8	22	16	2,2
Setscrews, fan drive pulley to hub	M10	44	33	4,5
Setscrews, fan	M8	22	16	2,2
Connector, oil cooler to oil filter head	$\frac{3}{4}$ UNF	37	27	3,8
Setscrews, coolant pump to cylinder block	M8	22	16	2,2
Setscrews, coolant pump to cylinder block	M10	44	33	4,5
Setscrews, coolant pump front body to rear body	M10	44	33	4,5
Flywheel and housing				
Setscrews, flywheel to crankshaft	$\frac{1}{2}$ UNF	105	77	10,7
Setscrews, cast iron flywheel housing to cylinder block	M10	44	33	4,5
- Stamped 8.8	M12	75	55	7,6
- Stamped 10.9	M10	63	46	6,4
- Stamped 10.9	M12	115	85	11,7
Setscrews, aluminium flywheel housing to cylinder block	M10	70	52	7,1
Setscrews, flywheel housing to cylinder block (paper joint)	M10	70	52	7,1
Electrical equipment				
Nut, alternator pulley:				
- Thick (24 mm A/F) A127, and motorola	M17	80	59	8,2
- Thin (22 mm A/F) A127, and motorola	M17	60	44	6,1
Fuelled start aid to induction manifold	$\frac{7}{8}$ UNF	31	23	3,1

Compression test data

Tests have shown that many factors affect compression pressures. Battery and starter motor condition, ambient conditions and the type of gauge used can give a wide variation of results for a given engine.

It is not possible to give accurate data for compression pressure, but tests have shown that the results should be within 2000/3500 kPa (300/500 lbf/in²) 21,0/35,0 kgf/cm² for diesel engines.

Compression tests should only be used to compare between the cylinders of an engine. If one or more cylinders vary by more than 350 kPa (50 lbf/in²) 3,5 kgf/cm², then those cylinders may be faulty.

Compression tests should not be the only method used to show the condition of an engine, but they should be used together with other symptoms and tests.

How to do a compression test

Caution: Before the compression test, ensure that the battery is in good condition and that it is fully charged. Also ensure that the starter motor is in good condition.

- 1 Ensure that the valve tip clearances are set correctly, see Operation 3-5.
- 2 Remove the atomisers, see Operation 11-5.
- 3 Fit a suitable gauge into the atomiser hole of the cylinder to be tested.
- 4 Ensure that the engine cannot start:

Disconnect the stop solenoid or put the stop control in the no-fuel position.

Operate the starter motor and note the pressure indicated on the gauge.

- 5 Repeat for each cylinder.

3

Cylinder head assembly

General description

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.

The cylinder head assembly has two valves fitted for each cylinder, each fitted with single valve springs. The face angle of the valves is 45°. The angle of the valve seats in the cylinder head is 46°.

The valves move in phosphated guides which can be renewed. The exhaust valve guide has a counterbore at the bottom and is a little longer than the inlet valve guide.

Both valve stems are fitted with oil seals which fit over the top of the valve guides.

The 4.41 engine does not have valve seat inserts fitted as standard in production, but inserts can be fitted in service for repair purposes.

Rocker cover

To remove and to fit

Operation 3-1

Engines are supplied with a rocker cover (A) made of a composite material.

To remove

- 1 Disconnect the breather pipe.
- 2 Remove the cap nuts (A2) together with the steel washers (A3) and the shim washers (A4) from the top of the rocker cover.
- 3 Lift off the rocker cover and the joint (A6).

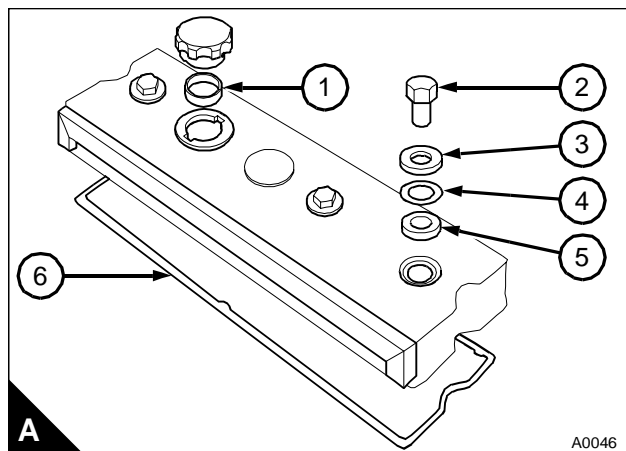
Caution: When the rocker cover is fitted, the cap nuts are tightened onto the nuts of the rocker brackets. During removal of the cap nuts, it is possible to loosen the nuts of the rocker brackets. The nuts of the rocker brackets should be tightened to the correct torque every time the cover is removed.

To fit

- 1 Check the seal of the oil filler cap (A1), the sealing washers (A5), the steel washer (A3) and, if fitted, the shim washer (A4) for the cap nuts (A2).
- 2 Check the condition of the rocker cover joint (A6). If necessary, the joint can be removed and renewed.
- 3 Clean the joint face of the cylinder head and fit the rocker cover.
- 4 Fit the sealing washers, the steel washers, the shims (if fitted) and the cap nuts.

Caution: Damage to the sealing washer can occur if the cap nut is not tightened centrally through the sealing washer and the rocker cover. If the sealing washer is damaged it must be renewed.

- 5 Tighten the cap nuts to 20 Nm (15 lbf ft) 2,1 kgf m.



Rocker assembly

To remove and to fit

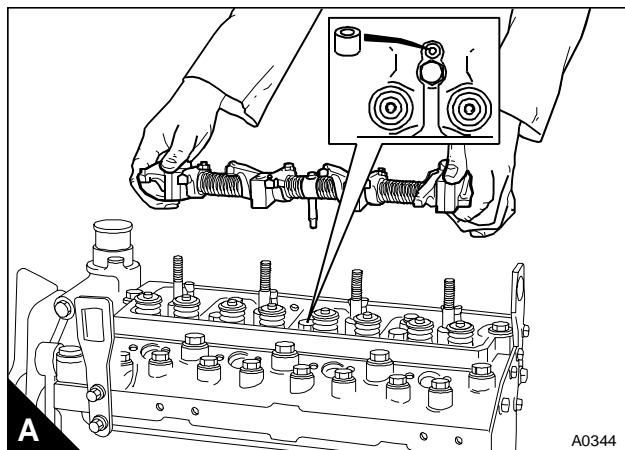
Operation 3-2

To remove

- 1 Remove the rocker cover, see Operation 3-1.
- 2 Release evenly and gradually the fasteners of the rocker shaft brackets; begin with the end brackets and move toward the centre. Remove the flange faced nuts and setscrews and lift off the rocker assembly.
- 3 Remove the rubber oil seal (A) from the oil supply connection or from the oil supply hole in the cylinder head.

To fit

- 1 Fit a new rubber oil seal in the oil supply hole in the cylinder head.
- 2 Check that the push rods fit correctly in the sockets of the tappets. Fit the rocker assembly; ensure that the oil supply connection is fitted correctly into the oil seal. Check that the ends of the adjustment screws fit correctly in the sockets of the push rods.
- 3 Fit the flange faced nuts and setscrews of the rocker shaft brackets and tighten the fasteners evenly and gradually; begin with the inner fasteners and work towards the end fasteners. Tighten the fasteners gradually and evenly to 75 Nm (55 lbf ft) 7,6 kgf m.



To dismantle and to assemble

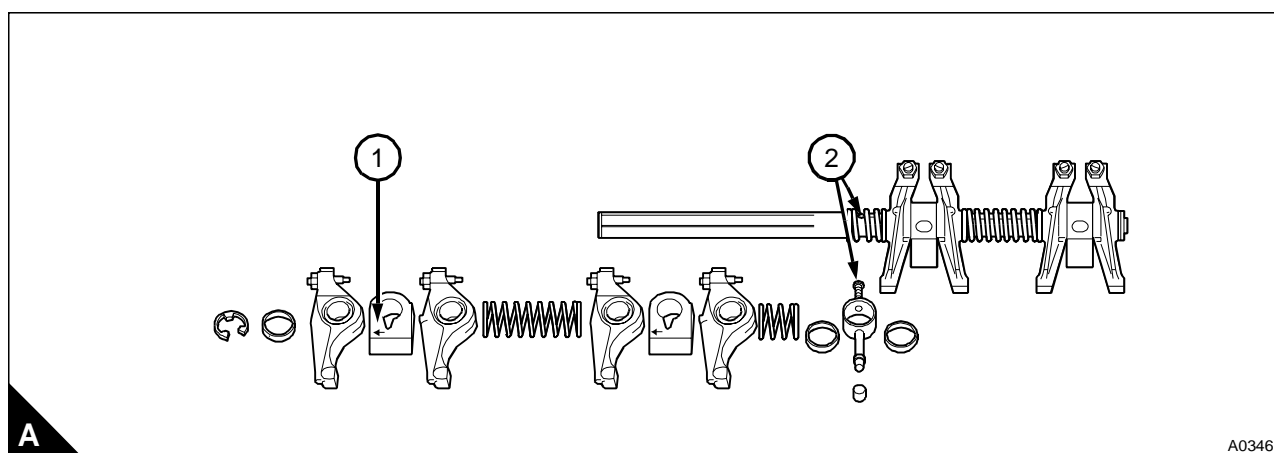
Operation 3-3

To dismantle

- 1 Remove the clips from both ends of the rocker shaft. Ensure that the ends of the rocker shaft are not damaged. Release the location screw (A2) for the oil supply connection.
- 2 Dismantle the assembly and make a note of the position of each component to ensure that they can be assembled more easily.

To assemble

- 1 Ensure that the oil holes in the rocker shaft and in the rocker levers are not restricted.
- 2 Lubricate the components with clean engine lubricating oil before assembly. Assemble the components in the correct order (A). Ensure that the arrow (A1) on the bracket faces away from the cylinder head and that the location screw (A2) for the oil supply connection is fitted correctly in the rocker shaft. Fit the clips to the ends of the rocker shaft.



To inspect and to correct

Operation 3-4

- 1 Clean and inspect all the components for wear and any other damage.
- 2 Check the clearance of the rocker levers on the rocker shaft. If the clearance is larger than 0,13 mm (0.005 in), renew the rocker lever and/or the rocker shaft.

Valve tip clearances

To check and to adjust

Operation 3-5

Notes:

- The valve tip clearance is measured between the top of the valve stem and the rocker lever (A). With the engine hot or cold, the correct clearances are 0,20 mm (0.008 in) for the inlet valves and 0,45 mm (0.018 in) for the exhaust valves. The valve positions are shown at (B).
- The sequence of valves from number 1 cylinder is shown in the table below. Number 1 cylinder is at the front of the engine.

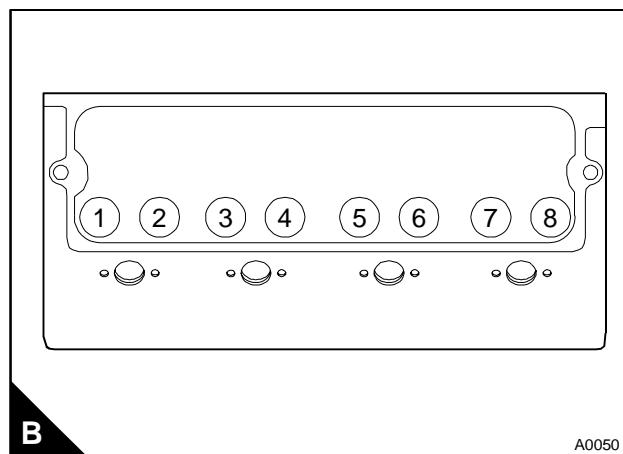
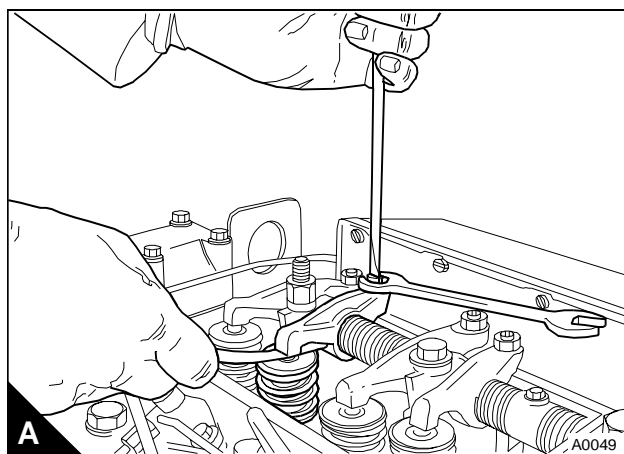
1 Rotate the crankshaft in the normal direction of rotation until the inlet valve (B8) of number 4 cylinder has just opened and the exhaust valve (B7) of the same cylinder has not closed completely. Check the clearances of the valves (B1 and B2) of number 1 cylinder and adjust them, if necessary.

2 Set the valves (B3 and B4) of number 2 cylinder as indicated above for number 4 cylinder. Then check / adjust the clearances of the valves (B5 and B6) of number 3 cylinder.

3 Set the valves (B1 and B2) of number 1 cylinder. Then check / adjust the clearances of the valves (B7 and B8) of number 4 cylinder.

4 Set the valves (B5 and B6) of number 3 cylinder. Then check / adjust the clearances of the valves (B3 and B4) of number 2 cylinder.

Cylinder and Valve number	1		2		3		4	
	1	2	3	4	5	6	7	8
Valve I = Inlet E = Exhaust	I	E	E	I	I	E	E	I



Valve springs

To change the valve springs (with cylinder head fitted)

Operation 3-6

Special requirements

Special tools			
Description	Part number	Description	Part number
Valve spring compressor	PD.6118B	Setscrew adaptor used with PD.6118B	PD.6118-8
Stud adaptor used with PD.6118B	PD.6118-7		

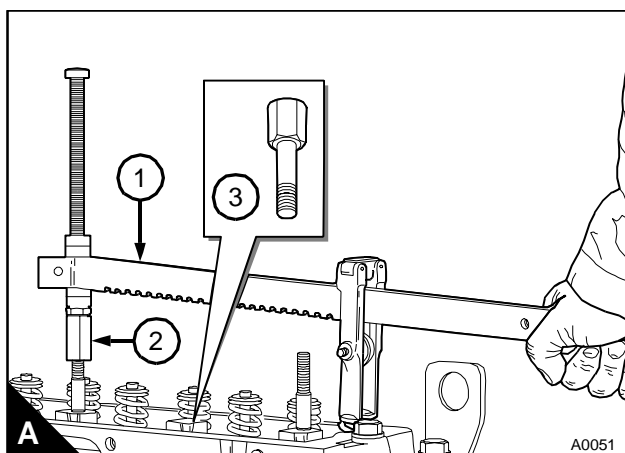
Warning! Wear eye protection during this operation.

Note: Steps 1 to 12 refer to a change of valve springs for a single cylinder.

- 1 Remove the rocker cover, see Operation 3-1.
- 2 Rotate the crankshaft in the normal direction of rotation until the inlet valve of the relevant cylinder has just opened and the exhaust valve has not fully closed. In this position the piston will be at approximately top dead centre (TDC).
- 3 Remove the rocker assembly, see Operation 3-2.
- 4 Fit the valve spring compressor (A1) and the relevant adaptor (A2 or A3).
- 5 Compress the valve spring and remove the collets. Ensure that the valve spring is compressed squarely or damage to the valve stem can occur.

Caution: Do not rotate the crankshaft while the valve springs are removed.

- 6 Release the valve spring compressor and remove the valve spring cap and valve spring.
- 7 Put the new valve spring in position.



Continued

8 Fit the valve spring cap.

Caution: Ensure that the valve spring is compressed squarely or damage can occur to the valve stem.

9 Fit the valve spring compressor, compress the valve spring and fit the collets. Remove the valve spring compressor.

10 Fit the rocker assembly, see Operation 3-2.

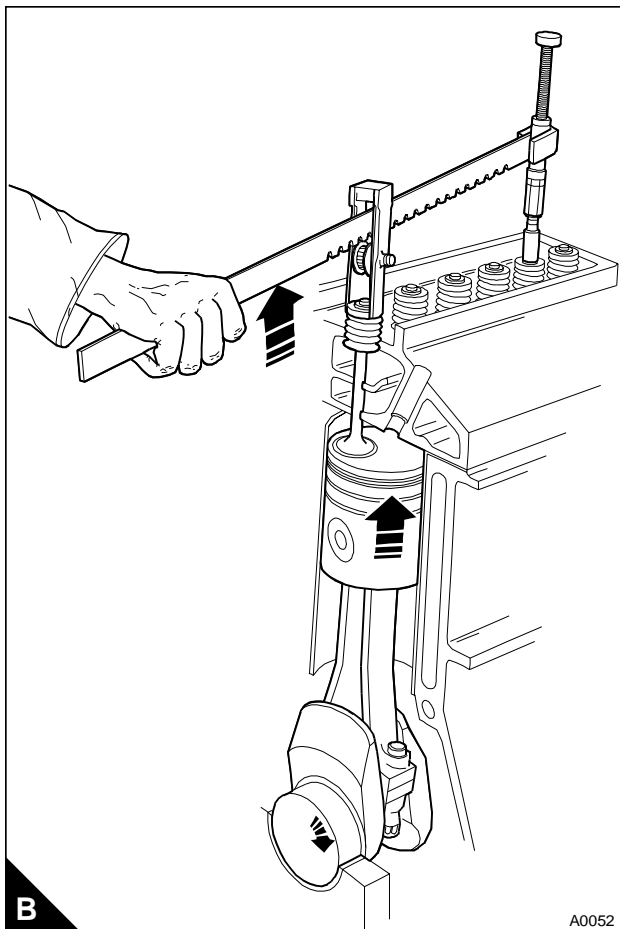
11 Check the valve tip clearances, see Operation 3-5.

12 Fit the rocker cover, see Operation 3-1.

Note: If other or all of the valve springs are to be changed, they can be changed two cylinders at a time. The cylinders are: 1 and 4, then 2 and 3.

If the rocker assembly has been removed, piston TDC can be found as follows:

- 1 Fit the valve spring compressor and compress the valve springs to open the valve.
- 2 Rotate the crankshaft, by hand, in the normal direction of rotation until the piston touches the valve.
- 3 Continue to rotate the crankshaft, and at the same time, release pressure on the valve spring compressor until the piston is at TDC (B).



Cylinder head assembly

To remove

Operation 3-7

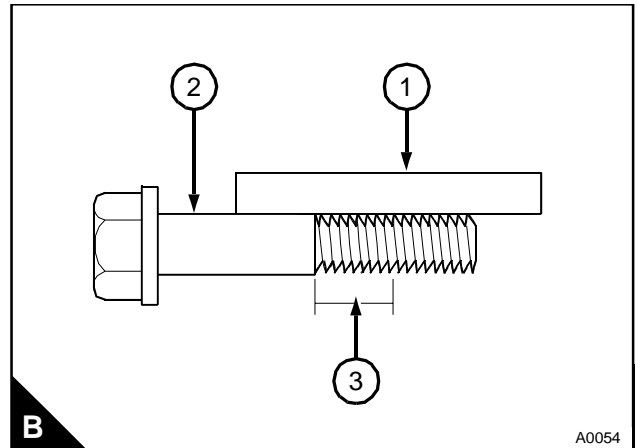
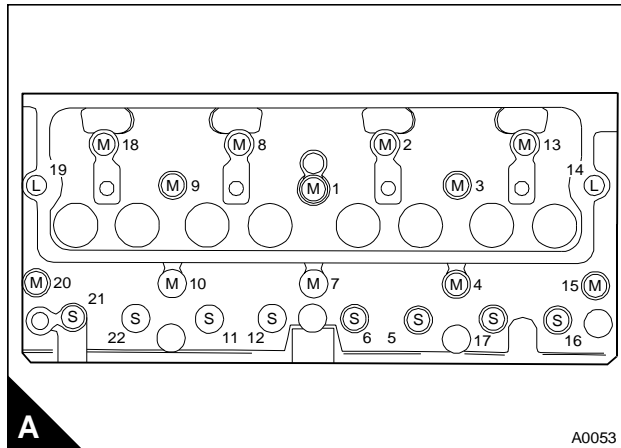
- 1 Drain the cooling system.
- 2 Disconnect the battery terminals.
- 3 Remove the air filter/cleaner hose at the induction manifold.
- 4 Remove the pipe which is fitted between the fuelled starting aid in the induction manifold and the fuel filter. Disconnect the electrical connection.
- 5 Remove the induction manifold.
- 6 Remove the exhaust manifold.
- 7 Remove the low-pressure fuel pipes which are fitted between the fuel injection pump and the fuel filter. Remove the fuel pipe fitted between the fuel lift pump and the fuel filter. Remove the fuel filter bracket together with the fuel filter.
- 8 Remove the high-pressure fuel pipes.
Caution: Where access to the fuel injection pump outlet unions is possible, ensure that a separate spanner is used to prevent movement of the fuel injection pump outlets when the connections of the high-pressure pipes are released. Fit suitable covers to all open connections on the fuel injection pump.
- 9 Remove the atomiser leak-off pipe.
- 10 Remove the atomisers, see Operation 11-5. Fit suitable covers to the nozzles and the open connections.
- 11 If a compressor is fitted: Remove the coolant pipe which is fitted between the cylinder head and the compressor. Then remove the coolant pipe which is fitted between the by-pass connection and the compressor.
- 12 Release the clip of the coolant by-pass hose at the cylinder head, and remove the hose.
- 13 Disconnect the coolant temperature sender unit.
- 14 Remove the rocker cover, see Operation 3-1
- 15 Remove the rocker assembly, see Operation 3-2.
- 16 Remove the push rods.

Continued

17 Release the cylinder head setscrews evenly and gradually in the reverse sequence to that shown in (A). Check the setscrews for distortion with a straight edge (B1) held along the setscrew (B2). If there is a reduction in the diameter of the thread (B3) that has not been in engagement with the cylinder block, the setscrew must be discarded.

Caution: Do not use a lever to separate the cylinder head from the cylinder block.

18 Remove the cylinder head and put it on a surface that will not damage the face of the cylinder head.



To fit

Operation 3-8**Special requirements**

Special tools	
Description	Part number
Angle gauge (to tighten cylinder head setscrews)	MS.1531

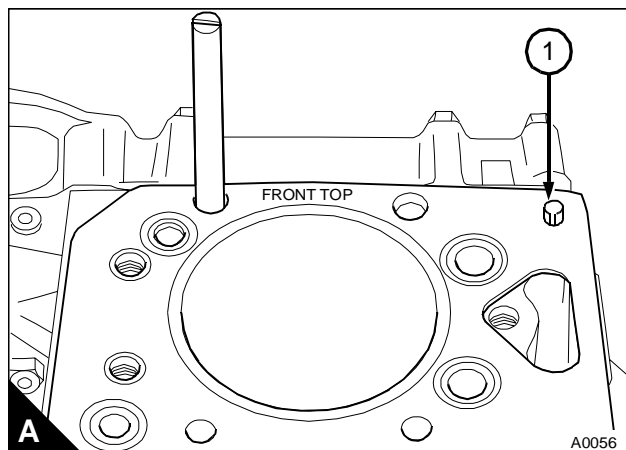
1 Clean the bottom face of the cylinder head and top face of the cylinder block. Ensure that there is no debris in the cylinder bores.

Note: The cylinder head has two location pins (A1), one at each end of the cylinder head, pressed into the cylinder block to hold the cylinder head gasket in the correct position before the cylinder head is fitted and to ensure that the head is in the correct position.

Cautions:

- *To prevent damage to the cylinder head gasket, ensure that the location pins are pressed in the cylinder block before the cylinder head is fitted.*
- *The cylinder head gasket must be fitted without jointing compound.*

2 Put the cylinder head gasket in position; It is stamped "FRONT TOP" for correct assembly (A).

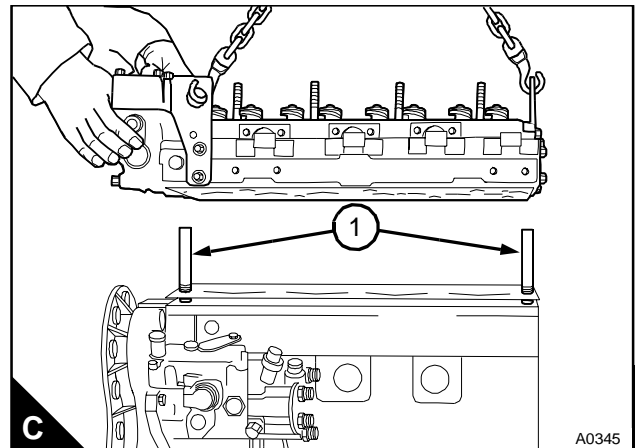
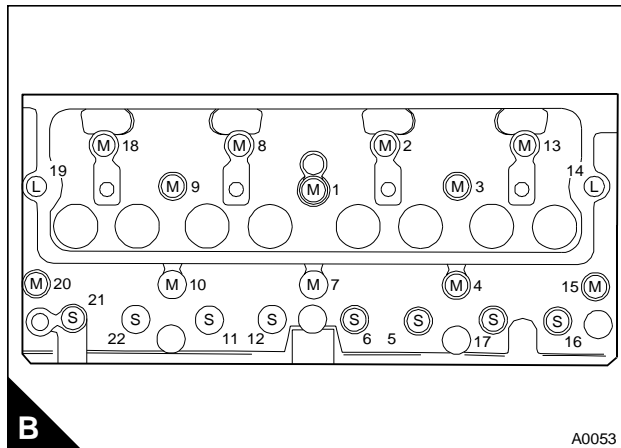
*Continued*

3 To ensure the cylinder head is fitted into the correct position, fit two suitable $\frac{1}{2}$ UNF guide studs (C1) in positions 15 and 20 (B). Put the cylinder head in position.

4 Lightly lubricate the threads of the cylinder head setscrews and the thrust faces of the setscrew heads. Engage some of the setscrews in their correct positions and remove the guide studs. Engage the remainder of the setscrews in their correct positions.

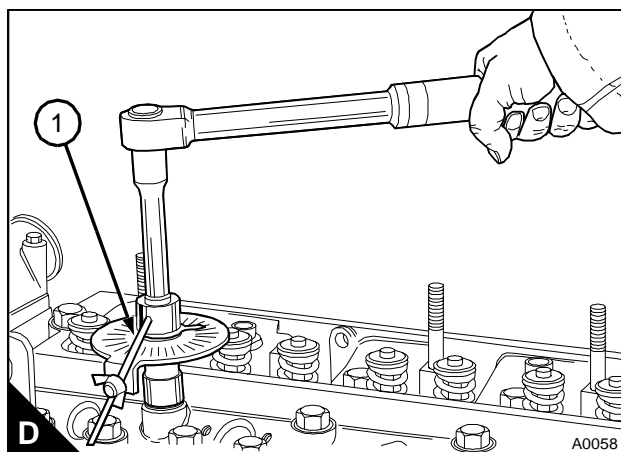
5 Gradually and evenly tighten the setscrews to 110 Nm (80 lbf ft) 11,1 kgf m in the sequence shown in (B).

6 Repeat step 5 to ensure that all the setscrews are tightened to the correct torque.



7 Tighten the setscrews, in the correct sequence, a further part of a turn according to the length of the setscrews, see (B). Short setscrews (S) must be turned a further 150° (2.5 flats). Medium length setscrews (M) must be turned a further 180° (3 flats). Long setscrews (L) must be turned a further 210° (3.5 flats). A special tool (D) can be used for this operation.

Fit the tool between the socket and the handle. Position the stop (D1) against a suitable protrusion on the cylinder head to prevent movement of the degree dial in a clockwise direction. Rotate the pointer to align with the relevant angle on the degree dial for the length of setscrew. Tighten the setscrew until the pointer on the tool is aligned with the zero position on the degree dial.



Continued

If no tool is available, make a suitable mark on the cylinder head in line with a corner of each setscrew (E). Make another mark, at the correct angle (counter-clockwise), on the edge of the flange of each fastener according to the length of the setscrew. Tighten each setscrew in the correct sequence until the marks on the flange are next to, and in line with, the marks on the cylinder head.

8 Put the push rods in position. Ensure that the end of each push rod fits correctly in the tappet socket.

9 Fit the rocker assembly, see Operation 3-1.

10 Set the valve tip clearances, see Operation 3-5.

11 Fit the atomisers, see Operation 11-5.

12 Fit the high-pressure fuel pipes; tighten the connection nuts to 22 Nm (16 lbf ft) 2,2 kgf m.

Caution: Where access to the fuel injection pump outlet unions is possible, ensure that a separate spanner is used to prevent movement of the fuel injection pump outlets when the connections of the high pressure pipes are tightened.

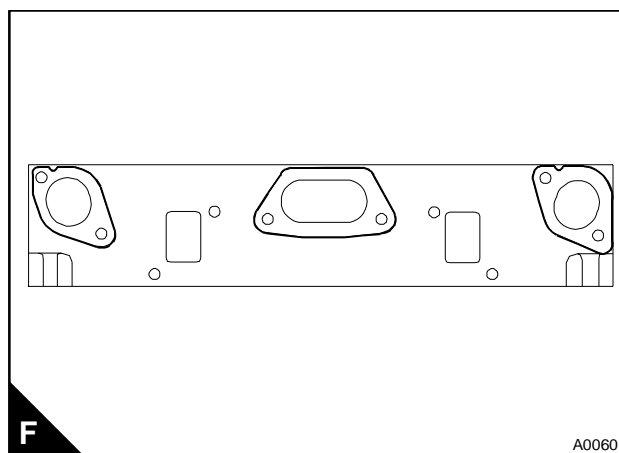
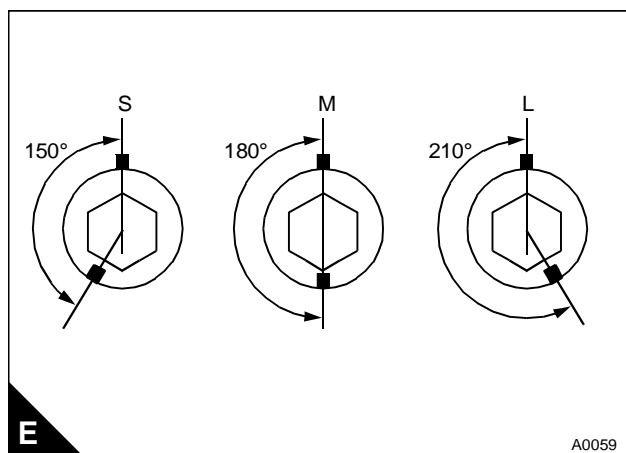
13 Fit the fuel filter and the bracket. Fit the low-pressure fuel pipes between the fuel injection pump and the fuel filter.

14 Fit the coolant by-pass connection; tighten the setscrews and hose clip.

15 If a compressor is fitted, fit the coolant pipe between the cylinder head and the compressor. Then fit the pipe between the coolant by-pass and compressor.

16 Fit the exhaust manifold. The manifold joints are fitted without jointing compound.

17 Fit the induction manifold. Ensure that the manifold joints for the front and rear positions are fitted with the notch at the top left when the manifold is fitted to the cylinder head (F). The manifold joint for the centre position can be fitted either way. Fit the joints without jointing compound.



Continued

-
- 18** Fit the fuel pipe between the fuel filter and the fuel lift pump.
 - 19** Fit the fuel pipe between the fuel filter and the fuelled starting aid in the induction manifold. Connect the electrical connection to the cold start device.
 - 20** Fit the electrical connection to the coolant temperature sender unit.
 - 21** Connect the coolant outlet and the hoses for the cab heater. Tighten the clips.
 - 22** Fill the cooling system.
 - 23** Connect the air filter/cleaner.
 - 24** Connect the battery.
 - 25** Eliminate air from the fuel system, see Operation 11-13 for Lucas DPA fuel injection pumps and Operation 11-17 for Stanadyne fuel injection pumps.
 - 26** Start the engine and run it at low speed, check that oil flows from the holes in the rocker levers. Stop the engine.
 - 27** Fit the rocker cover, see Operation 3-1.

Note: It is not necessary to tighten the cylinder head setscrews again with the engine hot or after a limited period in service.

Valves and valve springs

To remove

Operation 3-9

Special requirements

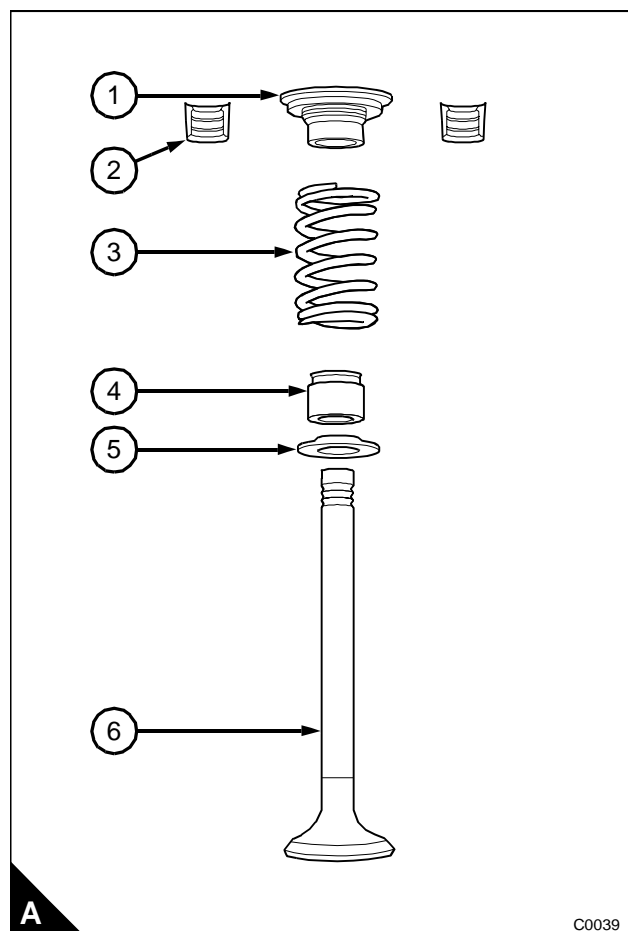
Special tools			
Description	Part number	Description	Part number
Valve spring compressor	PD.6118B	Setscrew adaptor	PD.6118-8
Stud adaptor	PD.6118-7		

Warning! Wear eye protection during this operation.

- 1 Remove the cylinder head assembly, see Operation 3-7.
- 2 Clean the bottom face of the cylinder head and check the depth of the heads of the valves below the face of the cylinder head, see Operation 3-11.
- 3 Make a suitable mark on the heads of the valves to ensure that the valves can be fitted in their original positions, if they are to be used again.

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

- 4 Use the valve spring compressor and the relevant adaptor to compress the valve spring and remove the collets.
- 5 Release the valve spring compressor and remove the valve spring cap, valve spring, valve stem seal and the valve seat washer.
- 6 Repeat steps 4 and 5 for the other valves.



To fit

Operation 3-10

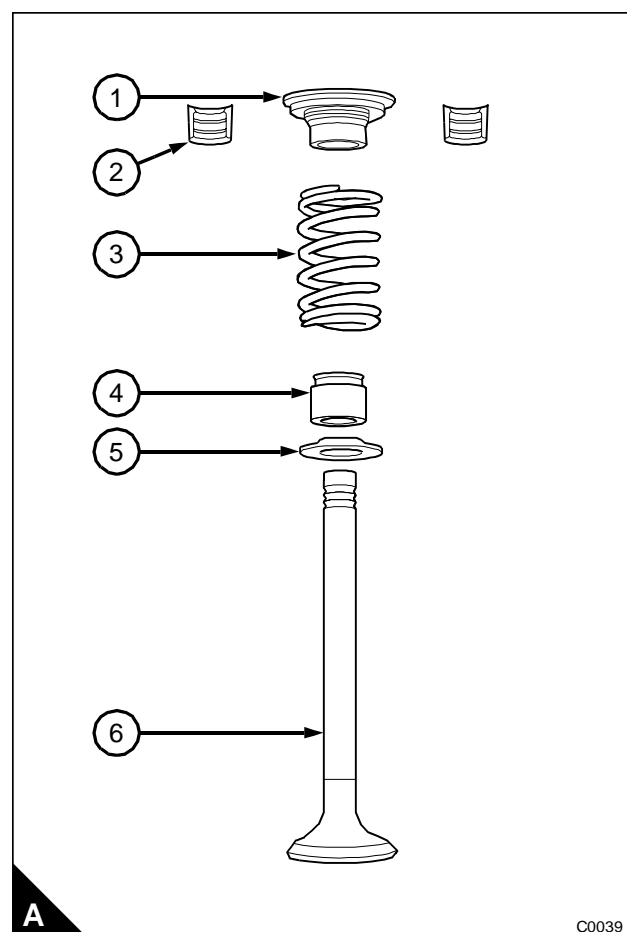
Special requirements

Special tools			
Description	Part number	Description	Part number
Valve spring compressor	PD.6118B	Setscrew adaptor	PD.6118-8
Stud adaptor	PD.6118-7		

Warning! Wear eye protection during this operation.

Note: The components of the valve assembly are shown in (A).

- 1 Lubricate the valve stem (A6) with clean engine oil and fit the valves in their respective guides.
 - 2 Fit the spring seat washer (A5). Fit new valve stem seal (A4) on the valve guides. Fit the valve spring (A3) on the spring seat washer. The spring can be fitted with either end to the cylinder head. Fit the valve spring cap (A1).
- Caution:** Ensure that the valve spring is compressed squarely or damage can occur to the valve stem.
- 3 Use the valve spring compressor and the relevant adaptor to compress the valve spring and fit the collets (A2).



To inspect and to correct

Operation 3-11

Special requirements

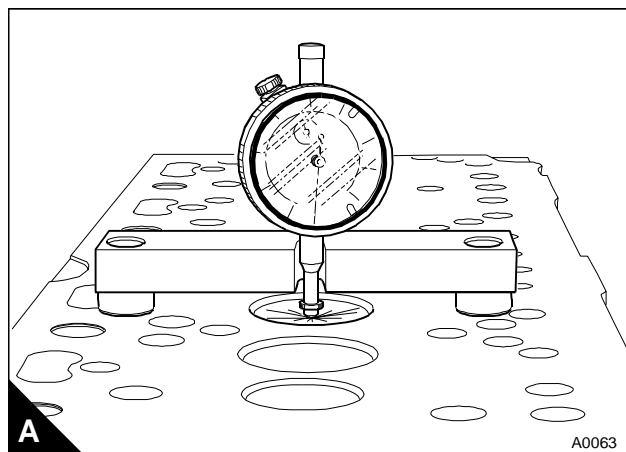
Special tools			
Description	Part number	Description	Part number
Gauge, valve depth	PD.41D	Dial gauge for use with PD.41D	PD.208

- 1 Check the depth of the valves below the face of the cylinder head before the valve springs are removed.
- 2 Ensure that the heads of the valves and the bottom face of the cylinder head are clean.
- 3 Put the valve depth gauge on the face of the cylinder head and zero the dial gauge.
- 4 Carefully put the valve depth gauge in position over the head of each valve (A) and make a note of the measurement. The maximum depth, in service, is given in the relevant Data and dimensions for the "Inlet and exhaust valves" on page 13.
- 5 If a valve is below the depth limit, check the valve depth with a new valve in position. If the valve depth is still below the limit and a valve seat insert is fitted, the insert must be renewed.
- 6 Where a valve seat insert is not fitted, the bottom face of the cylinder head can be machined to reduce the valve depth, or an insert can be fitted, see Operation 3-17.

Caution: If the bottom face of the cylinder head is to be machined, ensure that the thickness, of the cylinder head will not be less than 102,48 mm (4.035 in) after the cylinder head has been machined.

- 7 Check the valves for cracks. Check the stems of the valves for wear and for correct fit in their valve guides.
- 8 Check that the seat faces of the valves are not badly burnt or damaged. Seat faces of valves which are damaged can be ground on a special machine. Valves which have only a little damage can be lapped to their valve seats. When new valves are fitted, the valve depths must be checked, refer to step 1.
- 9 Check that the load on the valve springs is correct at their fitted length, refer to the relevant Data and dimensions for the "Valve guides and valve springs" on page 16.

Fit new valve springs at every complete engine overhaul.



Valve guides

To inspect

Operation 3-12

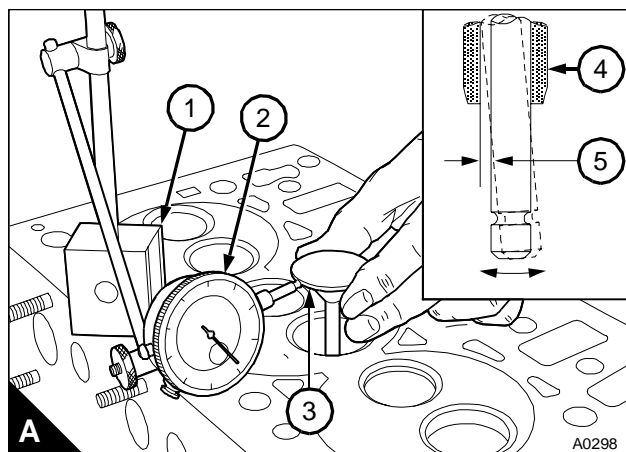
To check the valve guides for wear: The maximum clearance (A5), between the valve stem and the bore of the guide is 0,13 mm (0.005 in) for inlet valves and 0,15 mm (0.006 in) for exhaust valves. If the clearance, with a new valve fitted, is more than the limit, then a new valve guide (A4) must be fitted.

It is recommended that the procedure given below is used to check the valve guide clearance:

- 1 Put a new valve in the valve guide.
- 2 Put a dial test indicator with a magnetic base (A1) onto the face of the cylinder head.
- 3 With the valve lifted 15,0 mm (0.6 in) and the gauge (A2) in contact with the edge of the valve head (A3), move the valve radially away from the gauge. With the valve held in this position, set the gauge zero.
- 4 Move the valve radially across the axis of the cylinder head towards the gauge. Make a note of the reading on the gauge. If the reading is equal to or greater than the data given below, a new valve guide (A4) must be fitted.

Maximum permissible clearance with a valve lift of 15,0 mm (0.6 in):

- Inlet guide - 0,24 mm (0.009 in)
- Exhaust guide - 0,32 mm (0.013).



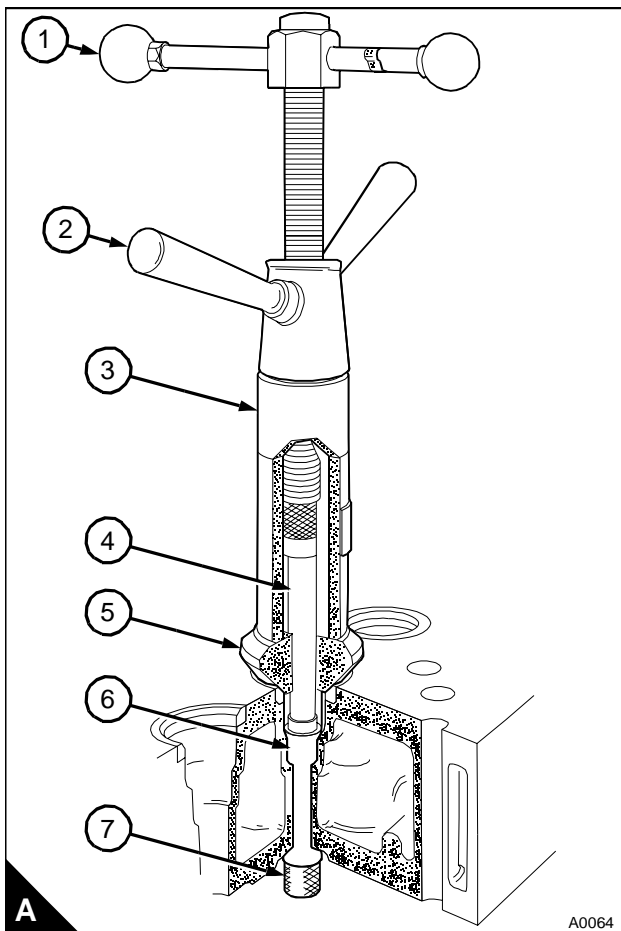
To remove

Operation 3-13

Special requirements

Special tools			
Description	Part number	Description	Part number
Remover/replacer for valve guides	PD.1D	Adaptor used with PD.1D	PD.1D-1A

- 1 Fit the adaptor (A4), PD.1D-1A, into the remover/replacer tool (A3), PD.1D.
- 2 With the adaptor fitted to the tool, put the spacer (A5) in position on the tool. Pass the adaptor through the valve guide and put the spacer and tool in position on the valve seat.
- 3 Fit the attachment (A7) to secure the adaptor to the valve guide.
- 4 Hold the top handle (A1) and turn the bottom handle (A2) clockwise to pull the valve guide out of the cylinder head.



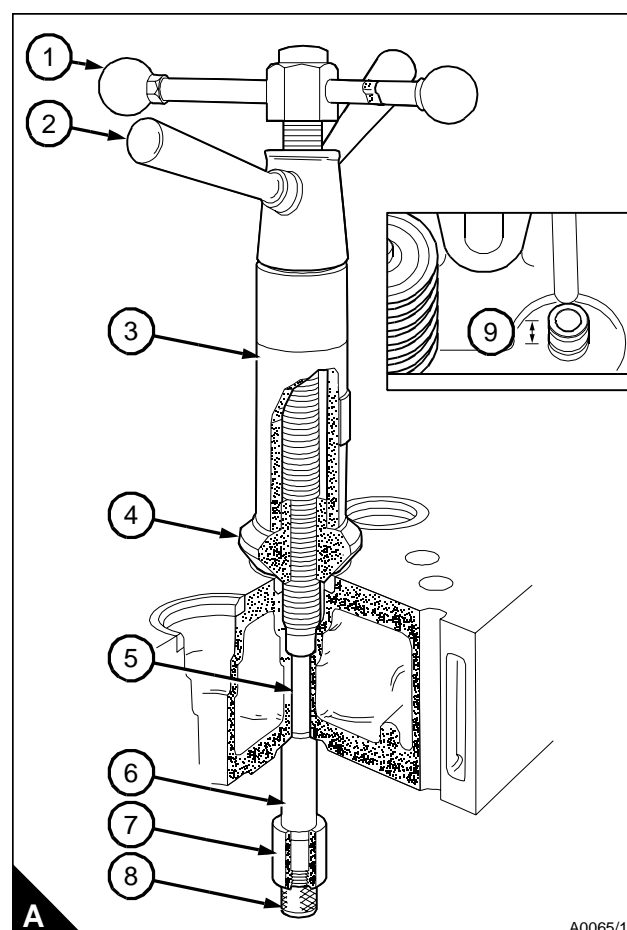
To fit

Operation 3-14

Special requirements

Special tools			
Description	Part number	Description	Part number
Remover/replacer for valve guides	PD.1D	Adaptor used with PD.1D and PD.1D-1A	PD.1C-6
Adaptor used with PD.1D	PD.1D-1A		

- 1 Clean the parent bore in the cylinder head for the valve guide.
- 2 Lubricate the outer surface of the new valve guide (A6) with clean engine lubricating oil.
- 3 Fit the adaptor (A5), PD.1D-1A, into the remover/replacer tool (B3), PD.1D.
- 4 With the adaptor fitted to the tool, put the spacer (A4) in position on the tool. Pass the adaptor through the cylinder head and put the spacer and tool assembly in position on the valve seat.
- 5 Put the valve guide in position on the adaptor and fit the distance piece (A7), PD.1C-6. Fit the attachment (A8) to secure the valve guide to the adaptor.
- 6 Hold the top handle (A1) and turn the bottom handle (A2) clockwise to pull the valve guide until the distance piece contacts the cylinder head.
- 7 When the valve guide is fitted correctly, the top of the valve guide will have a protrusion (A9) of 15,10 mm (0.594 in) above the valve spring seat.



Cylinder head

To inspect and to correct

Operation 3-15

- 1 Remove the cylinder head assembly, see Operation 3-7.
- 2 Remove the thermostat housing.
- 3 Inspect the cylinder head for signs of gas or coolant leakage.
- 4 Remove the valve springs and the valves, see Operation 3-9.
- 5 Clean the face of the cylinder head and the passages for coolant and for lubricating oil. The water jacket can be cleaned with a special solvent which must be used in accordance with the manufacturer's instructions.
- 6 Test the cylinder head for leaks at the pressure given in the relevant Data and dimensions for the "Cylinder head" on page 12.
- 7 When the cylinder head is thoroughly clean, check it for cracks. Inspect carefully the areas around the valve seats and around the holes for the atomiser nozzles.
- 8 The bottom face of the cylinder head can be machined if: there is distortion, see step 9; there are deep scratches; or, for engines without valve seat inserts, the valve depths are below the service limit.
- 9 Use a straight edge and feeler gauges to check the cylinder head for distortion across and along its bottom face, see "Maximum permissible distortion of cylinder head" on page 12. If the distortion is more than the given limit, the bottom face can be machined.

Cautions:

- *Remove only the minimum material and ensure that the thickness of the cylinder head will not be less than 102,48 mm (4.035 in) after the cylinder head has been machined.*
 - *After the cylinder head has been machined the valve seats must be corrected to give the correct valve head depth. Work to the minimum limit to allow for later wear.*
- 10 Check the valve seats for wear and for damage.
 - 11 Before any work is done on the valve seats, new valve guides must be fitted, see Operation 3-13 and Operation 3-14.
 - 12 Where there is little damage, the valve and valve seat can be lapped. When the valve seats are lapped keep the seat as narrow as possible and ensure that all the compound used to lap the valve and the seat is removed.
 - 13 More badly damaged valve seats can be corrected by use of the cutter tool, see Operation 3-16, or new inserts can be fitted, see Operation 3-17.

To correct a valve seat with a valve seat cutter

Operation 3-16

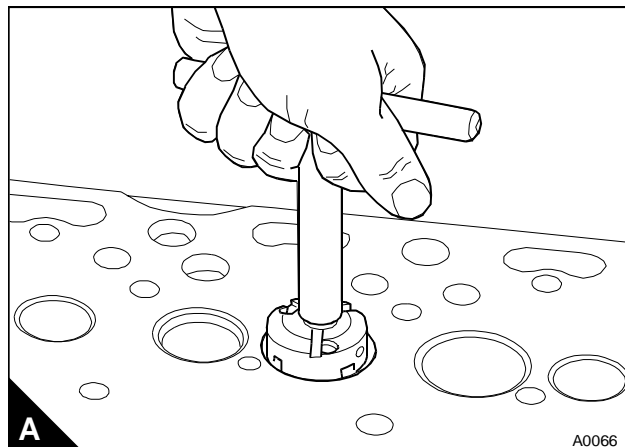
Special requirements

Special tools			
Description	Part number	Description	Part number
Cutter for inlet valve seats	MS.281 ⁽¹⁾	Pilot for use with valve seat cutters	MS.150-9.5 ⁽¹⁾
Cutter for exhaust valve seats	MS.275 ⁽¹⁾	Handle set for use with valve seat cutters	MS.76B ⁽¹⁾

⁽¹⁾ Included in set of adjustable cutters for valve seats, MS.76A.

- 1 Before any work is done on the valve seats, new valve guides must be fitted, see Operation 3-13 and Operation 3-14.
- 2 Fit the pilot in the valve guide and tighten the pilot.
- 3 Select the relevant cutter. Set the blades of the cutters to the diameter of the valve seat to be cut. Fit the cutter on the pilot and fit the handle (A). Ensure that the cutter is not allowed to fall on to the seat as this can damage the blades.
- 4 Carefully turn the cutter in a clockwise direction. Remove only the minimum material to ensure a good seat. Keep the seat as narrow as possible.
- 5 When the seat is cut, remove the cutter and the pilot. Remove any debris from the area of the valve seat and the port.
- 6 Fit the valve and lightly lap the valve and the seat.
- 7 Check that the valve depth is within limits, refer to the relevant Data and dimensions for the "Inlet and exhaust valves" on page 13.

Note: If a valve seat has become too damaged or too worn to correct, a valve seat insert can be fitted, see Operation 3-17.



To fit valve seat inserts

Operation 3-17

- 1 Remove the valve guide and clean the bore into which the guide is to be fitted.
- 2 Fit new valve guides, see Operation 3-13 and Operation 3-14.
- 3 With the bore of the new valve guide used as a pilot, machine the recess in the cylinder head to the dimensions shown in "Dimensions of recesses for valve seat inserts" on page 14, or machine out the old insert. Remove all debris and clean the insert recess.
- 4 If the bottom face of the cylinder head has been machined, the insert will have to be surface ground on the back face to ensure that there is no protrusion of the insert above the bottom face of the cylinder head. After the back of the insert has been ground, ensure that the outer edge of the back face has a 0,9/1,3 mm (0.035/0.051 in) chamfer at 30° to the vertical.
- 5 With the bore of the valve guide used as a pilot, and with the rear face of the insert towards the cylinder head, press in the insert with the valve seat insert tool, see "Valve seat insert tool" on page 15. Do not use a hammer on the insert and do not use lubrication. Use a hydraulic press or a hand press in one continuous movement. Ensure that the bottom of the insert is in contact with the bottom of the recess.
- 6 Cut the valve seat at an included angle of 88°, see Operation 3-16, and lap the valve on to the valve seat. Ensure that the depth of the valve head below the face of the cylinder head is within the production limits. Refer to the relevant Data and dimensions for the "Inlet and exhaust valves" on page 13.

Note: Work as near as possible to the minimum figure to allow for future wear on the valve seat.

4

Piston and connecting rod assemblies

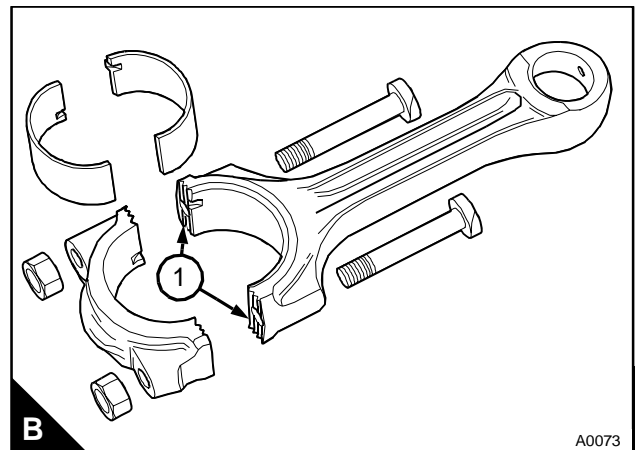
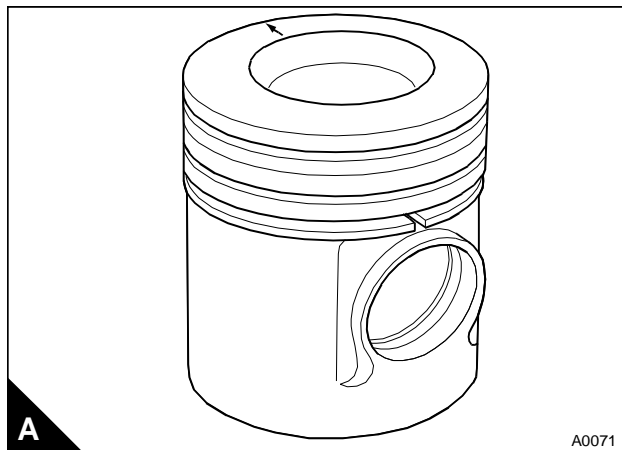
General description

The piston (A) used in 4.41 engine has a combustion chamber in the top of the piston. The combustion chamber is designed to give an efficient mix of fuel and air.

The pistons have two compression rings and an oil control ring. Axial location of the fully floating gudgeon pin is by circlips. The connecting rods are machined from "H" section forgings of molybdenum steel.

The location of the bearing caps to the connecting rods is made by serrations (B1) and the cap is retained by two nuts and bolts (B).

Note: Always use the engine identification number to order new parts.



Big end bearing

To remove

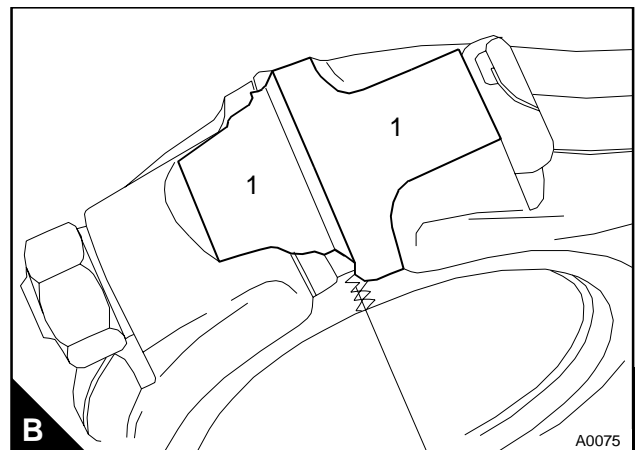
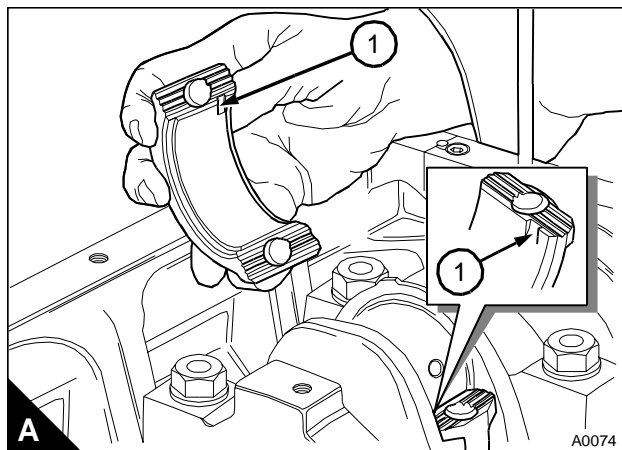
Operation 4-1

- 1 Drain the engine lubricating oil.
- 2 Remove the lubricating oil sump, see Operation 10-3.
- 3 Remove the lubricating oil strainer and suction pipe, see Operation 10-4 or remove the balancer unit, see Operation 5-13.
- 4 Rotate the crankshaft until the relevant connecting rod is at its lowest position.
- 5 Release the nuts and remove the bearing cap. Remove the bolts from the connecting rod.
- 6 Remove the lower half of the shell bearing from the cap, but keep it with its relevant cap.
- 7 Carefully push the connecting rod up the cylinder bore just enough to allow access to the upper half of the shell bearing. Remove the bearing from the connecting rod. Keep the bearings from the connecting rod and cap together.

To fit

Operation 4-2

- 1 Clean the bearing faces of the connecting rod and the crank pin.
- 2 Clean the complete bearing and lubricate the bearing surface and the crank pin with clean engine lubricating oil. Fit the upper half of the shell bearing to the connecting rod; ensure that the location tag is fitted correctly in its recess (A1). Fit the connecting rod to the crank pin; ensure that the assembly number on the connecting rod is on the same side as the other connecting rods.
- 3 Clean, lubricate and fit the lower half of the shell bearings into the cap; ensure that the location tag is fitted correctly in its recess (A1). Fit the connecting rod bolts with the flat side of the head of the bolts towards the connecting rod. Fit the cap to the connecting rod. Ensure that the assembly number on the cap is the same as that on the connecting rod and that both of the assembly numbers are on the same side (B).
- 4 Tighten the nuts gradually and evenly to the recommended torque of 125 Nm (92 lbf ft) 12,7 kgf m.
- 5 Ensure that the crankshaft rotates freely.
- 6 Fit the lubricating oil strainer and suction pipe, see Operation 10-4 or fit the balancer unit if the engine has one, see Operation 5-14.
- 7 Fit the lubricating oil sump, see Operation 10-3 and fill the sump to the correct level with lubricating oil of an approved grade.



To inspect

Operation 4-3

Check the bearings and the crank pin for wear or other damage.

Piston and connecting rod

To remove

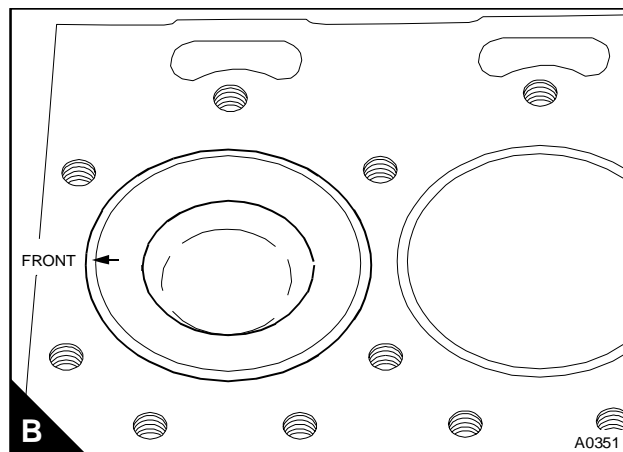
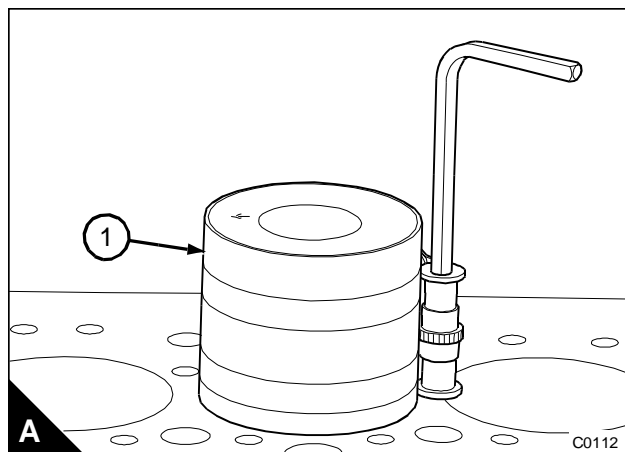
Operation 4-4

- 1 Drain the lubricating oil and the cooling system.
- 2 Remove the cylinder head assembly, see Operation 3-7.
- 3 Remove all carbon from the top of the bores of the cylinder liners.
- 4 Remove the lubricating oil sump, see Operation 10-3.
- 5 Remove the lubricating oil strainer and suction pipe, see Operation 10-4 or remove the balancer unit, see Operation 5-13.
- 6 Remove the big end caps and the big end bearings from the connecting rods, see Operation 4-1.
- 7 Push the pistons and the connecting rods out through the top of the cylinder liners. Keep the bearings and caps together to ensure that they can be fitted in their original positions.
- 8 Inspect the crank pins for damage.

Special requirements

Special tools	
Description	Part number
Piston replacer tool, No 8	-

- 1 Ensure that the piston, the cylinder bore, the crank pin and the big end of the connecting rod are clean. Lubricate the piston and the cylinder liner with clean engine lubricating oil.
 - 2 Rotate the crankshaft until the relevant crank pin is at its lowest position. Lubricate the crank pin with clean engine lubricating oil.
 - 3 Fit the upper half of the shell bearings to the connecting rod. Ensure that the location tag is fitted correctly in its recess. Lubricate the bearing with clean engine lubricating oil.
 - 4 Put the piston replacer tool in position at the top of the relevant cylinder. The tool has a tapered bore to compress the piston rings when the piston and connecting rod assembly is fitted. Ensure that the smaller end of the tapered bore is towards the face of the cylinder block.
 - 5 Put the piston ring gaps 120° apart. Pass the connecting rod through the piston replacer tool and allow the piston to enter the tool. The arrow or "F" mark (B) on the top of the piston must be towards the front of the engine. In this position the combustion bowl in the top of the piston will be towards the fuel injection pump side of the engine.
 - 6 Push the piston and connecting rod assembly through the piston replacer tool (A1) and onto the crank pin.
- Caution:** New nuts must be fitted to the big end bearing bolts.
- 7 Clean the connecting rod cap and the lower half of the shell bearings. Fit the bearing to the cap; ensure that the location tag is fitted correctly in its recess. Lubricate the bearing with clean engine lubricating oil. Fit the cap and ensure that the assembly number is the same as that on the connecting rod and that the numbers are on the same side. Fit new nuts; ensure that the flat side of the head of the bolts is towards the connecting rod. Tighten the fasteners gradually and evenly to the recommended torque of 125 Nm (92 lbf ft) 12,7 kgf m.



Continued

-
- 8 Check that the crankshaft will rotate freely.
 - 9 Check the piston height above the top face of the cylinder block, see Operation 4-6.
 - 10 Fit the lubricating oil strainer and suction pipe, see Operation 10-4 or fit the balancer unit, see Operation 5-14.
 - 11 Fit the lubricating oil sump, see Operation 10-3.
 - 12 Fit the cylinder head assembly, see Operation 3-8.
 - 13 Fill the sump to the correct level with lubricating oil of an approved grade.
 - 14 Fill the cooling system.

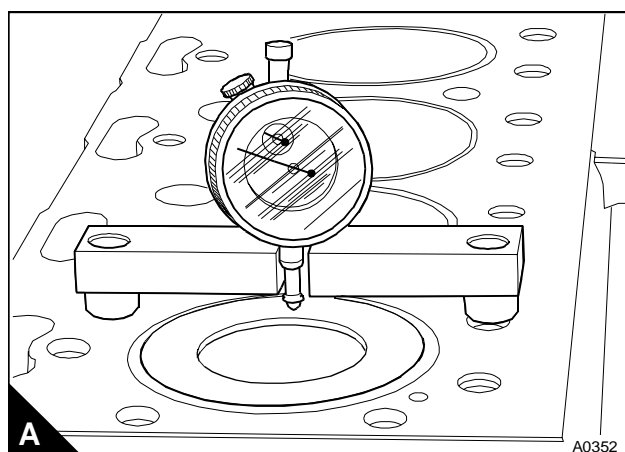
To check the piston height above the cylinder block

Operation 4-6

Special requirements

Special tools			
Description	Part number	Description	Part number
Piston height tool	PD.41D	Dial gauge for use with PD.41D	PD.208

- 1 Put the piston height tool on the face of the cylinder block and rotate the gauge dial to the zero position. Rotate the crankshaft until the piston is approximately at top dead centre (TDC). Carefully put the tool over the top of the piston with the plunger of the gauge in contact with the piston above the axis of the gudgeon pin (A).
- 2 Rotate the crankshaft to ensure that the piston is at the highest position and make a note of the gauge indication. The piston height above the face of the cylinder block should be 0,14/0,36 mm (0.005/0.014 in).



Piston rings

To remove and to fit

Operation 4-7

The piston has two compression rings and an oil control ring. All the piston rings are above the gudgeon pin. Piston rings have different design features. To ensure that the correct type 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 or put into position.

To remove

Remove the piston rings with a suitable ring expander. Keep the rings with their relevant piston.

To fit

Use a suitable piston ring expander to fit the piston rings.

1 Fit the spring of the oil control ring in the bottom groove with the latch pin inside both ends of the spring (A). Fit the oil control ring over the spring (B2). Ensure that the ring gap is at 180° to the latch pin.

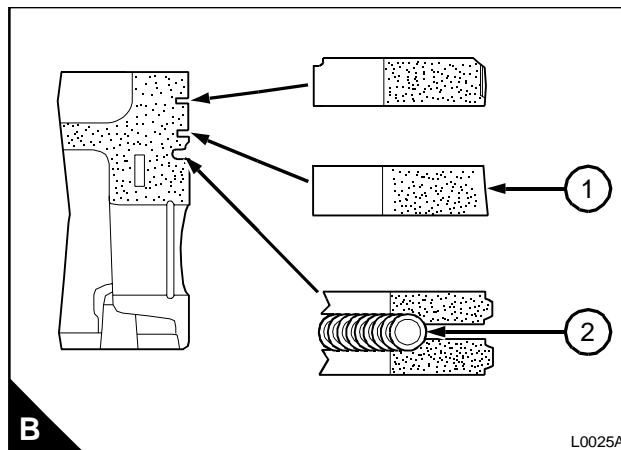
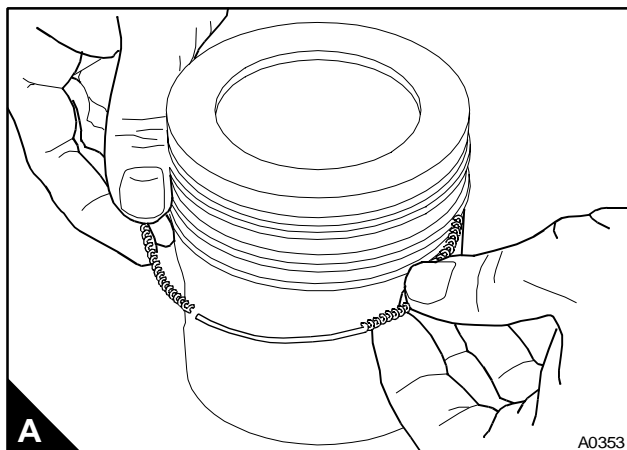
2 Fit the cast iron ring with the taper face (B1) to the second groove with the word "TOP" towards the top of the piston.

New second rings have a green identification mark which must be on the left of the ring gap when the ring is fitted and the piston is upright.

3 Fit the barrel faced top ring in the top groove, the word 'TOP' must be towards the top of the piston. The top ring has an internal step on the top face.

Note: New top rings have a red identification mark which must be on the left of the ring gap when the ring is fitted and the piston is upright.

4 Ensure that the ring gaps are 120° apart.

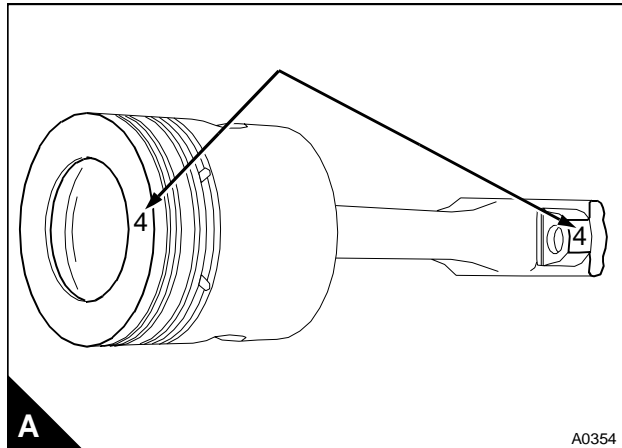


Piston and connecting rod assembly

To dismantle

Operation 4-8

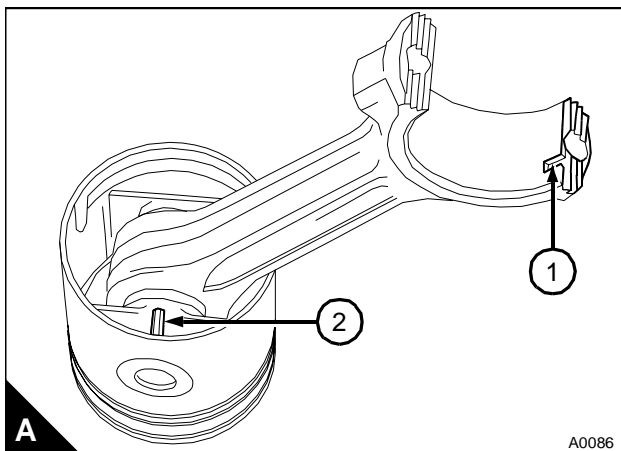
- 1 Remove the piston rings, see Operation 4-7.
- 2 Remove the circlips which retain the gudgeon pin.
- 3 Put a mark on the piston to indicate the cylinder number as shown on the connecting rod. Put the mark on the piston on the same side as the mark on the big end to ensure that they are assembled correctly (A).
- 4 Push the gudgeon pin out by hand. If the gudgeon pin is tight, heat the piston to 40/50 °C (100/120 °F) for easy removal of the gudgeon pin.



To assemble

Operation 4-9

- 1 Clean the bore of the small end bush and lubricate it with clean engine lubricating oil.
- 2 Fit a new circlip 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 with the recess for the location of the big end bearing (A1) on the same side as the lug on the gudgeon pin boss (A2). If the original piston is used, ensure that it is assembled to the correct connecting rod and is used in the original cylinder.
- 4 Lubricate the gudgeon pin bosses with clean engine lubricating oil and push in the gudgeon pin 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.
- 5 Fit a new circlip in the groove in the other gudgeon pin boss. Ensure that it fits correctly in the groove.
- 6 Fit the piston rings, see Operation 4-7.

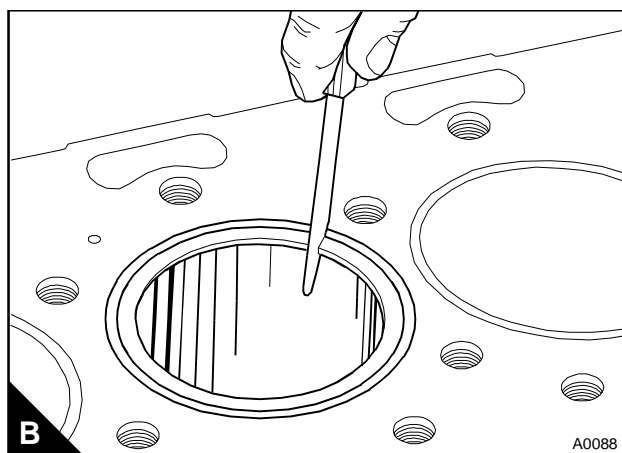
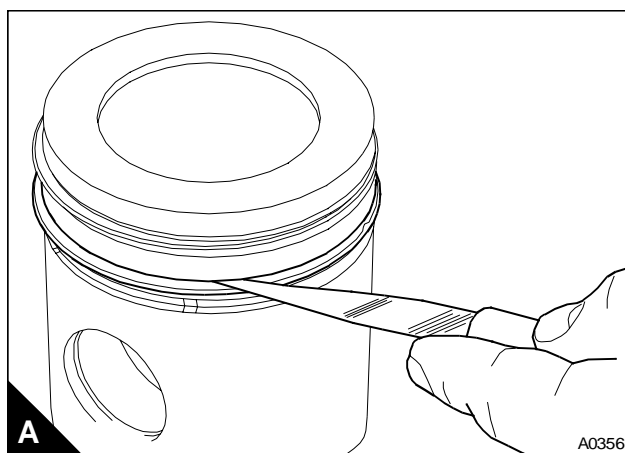


Piston and piston rings

To inspect

Operation 4-10

- 1 Check the piston for wear and other damage.
- 2 Check that the piston rings are free to move in their grooves and that the rings are not broken.
- 3 Remove the piston rings, see Operation 4-7, and clean the piston ring grooves and the piston rings.
- 4 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 in the relevant Data and dimensions for the "Pistons and connecting rods" on page 17, and renew the piston if necessary.
- 5 Clean all carbon from the top of the cylinder liners. Fit the piston rings in the top part of the cylinder liner and measure the ring gap with feeler gauges (B). The coil spring must be fitted to the oil control ring when the gap of this piston ring is measured. The piston ring gaps for new components are given in the relevant Data and dimensions for the "Pistons and connecting rods" on page 17.



Connecting rod

To inspect

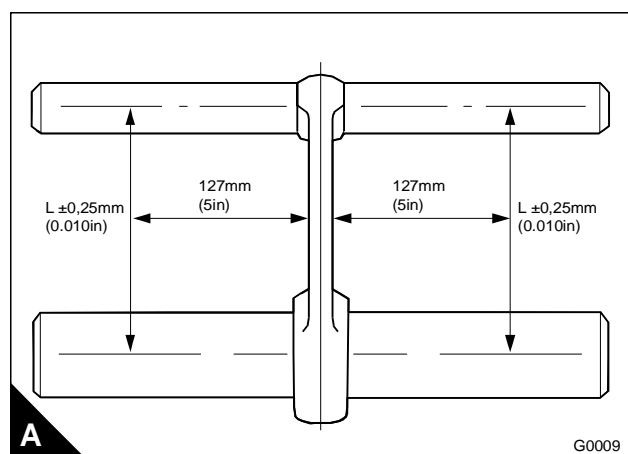
Operation 4-11

1 Check the connecting rod for distortion (A).

Note: The large and small end bores must be square and parallel with each other within the limits of $\pm 0,25$ mm (0.010 in) measured 127 mm (5.0 in) each side of the connecting rod axis on a test mandrel. With the small end bush fitted, the limits are reduced to $\pm 0,06$ mm (0.0025 in).

2 Check the small end bush for wear or for other damage and renew it, if necessary.

3 Check the fit of the gudgeon pin in the small end bush and check the gudgeon pin for wear, refer to the relevant Data and dimensions for the "Pistons and connecting rods" on page 17.



Small end bush

To remove and to fit

Operation 4-12

1 Press out the old bush with a suitable adaptor.

2 Clean the connecting rod bore and remove any sharp edges.

3 Press in the new bush. Ensure that the lubrication hole in the bush is on the same side as, and is aligned with, the hole in the top of the connecting rod.

4 Ream the bush to get the correct clearance between the gudgeon pin and the bush. Refer to the relevant Data and dimensions for the "Pistons and connecting rods" on page 17.

5

Crankshaft assembly

General description

The crankshaft is a chrome-molybdenum forging which has five main journals.

End-float is controlled by two half thrust washers on both sides of the centre main bearing.

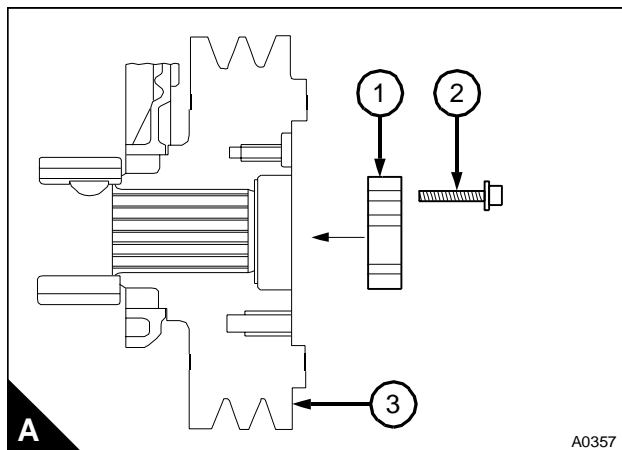
The main bearings have steel backs with a aluminium/tin bearing material. The main bearing caps are made of cast iron or spheroidal graphite (SG) iron.

The front and the rear oil seals are Viton lip seals with a dust lip to the outside of the main lip and with oil return grooves on the face of the main lip.

Warning! Read the safety precautions for "Viton seals" on page 7.

The crankshaft pulley (A3) is held in position by a plain thrust block (A1) and three setscrews (A2). The nose of the crankshaft is serrated for location.

A balancer unit is fitted to engines which have rigid mountings or which are part of the chassis or frame. The purpose of the balancer unit is to reduce the effect of the out-of-balance forces to an acceptable condition.



Crankshaft pulley

To remove and to fit

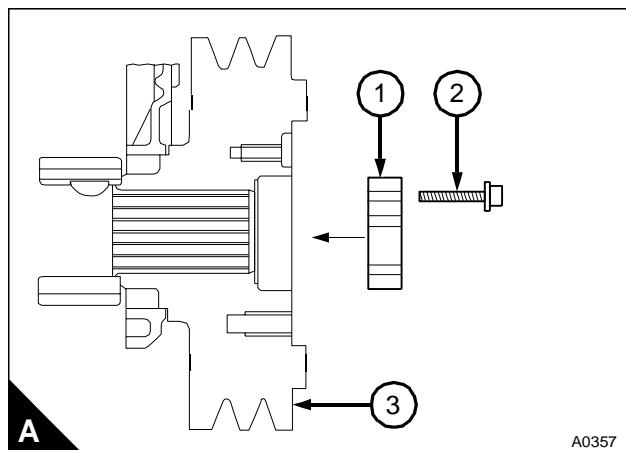
Operation 5-1

To remove

- 1 Remove the drive belt, see Operation 14-2.
- 2 Release the three setscrews (A2) which hold the pulley and remove the setscrews, the thrust block (A1) and the pulley (A3).
- 3 Clean the components and check for damage. Renew damaged components.

To fit

- 1 Put the pulley in position on the crankshaft. Lubricate lightly the threads of the setscrews with engine lubricating oil. Lubricate the main lip of the seal with clean engine oil. Fit the hub and the setscrews and tighten the setscrews gradually and evenly to 115 Nm (85 lbf ft) 11,8 kgf m.
- 2 Check each setscrew again to ensure that they are still to the correct torque.
- 3 Fit the drive belt, see Operation 14-2.



Rear oil seal assembly

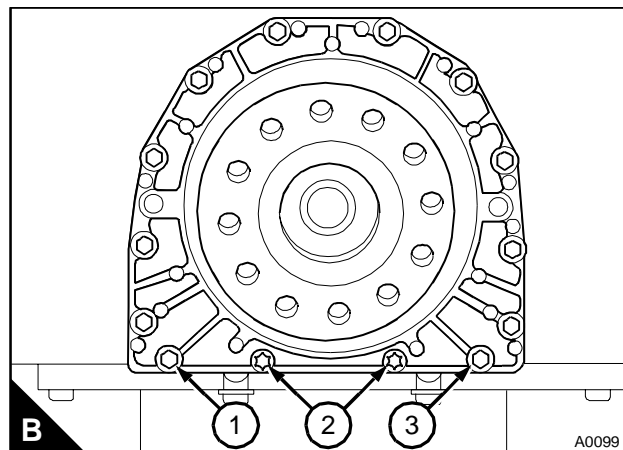
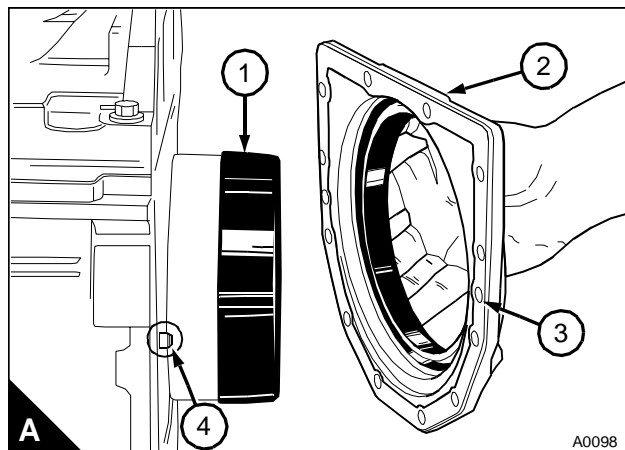
To remove and to fit

Operation 5-2

Special requirements

Special tools		Consumable products	
Description	Part number	Description	Part number
Replacer tool for rear oil seal	PD.145D	POWERPART Threadlock	21820222
		POWERPART Silicone rubber sealant	1861108

- 1 Remove the drive components from the rear end of the engine.
 - 2 Remove the flywheel, see Operation 13-1, and the flywheel housing, see Operation 13-3.
 - 3 Remove the setscrews and the cap screws from the housing and remove the housing and seal assembly.
 - 4 Inspect the seal for wear or for damage to the main lip and renew the seal, if necessary. If there is only a small scratch across the lip, renew the seal.
 - 5 Clean the faces of the cylinder block, the oil seal housing and the crankshaft flange.
 - 6 Check that the seal and the outer circumference of the crankshaft flange are not damaged. Where a new seal has been fitted, check that it is in the correct position in the housing.
 - 7 Ensure that the two dowels (A4) are fitted in the cylinder block. Put a new joint (A3) in position on the dowels, no jointing compound is necessary.
 - 8 Put the seal replacer tool on the crankshaft flange. Lubricate the crankshaft flange, the main lip of the seal and the seal replacer tool with clean engine lubricating oil. The lubrication of the seal is necessary to prevent damage to the seal when the engine is first started.
 - 9 Put the seal and housing (A2) on the replacer tool (A1) and carefully push the assembly into position on the crankshaft flange and onto the dowels. Remove the tool, fit the setscrews and the cap screws. Tighten the setscrews to 22 Nm (16 lbf ft) 2,2 kgf m and tighten the cap screws to 18 Nm (13 lbf ft) 1,9 kgf m.
- Note:** On the latest engines two torx screws (B2) are fitted instead of cap screws. Tighten the torx screws to 22 Nm (16 lbf ft) 2,2 kgf m. Two extra setscrews (B1 and B3) have also been fitted to later engines.



To renew the rear oil seal

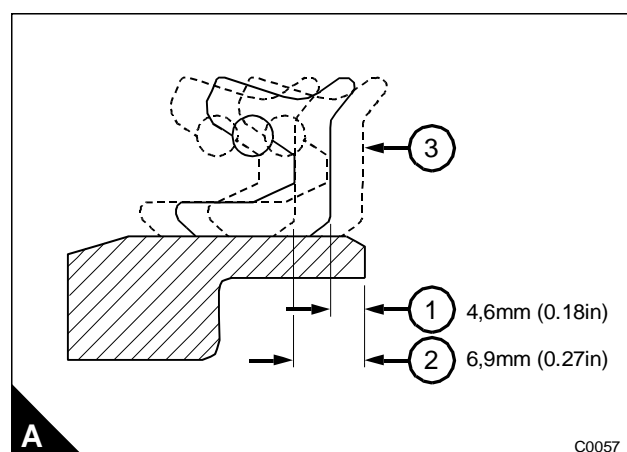
Operation 5-3

Special requirements

Special tools	
Description	Part number
Replacer tool for rear oil seal	PD.145D

There are three positions in which the seal can be fitted in the housing (A).

- Position 1 (A1) is used when a new seal is first fitted in service.
- Position 2 (A2) is used when a new seal is fitted in service and the crankshaft flange is worn in position 1.
- Position 3 (A3) can be used with a new seal in service, if a wet clutch is not used and the crankshaft is new or the crankshaft palm area has been corrected. Ensure that the seal is fitted square in the housing.



If all positions have been used it is permissible to grind the crankshaft flange, refer to the relevant Data and dimensions for the "Crankshaft" on page 18.

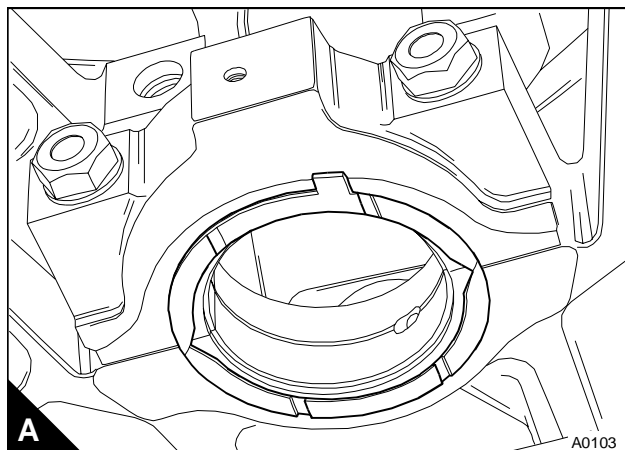
- 1 Remove the seal and housing assembly, see Operation 5-2.
- 2 Put the engine side of the housing on a suitable support and press out the seal with a suitable adaptor.
- 3 Lubricate the outer circumference of the seal and the bore of the seal housing with clean engine lubricating oil.
- 4 Put the engine side of the housing on a suitable support. Put the seal into position on the flywheel end of the bore with the spring of the seal towards the housing.
- 5 Use a press and the replacer tool, PD.145D, to fit the seal at the correct depth. The special tool has two sides and is used in accordance with either position "1" or "2". Press the seal into the housing to the correct position with the relevant side of the tool.

Thrust washers

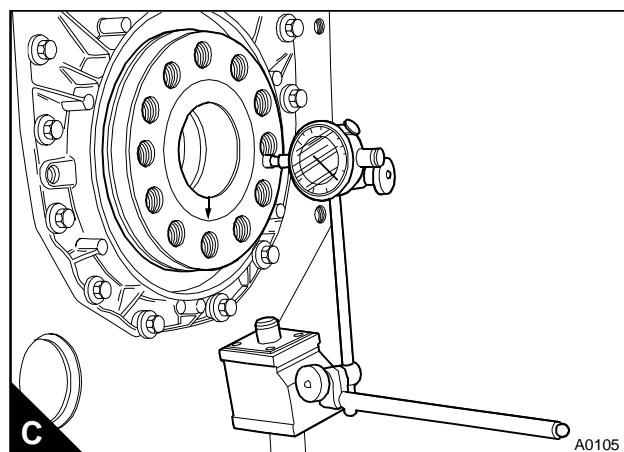
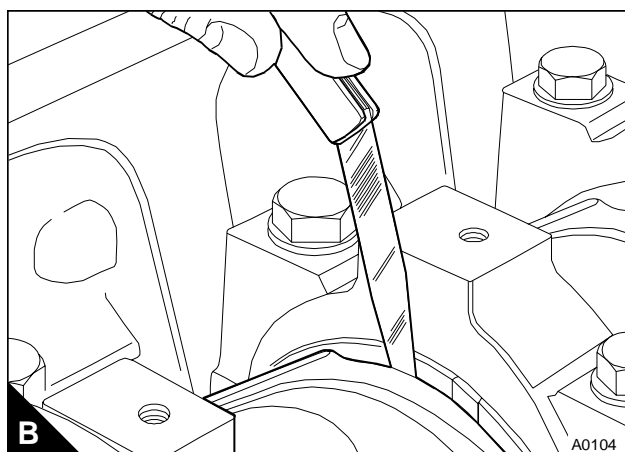
To check the crankshaft end-float

Operation 5-4

The axial movement of the crankshaft is controlled by two half thrust washers fitted both sides of the centre main bearing (A).



The end-float can be checked with a feeler gauge between a thrust washer and the crankshaft (B), or with a dial test indicator on one end of the crankshaft to check the movement (C).



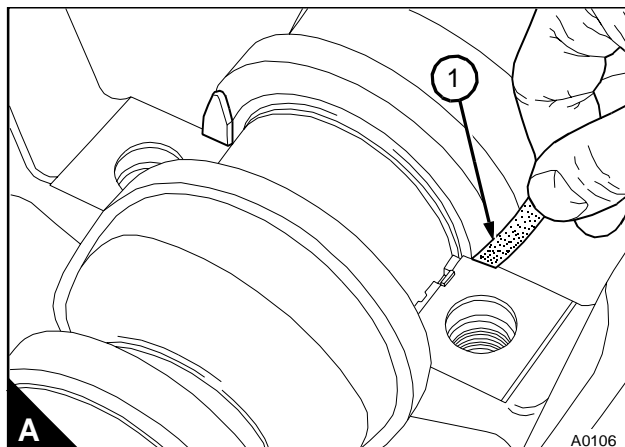
If the end-float is more than the tolerance given in the relevant Data and dimensions for the "Crankshaft" on page 18, thrust washers which are 0,019 mm (0.0075 in) oversize can be fitted.

The oversize thrust washers can be fitted to one or to both sides of the main bearing. They are fitted instead of the standard size washer, to reduce the end-float to the factory tolerances.

To remove

Operation 5-5

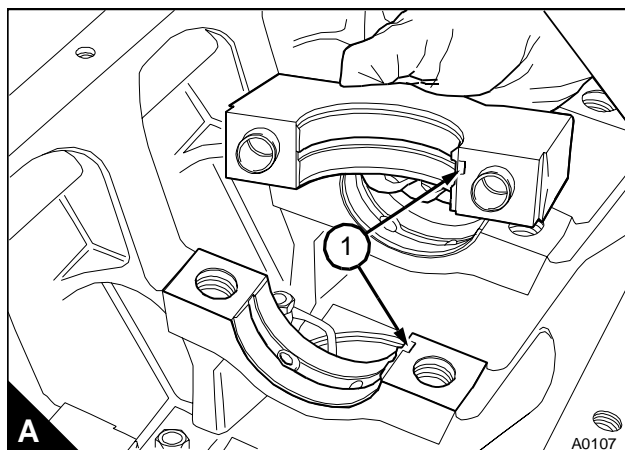
- 1 Drain the lubricating oil and remove the lubricating oil sump, see Operation 10-3.
- 2 If necessary, remove the balancer unit, see Operation 5-13.
- 3 If necessary, remove the lubricating oil strainer and suction pipe, see Operation 10-4.
- 4 Release the setscrews of the centre main bearing and remove the main bearing cap complete with the lower half thrust washers.
- 5 Press down one end of each upper half thrust washer, with a suitable tool made of a soft material (A1), to slide the washer from its recess. Where necessary, move the crankshaft to the front or to the rear to loosen a tight washer.



To fit

Operation 5-6

- 1 Lubricate the thrust washers with clean engine lubricating oil.
- 2 Slide the upper half thrust washers into their recesses in the cylinder block. Ensure that the sides of the thrust washers which have the grooves are against the crankshaft.
- 3 Fit the lower half thrust washers to the main bearing cap with the location tags in their recesses.
- 4 Ensure that the location thimbles are fitted correctly in the main bearing cap or in the cylinder block.
- 5 Ensure that the bearing is fitted correctly in the cap and that the bearing and the crankshaft journal are clean. Lubricate the bearing with clean engine lubricating oil.
- 6 Fit the cap with the location tags of both half of the shell bearings to the same side (A1). Tighten the main bearing setscrews gradually and evenly to 250 Nm (185 lbf ft) 26,0 kgf m.
- 7 Check the crankshaft end-float, see Operation 5-4.
- 8 If necessary, fit the balancer unit, see Operation 5-14.
- 9 If necessary, fit the lubricating oil strainer and the suction pipe, see Operation 10-4.
- 10 Fit the lubricating oil sump, see Operation 10-3, and fill it to the correct level with an approved lubricating oil.



Main bearings

To remove (with the crankshaft in position)

Operation 5-7

If the rear main bearing is to be removed with the crankshaft in position, the flywheel, the flywheel housing, the rear oil seal housing and the bridge piece will have to be removed.

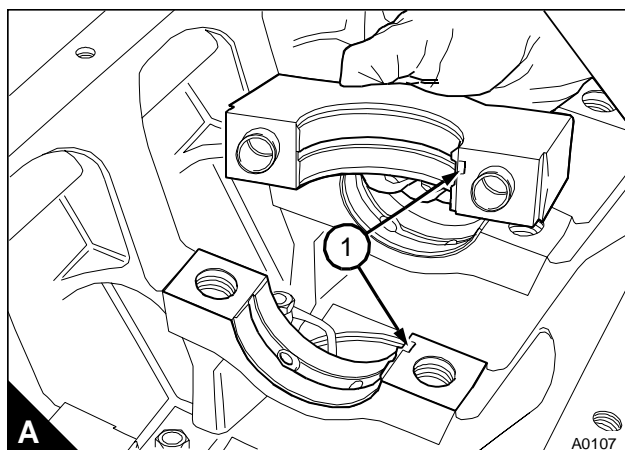
The balancer unit or the suction pipe and strainer, the delivery pipe and the relief valve will have to be removed.

- 1 Drain the lubricating oil and remove the sump, see Operation 10-3.
- 2 Remove all necessary components to get access to the specific bearing cap.
- 3 Release the setscrews of the bearing cap and remove the bearing cap. Remove the lower half of the shell bearing from the cap.
- 4 With a suitable tool, push the upper half of the shell bearing from the side opposite to the location tag to remove the bearing tag from its recess in the bearing housing. Carefully rotate the crankshaft to release the bearing from its housing. Keep the bearing halves in their relevant positions.

To fit (with the crankshaft in position)

Operation 5-8

- 1 Clean the upper half of the shell bearing and lubricate the bearing surface with clean engine lubricating oil.
Caution: Only the upper half of the bearing has lubrication holes and must be fitted to the side of the cylinder block.
- 2 Fit the plain end of the upper half of the shell bearing between the crankshaft journal and the side of the bearing housing which has the recess for the location tag. Slide the bearing into its housing until the tag on the bearing is fitted correctly in its recess in the housing.
- 3 Clean the lower half of the shell bearing and the cap, lubricate the bearing surface with clean engine lubricating oil.
- 4 Fit the bearing into the cap with the tag of the bearing fitted correctly in the recess in the cap.
- 5 Ensure that the location thimbles are fitted correctly to the cap or to the cylinder block. Fit the bearing cap with the location tags of both bearings on the same side (A1).
- 6 Inspect the setscrews for damage and for distortion and renew them if necessary. Lightly lubricate the setscrew threads with clean engine lubricating oil. Fit the setscrews and tighten the setscrews gradually and evenly to 250 Nm (185 lb ft) 26,0 kgf m.
- 7 Ensure that the crankshaft turns freely. If the thrust washers have been removed and fitted, check the crankshaft end-float, see Operation 5-4.
- 8 Fit all the components which were removed for access to the main bearing cap.
- 9 Fit the lubricating oil sump, see Operation 10-3 and fill it to the correct level with an approved lubricating oil.



To inspect

Operation 5-9

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

Crankshaft

To remove

Operation 5-10

Warnings!

- Use lift equipment or obtain assistance to lift heavy engine components such as the balancer unit, flywheel housing, crankshaft and flywheel.
- It is recommended that this operation is done with the engine upside down.

- 1 Before the engine is removed from the vehicle or from the machine, drain the lubricating oil and the coolant.
- 2 Remove the lubricating oil sump, see Operation 10-3.
- 3 Remove the fan, the drive belt, the fan drive pulley and housing and the coolant pump, refer to Chapter 12, Cooling system.
- 4 Remove the crankshaft pulley, see Operation 5-1.
- 5 Remove the alternator and its mounting bracket, see Operation 14-3.
- 6 Remove the compressor and its drive assembly, or remove the exhauster, see Operation 15-4.
- 7 Remove the timing case cover, see Operation 6-1.
- 8 Remove the fuel injection pump, see Operation 11-10 for Lucas DPA fuel injection pumps and Operation 11-14 for Stanadyne fuel injection pumps.
- 9 Remove the timing gears and the timing case, see Chapter 6, Timing case and drive assembly.
- 10 Remove the flywheel, see Operation 13-1, and the flywheel housing, see Operation 13-3.
- 11 Remove the rear oil seal housing, see Operation 5-2.
- 12 Remove the balancer, see Operation 5-13.
- 13 Remove the bridge piece and the rubber seals. Later engines may not have rubber seals fitted.

Warning! It is recommended that the operation that follows is done with the engine up side down.

- 14 Remove the caps of the connecting rods. Keep the shell bearings and caps together. Remove the bolts of the connecting rods and carefully push the pistons towards the top of their bores.
- 15 Ensure that the tops of the main bearing caps are stamped with their relevant position number. Remove the main bearing caps, the lower half of the shell bearings and the upper and lower thrust washers. Keep the shell bearings with their relevant caps.
- 16 Lift out the crankshaft. Remove the upper half of the shell bearings and keep each bearing with its relevant lower half and cap.

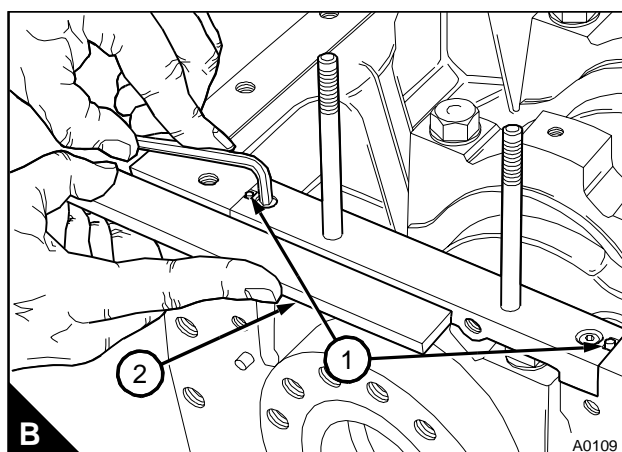
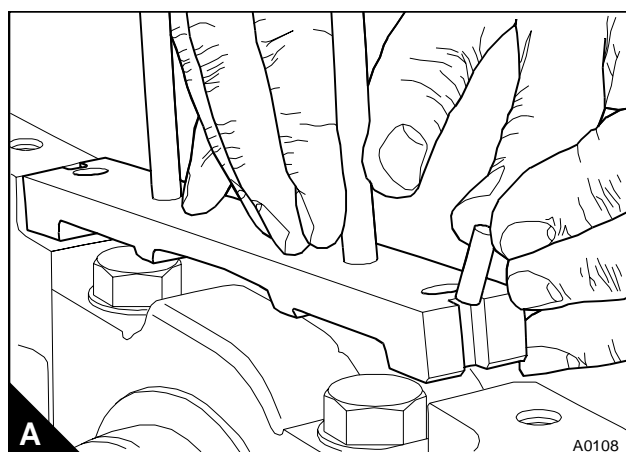
To fit

Operation 5-11

Special requirements

Consumable products			
Description	Part number	Description	Part number
POWERPART Silicone rubber sealant	1861108	POWERPART Liquid gasket	21820518

- 1 Ensure that all lubricating oil passages are clean and free from restriction.
- 2 Clean the main bearing housings and the upper half of the shell bearings. Fit the shell bearings with the location tags fitted correctly in their recesses. Lubricate the bearings with clean engine lubricating oil.
- 3 Ensure that the main journals of the crankshaft are clean. Put the crankshaft in position on the upper bearings.
- 4 Clean and lubricate the upper thrust washers and slide them into their recesses on both sides of the bearing housing. Ensure that the slotted sides of the thrust washers are towards the crankshaft.
- 5 Clean the bearing caps and the lower half of the shell bearings. Fit the bearings to the caps with the location tags fitted correctly in their recesses. Lubricate the bearings with clean engine lubricating oil.
- 6 Clean the lower thrust washers and lubricate them with clean engine lubricating oil. Fit the thrust washers on both sides of the bearing cap for the centre main bearing.
- 7 Check that the location thimbles for the main bearing caps are fitted correctly in the caps or in the cylinder block. Fit the bearing caps in their correct positions (as shown by the position number stamped on the top of the cap) with the location tags of the bearings on the same side. In this position the serial numbers stamped on the bearing caps will be in line. The serial number stamped on the bearing caps must be the same as the number stamped on the bottom face of the cylinder block.
- 8 Fit the setscrews to the main bearing caps and tighten the setscrews gradually and evenly to 250 Nm (185 lb ft) 26,0 kgf m.
- 9 **For early engines fitted with rubber seals:** Clean the bridge piece and the location areas for the bridge piece in the cylinder block. Apply a narrow strip of POWERPART Silicone rubber sealant in the corners and around the thread holes of the bridge piece seat in the cylinder block. Fit the bridge piece and the two rubber seals (A). The rubber seals will be a little higher than the bridge piece when they are fitted correctly. Use a straight edge (B2) to ensure that the bridge piece is in line with the rear face of the cylinder block. Tighten the bridge piece cap screws (B1) to 16 Nm (12 lbf ft) 1,6 kgf m.

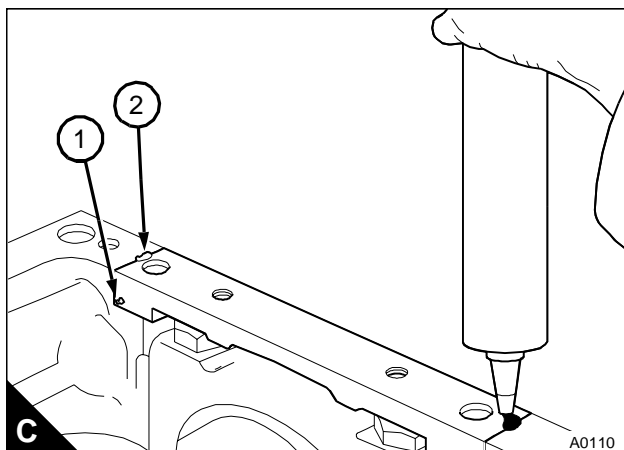


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For later engines fitted with POWERPART Liquid gasket: A bridge piece has been introduced which uses POWERPART Liquid gasket instead of the rubber seal in the groove at each end of the bridge piece. The groove at each end of the new bridge piece is cast and is off-centre. The procedure to fit the new bridge piece is the same as for the earlier bridge piece, except for the instructions given below. Apply a $\frac{1}{8}$ in (3.0 mm) bead of POWERPART Liquid gasket along the corner in the top of the recess in the cylinder block for the bridge piece.

When the bridge piece is in position and the cap screws have been tightened, inject POWERPART Liquid gasket into the groove (C2) at each end of the bridge piece. Continue to inject sealant until the groove is completely full and the sealant leaves the lower groove (C1) at the front and rear of the bridge piece.

It may be necessary to stop the sealant at one side of the lower groove in order to ensure it will flow from the opposite side of the groove.



Caution: When the sump joint is removed, damage can occur to the seal in the grooves of the bridge piece. If the seal is damaged, apply enough sealant to completely fill the grooves.

Note: The latest engines have setscrews in place of studs to fasten the sump to the bridge piece. The threads of the setscrews have a sealant applied by the manufacturer. When the setscrews are to be used again, ensure that the threads of the setscrews and of the bridge piece are clean and a sealant is applied to the threads of the setscrews. These instructions also apply to studs.

- 10 Fit the connecting rod caps, see Operation 4-2. Rotate the crankshaft two turns to ensure free movement.
- 11 Fit the balancer unit, see Operation 5-14.
- 12 Fit the rear oil seal housing, see Operation 5-2.
- 13 Fit the flywheel housing, see Operation 13-3, and the flywheel, see Operation 13-1.
- 14 Fit the timing case and the timing gears, see Chapter 6, Timing case and drive assembly.
- 15 Fit the fuel injection pump, see Operation 11-11 for Lucas DPA fuel injection pumps and Operation 11-15 for Stanadyne fuel injection pumps.
- 16 Fit the timing case cover, see Operation 6-2.
- 17 Fit the compressor and its drive assembly or fit the exhauster, see Operation 15-4.
- 18 Fit the alternator and its mounting bracket, see Operation 14-3.
- 19 Fit the crankshaft pulley, see Operation 5-1.
- 20 Fit the coolant pump, the fan drive pulley and housing, the drive belts and the fan, see Chapter 12, Cooling system.
- 21 Fit the lubricating oil sump, see Operation 10-3.
- 22 After the engine has been installed, fill the lubricating oil sump to the correct level with an approved oil. Fill the cooling system.

To inspect**Operation 5-12**

Check the crankshaft for wear and other damage. The maximum permissible wear and ovality on the crankshaft journals and crank pins is 0,04 mm (0.0016 in).

The main journals and the crank pins of standard size crank shafts can be machined to 0,25mm (0.010 in), 0,50mm (0.020 in) or 0,75 mm (0.030 in) undersize in diameter. Refer to "Crankshaft overhaul" on page 19. Special undersize bearings are available.

If the seal has been used in all of the service positions, the crankshaft palm can be machined to remove the wear marks. Further information can be found in the relevant Data and dimensions for the "Crankshaft" on page 18.

Balancer unit

To remove**Operation 5-13**

1 Drain the lubricating oil from the sump and remove the sump, see Operation 10-3.

Warning! *The weight of the unit is approximately 25 kg (55 lb).*

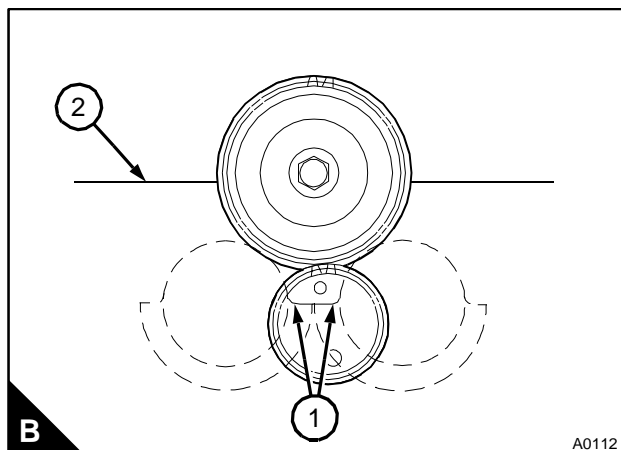
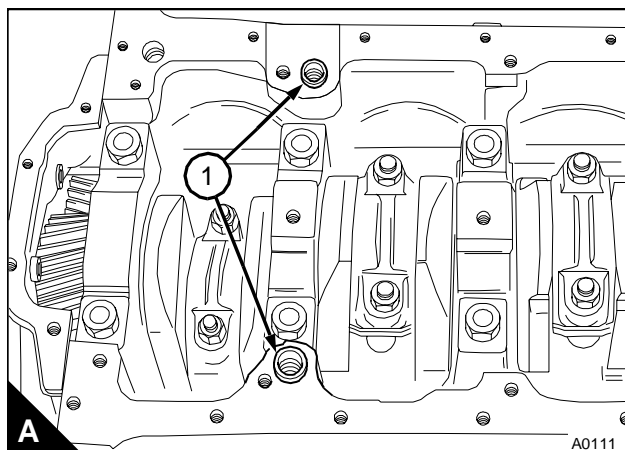
2 Provide a support for the balancer unit before release of the setscrews from the engine.

3 Release the setscrews and lower carefully the balancer unit. Make a note of the positions of the setscrews of different lengths.

To fit

Operation 5-14

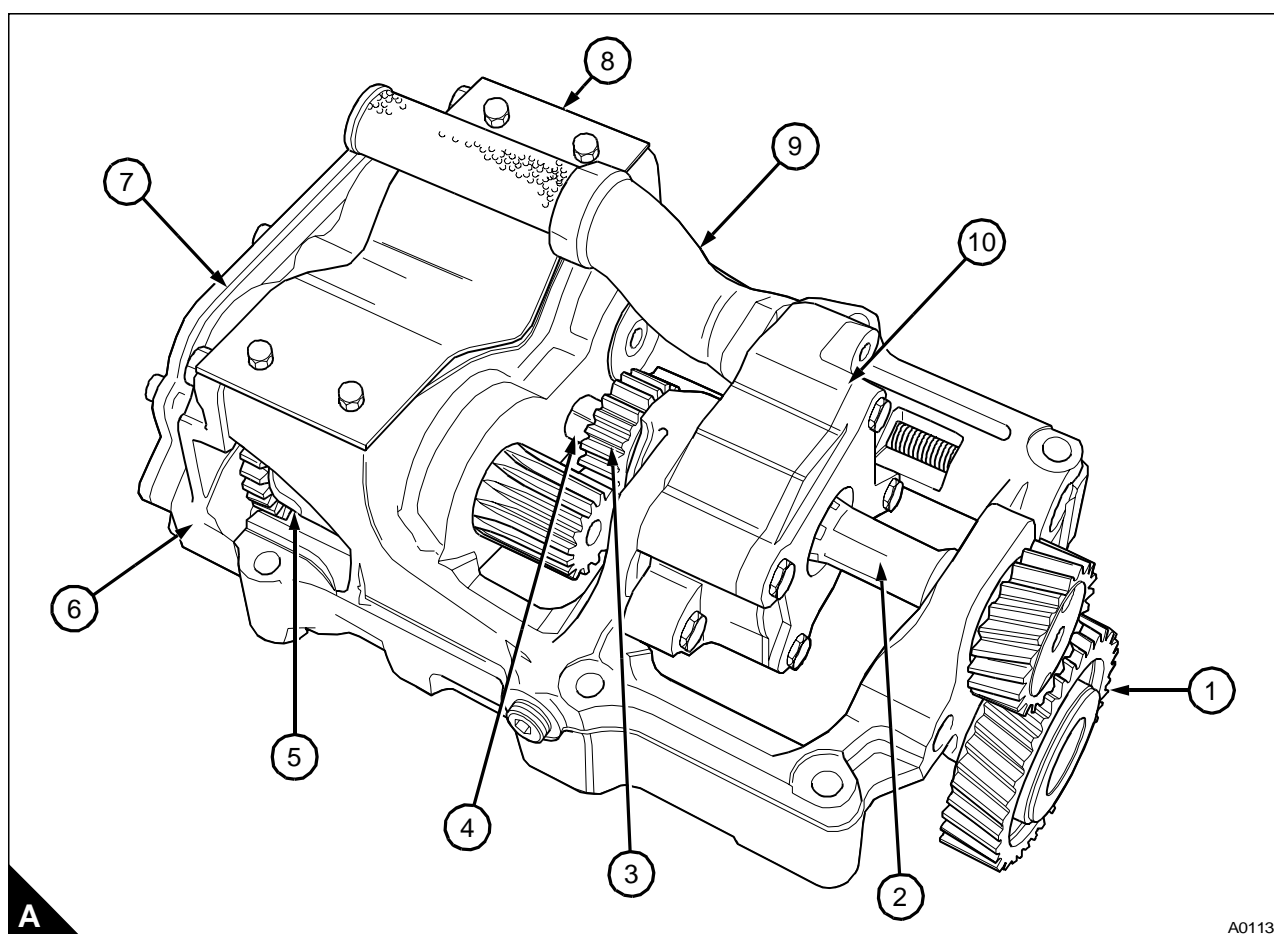
- 1 Ensure that the contact faces of the cylinder block and of the balancer unit are clean and that the two thimbles (A1) are fitted correctly to the cylinder block.
 - 2 Set the piston of number 1 cylinder to TDC, see Operation 8-2.
 - 3 Before the balancer unit is fitted, ensure that the flat faces of the balance weights are level with each other (B1) and the weights hang down away from the cylinder block (B2). The timing of the balance weights to the drive shaft is correct when the large hole and small hole in the front of the drive shaft gear are in the positions shown (B).
- Note:** If the gear position shown in (B) cannot be obtained, then the balancer must be partially dismantled and the timing corrected, refer to step 6 of Operation 5-16.
- 4 Fit the balancer unit to the cylinder block with the correct screws in the centre positions of the balancer frame. Ensure, when the idler and crankshaft gears are in mesh, that the flat faces of the balance weight are level with each other and that they are towards the cylinder block. Check that the balancer unit is fitted correctly on the thimbles and fit the remainder of the setscrews in their correct position. Tighten the setscrews to 54 Nm (40 lbf ft) 5,5 kgf m.
 - 5 Rotate the crankshaft through two turns to ensure that it is free to rotate.
 - 6 Fit the lubricating oil sump, see Operation 10-3 and fill the sump to the correct level with an approved oil.



To dismantle

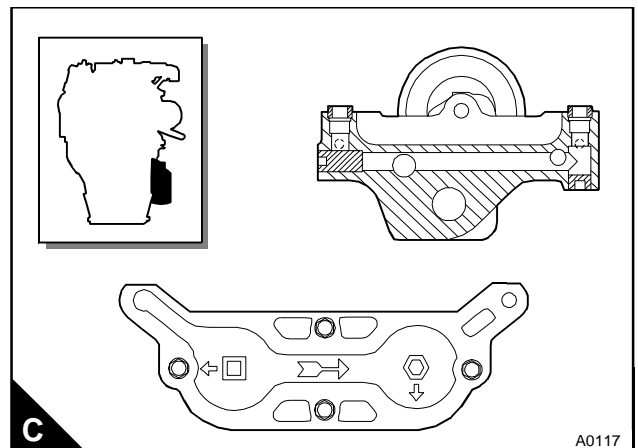
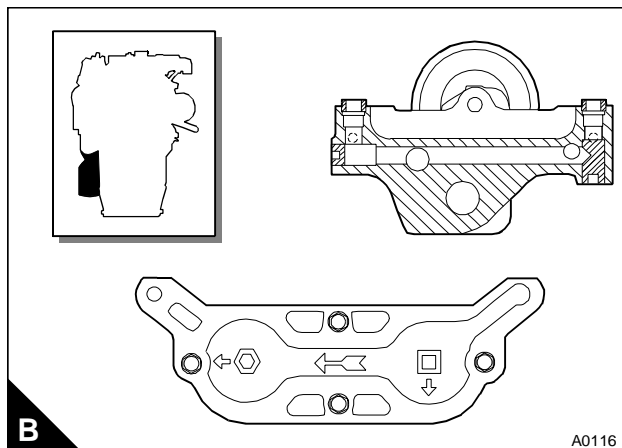
Operation 5-15

- 1 Remove the balance weight cover (A8).
- 2 Release the setscrew and remove the idler gear assembly (A1). Keep the components together as an assembly to protect the needle roller bearing.
- 3 Prevent movement of the drive shaft (A2) and loosen the nut (A4) of the drive gear for the balance weights (A3). Put a suitable flat distance piece in position between the nut and the balancer frame. Turn the nut until it is against the face of the distance piece. Continue to turn the nut with a suitable spanner until the Loctite seal on the splines of the drive shaft is broken and the gear is loose on the shaft. Remove the nut and the drive gear and remove the drive shaft. Ensure that the needle roller bearings are not damaged when the drive shaft is removed.
- 4 Release the setscrews which hold the lubricating oil pump and the suction pipe (A10 and A9) to the balancer frame and remove the lubricating oil pump and the suction pipe.
- 5 Release the setscrews and remove the transfer plate and joint for the lubricating oil (A7) from the rear of the balancer unit.



Continued

Make a note of the position of the direction arrows on the outside of the transfer plate (B or C) to ensure that it can be assembled correctly.



Notes:

- The latest oil transfer plate is fitted without a joint or sealant; always give the correct engine number when parts are needed.
- There are two plugs in the balancer frame, a short tapered plug with a hexagonal socket head and a long plug with a square socket head. These plugs control the flow of oil through the balancer frame. The position of the plugs is decided by which side of the engine the filter is fitted. When the filter is fitted on the left side, the short plug is fitted in the side of the balancer and the long plug is fitted in the bottom (B). When the filter is fitted on the right side of the engine, the short plug is fitted in the bottom of the balancer and the long plug is fitted in the side (C).

Caution: Removal of these plugs can cause damage to the threads in the balancer frame and a new balancer frame will be needed. When a balancer unit is to be fitted, ensure that the lubricating oil flow through the balancer frame is correct for the position of the lubricating oil filter.

6 Release the setscrews and remove the rear cover of the balancer frame (page 80/A6). A hammer and a suitable drift will be necessary to remove the rear cover from the dowels.

7 Remove the balance weights (page 80/A5). Ensure that the gear of the driven weight does not damage the bush in the balancer frame.

8 Dismantle the lubricating oil relief valve, see Operation 10-11.

9 Clean the lubricating oil passages with an approved kerosene cleaning solution and dry them with low pressure compressed air.

To assemble

Operation 5-16

Special requirements

Consumable products	
Description	Part number
POWERPART Nutlock	21820242

1 Ensure that the location thimble (A8) in the rear of the lubricating oil pump is 5,6/6,4 mm (0.220/0.252 in) above the rear face of the pump. Clean the contact faces of the lubricating oil pump and the balancer frame. Fit the lubricating oil pump (A16) to the balancer frame and tighten the setscrews to 27 Nm (20 lbf ft) 2,8 kgf m.

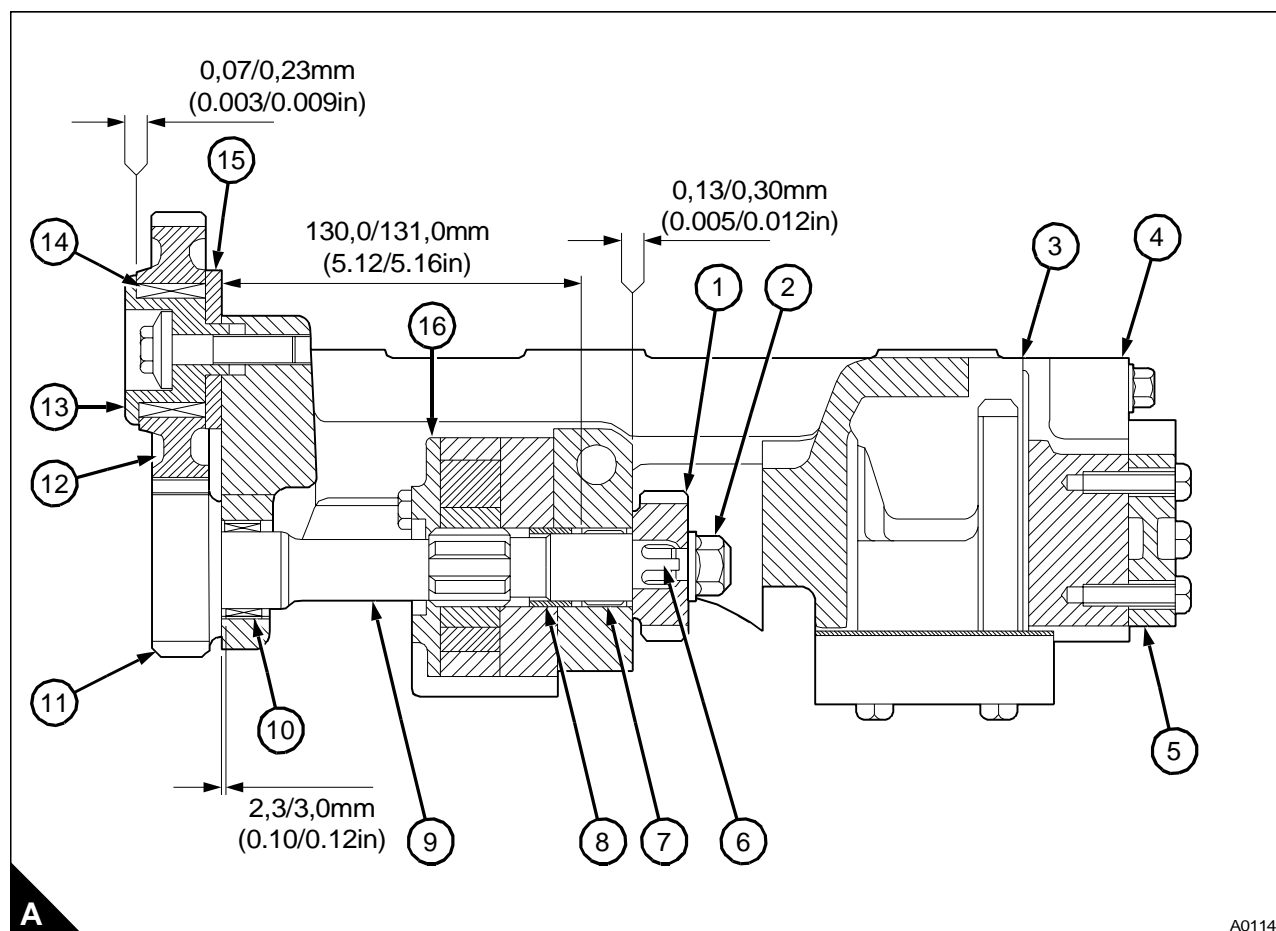
Note: The latest balancers do not have a thimble for the oil pump location. The location of the latest oil pump is by a spigot on the rear face of the pump.

2 Assemble the lubricating oil relief valve, see Operation 10-11.

3 Lubricate the needle roller bearings (A7 and A10) with clean engine lubricating oil. Fit the drive shaft (A9) and engage the splines for the lubricating oil pump with the pump rotor. Ensure that the needle roller bearing at the front of the balancer frame is not damaged by the splines on the drive shaft.

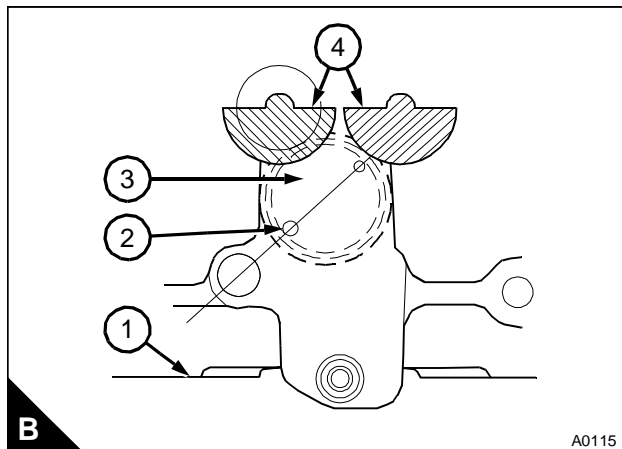
4 Clean and dry the splines (A6) and the thread on the end of the drive shaft. Apply a small amount of POWERPART Nutlock to the splines and to the thread. Fit the drive gear of the balance weights (A1) with the flat face of the gear towards the rear of the balancer unit. Fit and tighten the nut (A2) to 82 Nm (60 lbf ft) 8,4 kgf m. To tighten the nut, a peg spanner must be made to fit into the two holes in the front of the drive shaft and be suitable for use with a torque wrench. Fit the peg spanner to the front of the drive shaft. Hold the nut with a suitable spanner and apply the torque to the peg spanner.

5 Ensure that the drive shaft turns freely. Check the end-float of the drive shaft with feeler gauges between the front face of the drive gear for the balance weights and the frame (A).



Continued

6 Put the balancer frame upside down on the bench (B1). Turn the gear of the drive shaft (B3) until the larger of the two outer holes (B2) - in the front face of the drive gear - is in the position shown in (B). Ensure that the drive shaft will not move from this position. Lubricate the bushes in the rear of the balancer frame with clean engine lubricating oil and fit the balance weights in the position shown (B). Ensure that the flats on the balance weights are level with each other (B4). With the balance weights in the correct position, check that the drive shaft is still in the correct position.



7 Fit the two dowels to the rear face of the balancer frame. Lubricate the bushes in the rear cover of the balance frame with clean engine lubricating oil. Put the rear cover (page 82/A4) in position with the rear spigots of the balance weights in the bushes of the cover. Hit lightly the rear cover with a soft face hammer to fit the cover onto the dowels. Fit the cover setscrews and tighten them to 54 Nm (40 lbf ft) 5,5 kgf m.

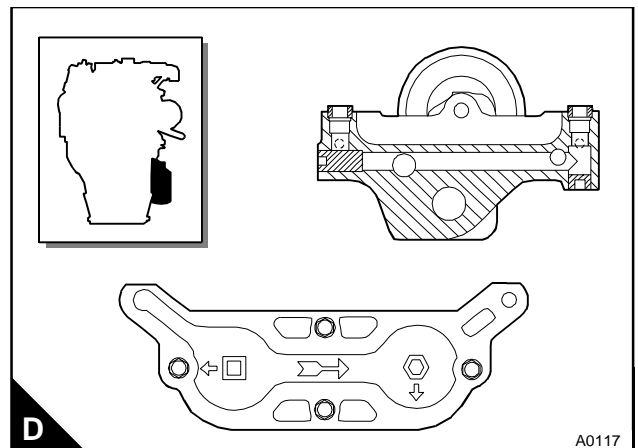
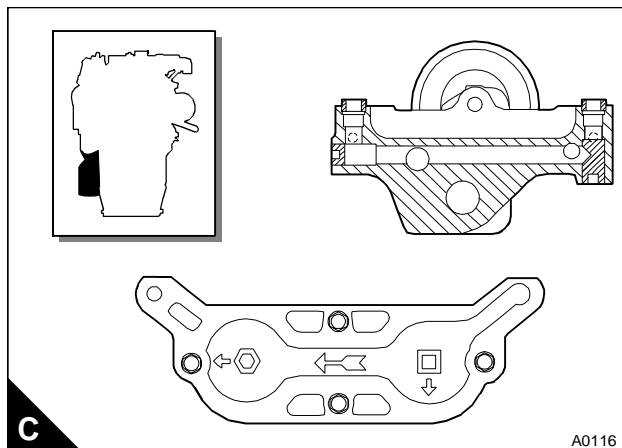
Check the end-float of the balance weights with feeler gauges between the rear face of the balance weights and the front face of the rear cover, refer to Operation 5-19. The correct end-float is given in the relevant Data and dimensions for the "Balancer unit" on page 21.

Check the backlash between the drive gear of the balance weights and the driven gear on the balance weight. The correct backlash is given in the relevant Data and dimensions for the "Balancer unit" on page 21.

8 Fit the oil transfer plate and the joint, if fitted, to the rear of the rear cover and tighten the setscrews to 30 Nm (22 lbf ft) 3,1 kgf m. Ensure that the plate is fitted correctly for the oil filter position.

Note: The direction arrow (C or D) indicates the direction of lubricating oil flow for left side (C) and right side (D) oil filter positions. The symbols and arrows (C or D) indicate the position of the plugs in the balancer frame and the shape of their socket heads.

9 Ensure that the plug on the bottom face of the frame is just below the face. If a new frame and plugs are used, ensure that the plugs are fitted correctly for the oil filter position and the symbols on the oil transfer plate.



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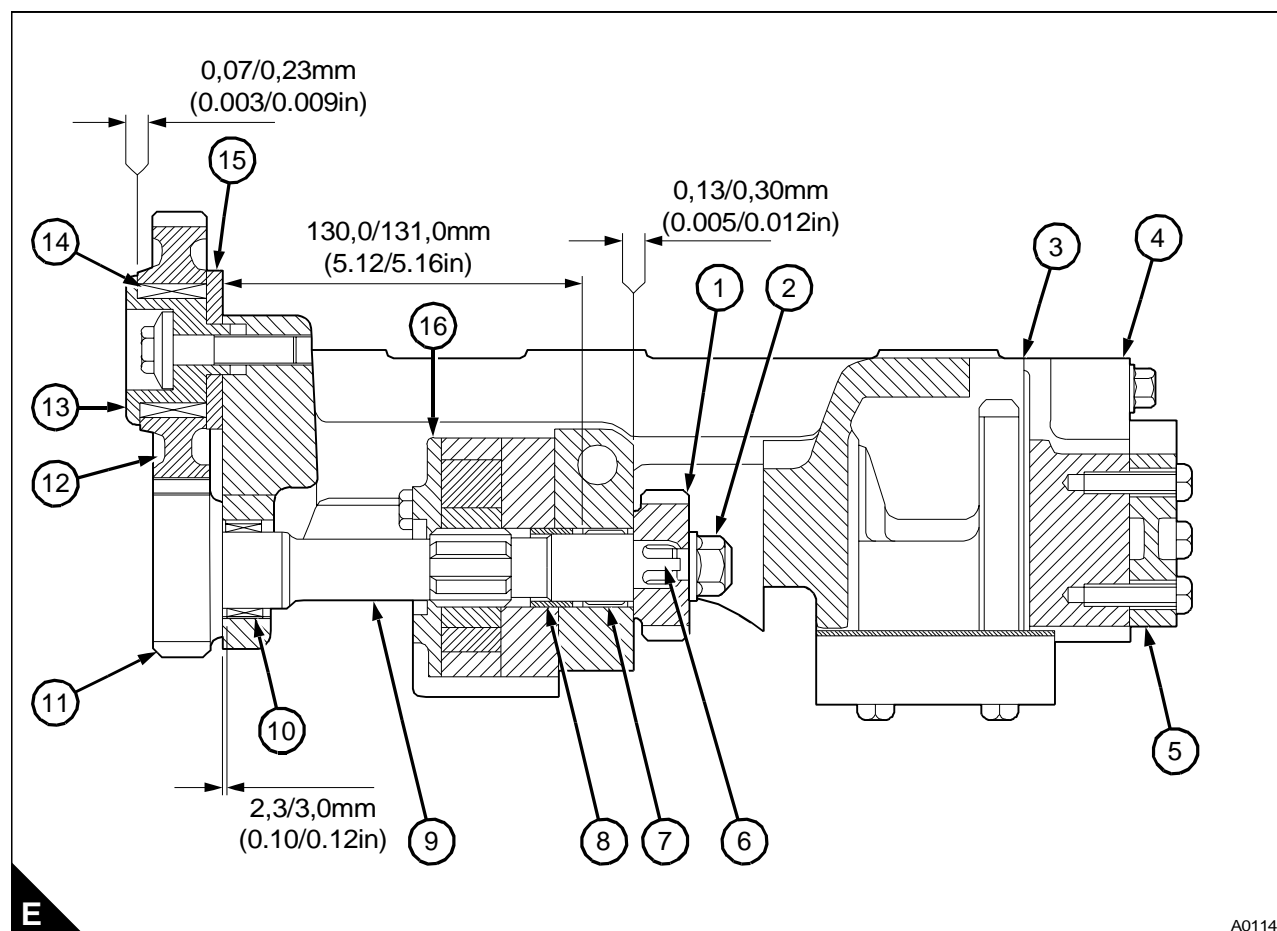
10 If necessary, press a new bearing (E14) into the idler gear (E12). Lubricate the bearing with clean engine lubricating oil. Fit the hub (E13) into the bearing and fit the thrust washer (E15) onto the rear of the hub. Ensure that the threads of the setscrew are clean and dry. Fit the setscrew through the assembly and apply a small amount of Loctite Nutlock to the thread. Fit the assembly to the front of the balancer unit with the idler gear in mesh with the gear of the drive shaft (E11). Tighten the setscrew to 93 Nm (68 lbf ft) 9,5 kgf m.

11 Check the end-float of the idler gear with a feeler gauge between the front face of the idler gear and the hub (E).

12 Check the backlash between the idler gear and the drive shaft gear. The correct backlash is given in the relevant Data and dimensions for the "Balancer unit" on page 21.

13 Fit the balance weight cover and tighten the setscrews.

14 Fit the suction tube and the joint and tighten the setscrews.



To inspect

Operation 5-17

- 1 Clean all the components before inspection.
- 2 Check the gear teeth and the splines of the drive shaft for wear or other damage. Renew the drive shaft if necessary.
- 3 Check the idler gear, needle roller bearing, hub and thrust washer for wear or other damage. Renew the components if necessary.
- 4 Check the drive gear for the balance weights for wear or other damage. Renew the gear if necessary.
- 5 Check the balance weights for wear or other damage. If either balance weight is worn or damaged, both balance weights must be renewed.
- 6 Check the needle roller bearings for the drive shaft for wear or other damage. Renew the bearings, see Operation 5-18, if necessary.
- 7 Check the bushes for the balance weights for wear or other damage. Renew the bushes if necessary, see Operation 5-19.
- 8 To inspect the lubricating oil pump, see Operation 10-9.

To remove and to fit the needle roller bearings for the drive shaft

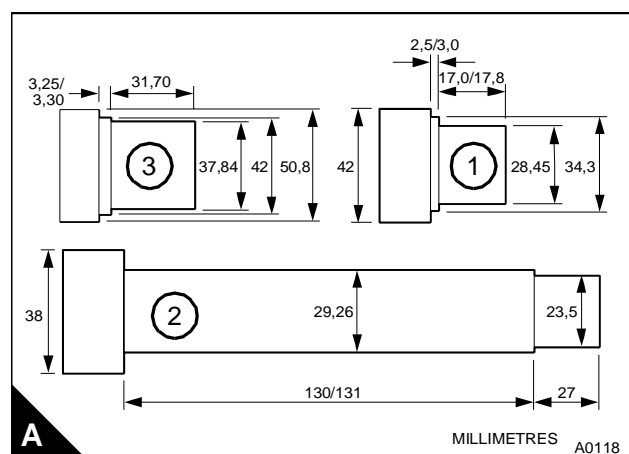
Operation 5-18

- 1 Press out the bearings with a suitable adaptor.
- 2 Clean the parent bores and lubricate them with clean engine lubricating oil.
- 3 Make a suitable adaptor to the dimensions given in (A2). Fit the rear bearing (Operation 5-16/A7) onto the adaptor with the stamped face of the bearing towards the shoulder of the adaptor. Press the bearing into the parent bore in a continuous movement until the shoulder of the adaptor is against the front face of the balancer frame.

In this position the front face of the bearing should be 130,0/131,0 mm (5.12/5.16 in) from the front face of the balancer frame, see Operation 5-16 (A).

- 4 Make a suitable adaptor to the dimensions given in (A1). Fit the front bearing (Operation 5-16/A10) onto the adaptor with the stamped face of the bearing toward the shoulder. Press the bearing into the parent bore in a continuous movement until the shoulder of the adaptor is against the front face of the balancer frame.

In this position the front face of the bearing should be 2,5/3,0 mm (0.01/0.12 in) from the front face of the balancer frame, see Operation 5-16 (A).



To remove and to fit the bushes for the balance weights

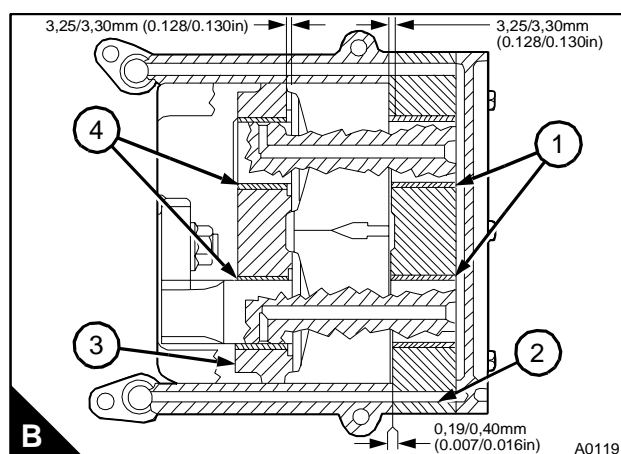
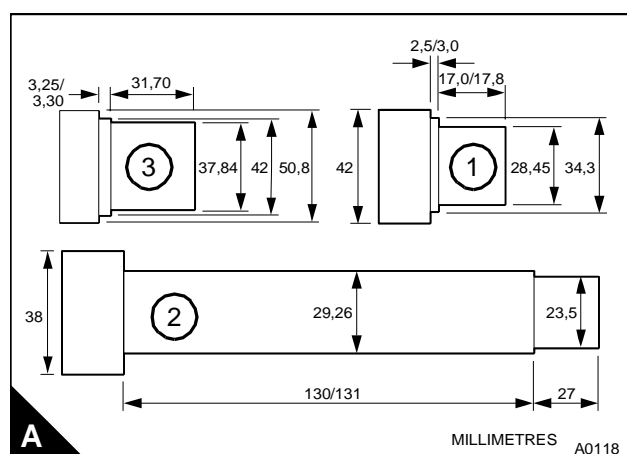
Operation 5-19

- 1 Press the bushes out of the balancer frame and the rear cover with a suitable adaptor.
- 2 Clean the parent bores and lubricate them with clean engine lubricating oil.
- 3 Make a suitable adaptor to the dimensions given in (A3). Fit a bush onto the adaptor. Press the bush (B4) into the parent bore in the rear of the balancer frame (B3), in a continuous movement, until the shoulder of the adaptor is against the rear face of the balancer frame.

In this position the rear face of the bush should be 3,25/3,30 mm (0.128/0.130 in) from the rear face of the balancer frame (B). Repeat this operation for the other bush.

- 4 Fit a bush (B1) onto the adaptor and put it into position at the front end of one of the parent bores in the rear cover (B2). Press in the bush, in a continuous movement, until the shoulder of the adaptor is against the front face of the rear cover.

In this position the front face of the bush should be 3,25/3,30 mm (0.128/0.130 in) from the front face of the rear cover (B). Repeat this operation for the other bush.



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6

Timing case and drive assembly

General description

The timing case is made of aluminium.

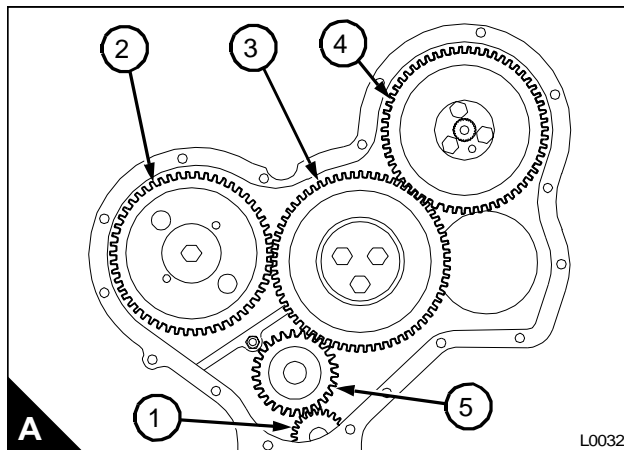
The timing gears are made of cast iron. A power take-off position (A1) is available on the right side of the aluminium timing case. When a power take-off is fitted some of the timing gears are made of steel, it is important that the correct gears are fitted. The complete engine number must be given to the distributor when a new gear is needed.

The drive from the crankshaft gear (A5) passes through an idler gear (A3) to the camshaft gear (A2) and to the gear of the fuel injection pump (A4). The drive from the crankshaft gear also passes through a lower idler gear to the gear of the balancer unit. The camshaft and the fuel injection pump run at half the speed of the crankshaft.

The aluminium cover of the timing case contains the front oil seal; this is made of Viton and has a dust lip in front of the main lip.

Warning! read the safety precautions for "Viton seals" on page 7.

The camshaft is made of cast iron. The cam lobes and the eccentric for the fuel lift pump are chill hardened.



Timing case cover

To remove

Operation 6-1

- 1 Remove the fan, see Operation 12-7 and the drive belts, see Operation 14-2.
- 2 If necessary, remove the fan drive pulley.
- 1 Remove the alternator together with its mounting bracket and front support plate, see Operation 14-3.
- 2 Remove the crankshaft pulley, see Operation 5-1.
- 3 Drain the coolant and remove the coolant pump, see Operation 12-3.
- 4 Release the setscrews and nuts of the cover and remove the cover. There is no need to remove the noise shield from the cover.

To fit

Operation 6-2

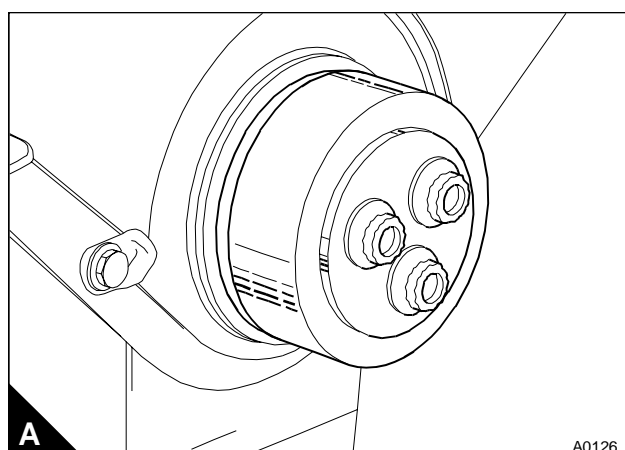
Special requirements

Special tools	
Description	Part number
Centralising tool	PD. 162B

- 1 Clean the faces of the timing case cover.
- 2 Put the cover and a new joint in position on the timing case. Loosely fit two setscrews which are in opposite locations to hold the cover in position. Fit the centralising tool in the oil seal housing (A) and use the special washer and the crankshaft pulley setscrews to put the cover in its correct position. Do not overtighten the setscrews. Fit the remainder of the setscrews and nuts and tighten all of the cover fasteners to 22 Nm (16 lbf ft) 2,2 kgf m. Remove the centralising tool.

Caution: It is important that the cover of the timing case is centred correctly. If the cover is not centred, the backlash between the fuel pump gear and coolant pump gear could be affected. This could cause the seizure of the fuel injection pump.

- 3 Fit the coolant pump, see Operation 12-4.
- 4 Fit the crankshaft pulley, see Operation 5-1.
- 5 Fit the alternator, see Operation 14-3.
- 6 Fit the drive belts, see Operation 14-2, and adjust the belt tension, see Operation 14-1.
- 7 Fit the fan, see Operation 12-7.
- 8 Fill the cooling system.



Front oil seal

To remove**Operation 6-3**

- 1 Remove the fan, see Operation 12-7 and the drive belts, see Operation 14-2.
- 2 Remove the crankshaft pulley, see Operation 5-1.
- 3 Remove the oil seal with a suitable lever behind the main lip of the oil seal.

Caution: Do not damage the edge of the oil seal housing.

To fit

Operation 6-4

Special requirements

Special tools			
Description	Part number	Description	Part number
Replacer tool for front oil seal	PD170	Fastener plate for use with PD.170	PD170-3
Pressure plate for use with PD.170	PD170-1	Adaptor for seal for use with PD.170	PD170-4
Sleeve for use with PD.170	PD170-2		

Note: The seal is fitted to a depth of 10,92/11,43 mm (0.431/0.450 in) from the front face of the oil seal housing to the flat front face of the oil seal.

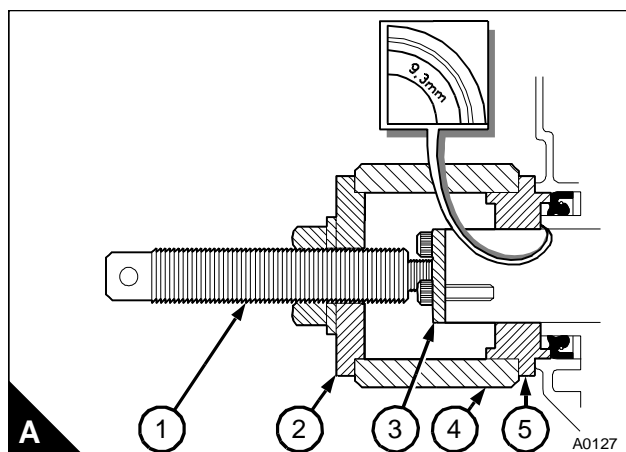
- 1 Clean the oil seal housing. Inspect the new seal for damage. If a scratch can be seen across the lip of the seal, do not fit the seal.
- 2 Lubricate the outer circumference of the oil seal with clean engine lubricating oil and enter the seal into the housing. Ensure that the spring loaded lip of the oil seal is towards the inside of the timing case cover and that the oil seal is square to the bore of the seal housing.
- 3 Assemble the oil seal replacer tool (A). Fit the fastener plate, PD.170-3, (A3) to the front of the crankshaft. For the standard seal, put the adaptor, PD.170-4, (A5) on the nose of the crankshaft and against the seal. Ensure that the adaptor has the side stamped 9,3 mm towards the seal. When the adaptor is fitted, ensure that the front lip of the seal is fully onto the taper of the adaptor.

Note: The other side of adaptor PD.170-8 can also be used to fit the standard seal.

Assemble the pressure plate, PD.170-1, (A2) together with the sleeve, PD.170-2, (A4) onto the threaded bar, PD.170, (A1). Put the tool assembly in position on the adaptor, PD.170-4 or PD.170-8, and tighten the threaded bar onto the stud of PD.170-3 (A3).

Fit a rod through the hole in the end of the threaded bar to prevent movement of the bar when the nut is tightened. Tighten the nut to push the seal into the housing to the correct depth. If the standard seal is to be pushed in to the service position, turn the nut until the face of PD.170-4 is against the face of the seal housing.

- 4 Remove the replacer tool and lightly lubricate the seal location area of the crankshaft pulley with clean engine lubricating oil. Fit the crankshaft pulley, see Operation 5-1.
- 5 Fit the drive belts, see Operation 14-2, and adjust the belt tension, see Operation 14-1.
- 6 Fit the fan, see Operation 12-7.



Idler gear and hub

To remove

Operation 6-5

1 Remove the timing case cover, see Operation 6-1.

2 Rotate the crankshaft until the marked teeth (B) of the crankshaft gear, the camshaft gear and the fuel pump gear are all in mesh with the idler gear.

Note: The marked teeth of the idler gear (A4) will not necessarily be in mesh with the marked teeth of the other gears because of the different speed of rotation of the idler gear.

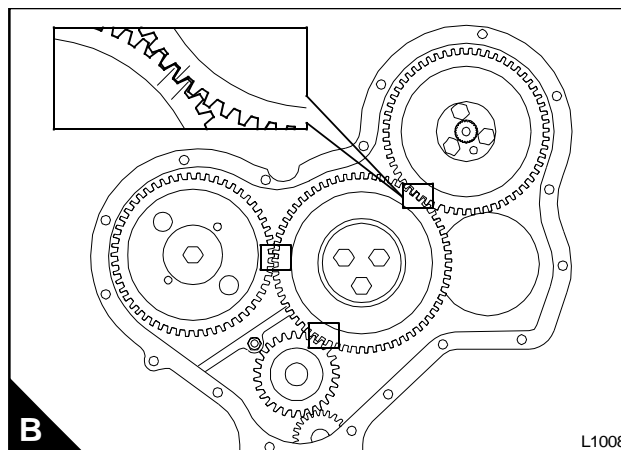
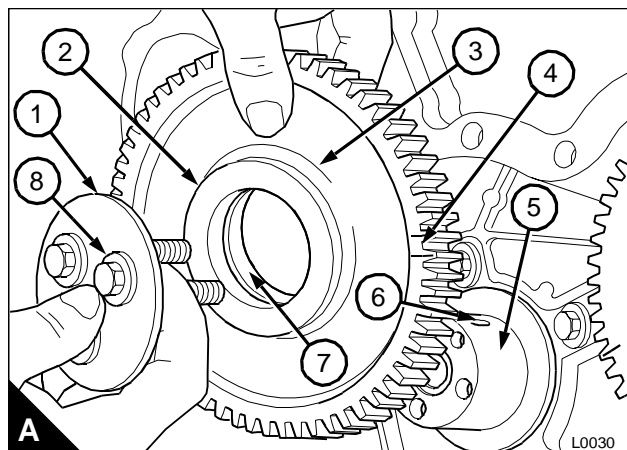
3 Release the three setscrews (A8), remove the plate (A1) of the idler gear and remove the gear (A3) from the idler gear hub (A5). The drive gear of the fuel injection pump may rotate counter clockwise when the idler gear is removed.

Caution: Do not turn the crankshaft with the idler gear removed.

4 Remove the idler gear hub, note the position of the oil hole (A6).

5 Inspect the gear and the bushes (A2) and (A7) for wear and other damage and renew as necessary. The gear and bushes are available as an assembly or separate bushes are available.

6 If the bushes are to be changed, remove them with a suitable puller. If a puller is not available, machine off the face of one of the bushes and press them out. Press in new bushes, machine the bores to get the correct clearance on the hub and machine the faces to get the correct end clearance. Refer to the relevant Data and dimensions for the "Timing case and drive assembly" on page 22.

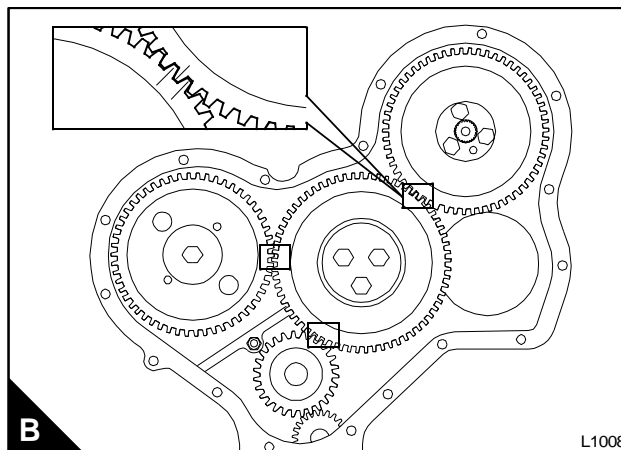
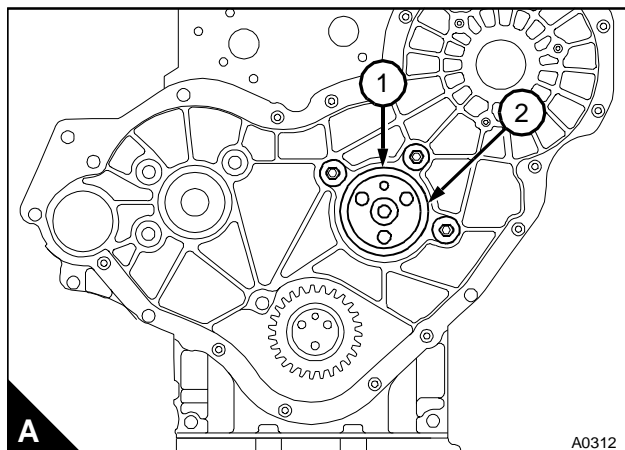


To fit

Operation 6-6

1 Use the three idler gear setscrews to ensure the correct position of the idler gear hub (A2) with the lubrication hole (A1) at the top. Push the hub into position and remove the setscrews.

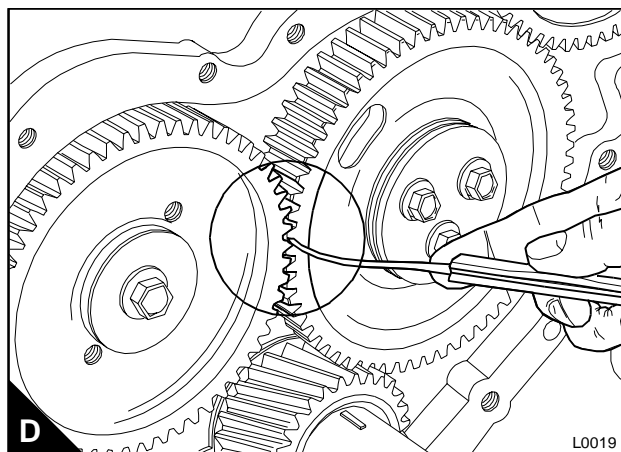
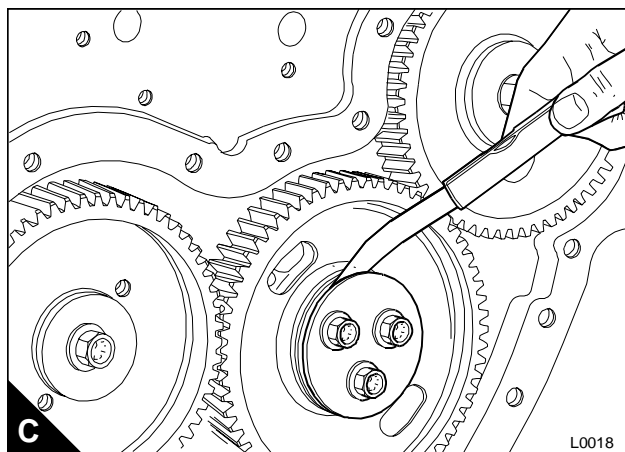
2 Lubricate the idler gear bushes with clean engine lubricating oil. Align the timing marks on the idler gear with the marks on the crankshaft and camshaft gears (B).



3 If necessary, rotate the gear of the fuel injection pump clockwise to align the relevant timing mark with the marks on the idler gear and slide the idler gear into position. On engines with gears which do not have timing marks align the temporary mark on the fuel pump gear with the mark on the timing case before the idler gear is fitted. Remove the marks on the fuel pump gear and the timing case after the idler gear has been fitted.

Check that all the timing marks are in correct mesh (A). Fit the plate and the setscrews to the idler gear hub and tighten the setscrews to 44 Nm (33 lbf ft) 4,5 kgf m.

4 Check the idler gear end-float (C) and the timing gear backlash (D).



5 Fit the timing case cover, see Operation 6-2.

6 Fit the coolant pump, see Operation 12-4.

7 Fit the crankshaft pulley, see Operation 5-1.

8 Where necessary, fit the fan drive pulley.

9 Fit the drive belts, see Operation 14-2, and adjust the belt tension, see Operation 14-1.

10 Fit the fan, see Operation 12-7.

11 Fill the cooling system.

Fuel pump gear

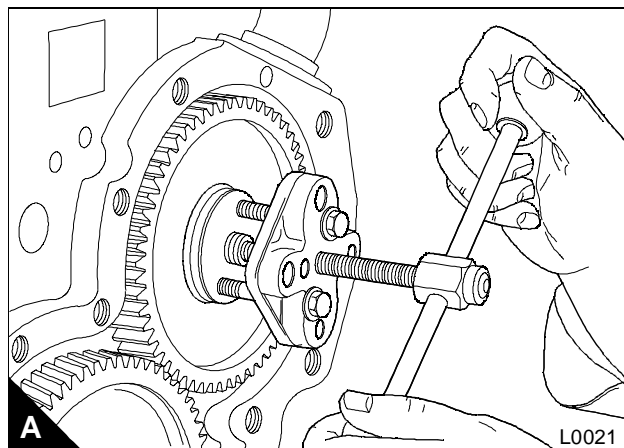
To remove

Operation 6-7

Special requirements

Special tools			
Description	Part number	Description	Part number
Gear puller	PD.155C	Adaptors for use with PD.155C	PD.155B-5

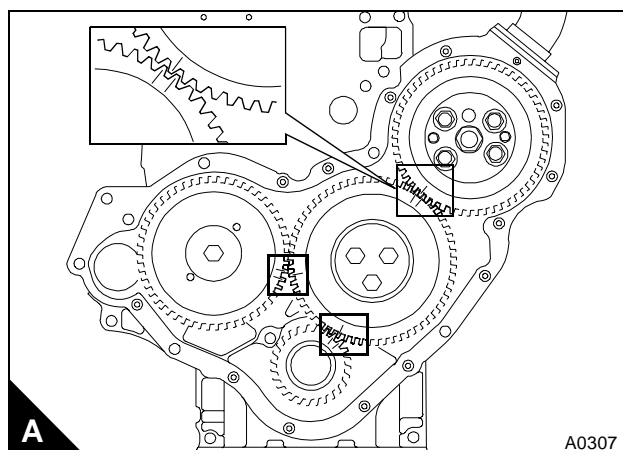
- 1 Remove the timing case cover, see Operation 6-1.
 - 2 Rotate the crankshaft until the marked teeth of the crankshaft gear, the camshaft gear and the fuel pump gear are all in mesh with the idler gear. The marked teeth of the idler gear will not necessarily be in mesh with the marked teeth of the other gears because of the different speed of rotation of the idler gear.
 - 3 Remove the nut and the spring washer from the fuel pump gear.
 - 4 Remove the idler gear, see Operation 6-5.
 - 5 Remove the fuel pump gear with the puller and the adaptors (A).
- Note:** Ensure that the key in the fuel pump shaft is not lost.
- 6 Inspect the gear for wear and other damage and renew it, if necessary.



To fit

Operation 6-8

- 1 Ensure that the key is fitted correctly in the fuel pump shaft. Fit the gear and the spring washer and loosely fit the setscrew(s).
- 2 Rotate the fuel pump gear to ensure that the relevant marked tooth of the fuel pump gear will align with the marked teeth of the idler gear (A). Fit the idler gear, see Operation 6-6.
- 3 Tighten the setscrew(s) of the fuel pump gear to 27 Nm (20 lbf ft) 2,8 kgf m. The teeth of the drive gear and the idler gear should be fully in mesh when the fuel pump gear is tightened onto the hub of the fuel injection pump.
- 4 If a new gear has been fitted, check the backlash.
- 5 Fit the timing case cover, see Operation 6-2.
- 6 Fit the crankshaft pulley, see Operation 5-1.
- 7 If necessary, fit the fan drive pulley.
- 8 Fit the drive belts, see Operation 14-2, and adjust the belt tension, see Operation 14-1.
- 9 Fit the fan, see Operation 12-7.
- 10 Fill the cooling system.



Camshaft gear

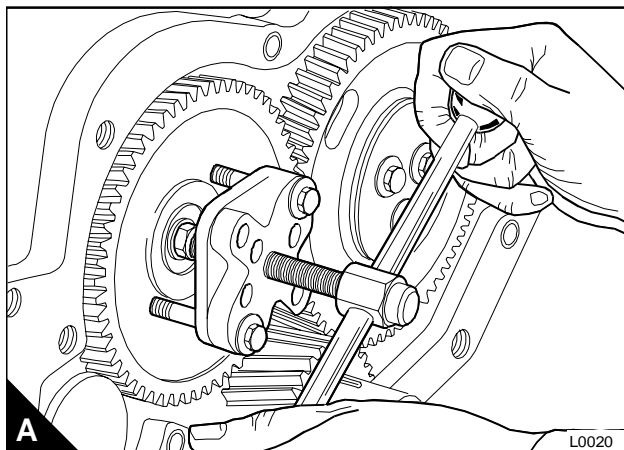
To remove

Operation 6-9

Special requirements

Special tools			
Description	Part number	Description	Part number
Gear puller	PD.155C	Adaptors for use with PD.155C	PD.155B-5

- 1 Remove the timing case cover, see Operation 6-1.
- 2 Rotate the crankshaft until the marked teeth of the crankshaft gear, the camshaft gear and the fuel pump gear are all in mesh with the idler gear. The marked teeth of the idler gear will not necessarily be in mesh with the marked teeth of the other gears because of the different speed of rotation of the idler gear.
- 3 Remove the setscrew and washer of the camshaft gear. Put a suitable adaptor onto the end of the camshaft and remove the gear with the puller and adaptor (A). Ensure that the key in the camshaft is not lost.
- 4 Inspect the gear for wear and any other damage and renew it, if necessary.



To fit

Operation 6-10

- 1 Ensure that the key in the camshaft is fitted correctly.
- 2 Remove the idler gear, see Operation 6-5.
- 3 Fit the camshaft gear to the camshaft with the marked teeth towards the front and the keyway correctly aligned with the key. If necessary, lightly hit the gear with a soft face hammer to engage the key into the keyway.
- 4 Fit the idler gear with the marked teeth in correct mesh, see Operation 6-6. If the camshaft has to be turned and a valve hits a piston, disengage the rocker assembly.
- 5 Fit the washer and the setscrew for the camshaft gear and tighten the setscrew to press the camshaft gear into position. Tighten the setscrew to 78 Nm (58 lbf ft) 8,0 kgf m. If a new camshaft gear has been fitted, check the backlash.
- 6 Fit the timing case cover, see Operation 6-2.
- 7 Fit the coolant pump, see Operation 12-4.
- 8 Fit the crankshaft pulley, see Operation 5-1.
- 9 Fit the drive belts, see Operation 14-2, and adjust the belt tension, see Operation 14-1.
- 10 Fit the fan, see Operation 12-7.
- 11 If it was drained earlier, fill the cooling system.

Crankshaft gear

To remove**Operation 6-11**

- 1 Remove the timing case cover, see Operation 6-1.
- 2 Rotate the crankshaft until the marked teeth of the crankshaft gear, the camshaft gear and the fuel pump gear are all in mesh with the idler gear. The marked teeth of the idler gear will not necessarily be in mesh with the marked teeth of the other gears because of the different speed of rotation of the idler gear.
- 3 Remove the idler gear, see Operation 6-5.
- 4 The crankshaft gear is a transition fit on the crankshaft. It may slide off easily or, if it is a tight fit and the gear is to be renewed, it may be necessary to remove the crankshaft, see Operation 5-10, to remove the gear safely.

To fit**Operation 6-12**

- 1 The gear can fit easily, or it may be necessary to heat the gear before it will fit onto the crankshaft. If the gear is to be heated, heat it in an oven to not more than 180 °C (226 °F). If an oven is not available, heat it in coolant which is at its boiling point. Do not use a flame as this can cause local damage. Fit the gear with the timing marks to the front.
- 2 Fit the idler gear, see Operation 6-6 and ensure that all the timing marks are correctly aligned.
- 3 Fit the timing case cover, see Operation 6-2.
- 4 Fit the coolant pump, see Operation 12-4.
- 5 Fit the crankshaft pulley, see Operation 5-1.
- 6 Fit the drive belts, see Operation 14-2, and adjust the belt tension, see Operation 14-1.
- 7 Fit the fan, see Operation 12-7.
- 8 Fill the cooling system.

Timing case

To remove

Operation 6-13

- 1** Remove the timing case cover, see Operation 6-1.
- 2** Rotate the crankshaft until the marked teeth of the crankshaft gear, the camshaft gear and the fuel pump gear are all in mesh with the idler gear. The marked teeth of the idler gear will not necessarily be in mesh with the marked teeth of the other gears because of the different speed of rotation of the idler gear.
- 3** Remove the fuel injection pump, see Operation 11-10 for Lucas DPA fuel injection pumps and Operation 11-14 for Stanadyne fuel injection pumps.
- 4** Remove the idler gear, see Operation 6-5, and the camshaft gear, see Operation 6-9.
- 5** Remove the setscrews which hold the timing case to the cylinder block and the setscrews which hold the sump to the bottom of the timing case.
- 6** Remove the timing case and the joint, do not allow the idler gear hub to fall. Ensure that the camshaft thrust washer is not lost.

To fit

Operation 6-14**Special requirements**

Consumable products			
Description	Part number	Description	Part number
POWERPART Jointing compound	1861155 or 1861117	POWERPART Nutlock	21820242

1 Ensure that the sump joint is not damaged. If the joint is damaged, remove the sump and fit it with a new joint after the timing case has been fitted. The front section of the joint can be cut away and the front section of a new joint fitted, without the removal of the sump, but extreme care must be used to prevent possible leaks.

2 If the sump has been removed, fit the idler gear hub (A2) to the front of the cylinder block; use the three setscrews of the idler gear to hold the hub in position. Ensure that the oil hole is at the top.

3 Ensure that the thrust washer for the camshaft is in position.

4 Fit a new joint for the timing case to the cylinder block. Cut the bottom ends of the joint to fit correctly. Apply POWERPART Jointing compound to the bottom ends of the joint.

5 Put the timing case in position. If the sump has not been removed, fit the idler gear hub, refer to step 2. Fit the three setscrews (A1) around the idler gear hub. Ensure that the bottom of the timing case is correctly aligned with the bottom of the cylinder block before the setscrews are tightened. Put the alternator and its front support plate in position and fit and tighten the remainder of the setscrews of the timing case. If the front support plate has been separated from the alternator bracket, ensure that the right side of the plate is level with the machined face on the cylinder block where the alternator bracket is fitted. If a new timing case is fitted, remove the two studs from the timing case and clean the threads which fit into the timing case. Seal the threads with POWERPART Nutlock and fit the studs into the new timing case. Remove the setscrews from the idler gear hub.

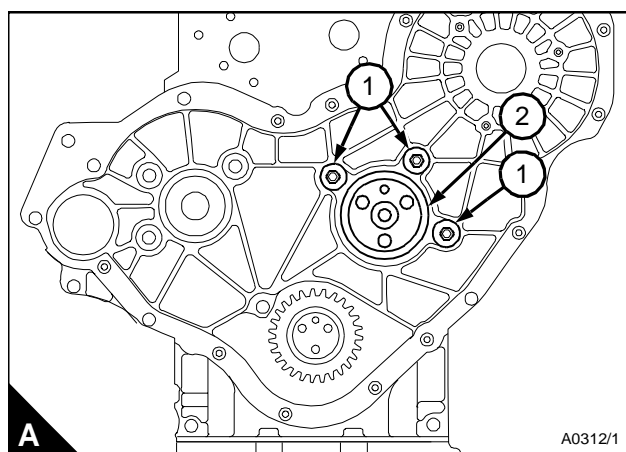
6 If necessary, fit the lubricating oil sump, see Operation 10-3.

7 Fit the camshaft gear, see Operation 6-10, and the idler gear, see Operation 6-6. Ensure that all the timing marks are correctly aligned.

8 If the timing case is new and the old timing case had a timing mark, put a timing mark on the new timing case, see Operation 8-7.

Fit the fuel injection pump and the drive gear, see Operation 11-11 for Lucas DPA fuel injection pumps and Operation 11-15 for Stanadyne fuel injection pumps.

Eliminate air from the fuel system, see Operation 11-13 for Lucas DPA fuel injection pumps and Operation 11-17 for Stanadyne fuel injection pumps.

*Continued*

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- 9** Fit the timing case cover, see Operation 6-2.
 - 10** Fit the coolant pump, see Operation 12-4.
 - 11** Fit the crankshaft pulley, see Operation 5-1.
 - 12** Fit the alternator, see Operation 14-3 and the alternator front bracket.
 - 13** Fit the drive belts, see Operation 14-2 and adjust the belt tension, see Operation 14-1.
 - 14** Fit the fan, see Operation 12-7.
 - 15** Fill the cooling system.
 - 16** If, necessary, fill the sump to the correct level with an approved lubricating oil.

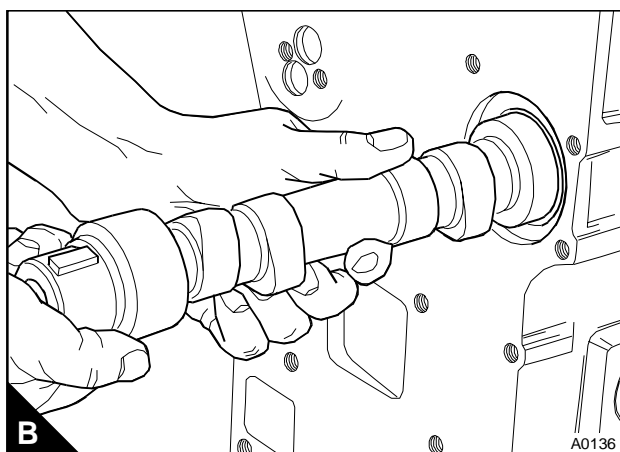
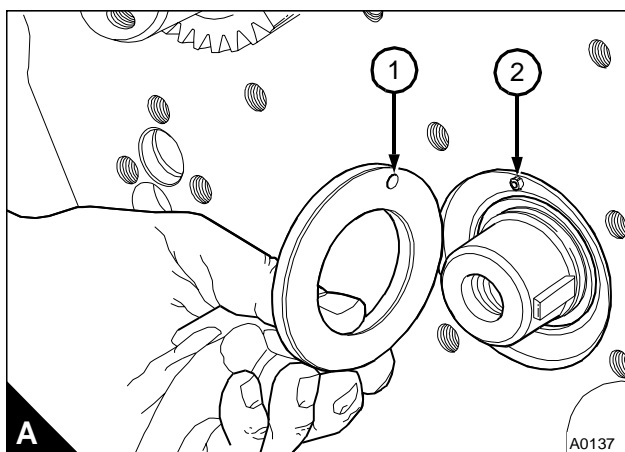
Camshaft and tappets

To remove

Operation 6-15

Note: Before the engine is removed from the vehicle or the machine, drain the lubricating oil and the coolant.

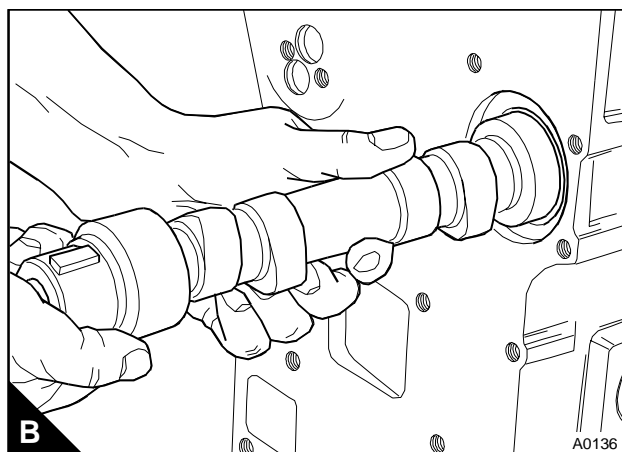
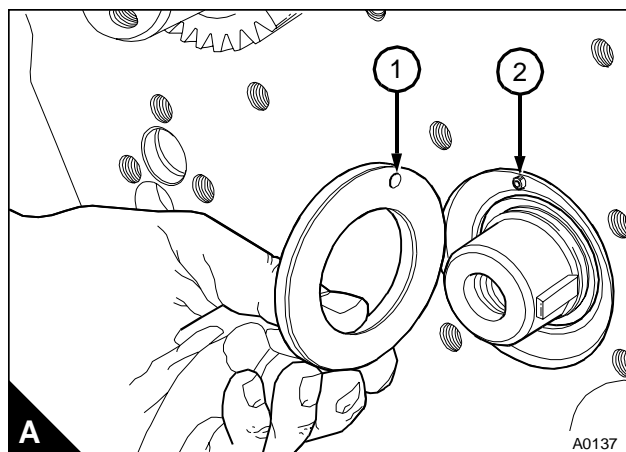
- 1 Remove the exhauster, see Operation 15-4.
- 2 Remove the timing case cover, see Operation 6-1.
- 3 Remove the timing gears, see Operation 6-5, Operation 6-7 and Operation 6-9.
- 4 Remove the fuel injection pump, see Operation 11-10 for Lucas DPA fuel injection pumps and Operation 11-14 for Stanadyne fuel injection pumps.
- 5 Remove the timing case, see Operation 6-13.
- 6 Remove the rocker cover, the rocker assembly and the push rods, see Chapter 3, Cylinder head assembly.
- 7 Remove the fuel lift pump, see Operation 11-6.
- 8 Turn the engine upside down and remove the lubricating oil sump, see Operation 10-3.
- 9 Remove the camshaft thrust washer (A) and carefully remove the camshaft (B).
- 10 Remove the tappets, retain them in the correct sequence for assembly.
- 11 Inspect the camshaft and the tappets for wear and other damage, also inspect the camshaft bush. Renew the components as necessary.



To fit

Operation 6-16

- 1 Ensure that all components are clean and are lubricated with clean engine lubricating oil.
- 2 Fit the tappets in position.
- 3 Carefully fit the camshaft (B).
- 4 Fit the camshaft thrust washer (A1). Ensure that it is fitted correctly on the hollow dowel (A2).
- 5 Fit the timing case together with a new joint, see Operation 6-14.
- 6 Check that the camshaft end-float is within the limits shown in the relevant Data and dimensions for the "Timing case and drive assembly" on page 22.
- 7 Rotate the camshaft until the cam for the fuel lift pump is at the minimum lift position and fit the fuel lift pump, see Operation 11-6.
- 8 Turn the engine to an upright position. Rotate the crankshaft until the keyway in the crankshaft is at the top. Fit the timing gears, see Operation 6-6, Operation 6-8 and Operation 6-10 and ensure that all the timing marks are correctly aligned.
- 9 Fit the fuel injection pump, see Operation 11-11 for Lucas DPA fuel injection pumps and Operation 11-15 for Stanadyne fuel injection pumps.
- 10 Fit the push rods, the rocker assembly and the rocker cover, see Chapter 3, Cylinder head assembly.
- 11 Set the valve tip clearances, see Operation 3-5.
- 12 Fit the timing case cover, see Operation 6-2 and the lubricating oil sump, see Operation 10-3.
- 13 Fit the exhauster, see Operation 15-4.
- 14 Fit the coolant pump, see Operation 12-4.
- 15 Fit the crankshaft pulley, see Operation 5-1.
- 16 If necessary, fit the alternator and its mounting brackets.
- 17 Fit the drive belts, see Operation 14-2, and adjust the belt tension, see Operation 14-1.
- 18 Fit the fan, see Operation 12-7.
- 19 After the engine has been installed:
Fill the cooling system. Fill the lubricating oil sump to the correct level with an approved lubricating oil.
Eliminate air from the fuel system, see Operation 11-13 for Lucas DPA fuel injection pumps and Operation 11-17 for Stanadyne fuel injection pumps.



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7

Cylinder block assembly

General description

The cylinder block is made of cast iron and provides a full length support for the dry liners which are also made of cast iron. Production liners are a press fit in the block and service liners are a transition fit. Both types of liners are honed with silicon carbide tools to a controlled finish to ensure long life and low oil consumption. A bush is fitted in the cylinder block for the front camshaft journal and the other camshaft journals run directly in the block.

Cylinder block

To dismantle

Operation 7-1

- 1 Drain the cooling system and the lubricating oil.
- 2 Remove the engine from the vehicle or machine.
- 3 Remove the alternator drive belts, see Operation 14-2, and the alternator and its mounting brackets, see Operation 14-3.
- 4 Remove the fan, the fan drive and the coolant pump, see Chapter 12, Cooling system.
- 5 Remove the exhauster, where fitted, see Operation 15-4.
- 6 Remove the fuel filter, the atomisers and the fuel injection pump, see Chapter 11, Fuel system.
- 7 Remove the lubricating oil cooler, where fitted, see Operation 12-8.
- 8 Remove the lubricating oil filter assembly and the lubricating oil sump, see Operation 10-3.
- 9 Remove the fuel lift pump, see Operation 11-6.
- 10 Remove the starter motor, see Operation 14-5.
- 11 Remove the cylinder head assembly, see Operation 3-7.
- 12 Remove the timing case and the timing gears, see Chapter 6, Timing case and drive assembly.
- 13 Remove the lubricating oil pump, see Operation 10-6, and the pressure relief valve, see Operation 10-10, or remove the balancer unit, see Operation 5-13.
- 14 Remove the piston and connecting rod assemblies, see Operation 4-4.
- 15 Remove the camshaft and the tappets, see Operation 6-15.
- 16 Remove the flywheel, see Operation 13-1, and the flywheel housing, see Operation 13-3.
- 17 Remove the rear oil seal assembly, see Operation 5-2, and the crankshaft, see Operation 5-10.
- 18 Inspect the cylinder block, see Operation 7-3.

To assemble

Operation 7-2

Special requirements

Consumable products	
Description	Part number
POWERPART Nutlock	21820242

- 1 Clean thoroughly the new cylinder block. Ensure that all the oil passages are clean and free from debris.
- 2 Remove the threaded plugs from the old cylinder block and clean the threads. Seal the threads with POWERPART Nutlock, or a similar sealant, and fit the threaded plugs into the new cylinder block.
- 3 Fit the crankshaft, see Operation 5-11, and the rear oil seal assembly, see Operation 5-2.
- 4 Fit the piston and connecting rod assembly, see Operation 4-5.
- 5 Fit the flywheel housing, see Operation 13-3, and the flywheel, see Operation 13-1.
- 6 Fit the tappets and the camshaft, see Operation 6-16.
- 7 Fit the lubricating oil pump, see Operation 10-7, and the pressure relief valve, see Operation 10-10, or fit the balancer unit, see Operation 5-14.
- 8 Fit the timing case and the timing gears, see Chapter 6, Timing case and drive assembly.
- 9 Fit the cylinder head assembly, see Operation 3-8.
- 10 Fit the starter motor, see Operation 14-5.
- 11 Fit the fuel lift pump, see Operation 11-6.
- 12 Fit the lubricating oil filter assembly and the lubricating oil sump, see Operation 10-3.
- 13 If necessary, fit the lubricating oil cooler, see Operation 12-8.
- 14 Fit the fuel filter, the atomisers and the fuel injection pump, see Chapter 11, Fuel system.
- 15 If necessary, fit the exhauster, see Operation 15-4.
- 16 Fit the fan, the fan drive and the coolant pump, see Chapter 12, Cooling system.
- 17 Fit the alternator and its mounting brackets, see Operation 14-3, and the alternator drive belts, see Operation 14-2.
- 18 Install the engine into the vehicle or machine.
- 19 Fill the cooling system.
- 20 Fill the lubricating oil sump to the correct level with an approved lubricating oil.
- 21 Eliminate air from the fuel system, see Operation 11-13 for Lucas DPA fuel injection pumps and Operation 11-17 for Stanadyne fuel injection pumps.

To inspect

Operation 7-3

- 1 Clean the passages for the coolant and for the oil.
- 2 Check the cylinder block for cracks and for other damage.
- 3 The top face of the cylinder block must not be machined as this will affect the liner flange depth and the piston height above the top face of the cylinder block.
- 4 Check the camshaft bush for wear. If the bush is to be renewed, use a suitable adaptor to press it out of the bore. Ensure that the lubricating oil hole in the new bush will be towards the front of the engine, when fitted. Press in the bush with the oil hole on the same side and aligned with the oil hole in the block until the front end of the bush is aligned with the face of the recess.

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, a service liner is available.

The condition of a cylinder liner is decided by:

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

Note: It will not be necessary to renew the liners, if:

- The honed finish can still be clearly seen.
- The engine performance and oil consumption is 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 finish 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:

- *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 recover a glazed liner

Operation 7-5

A tool, known as a "Flex-Hone", is available to correct the liner surface. This tool can be used with an electric hand drill at low speed. The pistons and connecting rods must be removed and the piston cooling jets, where fitted, must also be removed. Use covers to protect all engine components from the debris which is caused during the process. Details and supply of the "Flex-hone" are available from:

Pacehigh: PO box 128, Hatfield, Herts, AL9 5LD. Tel: 01707 665707. Fax: 01707 646816.

- 1 Grade 80SC Flex-Hone is to be used. A 4 inch or 4 $\frac{1}{8}$ inch size Flex-Hone can be used according to how badly the bore is glazed.
- 2 New Flex-Hones must be operated in an old liner before use on an engine to remove all loose material and sharp edges.
- 3 Lubricate lightly the liner and the Flex-Hone with clean engine lubricating oil.
- 4 Put the tool in position on top of the liner, but do not press the tool into the liner until the tool is operated.
- 5 Operate the tool and move it up and down the liner bore once a second for 30-50 seconds. Remove the tool while it rotates.
- 6 Clean thoroughly the liner bore to remove all dirt from the operation, use a hard brush and kerosene.
- 7 Dry the liners and remove carefully all the covers used to protect the components. Clean thoroughly all the engine components which have been affected by debris.
- 8 Ensure that new piston rings are fitted when the engine is assembled in accordance with Operation 4-7.

Caution: After a glazed bore has been corrected, the following recommendations are advised for the first 240 km (150 miles) or 5 hours of operation:

- Do not operate the engine at full load.
- Do not operate the engine at high speed.
- Do not allow the engine to run at low idle speed for extended periods.

To remove

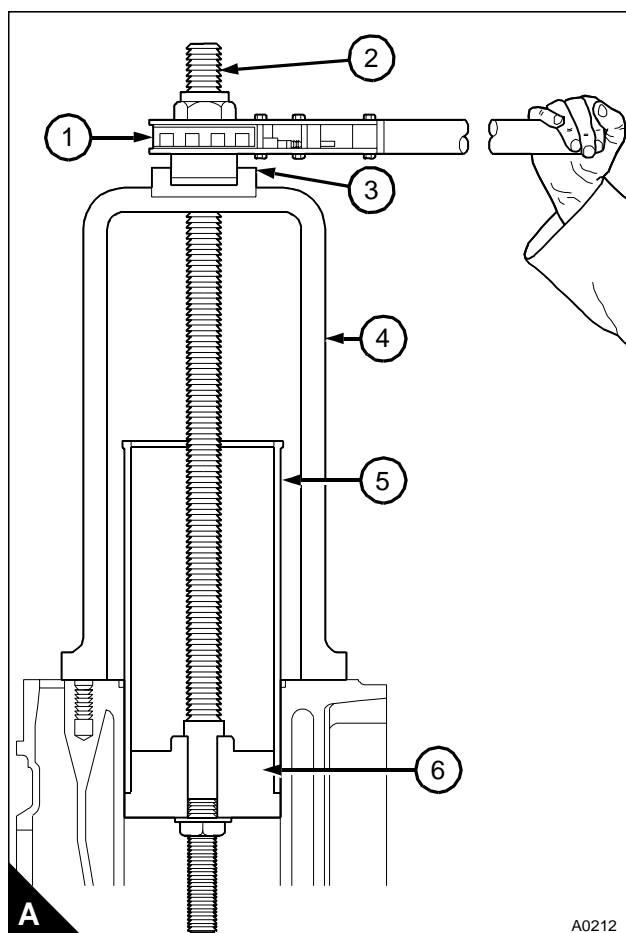
Operation 7-6

Special requirements

Special tools			
Description	Part number	Description	Part number
Remover/replacer for cylinder liner	PD.150B	Adaptors for use with PD.150B	PD.150-7A

Note: Where several liners are to be removed or a very tight production liner is fitted, a press should be used. Where a single liner is to be removed or the crankshaft is to remain in position, a tool for hand operation is available.

- 1 Drain the lubricating oil and remove the lubricating oil sump, see Operation 10-3.
- 2 Remove the cylinder head assembly, see Operation 3-7.
- 3 Remove the piston and connecting rod assembly, see Operation 4-4.
- 4 Rotate the crankshaft to give access to the cylinder liner. Protect the crank pin.
- 5 Put the tool (A4) on the top face of the cylinder block and over the centre of the liner (A5). Ensure that the base of the tool is not on top of the liner flange of the next cylinder.

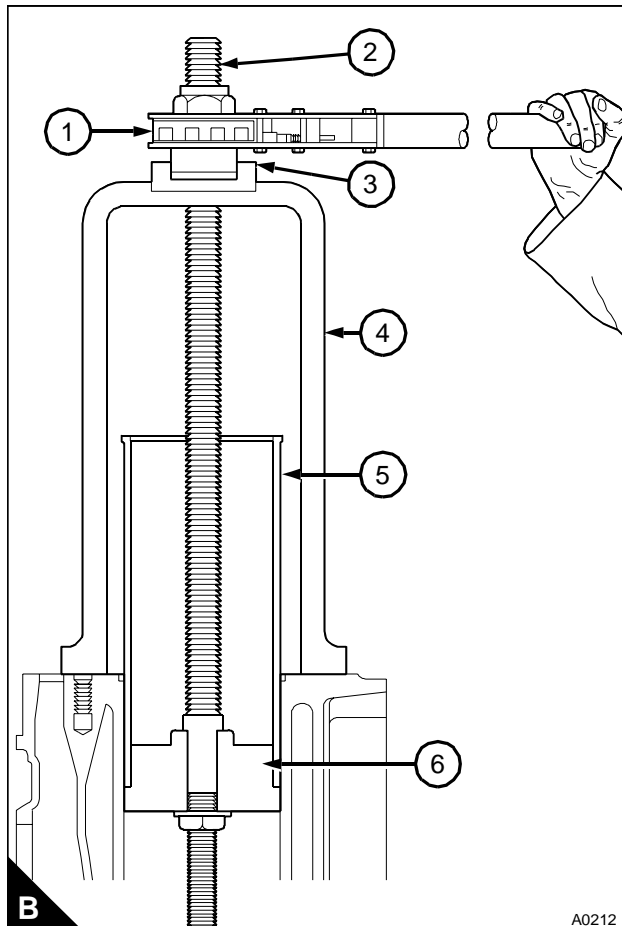


Continued

6 Put the bearing (B3) in the recess in the top of the tool with the flat face of the bearing to the bottom of the recess.

7 Fit the threaded rod (B2) through the bearing and the top of the tool until the handle (B1) is in the recess in the top of the bearing. In this position adjust the threaded rod until the end is below the bottom of the cylinder liner. Fit the adaptor PD.150-7A (B6) onto the threaded rod and against the bottom of the cylinder liner. Ensure that the two lugs on the top of the adaptor engage with the flats on the threaded rod. Fit the washer and nut and tighten the nut onto the adaptor.

8 Lubricate the ratchet of the handle and the threaded rod with Shell Spirax oil or an equivalent oil. Operate the handle and pull the cylinder liner out of the top of the cylinder block.



To fit a service liner

Operation 7-7

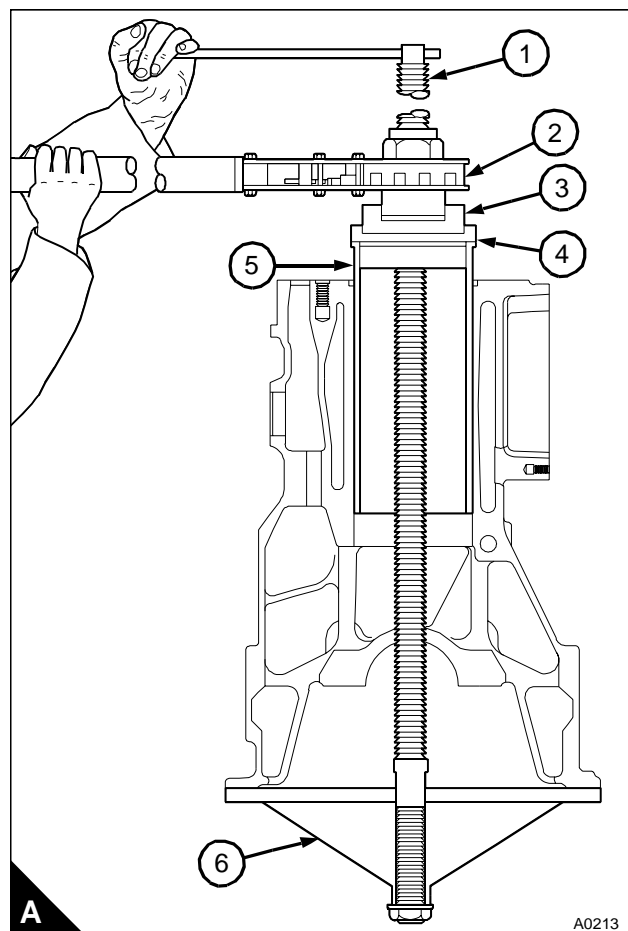
Special requirements

Special tools		Consumable products	
Description	Part number	Description	Part number
Remover/replacer for cylinder liner	PD.150B	POWERPART Retainer (oil tolerant)	21820603
Adaptors for use with PD.150B	PD.150-7A		
Depth gauge, liner flange	PD.41D	Loctite Safety Solvent or a similar product	
Dial gauge for use with PD.41D	PD.208		

A service liner is a transition fit of $\pm 0,03$ mm (± 0.001 in) in the parent bore. A special tool will not be necessary to fit some liners, but where a liner is a tight fit, tool PD.150B can be used.

Caution: Do not hit a liner with a hammer.

- 1 Clean thoroughly the parent bore. Clean the top 50 mm (2.0 in) and the recess for the liner flange with Loctite Safety Solvent or a similar product; use it in accordance with the manufacturer's instructions.
- 2 Clean thoroughly the outer surface of the liner with Loctite Safety Solvent.
- 3 Lubricate lightly the parent bore with clean engine lubricating oil, except for the top 50 mm (2.0 in).
- 4 Engage the cylinder liner (A5) into the parent bore; ensure that the liner is vertical. Put the adaptor PD.150-7A (A4) onto the top of the liner with the shoulder of the adaptor on the liner flange. Put the bearing (A3) into position in the recess in the top of the adaptor with the flat face of the bearing to the bottom of the recess.
- 5 Fit the threaded rod (A1) through the bearing, the adaptor and the liner until the handle is against the recess in the bearing. In this position adjust the threaded rod until the end is below the bottom face of the cylinder block.



Continued

6 Fit the adaptor PD.150B/6 (B6) onto the threaded rod; ensure that the flat face of the adaptor is against the bottom face of the cylinder block. Fit the washer and the nut; ensure that the threaded rod is in the centre of the liner and tighten the nut onto the adaptor.

7 Lubricate the ratchet of the handle (B2) and the threaded rod with Shell Spirax oil or an equivalent oil. Operate the handle and press the liner into the parent bore to within 50 mm (2.0 in) of the fitted position. Clean the area below the flange of the liner with Loctite Safety Solvent.

Apply POWERPART Retainer (oil tolerant) to the top 25 mm (1.0 in) of the outer surface of the liner and under the flange; also apply POWERPART Retainer (oil tolerant) to the bottom of the flange recess in the parent bore.

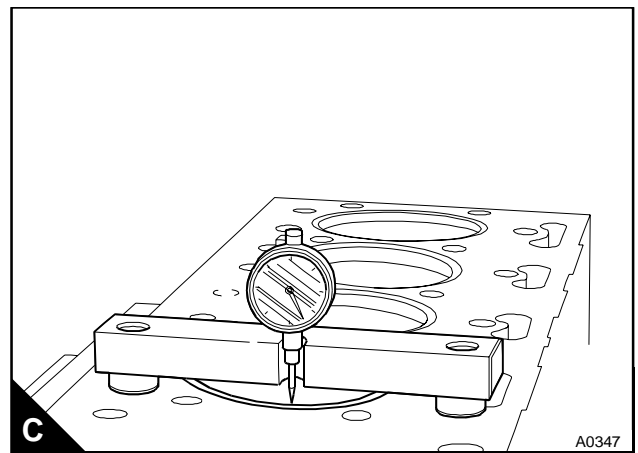
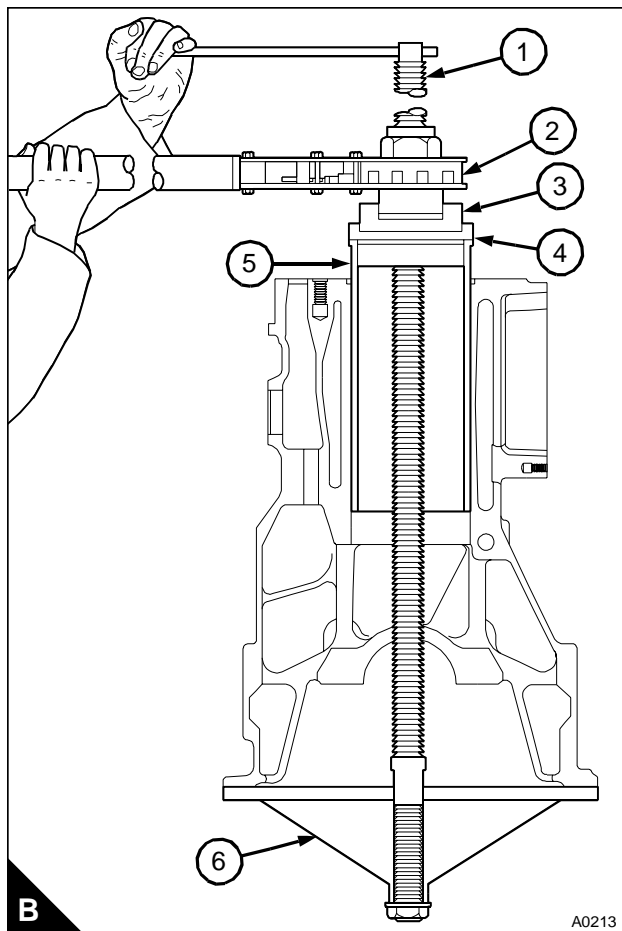
8 Press the liner in to the fully fitted position. Remove the tool and clean the retainer from the top of the cylinder block.

9 Allow 15 minutes to elapse before the liner bore dimension is checked. The retainer will reach full strength after 6 hours.

The inside diameter of a service liner, when fitted, should be 101,92/101,117 mm (3.980/3.981 in)

10 Fit new piston rings, see Operation 4-7.

11 Use tool PD.41D to check that the liner flange is between 0,10 mm (0.004 in) above to 0,10 mm (0.004 in) below the top face of the cylinder block (C).



Continued

12 Fit the piston and connecting rod assembly, see Operation 4-5.

13 Fit the cylinder head assembly, see Operation 3-8.

14 Fit the lubricating oil sump, see Operation 10-3, and fill it to the correct level with an approved lubricating oil.

Caution: *After a new service liner has been fitted, these recommendations are advised for the first 240 km (150 miles) or 5 hours of operation:*

- Do not operate the engine at full load.
- Do not operate the engine at high speed.
- Do not allow the engine to run at low idle speed for extended periods.

8

Engine timing

Lucas DPA fuel injection pumps

General description

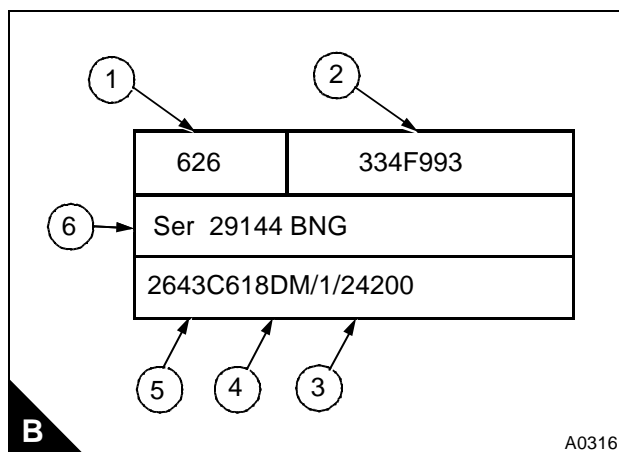
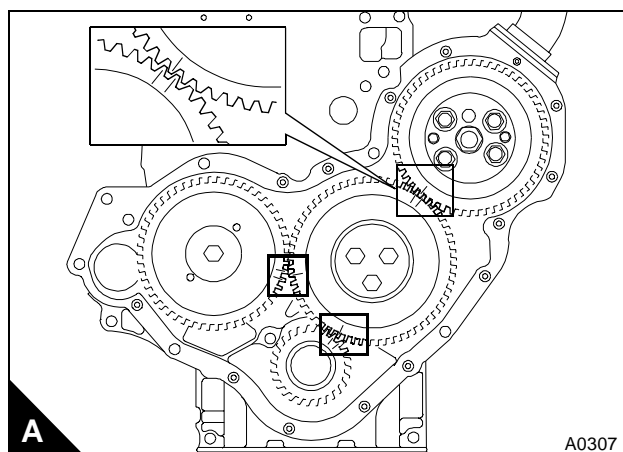
Operation 8-1

The timing gears are stamped with timing marks to ensure that they are assembled correctly (A). The stamped teeth of the crankshaft, camshaft and fuel pump gears will be in mesh with the idler gear when number 1 piston is at top dead centre (TDC) on the compression stroke. The marked teeth of the idler gear may not necessarily be in mesh in this position, because of the different speeds at which the gears rotate. The fuel pump gear has timing marks for four and six cylinder engines. Also the gear is stamped with the letter "C" where a Lucas fuel pump is fitted. The letter "M" is stamped on the fuel pump gear to indicate that the threads for the screws of the gear puller are metric.

A data plate is fitted to the side of the pump. An example of the information shown on the plate (B) is:

- Manufacturers model number (B1)
- Manufacturers description number (B2)
- Maximum engine no load speed (B3)
- Fuel pump code letters (B4)
- Perkins part number (B5)
- Fuel pump serial number (B6).

Note: For details of the fuel pump code letters for the engine see "Static timing - CAV fuel injection pump" on page 24.



To set number 1 piston to TDC on the compression stroke

Operation 8-2

Special requirements

Special tools			
Description	Part number	Description	Part number
Valve spring compressor	PD.6118B	Setscrew adaptor for use with PD.6118B	PD.6118B-8
Stud adaptor for use with PD.6118B	PD.6118B-7		

1 Fasten a temporary pointer to the timing case cover with its tip near to the outer edge of the crankshaft pulley or damper (A1).

2 Remove the rocker cover, see Operation 3-1.

3 Rotate the crankshaft, clockwise from the front, until the push rod for the inlet valve of the rear cylinder just tightens.

4 Remove the spring clip and the spacer from the front of the rocker shaft. Release the fasteners of the front two pedestals of the rocker shaft and remove the front rocker lever; tighten the fasteners of the rocker shaft pedestals.

5 Remove the valve springs from the front valve with the valve spring compressor PD.6118B and the adaptor PD.6118-7, for pedestal studs, or the adaptor PD.6118-8, for pedestal setscrews.

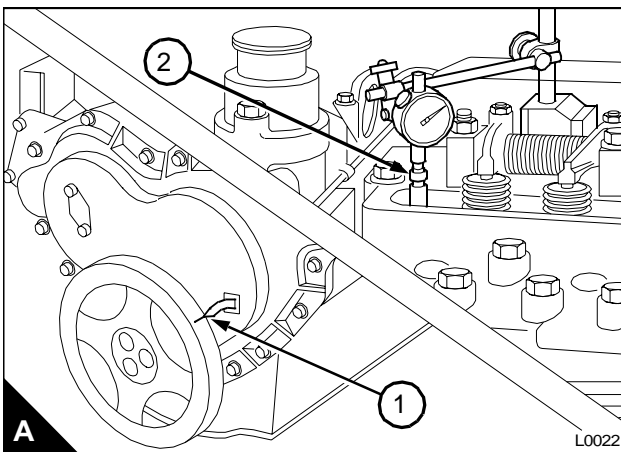
Caution: Fit a suitable collar near the top of the valve to hold the valve if the crankshaft is rotated too far.

6 Allow the valve to be held by the top of the piston.

7 Fasten a dial test indicator with its plunger in contact with the top of the valve stem (A2) and with a reading shown on the gauge. Rotate slowly the crankshaft, clockwise from the front, until the clockwise movement of the dial gauge pointer just stops. Make a suitable mark on the crankshaft pulley or damper to align with the temporary pointer.

Continue to rotate the crankshaft, in the same direction, until the gauge pointer just begins to move in a counter-clockwise direction. Make another mark on the pulley or damper to align with the pointer. Mark the centre point between the two marks on the pulley or damper and remove the other two marks.

8 Rotate the crankshaft approximately 45° counter clockwise from the front and then clockwise until the mark on the pulley or damper is aligned with the pointer. Number 1 piston is now at TDC on the compression stroke.



Another method to set number 1 piston to TDC on the compression stroke Operation 8-3

- 1** Fasten a temporary pointer to the timing case cover (or other suitable position) with its tip near to the outer edge of the crankshaft damper or pulley.
- 2** Loosen the setscrews that retain the atomisers.
- 3** Remove the rocker cover.
- 4** Rotate the crankshaft clockwise, from the front, until the push rod for the inlet valve of the rear cylinder just tightens.
- 5** Rotate the crankshaft a further $\frac{1}{8}$ of a turn clockwise. Insert a suitable lever between the rocker lever and the valve spring cap of number 1 inlet valve. Open the inlet valve and put a spacer approximately 5,0 mm (0.2 in) thick between the valve tip and the rocker lever.
- 6** Slowly rotate the crankshaft counter-clockwise until the piston makes contact with the open valve. Make a temporary mark on the damper or pulley to align accurately with the tip of the pointer.
- 7** Rotate the crankshaft clockwise one or two degrees and remove the spacer between the valve and the rocker lever. Rotate the crankshaft $\frac{1}{4}$ of a turn counter-clockwise. Put the spacer between the valve tip and the rocker lever.
- 8** Slowly rotate the crankshaft clockwise until the piston makes contact with the open valve. Make another temporary mark on the damper or pulley to align accurately with the tip of the pointer.
- 9** Make a temporary mark at the centre point between the two marks on the damper or pulley and remove the other two marks. Rotate the crankshaft counter-clockwise $\frac{1}{8}$ of a rotation and remove the spacer between the valve and the rocker lever. Slowly rotate the crankshaft clockwise until the mark on the damper or pulley aligns accurately with the tip of the pointer. Number 1 piston is now at TDC on the compression stroke.

To check the valve timing

Operation 8-4

- 1 Set the piston of number 1 cylinder to TDC on the compression stroke, see Operation 8-2.
- 2 Remove the dial test indicator from number 1 inlet valve and fit the valve springs and the rocker lever. Ensure that the fasteners for the rocker shaft pedestals are to the correct torque.
- 3 Rotate the crankshaft, clockwise from the front, until the inlet valve of the rear cylinder is fully open.
- 4 Set the valve tip clearance of number 1 cylinder inlet valve to 1,5 mm (0.059 in).
- 5 Rotate the crankshaft, clockwise from the front, until the push rod of number 1 cylinder inlet valve just tightens. In this position, check if the mark on the crankshaft pulley is within $\pm 2\frac{1}{2}^\circ$ of the temporary pointer. Use the formula below to find the measurement which is equal to $2\frac{1}{2}^\circ$ on the pulley.

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

C = Circumference of pulley

P = 2.5 degrees

- 6 If the timing is more than $2\frac{1}{2}^\circ$ out of position, the timing gears are probably not in correct mesh.

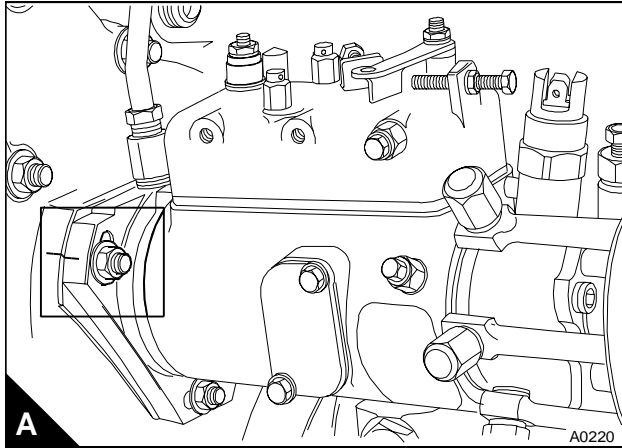
Note: One tooth on the camshaft gear is equivalent to 22 mm (0.9 in) at the circumference of a pulley of 193,5 mm (7.5 in) diameter.

- 7 Rotate the crankshaft, clockwise from the front, until the inlet valve of the rear cylinder is fully open. Set the valve tip clearance of the inlet valve of number 1 cylinder to 0,20 mm (0.008 in).
- 8 Fit the rocker cover, see Operation 3-1.
- 9 Remove the temporary pointer from the timing case and the timing mark from the pulley or damper.

To check the timing of the fuel injection pump**Operation 8-5**

If the mark on the flange of the fuel injection pump is in line with the mark on the timing case (A), the timing of the fuel injection pump should be correct.

If the timing marks are in line and the engine performance indicates that the timing is not correct, check that the marks on the flange and on the timing case are in their correct positions, see Operation 8-6 and Operation 8-7.



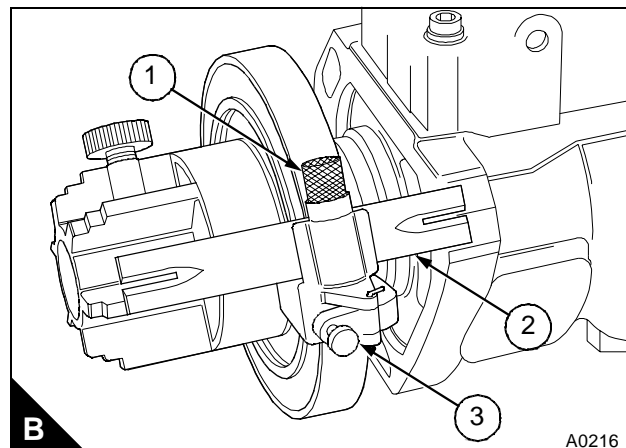
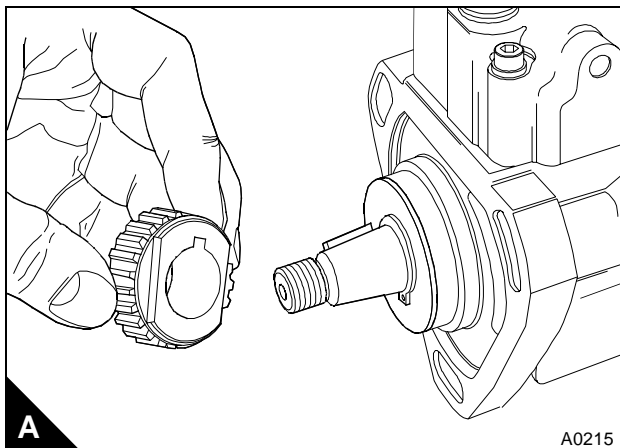
To check the timing mark of the fuel injection pump

Operation 8-6

Special requirements

Special tools			
Description	Part number	Description	Part number
Universal timing tool	MS.67B	Gear adaptor for use with MS.67B	PD.67-3

- 1 Remove the fuel injection pump, see Operation 11-10.
- 2 Fit the adaptor PD.67-3 (A) to the drive shaft of the fuel pump and fasten it with the nut of the fuel pump gear.
- 3 Remove the banjo bolt from number 1 high-pressure outlet (outlet "W") and fit a banjo bolt which does not contain a pressure valve.
- 4 Connect number 1 outlet to an atomiser tester. Operate the hand pump until a pressure of 30 atm (440 lbf in²) 31 kgf/cm² is indicated on the gauge.
- 5 Loosen the screw (B3) on the timing tool MS.67B and set the timing tool to the correct angle, see "Static timing - CAV fuel injection pump" on page 24. Tighten the screw.
- 6 Fit the timing tool to the adaptor on the fuel pump drive shaft. Rotate the drive shaft of the fuel pump by hand in the normal direction of rotation - see arrow on pump data plate - until the fuel pressure prevents movement. In this position, the fuel pump is set at the start of injection from number 1 outlet.
- 7 Loosen the screw (B1). Slide the pointer (B2) forward until it is over the centre of the pump flange and check that the mark on the flange is in the centre of the slot in the pointer.
- 8 If the mark is not correct, remove the timing tool and eliminate the mark. Fit the timing tool and ensure that the fuel pump is at the start of injection for number 1 cylinder. Loosen the screw (B1). Slide the pointer forward to the complete width of the flange and tighten the screw. Make a new mark on the flange of the pump through the slot in the pointer.
- 9 Remove the timing tool and the adaptor.
- 10 Disconnect the atomiser tester and fit the original banjo bolt to number 1 high-pressure outlet.
- 11 Fit the fuel injection pump, see Operation 11-11.
- 12 Eliminate air from the fuel system, see Operation 11-13.



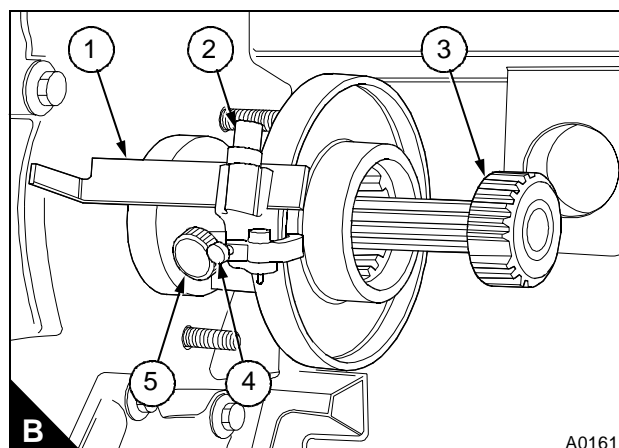
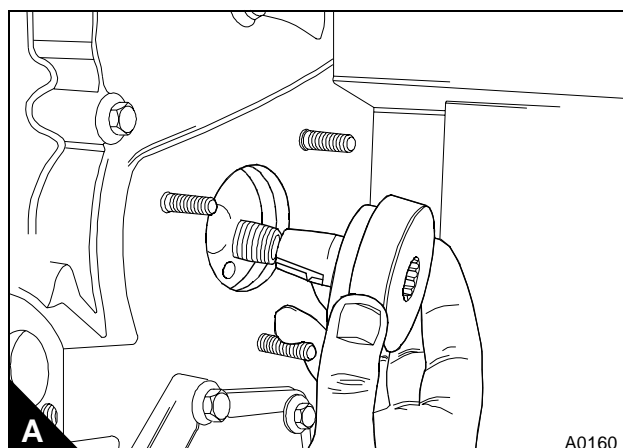
To check the engine timing mark

Operation 8-7

Special requirements

Special tools			
Description	Part number	Description	Part number
Universal timing tool	MS.67B	Adaptor for use with MS.67B	PD.67-2
Pointer for use with MS.67B	PD.67-4		

- 1 Set the piston of number 1 cylinder to TDC on the compression stroke, see Operation 8-2.
- 2 Remove the fuel injection pump and its joint, see Operation 11-10.
- 3 Align the key in the adaptor PD.67-2 (A) with the keyway in the gear of the fuel injection pump and fit the adaptor to the gear. Ensure that the adaptor is against the rear face of the timing case. Secure the adaptor to the gear with the nut supplied with the adaptor.
- 4 Loosen the screw (B4) on the timing tool MS.67B. Set the timing tool to the correct engine check angle, see "Static timing - CAV fuel injection pump" on page 24, and tighten the screw. Loosen the screw (B5) and fit the splined shaft (B3) into the timing tool (B). Loosen the screw (B2). Fit the 90° pointer PD.67-4 (B1) and tighten the screw.
- 5 Fit the splined shaft of the timing tool to the adaptor. Slide the timing tool along the splined shaft until it is against the adaptor and tighten the screw (B5).
- 6 Loosen the lock screw (B2). Slide the pointer forward until the flat face is against the rear face of the timing case and tighten the screw. If the mark on the timing case is correct, the mark will align with the top edge of the pointer (B1). If the mark is not correct, remove the timing tool and eliminate the mark on the timing case. Fit the timing tool. Ensure that the pointer is against the timing case and make a new mark on the timing case along the top straight edge of the pointer.
- 7 Remove the timing tool and the adaptor.
- 8 Fit the fuel injection pump and a new joint, see Operation 11-11.
- 9 Remove the dial gauge from number 1 cylinder inlet valve and fit the valve springs and the rocker lever. Set the valve tip clearance of number 1 cylinder inlet valve to 0,20 mm (0.008 in).
- 10 Fit the rocker cover, see Operation 3-1.
- 11 Eliminate air from the fuel system, see Operation 11-13.



Stanadyne fuel injection pumps

General description

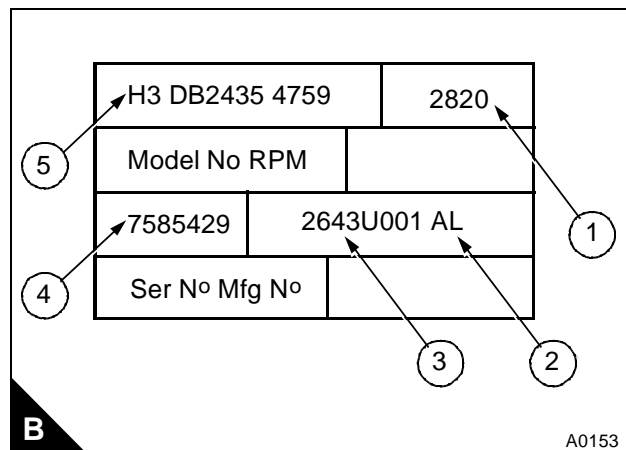
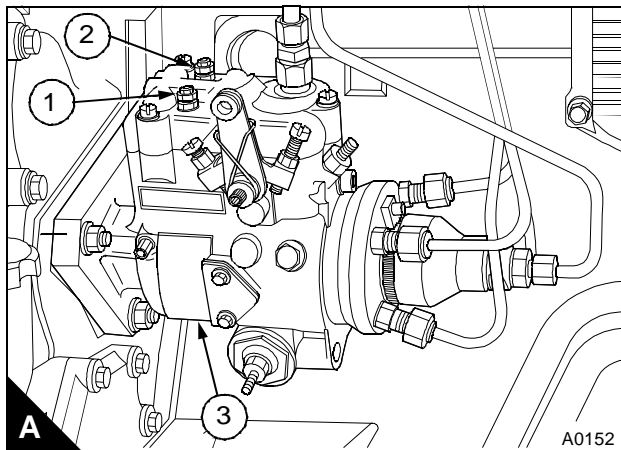
Operation 8-8

The electrical stop solenoid on these fuel pumps is fitted inside the governor housing. The earth connection (A1) and the electrical connection (A2) are on top of the governor housing.

A data plate (A3) is fitted to the side of the pump . An example of the information shown on the plate (B) is:

- Maximum engine no load speed (B1)
- Fuel pump code (B2)
- Perkins part number (B3)
- Fuel pump serial number (B4)
- Manufacturers model number (B5)

Note: For details of the fuel pump code for the engine see "Static timing - Stanadyne fuel injection pump" on page 24.



To set number 1 piston to TDC on the compression stroke

Operation 8-9

Refer to procedure for Lucas DPA pumps, see Operation 8-2.

To check the valve timing

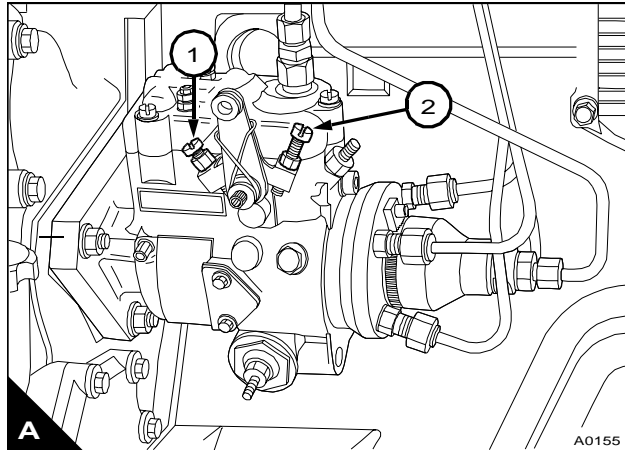
Operation 8-10

Refer to procedure for Lucas DPA pumps, see Operation 8-4.

To check the timing of the fuel injection pump**Operation 8-11**

If the mark on the flange of the fuel injection pump is in line with the mark on the timing case (A1), the timing of the fuel injection pump should be correct.

If the timing marks are in line and engine performance indicates that the timing is not correct, check that the marks on the flange and on the timing case are in their correct positions, see Operation 8-12.



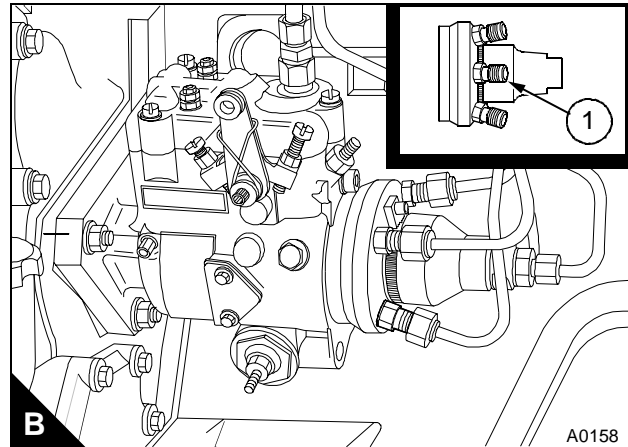
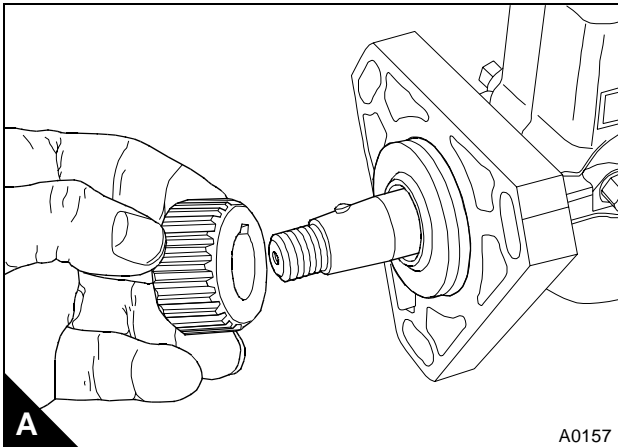
To check the timing mark of the fuel injection pump

Operation 8-12

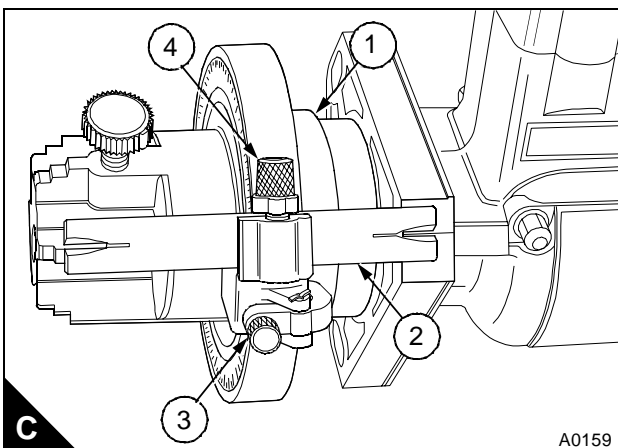
Special requirements

Special tools			
Description	Part number	Description	Part number
Universal timing tool	MS.67B	Gear adaptor for use with MS.67B	PD.67-3

- 1 Remove the fuel injection pump from the engine, see Operation 11-14.
- 2 Fit the adaptor PD.67-3 (A) to the drive shaft of the fuel pump and fasten it with the nut of the fuel pump gear.
- 3 Connect number 1 outlet (B1) to an atomiser tester. Operate the hand pump until a pressure of not more than 50 atm (735 lbf in²) 52 kgf/cm² is indicated on the gauge.

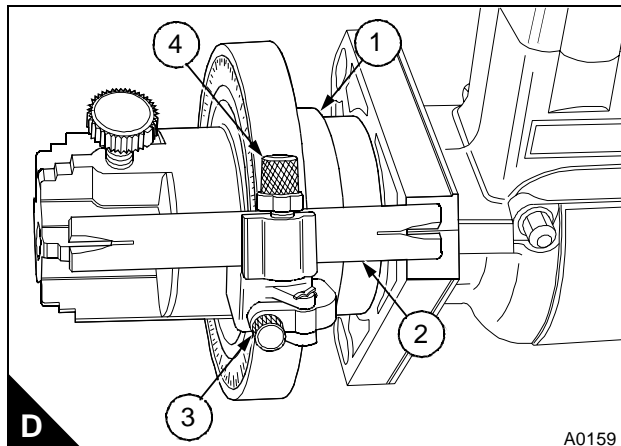


- 4 Rotate the drive shaft of the fuel pump clockwise from the drive end of the pump until the pin in the shaft aligns with number 1 outlet. Loosen the screw (C3) on the timing tool MS.67B and set the timing tool to the correct pump mark angle, see "Static timing - Stanadyne fuel injection pump" on page 24. Tighten the screw.
- 5 Put the sleeve (C1) for the timing tool in position on the fuel pump. Fit the timing tool to the adaptor on the fuel pump drive shaft. Rotate the shaft backwards and forwards until the fuel pressure prevents movement of the shaft. This is necessary as fuel must pass the delivery valve in the fuel pump before the fuel pressure will prevent movement of the shaft. In this position, the fuel pump is set at the start of injection from number 1 outlet.



Continued

- 6** Loosen the screw (D4). Slide the pointer (D2) forward until it is over the centre of the pump flange and check that the mark on the flange is in the centre of the slot in the pointer.
- 7** If the mark on the flange is not correct, remove the timing tool and eliminate the mark. Fit the timing tool and ensure that the fuel pump is at the start of injection for number 1 cylinder. Loosen the screw (D4). Slide the pointer forward to the complete width of the flange and tighten the screw. Make a new mark on the flange of the pump through the slot in the pointer.
- 8** Remove the timing tool, the sleeve and the adaptor.
- 9** Disconnect the atomiser tester from number 1 high-pressure outlet.
- 10** Fit the fuel injection pump, see Operation 11-15.
- 11** Eliminate air from the fuel system, see Operation 11-17.



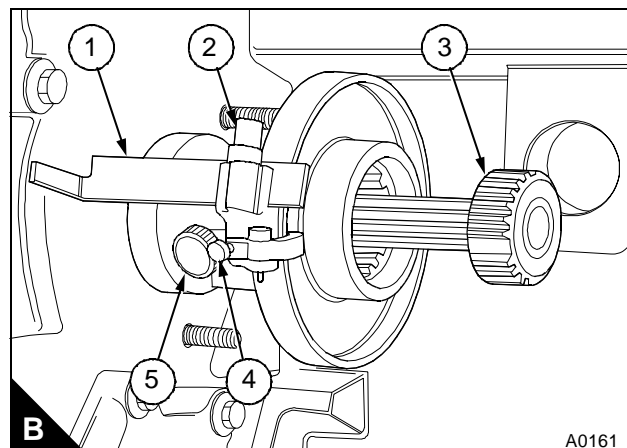
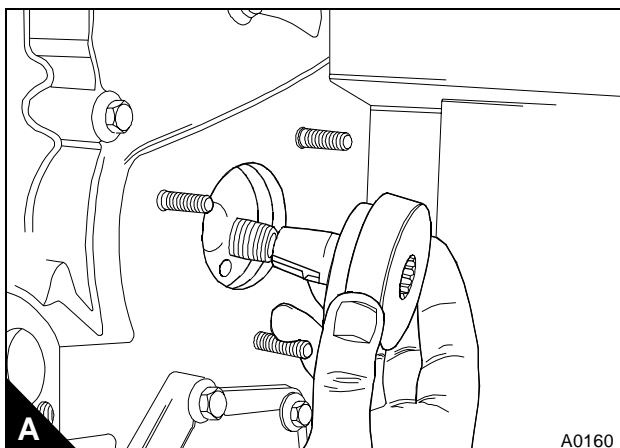
To check the engine timing mark

Operation 8-13

Special requirements

Special tools			
Description	Part number	Description	Part number
Universal timing tool	MS.67B	Adaptor for use with MS.67B	PD.67-2
Pointer for use with MS.67B	PD.67-4		

- 1 Set the piston of number 1 cylinder to TDC on the compression stroke.
- 2 Remove the fuel injection pump and its joint from the pump flange, see Operation 11-14.
- 3 Align the key in the adaptor PD.67-2 (A) with the keyway in the gear of the fuel injection pump and fit the adaptor to the gear. Ensure that the adaptor is against the rear face of the timing case. Secure the adaptor to the gear with the nut supplied with the adaptor.
- 4 Loosen the screw (B4) on the timing tool MS.67B. Set the timing tool to the correct engine check angle, see "Static timing - Stanadyne fuel injection pump" on page 24, and tighten the screw. Loosen the screw (B5) and fit the splined shaft (B3) into the timing tool (B). Loosen the screw (B2). Fit the 90° pointer PD.67-4 (B3) and tighten the screw.
- 5 Fit the splined shaft (B3) of the timing tool to the adaptor. Slide the timing tool along the splined shaft until it is against the adaptor and tighten the screw (B5).
- 6 Loosen the lock screw (B2). Slide the pointer forward until the flat face is against the rear face of the timing case and tighten the screw. Rotate the timing tool clockwise, as seen from the rear of the engine, to remove the backlash. If the mark on the timing case is correct, the mark will align with the top edge of the pointer (B1). If the mark is not correct, remove the timing tool and eliminate the mark on the timing case. Fit the timing tool. Ensure that the pointer is against the timing case and make a new mark on the timing case along the top straight edge of the pointer.
- 7 Remove the timing tool and the adaptor.
- 8 Fit a new joint to the fuel injection pump flange and fit the pump, see Operation 11-15.
- 9 Remove the dial gauge from the inlet valve of the number 1 cylinder and fit the valve springs and the rocker lever. Set the valve tip clearance of number 1 cylinder inlet valve to 0,20 mm (0.008 in).
- 10 Fit the rocker cover, see Operation 3-1.
- 11 Eliminate air from the fuel system, see Operation 11-17.



9

Aspiration system

Open engine breather

An open breather is fitted to the engine which has a pipe connected to the rocker cover, crankcase emissions pass directly from the engine.

Ensure that the breather pipe is not restricted.

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10

Lubrication system

General description

Pressure lubrication is supplied by a rotor type pump which is driven through an idler gear from the crankshaft gear. The pump has an inner rotor and an outer rotor which are off-centre to each other. There is a key between the inner rotor and the drive shaft. The inner rotor has six lobes which mesh with the seven lobes of the outer rotor. When the pump rotates, the space between the lobes of the outer rotor which are in mesh increases to cause a suction or decreases to cause a pressure increase. If a balancer unit is fitted, the oil pump is fitted to the balancer frame and is driven by the balancer drive shaft. Refer to "Lubrication system flow diagram for the relief valve and balancer" on page 133.

Lubricating oil (page 132/A1) from the sump passes through a strainer and pipe to the suction side of the pump.

The lubricating oil (page 132/A2) passes from the outlet side of the pump through a pipe to a relief valve, which is fitted to the bottom of the left side of the cylinder block.

If a balancer unit is fitted, the relief valve is fitted in the frame of the balancer. The relief valve opens if the oil pressure is too high; this allows some of the lubricating oil to return to the sump.

From the relief valve, lubricating oil passes to a plate type oil cooler (if one is fitted). The oil cooler is fitted to the oil filter head and has ten plates. Lubricating oil from the oil cooler, passes to an oil filter. The oil filter can be fitted to the left or right side of the engine. If the filter is fitted to the right side of the engine, the oil passes through a pipe connected between the relief valve and the right side of the cylinder block. Refer to "Lubrication system flow diagram for the relief valve and balancer" on page 133. The oil passes from the pipe through a passage in the right side of the cylinder block to an oil cooler and then to the oil filter.

The lubricating oil passes from the filter to the pressure rail which is drilled the complete length of the left side of the cylinder block. If the oil filter is on the right side of the engine, the oil passes through a passage drilled across the cylinder block to the pressure rail.

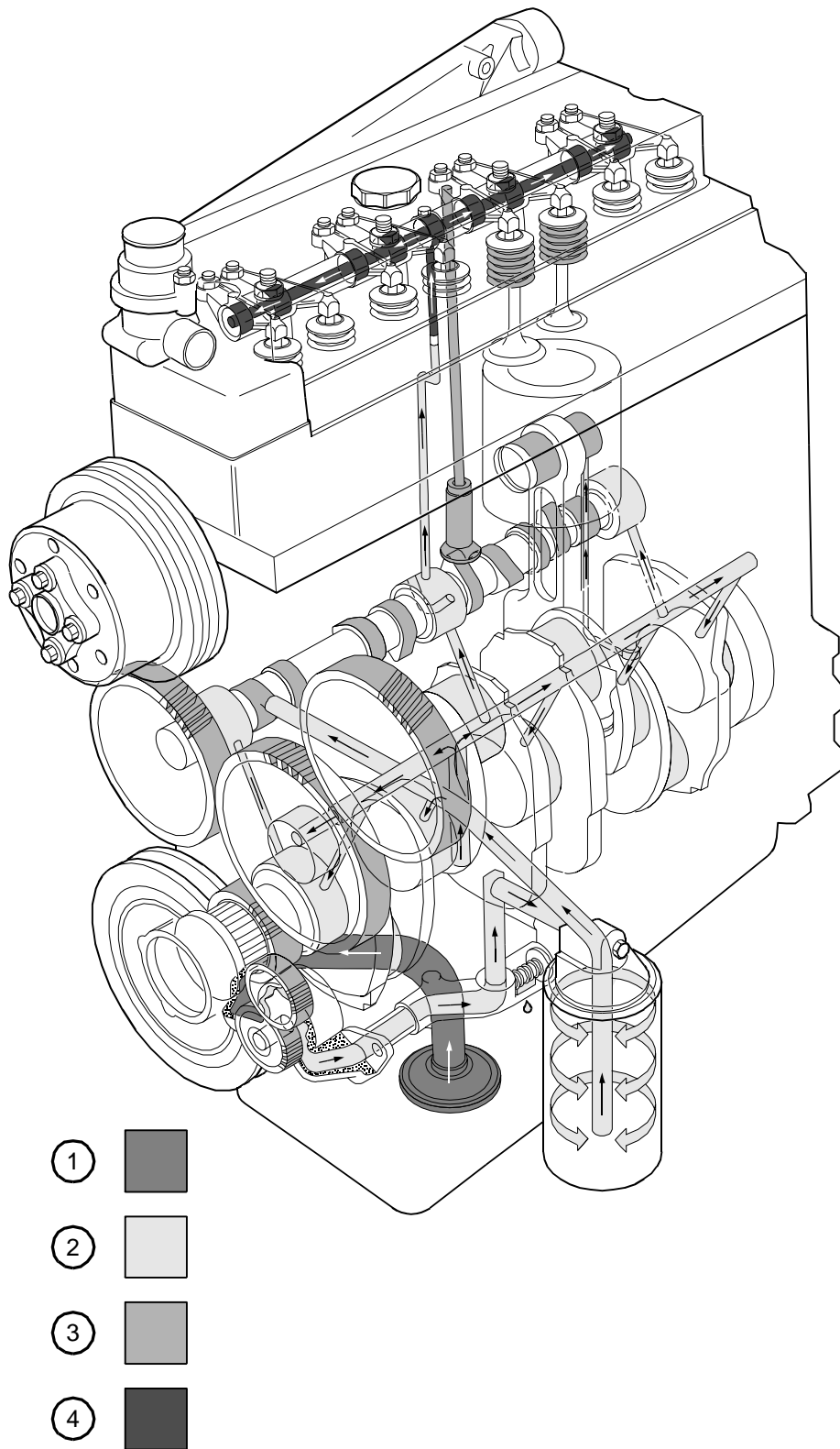
From the pressure rail, lubricating oil passes to the main bearings of the crankshaft and through passages in the crankshaft to the big end bearings. The pistons and the cylinder bores are lubricated by splash and oil mist.

Lubricating oil (page 132/A3) passes from the main bearings through passages in the cylinder block to the journals of the camshaft. Lubricating oil passes from the centre journal of the camshaft through a passage in the cylinder block and cylinder head to a restriction in the pedestal of the rocker shaft, at a reduced pressure (page 132/A4), to the rocker bushes.

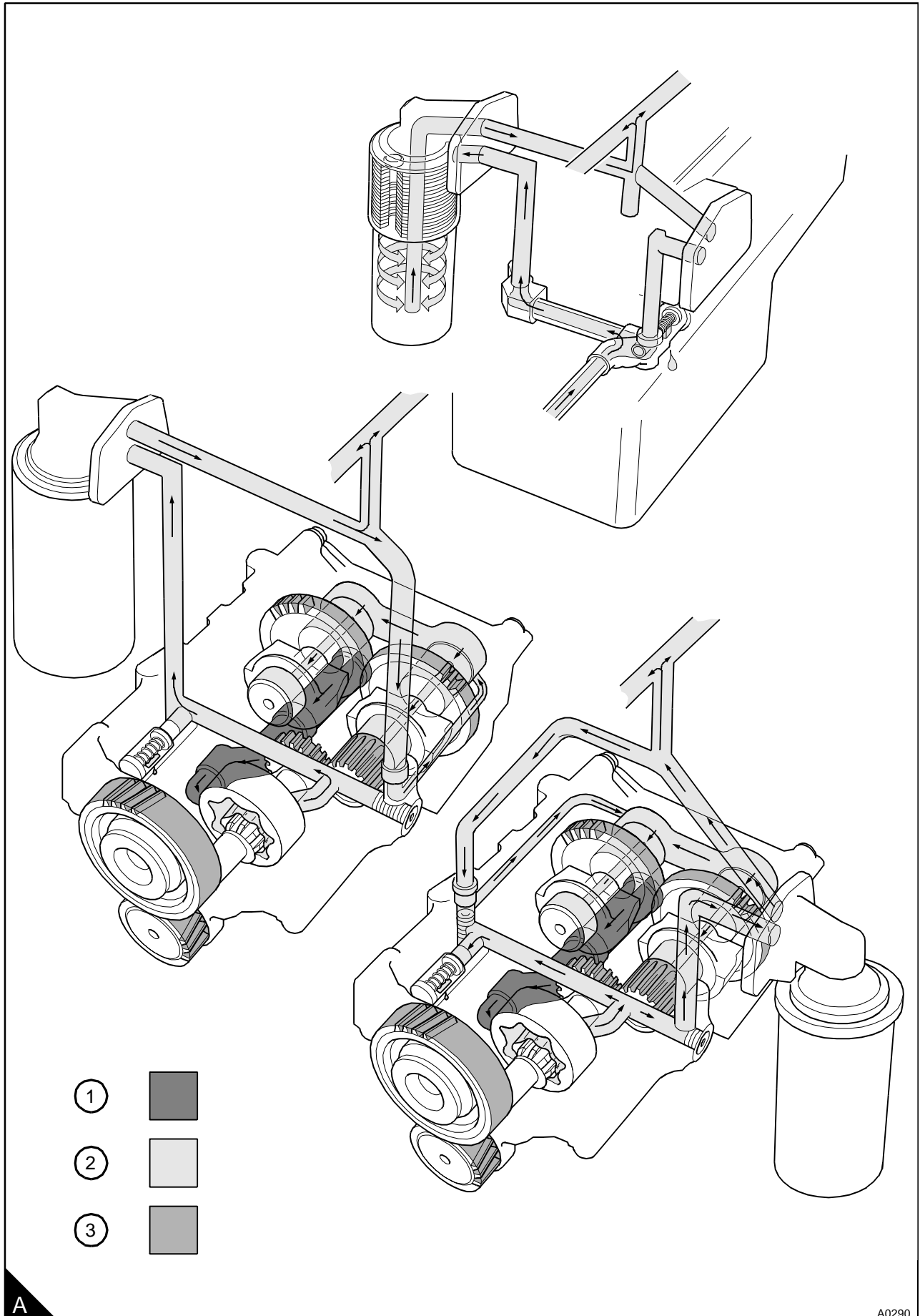
The oil passes through a passage in the rocker shaft to the bearings of the rocker levers. The valve stems, valve springs and the tappets are lubricated by splash and oil mist.

The hub of the idler gear is lubricated by oil from the pressure rail and the timing gears are splash lubricated.

Lubrication system flow diagram



Lubrication system flow diagram for the relief valve and balancer



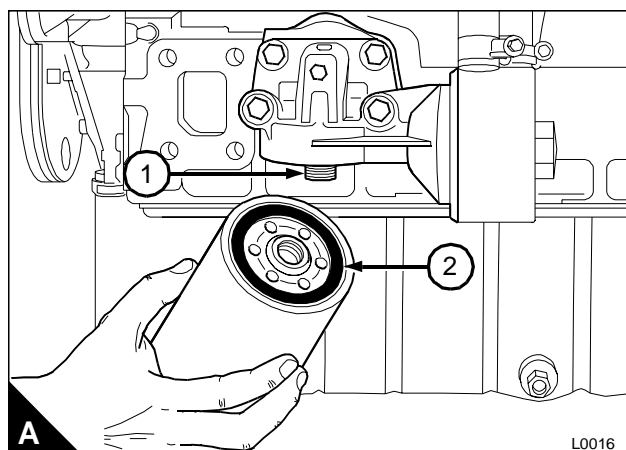
Filter canister

To renew

Operation 10-1

- 1 Put a tray under the filter to retain spilt lubricating oil.
- 2 Remove the filter canister with a strap wrench or similar tool. Ensure that the adaptor (A1) is secure in the filter head. Discard the canister.
- 3 Clean the filter head.
- 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 Ensure that there is lubricating oil in the sump. Ensure that the engine will not start and operate the starter motor until the oil pressure is obtained. To ensure that the engine will not start, either put the manual control in the "stop" position or disconnect the electrical stop control of the fuel injection pump. Operate the starter motor until the oil pressure warning light is extinguished or there is a reading on the gauge.
- 7 Operate the engine and check for leakage from the filter. When the engine has cooled, check the oil level on the dipstick and put more oil into the sump, if necessary.

Caution: The canister contains a valve and special tube to ensure that lubricating oil does not drain from the filter. Therefore, ensure that the correct Perkins POWERPART canister is used.



Filter head

To remove and to fit

Operation 10-2

Special requirements

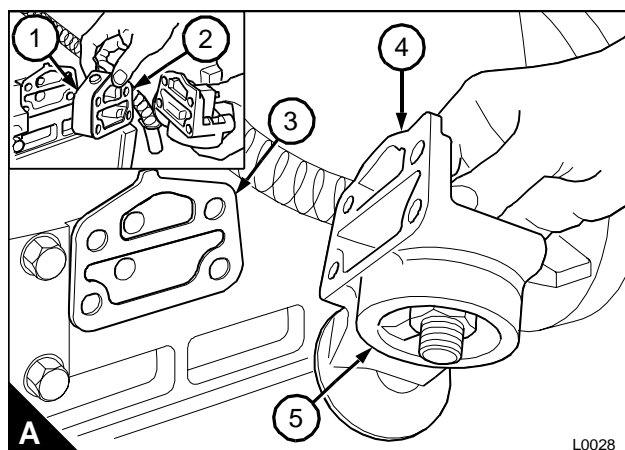
Consumable products	
Description	Part number
POWERPART Nutlock	21820242

- 1 Put a tray under the filter head to contain spilt lubricating oil.
- 2 Remove the filter canister, see Operation 10-1.
- 3 Remove the oil cooler from the filter head, if one is fitted, see Operation 12-8.
- 4 Release the setscrews and remove the filter head (A4) from the cylinder block. Discard the joint (A3).
- 5 Clean the joint face of the filter head (A5) and the flange of the oil cooler, If one is fitted. Fit the filter head and a new joint.

Note: Some engines have an adaptor (A1) between the cylinder block and the filter head. If an adaptor is used, two joints are fitted (A2) and (A3).

Apply POWERPART Nutlock to the first three threads of the setscrews and tighten the setscrews.

- 6 Fit the oil cooler to the filter head, if one is fitted, see Operation 12-8.
- 7 Fit new filter canister, see Operation 10-1.



Sump

To remove and to fit

Operation 10-3

- 1 Operate the engine until it is warm.
- 2 Stop the engine, remove the sump drain plug and its "O" ring and drain the oil. where necessary, remove the dipstick and the dipstick tube.
- 3 Provide a support for the sump and remove the setscrews and the two nuts which fasten the sump to the cylinder block and to the timing case. lower the sump and remove the joint.
- 4 Wash the sump with an approved cleaning fluid, ensure all the cleaning fluid is removed. clean the flange face of the sump and of the cylinder block. if necessary, renew the felt dust seal which is fitted to the rear of the sump flange on some engines.
- 5 Fit the sump together with a new joint and ensure the correct location with a setscrew on each side. fit the remainder of the setscrews and the nuts and tighten all the fasteners to 22 Nm (16 lbf ft) 2,2 kgf m. fit the drain plug together with a new "O" ring and tighten the plug to 34 nm (25 lbf ft) 3,5 kgf m. where necessary, fit the dipstick tube and the dipstick. Fill the sump to the "max" level on the dipstick with an approved lubricating oil.

Oil strainer and suction pipe

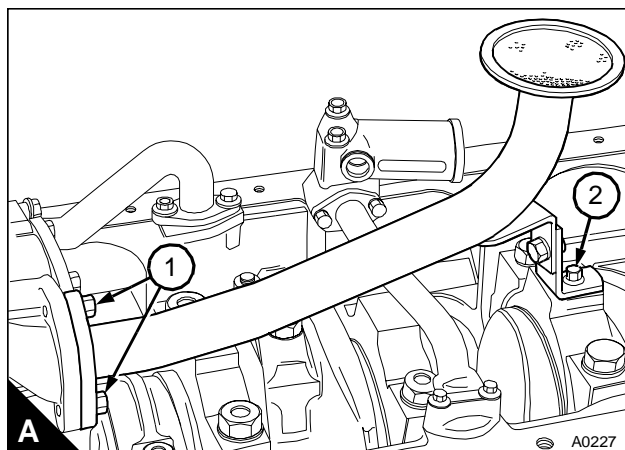
To remove and to fit

Operation 10-4

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

When a balancer is fitted, the suction pipe is normally a short pipe which is fastened to the balancer frame and a pipe bracket is not fitted. The short oil strainer and suction pipe are made of a composite material. This arrangement has an "O" ring seal on the flange face of the oil pump instead of a joint.

- 1 Remove the sump, see Operation 10-3.
- 2 Release the setscrew which holds the bracket to the main bearing cap (A2).
- 3 Release the setscrews from the flange of the suction pipe (A1). Remove the suction pipe and strainer. Remove and the old joint or the "O" ring. Clean the flange face of the oil pump and of the suction pipe.
- 4 Loosely assemble the bracket of the suction pipe to the correct main bearing cap. Fit the suction pipe to the oil pump together with a new joint or an "O" ring. Tighten the setscrews. Tighten the setscrew of the suction pipe bracket. Ensure that there is no stress on the suction pipe.
- 5 Fit the sump, see Operation 10-3, and fill it with an approved oil to the correct level on the dipstick, refer to the User's Handbook.



To inspect and to correct

Operation 10-5

- 1 Wash the assembly in an approved cleaning fluid and dry it thoroughly.
- 2 Check the pipe, the strainer and the welded joints for cracks and other damage. Check that the mounting bracket is secure.
- 3 If the damaged component cannot be welded correctly, renew the assembly.
- 4 Composite material parts must be renewed if they have cracks or damage.

Lubricating oil pump

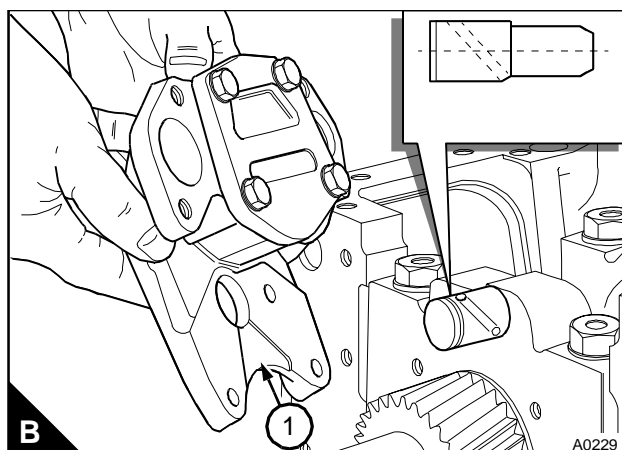
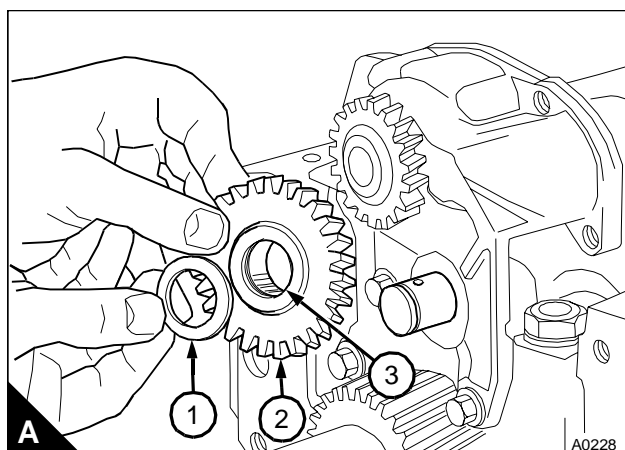
To remove

Operation 10-6

The oil pump is integral with the balancer unit, see Operation 5-13 for removal instructions.

The lubricating oil pump has a channel (B1) in the body of the pump. On some engines lubricating oil from the front main bearing passes down the channel in the body of the pump to an oil hole in the idler shaft. The lubricating oil then passes through the hole in the idler shaft to the bush in the idler gear. There will not be a hole in the idler gear shaft if extra lubricating oil is not needed in the idler gear bush.

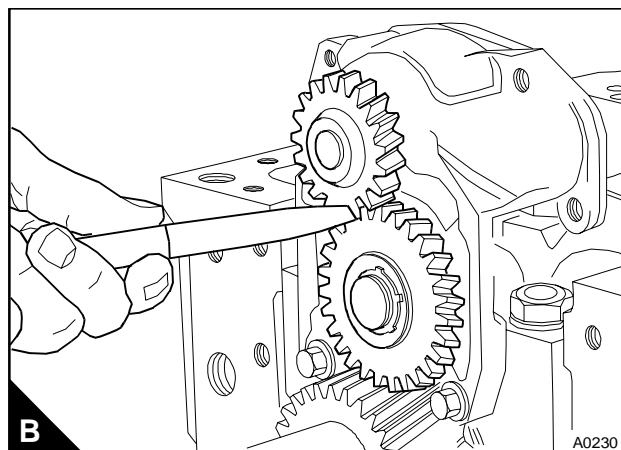
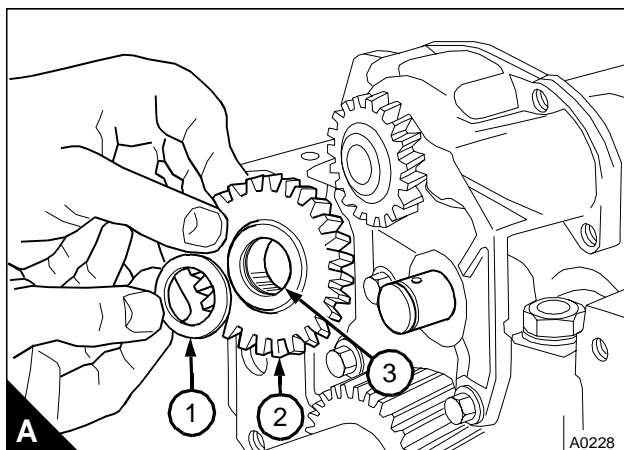
- 1 Drain the lubricating oil and remove the lubricating oil sump, see Operation 10-3.
- 2 Remove the suction pipe and strainer, see Operation 10-4.
- 3 Remove the oil pressure relief valve, see Operation 10-10, and the delivery pipe.
- 4 The oil pump is fitted to number 1 main bearing cap. The oil pump can be removed with the main bearing cap, if a suitable spanner is available that will enable the torque to be applied correctly to the setscrews of the main bearing cap when it is fitted. If a suitable spanner is not available, the timing case must be removed, see Operation 6-13.
- 5 Release the circlip which retains the idler gear of the oil pump and remove the washer (A1) and the idler gear (A2).
- 6 Release the setscrews and remove the oil pump (B).



To fit

Operation 10-7

- 1 Fill the oil pump with clean engine lubricating oil. Fit the oil pump to the main bearing cap and tighten the setscrews to 22 Nm (16 lbf ft) 2,2 kgf m.
 - 2 Check the idler gear and the bush for wear and other damage. If the gear and/or bush are damaged, they can be renewed as an assembly or the bush can be renewed as a single item. Check the shaft of the idler gear for wear or other damage. If the shaft is worn or damaged, renew the shaft, see Operation 10-8. Lubricate the bush (A3) with clean engine lubricating oil and fit the idler gear (A2), the washer (A1) and the circlip.
 - 3 Check that there is a minimum of 0,076 mm (0.003 in) backlash between the oil pump gear and the idler gear (B).
 - 4 If number 1 main bearing cap was removed, lubricate the bearing with clean engine lubricating oil and fit the bearing cap. Tighten the setscrews to 265 Nm (196 lbf ft) 27,0 kgf m. If the timing case was removed, fit the timing case, see Operation 6-14.
 - 5 Check that there is a minimum of 0,076 mm (0.003 in) backlash between the oil pump idler gear and the crankshaft gear.
- If the latest lubricating oil pump with the oil supply channel is fitted, the end-float for the idler gear is 0,012/0,643 mm (0.0005/0.0253 in)
- 6 Fit the suction pipe and strainer, see Operation 10-4.
 - 7 Fit the delivery pipe and oil pressure relief valve, see Operation 10-10.
 - 8 Fit the lubricating oil sump, see Operation 10-3.
 - 9 Fill the sump to the correct mark on the dipstick with an approved lubricating oil, refer to the User's Handbook.



To renew the shaft for the idler gear

Operation 10-8

Special requirements

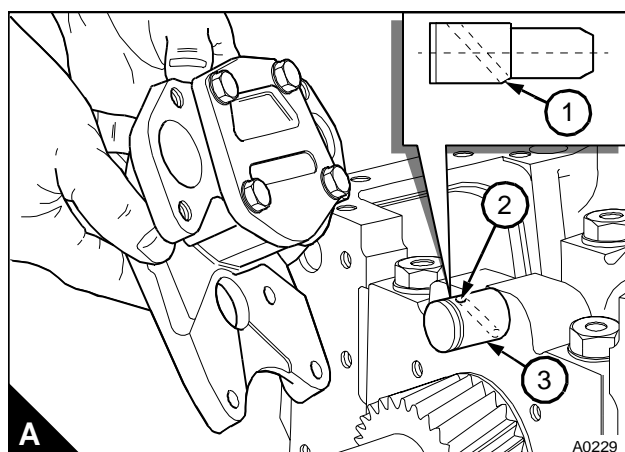
Consumable products	
Description	Part number
POWERPART Retainer (oil tolerant)	21820603

1 Support the front of the bearing cap. Put a suitable adaptor on the small diameter of the idler shaft and press the idler shaft out of the bearing cap.

2 Ensure that the idler shaft and the hole in the bearing cap are clean. Support the rear of the bearing cap and ensure that the cap will not move when the idler shaft is pressed in. Apply POWERPART Retainer to the small diameter of the idler shaft.

If the idler shaft (A3) has an oil hole ensure that the hole (A2) in the idler shaft is at the top and that the flat (A1) is at the bottom before the shaft is pressed into the bearing cap.

Enter the chamfer of the idler shaft into the hole. Ensure that the idler shaft is square to the bearing cap and press in the shaft onto its shoulder. Remove the surplus POWERPART Retainer and ensure that the oil hole is not filled with retainer.

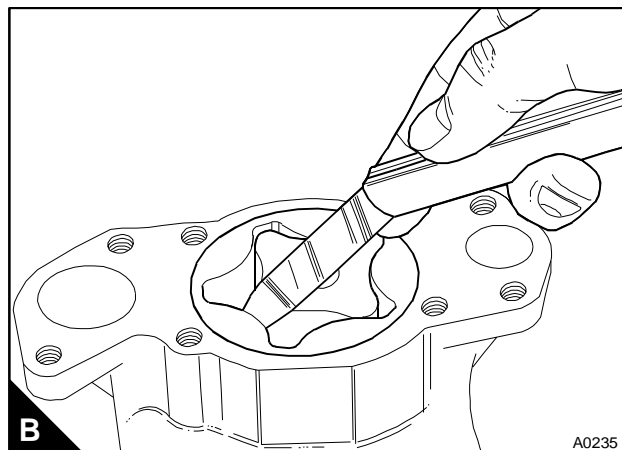
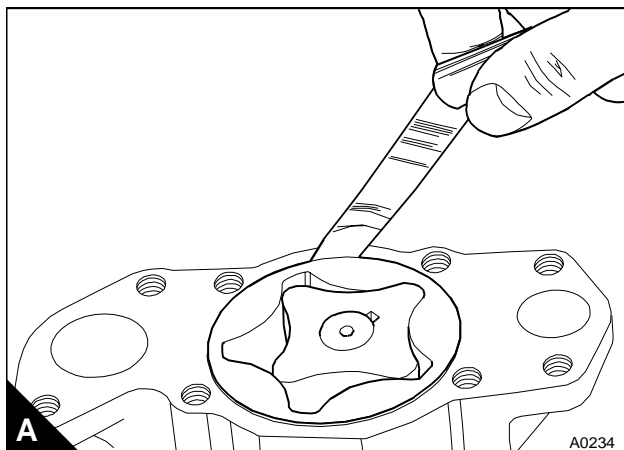


To inspect

Operation 10-9

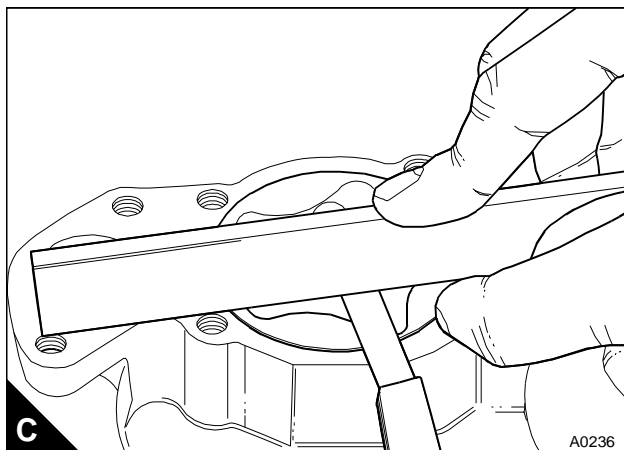
If any part is worn enough to have an effect on the performance of the oil pump, the complete oil pump must be renewed.

- 1 Release the setscrews and remove the cover of the oil pump. For pumps which are fitted to a balancer unit, remove the single setscrew and the cover.
- 2 Remove the outer rotor and clean thoroughly all the parts. Check for cracks and any other damage.
- 3 Fit the outer rotor and check the outer rotor to body clearance (A).
- 4 Check the inner rotor to outer rotor clearance (B).



- 5 Check the rotor end-float with a straight edge and a feeler gauge (C). For all the above clearances, refer to the relevant Data and dimensions for the "Lubrication system" on page 24.

- 6 Clean the top face of the oil pump and the bottom face of the cover and fit the cover. Tighten the setscrews to 28 Nm (21 lbf ft) 2,9 kgf m. For pumps which are fitted to a balancer unit, put the cover in position and tighten the single setscrew to 22 Nm (16 lbf ft) 2,2 kgf m.



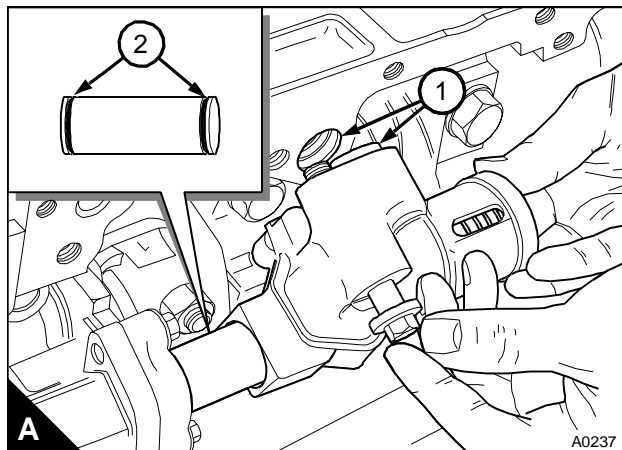
Relief valve

To remove and to fit

Operation 10-10

The relief valve is fitted inside the balancer frame. The relief valve of these engines cannot be removed as an assembly.

- 1 Drain the lubricating oil and remove the sump, see Operation 10-3.
- 2 Release the setscrew and rotate the relief valve to withdraw the thimble from the cylinder block (A1). Pull the relief valve from the delivery pipe and pull the delivery pipe from the oil pump. Renew the "O" rings (A2). Lightly lubricate the "O" rings with clean engine lubricating oil and push the delivery pipe into the oil pump. Push the relief valve onto the delivery pipe and fit the relief valve to the cylinder block; ensure that the thimble is correctly fitted and tighten the setscrew.

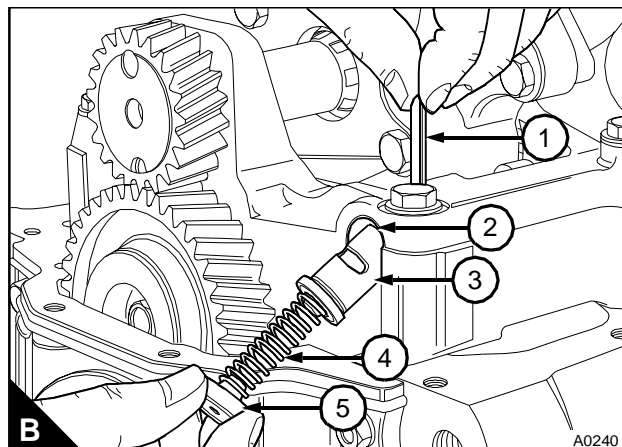
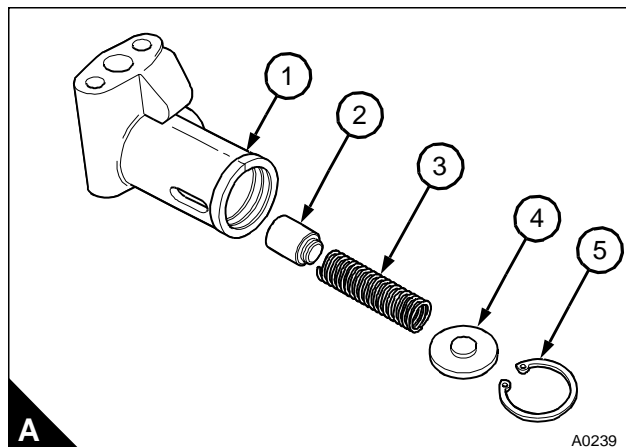


To dismantle and to assemble

Operation 10-11

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

- 1 Apply pressure to the end plate (A4 or B5) of the spring assembly; release the circlip (A5) or remove the pin (B1) and carefully release the pressure to remove the end plate and the spring (A3 or B4) from the valve body. Remove the plunger (A2 or B3) from the bore of the body (A1 or B2).
- 2 Ensure that all the components are cleaned and then lubricated lightly with clean engine lubricating oil.
- 3 Fit the plunger into the bore with its hollow end to the inside. Fit the spring and the end cap into the bore with the ends of the spring fitted around the bosses of the plunger and the end plate. Apply pressure to the end plate and fit the circlip into its groove or fit the pin into the holes in the balancer frame.



To inspect

Operation 10-12

Do not try to 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 and, if possible, check the load necessary to compress the spring to its fitted length. Refer to the relevant Data and dimensions for the "Lubrication system" on page 24.
- 2 Check the plunger for wear and other damage and ensure that it slides easily in the bore of the relief valve.
- 3 Check the body and the end plate for wear and other damage.
- 4 Renew worn or damaged components.

11

Fuel system

General description

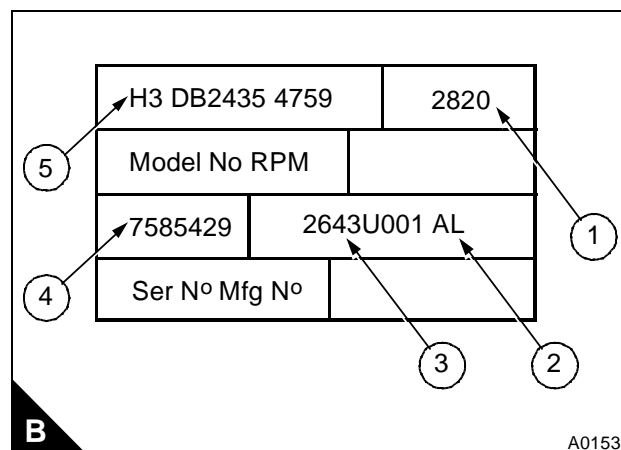
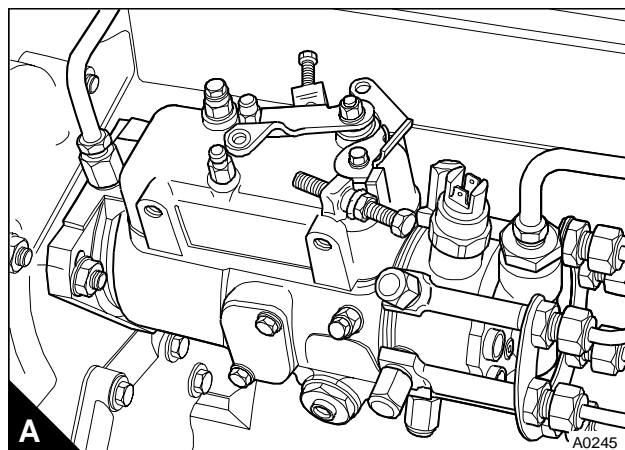
Cautions:

- *It is very important that dirt does not enter the fuel system. Before a connection is disconnected, clean thoroughly the area around the connection. After the component has been disconnected, fit a suitable cover to all open connections.*
- *Do not clean an engine while it runs. If cold cleaning fluids are applied to a hot engine, certain components on the engine may be damaged.*

The Lucas DPA fuel injection pump (A) has a mechanical governor to control the engine speed.

A data plate is fitted to the side of the pump. A typical data plate (B) and an example of the information shown on the plate is:

- Maximum engine no load speed (B1)
- Fuel pump code (B2)
- Perkins part number (B3)
- Fuel pump serial number (B4)
- Manufacturers model number (B5)



Continued

For details of the fuel pump code for the engine see the "Static timing - CAV fuel injection pump" on page 24 for Lucas DPA fuel injection pumps and "Static timing - Stanadyne fuel injection pump" on page 24 for Stanadyne fuel injection pumps.

The "low spring" atomisers receive high pressure fuel from the fuel injection pump and inject this fuel into the combustion chamber of the pistons as a very fine spray. The atomisers are set in the factory, but they must be checked in accordance with the preventive maintenance schedules. The pressure at which atomisers operate can be adjusted by a change of shims fitted above the spring.

For details of the atomiser service setting pressures for the engine for both Lucas DPA fuel injection pumps and Stanadyne fuel injection pumps, refer to "Atomiser service settings" on page 26.

The fuel injection equipment must only be checked and adjusted by personnel who have had the correct training.

The fuel lift pump is of the diaphragm type and is mechanically driven. It is fitted on the right side of the cylinder block and is driven by an eccentric on the camshaft. The pump is fitted with a priming lever.

Fuel filter element

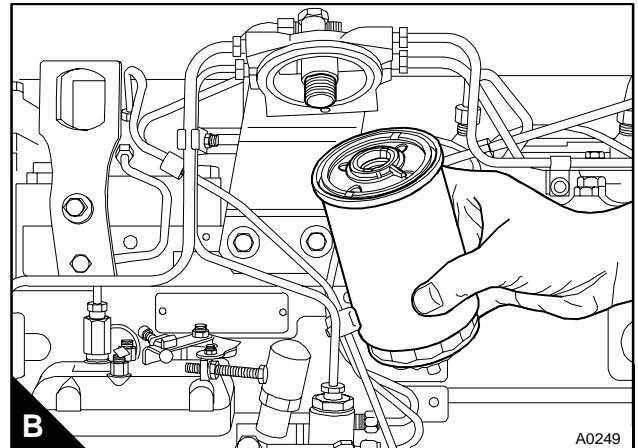
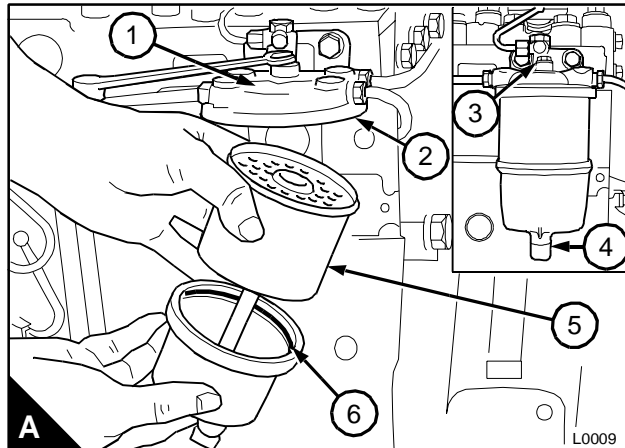
Fuel filter element types

Operation 11-1

A separate element type (A) is fitted, where the filter element is held between the filter head and the bottom cover, refer to Operation 11-2.

The canister type (B) where the filter element has an internal thread at the top and is fastened to a threaded adaptor in the filter head, refer to Operation 11-3.

Some of the latest engines have a clean side return system. Spill fuel from the fuel injection pump and atomisers is returned directly to the inlet side of the fuel injection pump instead of the fuel filter inlet.



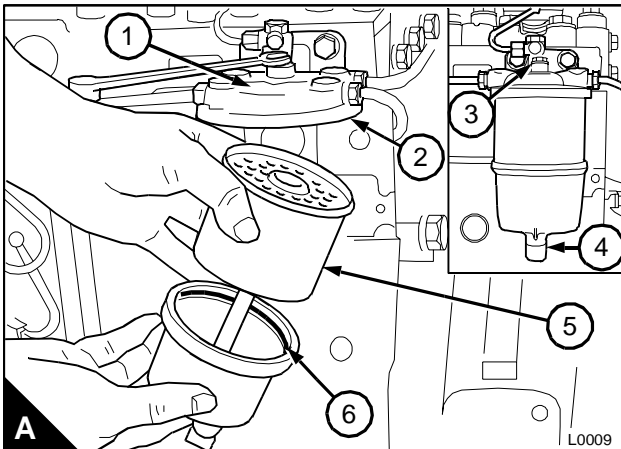
To renew the filter element of the separate element type

Operation 11-2

Cautions:

- *It is important that only the genuine Perkins fuel filter element is used. The use of a wrong element can damage the fuel injection pump.*
- *Do not allow dirt to enter the fuel system. Before a connection is disconnected, clean thoroughly the area around the connection. After a component has been disconnected, fit a suitable cover to all open connections.*

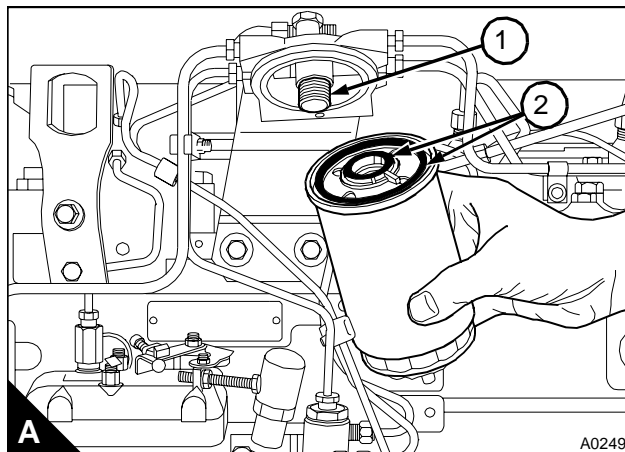
- 1 Clean the outside surfaces of the fuel filter assembly.
- 2 Loosen the drain device at the bottom of the filter (A4) and allow the water/fuel to drain into a suitable container.
- 3 Hold the bottom cover of the filter element and release the setscrew (A3) which is fitted through the filter head above the centre of the element.
- 4 Lower the bottom cover of the filter.
- 5 Remove the element (A5) and discard it.
- 6 Clean the inside surfaces of the filter head and of the cover.
- 7 Renew the joints (A2) and (A6) lightly lubricate them with clean fuel. The largest joint (A2) is fitted to the filter head and the smallest joint (A6) is fitted to the bottom cover.
- 8 Put the bottom cover under the new element and hold it squarely to the filter head. Ensure that the element is fitted in the centre against the joint in the filter head. With the assembly in this position, engage and tighten the setscrew.
- 9 Eliminate the air from the fuel filter, see Operation 11-13 for Lucas DPA fuel injection pumps and Operation 11-17 for Stanadyne fuel injection pumps.



To renew the filter element of the canister type

Operation 11-3

- 1 Thoroughly clean the outside surfaces of the fuel filter assembly.
- 2 Loosen the drain device at the bottom of the canister and allow the water/fuel to drain into a suitable container.
- 3 Use a strap wrench or similar tool to loosen the filter canister and remove the canister.
- 4 Ensure that the threaded adaptor (A1) is secure in the filter head and that the inside of the head is clean.
- 5 Lubricate lightly the seals (A2) on the top of the new canister with clean fuel. Fit the new canister to the filter head and tighten by hand only.
- 6 Eliminate the air from the fuel filter, see Operation 11-13 for Lucas DPA fuel injection pumps and Operation 11-17 for Stanadyne fuel injection pumps.



Atomisers

Atomiser fault

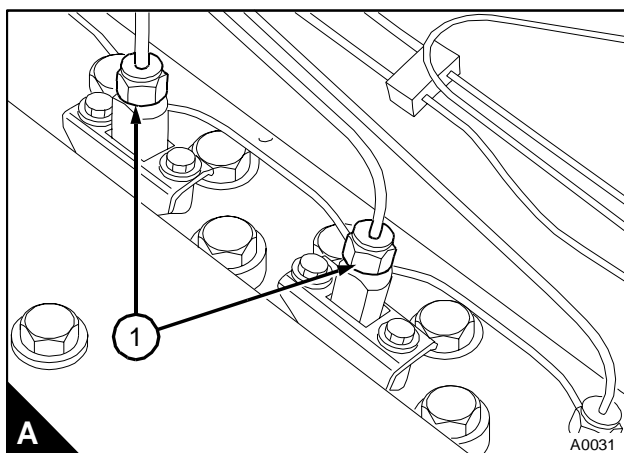
Operation 11-4

Warnings!

- *If your skin comes into contact with high-pressure fuel, obtain medical assistance immediately.*
- *Keep away from moving parts during engine operation. Some moving parts cannot be seen clearly while the engine runs.*

An atomiser fault can cause an engine misfire.

In order to find which atomiser is defective, operate the engine at a fast idle speed. Loosen and tighten the union nut (A1) of the high-pressure fuel pipe at each atomiser. Do not loosen the union nut more than half a turn. When the union nut of the defective atomiser is loosened, it has little or no effect on the engine speed.



To remove and to fit

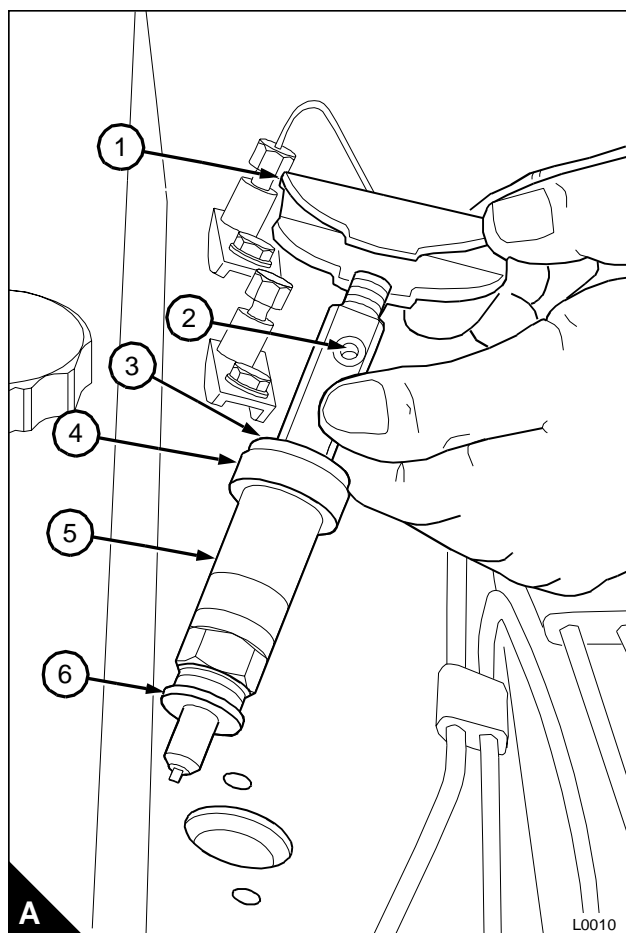
Operation 11-5

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

- 1 Remove the fuel leak-off pipe.
- 2 Remove the union nuts of the high-pressure pipe from the atomiser and from the fuel injection pump. Do not bend the pipe. If necessary, remove the pipe clamps.
- 3 Remove the atomiser setscrews and remove the clamp (A1), the atomiser (A5) and its seat washer (A6). Remove the dust seal (A4) and the spacer (A3) and fit the spacer and a new dust seal onto the new atomiser.
- 4 Put the new atomiser in position with its spacer, new dust seal and a new seat washer, ensure that the fuel leak-off connection (A2) is not toward the engine. Position the clamp and engage the atomiser setscrews. Ensure that the atomiser is not tilted and tighten the setscrews for the clamp evenly and gradually to 12 Nm (9 lbf ft) 1,2 kgf m.

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

- 5 Fit the high-pressure fuel pipe and tighten the union nuts to 22 Nm (16 lbf ft) 2,2 kgf m. If necessary, fit the pipe clamps.
- 6 Renew the sealing washers and fit the leak-off pipe. Tighten the banjo bolt to 9,5 Nm (7,0 lbf ft) 1,0 kgf m.
- 7 Operate the engine and check for leakage of fuel and air.



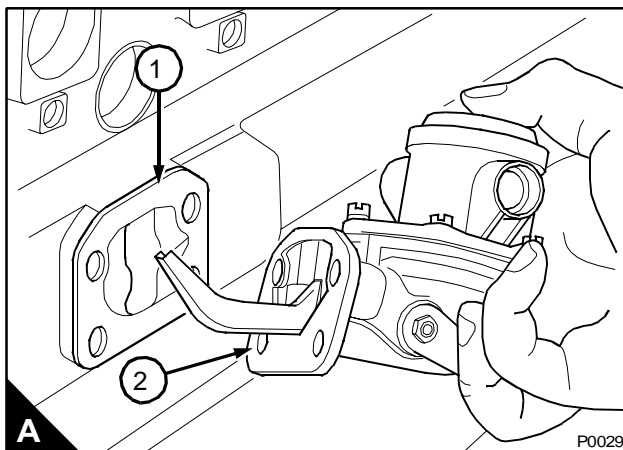
Fuel lift pump

To remove and to fit

Operation 11-6**Special requirements**

Consumable products	
Description	Part number
POWERPART Nutlock	21820242

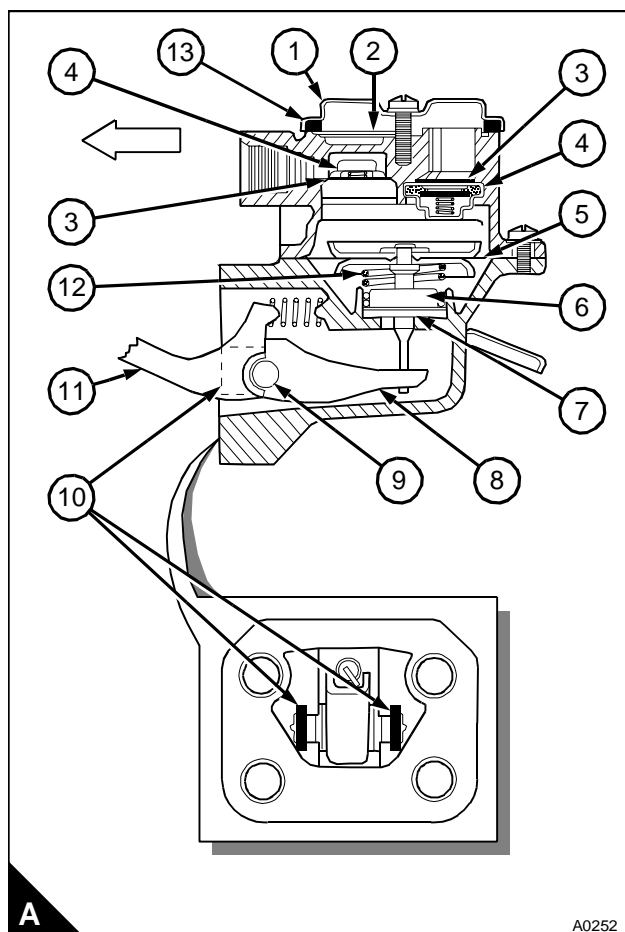
- 1 Disconnect the fuel pipes from the fuel lift pump.
- 2 Release the setscrews, remove the fuel lift pump (A). The lift pump may be difficult to remove from the engine. If this occurs the crankshaft must be rotated until the camshaft eccentric, that operates the lift pump, is in a position which will free the rocker lever of the lift pump.
- 3 Ensure that the camshaft eccentric is in the minimum lift position before the lift pump is fitted. Clean the joint face of the lift pump (A2) and the cylinder block and fit the lift pump together with a new joint (A1). Apply POWERPART Nutlock to the first three threads of the setscrews and tighten them gradually and evenly to 22 Nm (16 lbf ft) 2,2 kgf m.
- 4 Connect the fuel pipes and, if necessary, fit the heat shield.
- 5 Release the vent screw on the fuel filter head and operate the priming lever of the fuel lift pump to eliminate any air between the lift pump and the fuel filter. Operate the lift pump until fuel, free of air, comes from the vent screw. Tighten the vent screw.
- 6 Operate the engine and check for any fuel or air leakage.



To dismantle

Operation 11-7

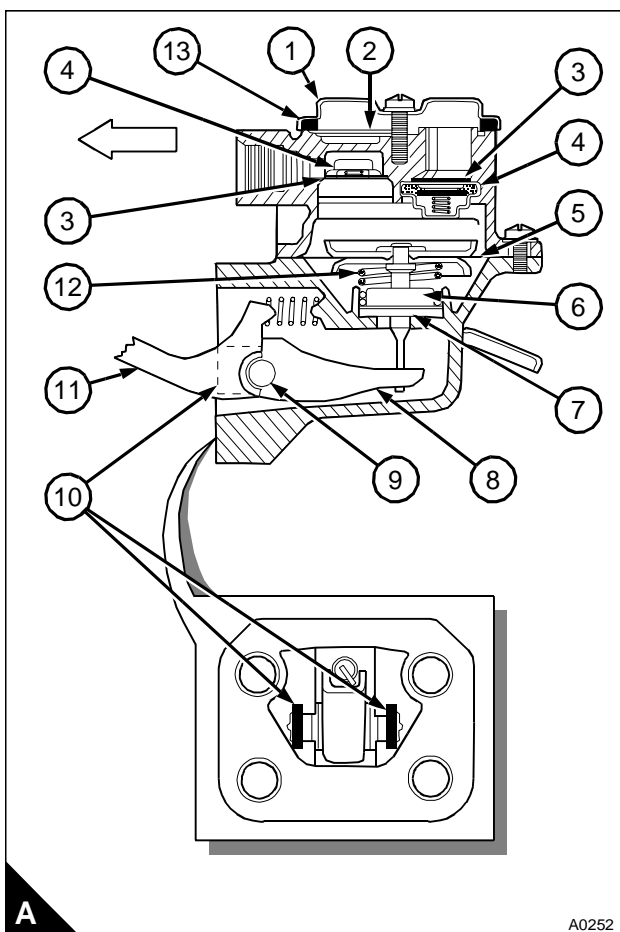
- 1 Clean the outside surfaces of the fuel lift pump.
- 2 Make a mark across the flanges of the two halves of the pump to ensure correct relationship when the pump is assembled.
- 3 Remove the cover (A1) and the gauze (A2). Release the setscrews and separate the two halves of the pump.
- 4 Turn the diaphragm assembly (A5) 90° to release the pull rod from the link arm (A8) and remove the diaphragm assembly. Remove the stem seal (A6), the spring seat washer (A7) and the spring (A12) from the pull rod. The diaphragm and pull rod assembly is renewed as an assembly and no service is possible on the diaphragm.
- 5 The valves (A4) are peened in and can be removed with a suitable lever. Some of the peened metal will have to be removed before the valves can be removed.
- 6 To remove the link arm: Hold the rocker lever (A11) in a vice and hit the body of the lift pump with a soft face hammer to release the two retainers (A10). Be careful not to damage the joint face of the pump body. Remove the rocker lever, the pin (A9), the link arm and the return spring. Check the components for wear and other damage.



To assemble

Operation 11-8

- 1 Thoroughly clean the valve housings. Fit new seat washers (A3) and push the new valves (A4) into position. As the valves are the same, but one valve is fitted in reverse of the other, it is possible to fit the valves upside down. To ensure that the valves are fitted correctly, fit them as shown in A. When the valves are correctly fitted, peen the edge of the valve housings in six places, evenly divided, to keep the valves in position.
- 2 Fit the rocker lever (A11), pin (A9) and link arm assembly (A8) into the bottom half of the lift pump. Fit the return spring; ensure that the ends of the spring are in their correct location.
- 3 With a light hammer and a suitable adaptor, fit two new retainers (A10) in their grooves in the casing until they fasten the pin. Peen the open ends of the grooves to fasten the retainers in position.
- 4 Fit the diaphragm spring (A12) into its location under the diaphragm (A5) and put the spring seat washer (A7) and a new stem seal (A6) into position on the pull rod. Ensure that the small diameter at the top of the seal is on the round section of the pull rod.
- 5 Put the diaphragm assembly in position over the lower half of the body with the blade of the pull rod aligned with the slot in the link arm. Press lightly down on the diaphragm until the notch in the pull rod is in the slot in the link arm and turn the diaphragm 90° in either direction. This action will engage and retain the pull rod in the slot of the link arm.
- 6 Push the rocker arm towards the pump body until the diaphragm is level with the body flange and fit the top half of the body in position with the marks on the flanges aligned. Keep the pressure on the rocker arm; fit the spring washers and the screws and tighten them evenly.
- 7 Fit the gauze filter (A2) and the cover (A1), ensure that the rubber seal (A13) is fitted correctly and tighten the screw.



To test

Operation 11-9

- 1** Disconnect the fuel outlet pipe from the fuel lift pump. Fit a 0-70 kPa (0-10 lbf/in²) 0-0,7 kgf/cm² pressure gauge to the outlet of the lift pump. Release the connection at the gauge and operate the priming lever of the lift pump to eliminate air from the pipe. When fuel, free of air, flows from the pipe tighten the connection. Ensure that there are no leaks at the connections between the pump and the gauge.
- 2** Operate the starter motor for 10 seconds with the engine stop control in the stop position or with the stop solenoid disconnected.
- 3** Note the maximum pressure indicated on the gauge. If the pressure indicated is less than the test pressure shown in the relevant Data and dimensions for the "Fuel lift pump" on page 25, repair or renew the pump. Also check the rate at which the pressure reduces to half the maximum pressure obtained. If this is less than 30 seconds, repair or renew the pump.
- 4** Remove the gauge and connect the outlet pipe to the lift pump. Release the vent screw on the fuel filter head and operate the priming lever until fuel, free of air, flows from the vent screw. Tighten the vent screw.
- 5** Connect the engine stop solenoid.

Lucas DPA fuel injection pump

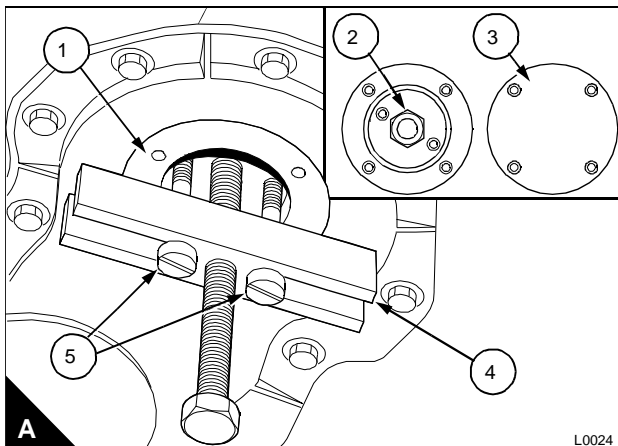
To remove

Operation 11-10

Special requirements

Special tools			
Description	Part number	Description	Part number
Gear puller	PD.155C	Spanner for flange nuts of fuel injection pump	PD.199
Adaptors for use with PD.155C	PD.155B-5		

- 1 Remove all the pipes, disconnect the stop control and the control rod of the fuel injection pump.
- 2 Remove the gear cover (A3) from the cover of the timing case (A1). Remove the gear nut (A2) and the spring washer.
- 3 Rotate the crankshaft to ensure that the keyway in the drive gear of the fuel pump is at or is near to the top.
- 4 Remove the setscrew and the nut of the support bracket below the fuel pump. Release the flange nuts of the fuel pump. If access to the flange nuts of the fuel pump is restricted by, for example, a compressor, use tool PD.199 to release the flange nuts.
- 5 Loosen the drive gear of the fuel injection pump with the puller PD.155C (A4) and the adaptors PD.155B-5 (A5).
- 6 Remove the fuel pump; ensure that the key does not fall from the drive shaft.



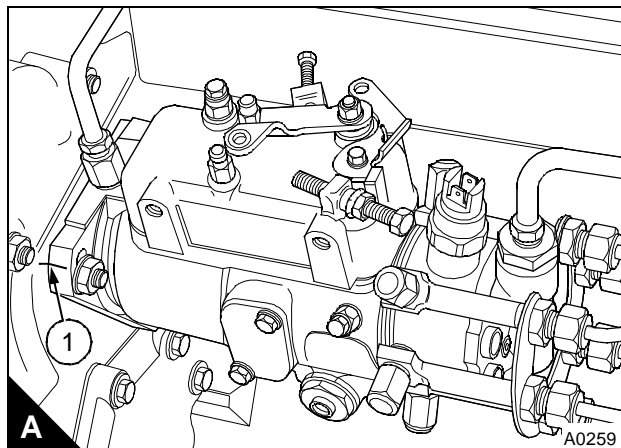
To fit

Operation 11-11

Special requirements

Special tools	
Description	Part number
Spanner for flange nuts of fuel injection pump	PD.199

- 1 Rotate the drive shaft of the fuel injection pump to align the key with the keyway in the drive gear. Ensure that the key is correctly fitted and fit the fuel pump to the gear.
- 2 Align the mark on the flange of the fuel pump with the mark on the rear face of the timing case (A1). Fit the flange nuts of the fuel pump and the setscrew and the nut of the support bracket. Ensure that force is not applied to the fuel pump when the support bracket is fitted.
- 3 Fit the spring washer and the nut to the drive shaft of the fuel pump and tighten the nut to 80 Nm (59 lbf ft) 8,2 kgf m. Fit the gear cover to the cover of the timing case together with a new joint.
- 4 Fit all the pipes. Connect the stop control and the control rod of the fuel pump.
- 5 Eliminate air from the fuel system, see Operation 11-13.
- 6 Operate the engine and check for leakage. With the engine at the normal temperature of operation, check that the idle speed is correct, see Operation 11-12.
- 7 If a new fuel pump has been fitted, check the maximum no load speed, see Operation 11-12.



To adjust

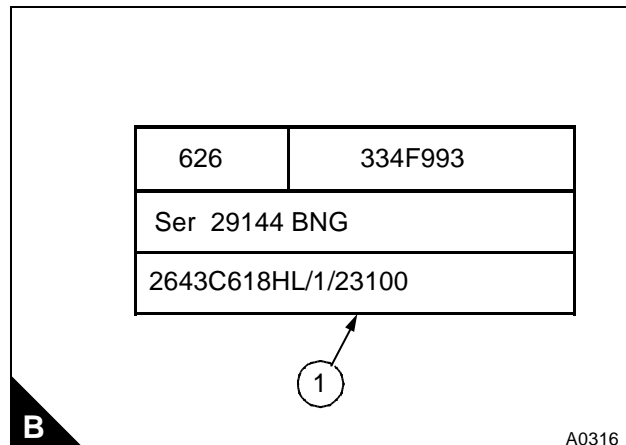
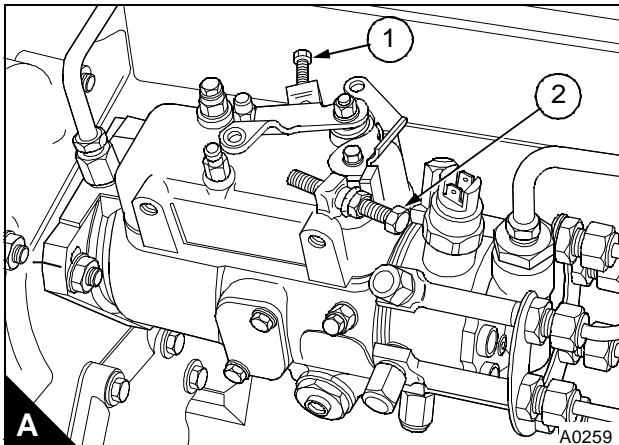
Operation 11-12

1 Operate the engine until it reaches its normal temperature of operation and check the idle speed. If necessary, adjustment can be made by the inner adjustment screw (A1). Release the lock nut and rotate the adjustment screw clockwise to increase the speed or counter-clockwise to decrease the speed. When the speed is correct, tighten the lock nut. The setting of the idle speed can change for different applications. The correct speed will normally be given in the manufacturer's handbook for the application. If it is not given, apply to your nearest Perkins distributor or to Technical Services Department, Perkins International Ltd, Peterborough, England.

Caution: The setting for the maximum no load speed can change for different applications. Always check the fuel injection pump data plate (B) fitted to a specific engine, before any adjustment to the maximum no load speed.

2 With the engine at its normal temperature of operation, check the maximum no load speed. The maximum no load speed is indicated by the last part of the setting code for the fuel injection pump. The setting code can be found on the data plate (B1) on the side of the fuel pump. A typical setting code is 2643C618HL/1/2310. In this example, the maximum no load speed is 2310 rev/min. If necessary, this speed can be adjusted by the outer adjustment screw (A2). Release the lock nut and rotate the adjustment screw counter-clockwise to increase, or clockwise to decrease, the speed. When the speed is correct, tighten the lock nut and seal the screw. The person who fits the pump must ensure that the adjustment screw is suitably sealed against interference after it has been set initially.

The adjustment screw on original fuel pumps is set and sealed by the manufacturer. The setting must not be changed as this could affect the engine warranty.



To eliminate air from the fuel system

Operation 11-13

If air enters the fuel system, it must be removed before the engine can be started.

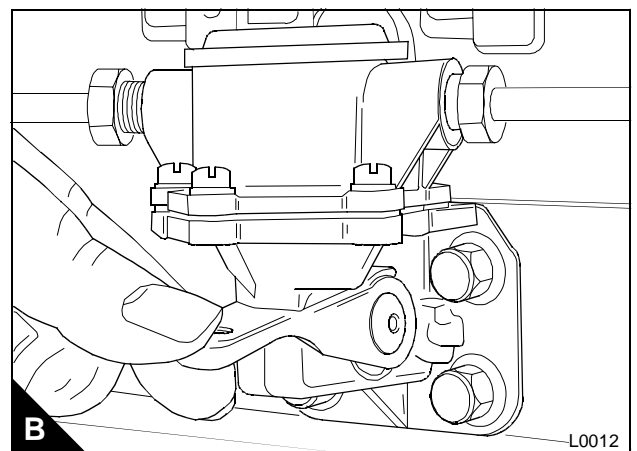
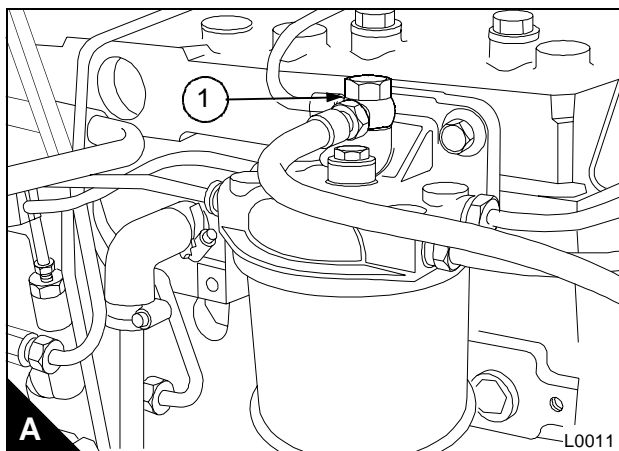
Air can enter the system if:

- The fuel tank is drained during normal operation.
- The low-pressure fuel pipes are disconnected.
- A part of the low-pressure fuel system leaks during engine operation.

In order to eliminate air from the fuel system, proceed as follows:

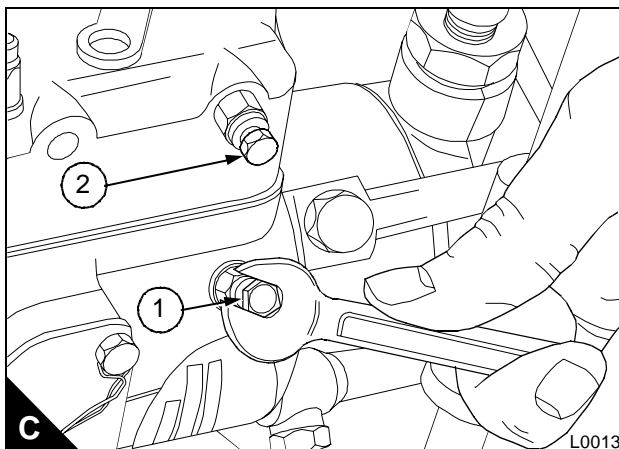
- 1 Loosen the banjo bolt connection (A1) on the top of the filter head.
- 2 Operate the priming lever on the fuel lift pump (B) until fuel, free from air, comes from the filter vent point. Tighten the banjo bolt connection.

Note: If the drive cam of the fuel lift pump is at the point of maximum cam lift, it will not be possible to operate the priming lever. In this situation, the crankshaft must be turned one revolution.



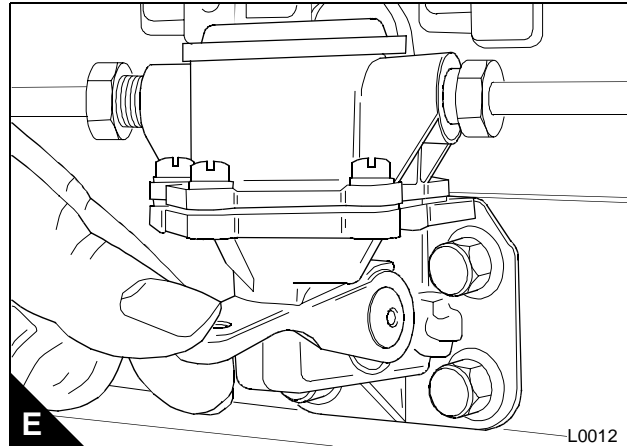
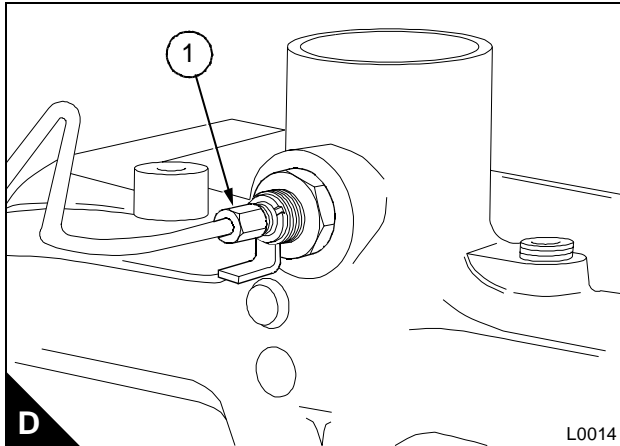
- 3 Ensure that the manual stop control is in the "run" position. If an electrical stop control is used, turn the start key to the "R" position.

- 4 Loosen the vent screw in the lock screw (C1) for the hydraulic head. Operate the priming lever of the fuel lift pump until fuel, free from air, comes from the vent screw. Tighten the vent screw. Loosen the vent screw (C2) on the governor cover. Operate the priming lever of the fuel lift pump until fuel, free from air, comes from the vent screw. Tighten the vent screw.



Continued

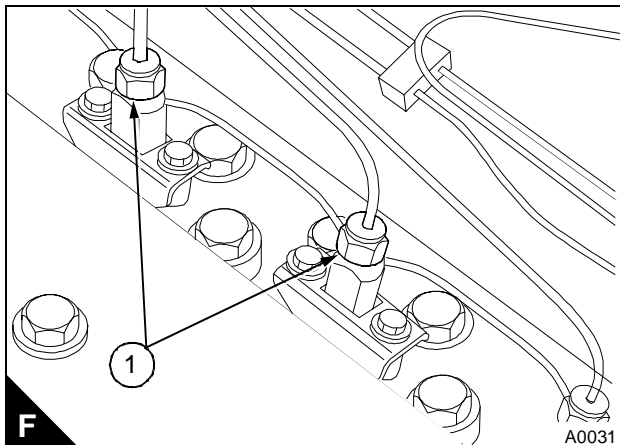
5 If the pipe to the fuelled starting aid has been drained, loosen the union nut (D1) at the fuelled starting aid and operate the lift pump (E) until fuel, free from air, comes from the connection. Tighten the union nut at the starting aid. Use a spanner on the hexagon of the fuelled starting aid to prevent its movement when the union nut is loosened and tightened.



6 Loosen the union nuts (F1) of the high-pressure pipes a half turn at two of the atomisers. Operate the starter motor until fuel free from air, comes from the pipe connections. Tighten the high pressure pipe connections to 22 Nm (16 lbf ft) 2,2 kgf m.

7 The engine is now ready to start.

If the engine runs correctly for a short time and then stops or runs roughly, check for air in the fuel system. If there is air in the fuel system, there may be a leak in the low pressure system.



Stanadyne fuel injection pump

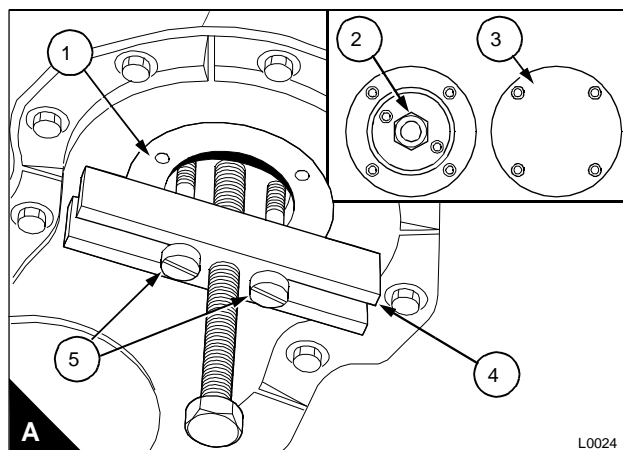
To remove

Operation 11-14

Special requirements

Special tools			
Description	Part number	Description	Part number
Gear puller	PD.155C	Adaptors for use with PD.155C	PD.155B-5

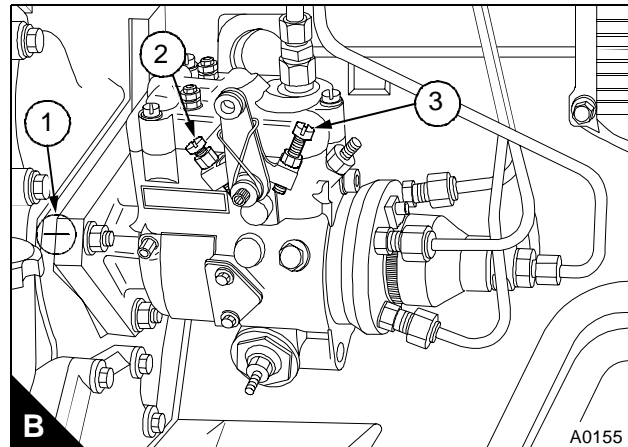
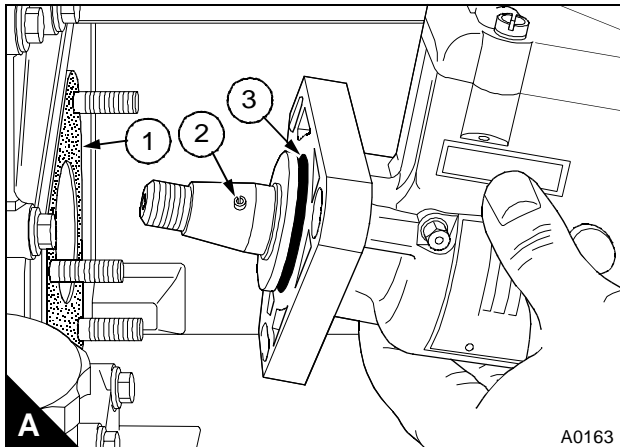
- 1 Remove the fuel pipes, disconnect the electrical stop control and the control rod of the fuel injection pump.
- 2 Remove the gear cover (A3) from the cover of the timing case (A1). Remove the gear nut (A2) and the spring washer.
- 3 Release the flange nuts of the fuel pump. If access to the flange nuts of the fuel pump is restricted by, for example, a compressor, use tool PD.199 to release the flange nuts.
- 4 Loosen the drive gear of the fuel injection pump with the puller PD.155C (A4) and the adaptors PD.155B-5 (A5).
- 5 Remove the fuel injection pump.



To fit

Operation 11-15

- 1 Fit a new joint (A1) to the timing case. Fit a new "O" ring (A3) to the fuel pump.
- 2 Rotate the drive shaft of the fuel pump to align the pin (A2) or key with the keyway in the drive gear. Ensure that the pin or key is correctly fitted and fit the fuel pump to the gear. Fit the spring washer and the nut to retain the drive gear and tighten the nut lightly.
- 3 Align the mark on the flange of the fuel pump with the mark on the rear face of the timing case (B1). Fit the flange nuts of the fuel pump. Tighten them to 22 Nm (16 lbf ft) 2,2 kgf m.
- 4 Fully tighten the nut for the drive gear to 80 Nm (59 lbf ft) 8,2 kgf m. Fit a new joint for the gear cover and fit the gear cover.
- 5 Fit the fuel pipes. Connect the electrical stop control and the control rod of the fuel pump.
- 6 Eliminate air from the fuel system, see Operation 11-17.
- 7 Operate the engine and check for leakage. With the engine at the normal temperature of operation, check that the idle speed is correct, see Operation 11-16.
- 8 If a new fuel pump has been fitted, check the maximum no load speed, see Operation 11-16.



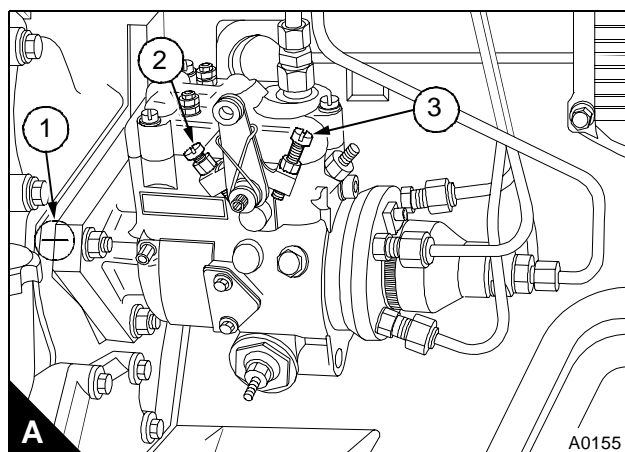
To adjust

Operation 11-16

1 Operate the engine until it reaches its normal temperature of operation and check the idle speed. If necessary, adjustment can be made by the adjustment screw (A2). Release the lock nut and rotate the adjustment screw clockwise to increase the speed or counter-clockwise to decrease the speed. When the speed is correct, tighten the lock nut. The correct speed will normally be given in the manufacturer's handbook for the application. If it is not given, apply to your nearest Perkins distributor or to Technical Services Department, Perkins International Ltd, Peterborough, England.

Caution: The setting for the maximum no load speed can change for different applications. Always check the fuel injection pump data plate (B) fitted to a specific engine, before any adjustment to the maximum no load speed.

2 With the engine at its normal temperature of operation, check the maximum no load speed on the fuel pump data plate. An example is given at (B1); if necessary, this speed can be adjusted by the adjustment screw (A3). Release the lock nut and rotate the adjustment screw counter-clockwise to increase the speed, or clockwise to decrease, the speed. When the speed is correct, tighten the lock nut and seal the screw. The person who fits the pump must ensure that the adjustment screw is suitably sealed against interference after it has been set initially. The adjustment screw on original fuel pumps is set and sealed by the manufacturer. The setting must not be changed as this could affect the engine warranty.



H3 DB2435 4759		2820
Model No RPM		
7585429	2643U001 AL	
Ser N° Mfg N°		

1

B

A0153

To eliminate air from the fuel system

Operation 11-17

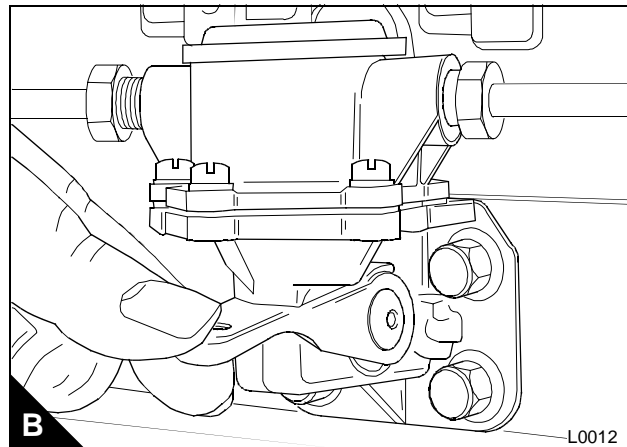
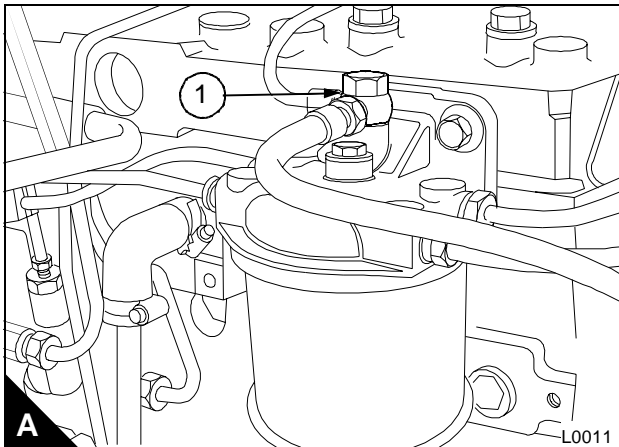
If air enters the fuel system, it must be removed before the engine can be started.

Air can enter the system if:

- The fuel tank is drained during normal operation.
- The low-pressure fuel pipes are disconnected.
- A part of the low-pressure fuel system leaks during engine operation.

In order to eliminate air from the fuel system, proceed as follows:

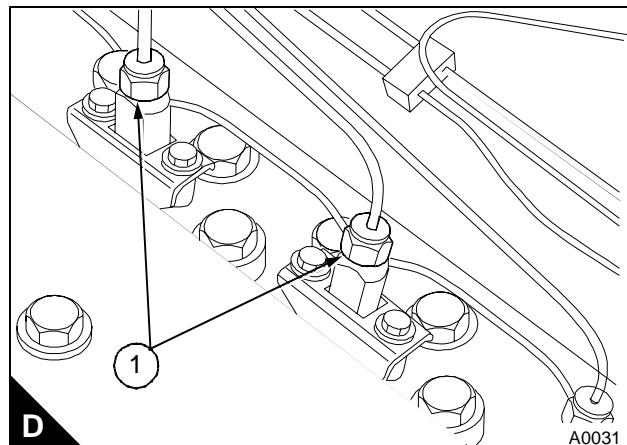
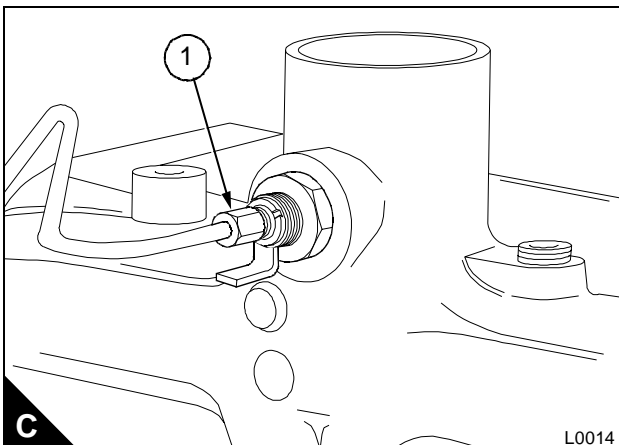
- 1 Loosen the vent plug (A1) on the top of the filter head.
- 2 Operate the priming lever on the fuel lift pump (B) until fuel, free from air, comes from the filter vent point. Tighten the vent plug.



Note: If the drive cam of the fuel lift pump is at the point of maximum cam lift, it will not be possible to operate the priming lever. In this situation, the crankshaft must be rotated one revolution.

- 3 If the pipe to the fuelled starting aid has been drained, loosen the union nut (C1) at the fuelled starting aid and operate the lift pump until fuel, free from air, comes from the connection. Tighten the union nut at the starting aid. Use a spanner on the flats of the fuelled starting aid to prevent its movement when the union nut is loosened and tightened.

- 4 Loosen the union nuts (D1) of the high-pressure pipes a half a turn at two of the atomisers.



Continued

5 Put the electrical system switch to the "ON" position. Operate the starter motor until fuel, free from air, comes from the pipe connections. Tighten the high-pressure pipe connections to 22 Nm (16 lbf ft) 2,2 kgf m. Return the switch to the "OFF" position.

6 The engine is now ready to start.

If the engine runs correctly for a short time and then stops or runs roughly, check for air in the fuel system. If there is air in the fuel system, there is probably a leak in the low pressure system.

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12

Cooling system

General description

Coolant from the bottom of the radiator passes through the centrifugal coolant pump, which is fitted onto the front of the timing case to assist the flow of the coolant through the system.

The pump is driven by a "V" belt from the crankshaft pulley.

From the pump, the coolant passes through a passage in the timing case to a passage in the left side of the cylinder block and to the rear of the cylinder block.

Some coolant passes to a plate type oil cooler fitted to the oil filter head.

The coolant then passes around the cylinders and up into the cylinder head. The coolant leaves the cylinder head at the front and passes into the thermostat housing.

If the thermostat is closed, the coolant goes directly through a by-pass to the inlet side of the coolant pump. If the thermostat is open, the thermostat closes the by-pass and the coolant passes to the top of the radiator.

Thermostats

To remove and to fit

Operation 12-1

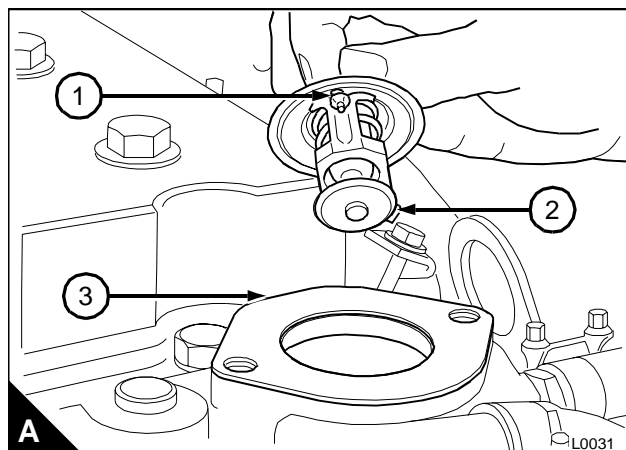
Note: Identification of the thermostat is by the nominal temperature which is stamped on the by-pass valve (A2) of the thermostat.

To remove

- 1 Drain the coolant level in the cooling system to below the thermostat position and disconnect the top hose from the coolant outlet connection.
- 2 Release the setscrews and remove the coolant outlet connection.
- 3 Remove the thermostat (A).

To fit

- 1 Ensure that the joint faces of the housing and the outlet are clean and that the jiggle pin (A1) in the thermostat is free to move.
- 2 Put the new thermostat in position in the housing.
- 3 Fit a new joint (A3) and the coolant outlet connection. Tighten the setscrews.
- 4 Connect the top hose and fill the cooling system.



To test

Operation 12-2

- 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. The correct temperatures are given in the relevant Data and dimensions for the "Thermostat" on page 26.

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

Coolant pump

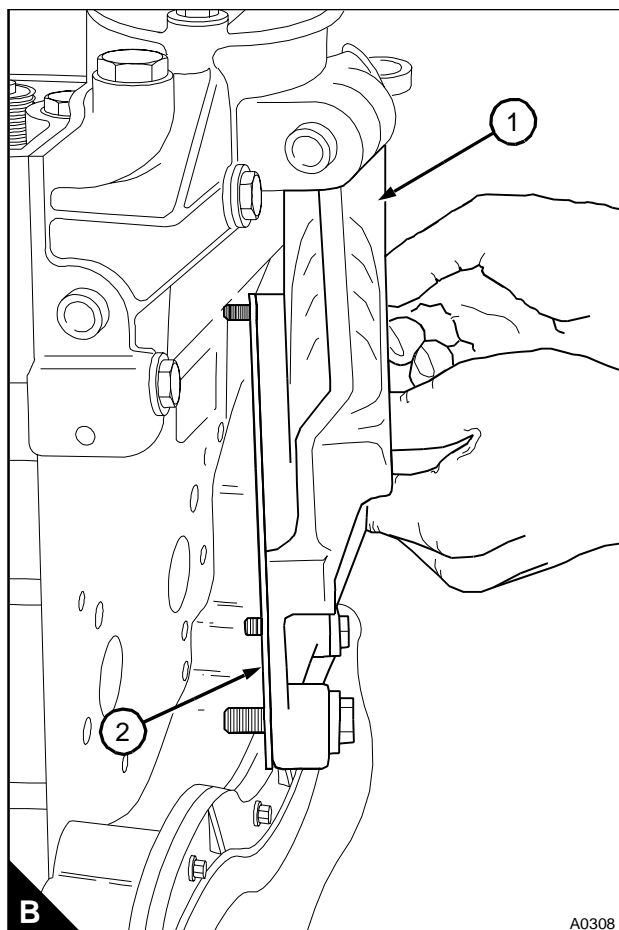
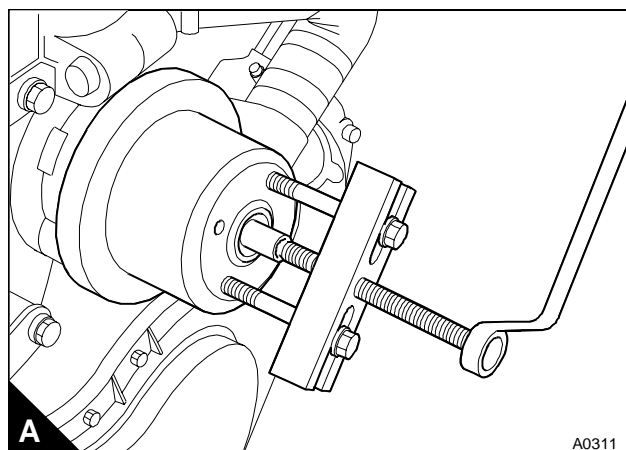
To remove

Operation 12-3

Special requirements

Special tools	
Description	Part number
Gear puller	PD.155C

- 1 Remove the fan, see Operation 12-7.
- 2 Remove the fan belt, see Operation 14-2.
- 3 Drain the cooling system and disconnect the hose connections to the coolant pump.
- 4 Remove the nut, spring washer and plain washer from the pump pulley. It may be necessary to use extractor PD. 155C to remove the pulley from the pump shaft (A).
- 5 If the pump is to be dismantled remove the key from the keyway of the pump shaft.
- 6 Remove the four setscrews which secure the coolant pump to the rear body of the pump (B) and remove the pump from the engine.
- 7 Remove the coolant pump and discard the joint.
- 8 If it is necessary to remove the rear body (B1) of the pump from the cylinder block: Remove the setscrew for the alternator adjustment linkage and the spacer. Remove the four other setscrews and remove the rear body from the cylinder block. Discard the joint (B2).



To fit

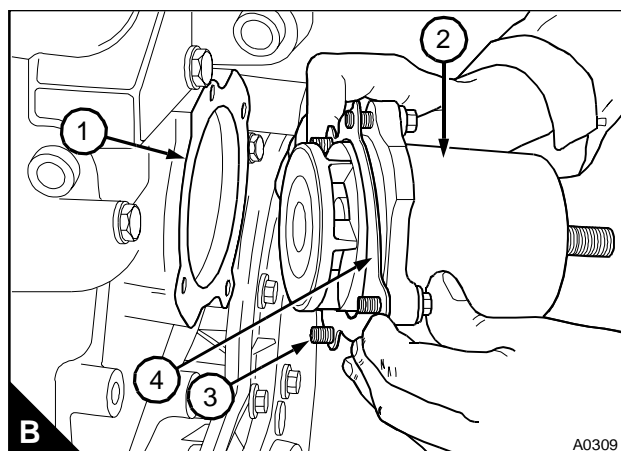
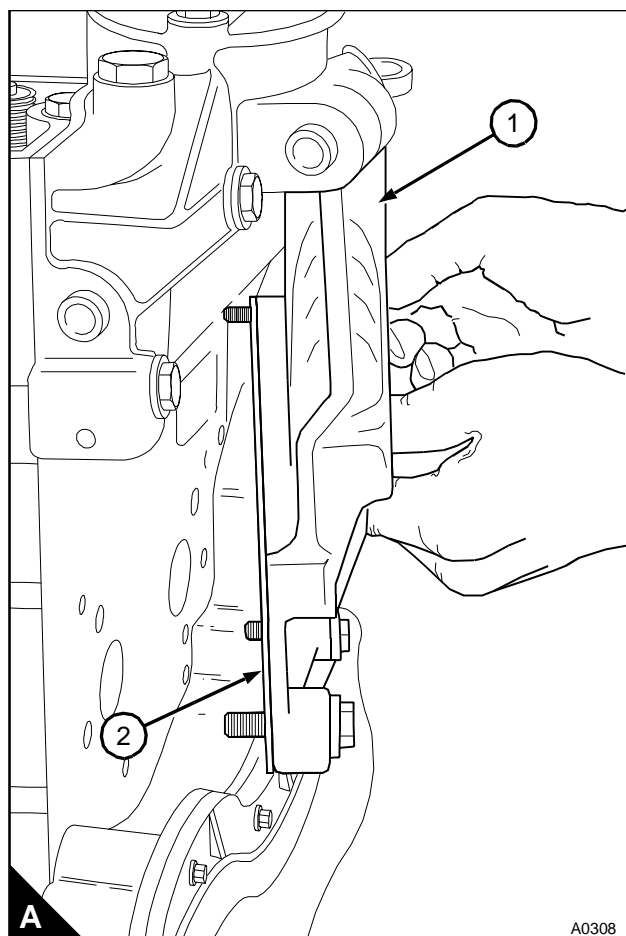
Operation 12-4

Special requirements

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

Note: The joints are fitted without jointing compound.

- 1 If the rear body of the pump (A1) was removed from the cylinder block: Thoroughly clean the joint faces of the cylinder block and pump rear body. Fit a new joint (A2) between the rear body of the pump and the cylinder block.
- 2 Fit the rear body of the pump and the joint to the cylinder block. Fit the spacer and adjustment linkage for the alternator and tighten the M10 setscrews to 44 Nm (33 lbf ft) 4,5 kgf m and the M12 setscrews to 75 Nm (55 lbf ft) 7,6 kgf m.
- 3 Thoroughly clean the joint faces of the pump rear body and coolant pump (B2). Fit a new joint (B4) to the coolant the pump.
- 4 Fit the coolant pump and joint to the rear pump body and tighten the four M10 setscrews (B3) to 44 Nm (33 lbf ft) 4,5 kgf m.
- 5 Fit the key to the keyway and put the pulley onto the pump shaft. Put the plain washer and the spring washer in position onto the pulley. Fit the nut and tighten it to 82 Nm (60 lbf ft) 8,2 kgf m.
- 6 Connect the hoses to the coolant pump, tighten the clips and fill the cooling system.
- 7 Fit the fan belt, see Operation 14-2.
- 8 Fit the fan, see Operation 12-7.



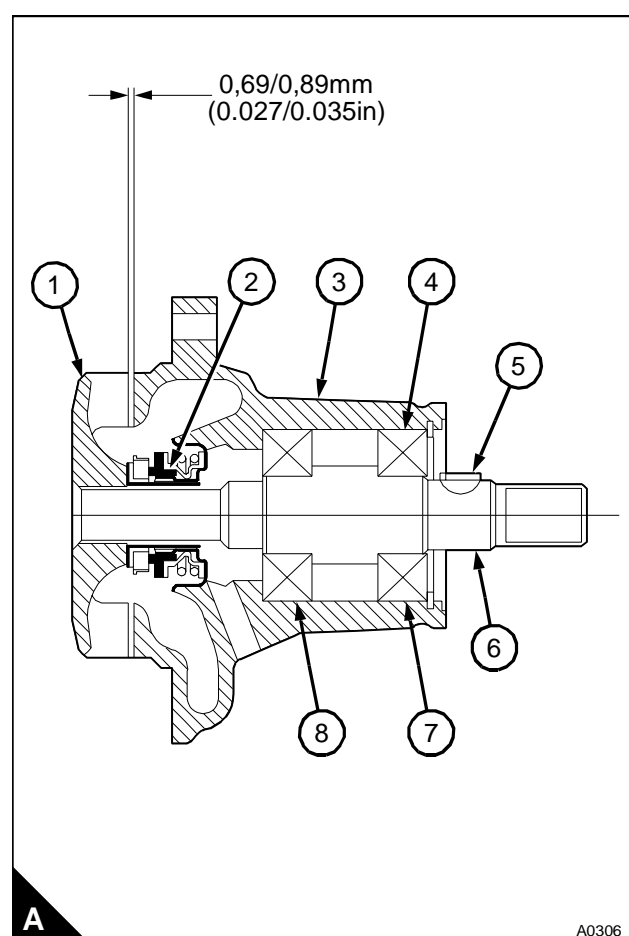
To dismantle

Operation 12-5

Special requirements

Special tools	
Description	Part number
Standard bench press	-

- 1 Remove the coolant pump (A) from the engine, see Operation 12-3.
- 2 Remove the circlip (A4) for the bearing housing.
- 3 Support the pulley end of the pump and press the shaft (A6) through the impeller (A1) and coolant seal (A2). This will remove the bearing (A7).
- 4 Remove the impeller. Discard the coolant seal.
- 5 Support the pulley end of the pump and press out the bearing (A8). Discard the bearings.
- 6 Clean the body of the pump in a suitable safe cleaning fluid. Inspect the pump body for cracks.



To assemble

Operation 12-6

Special requirements

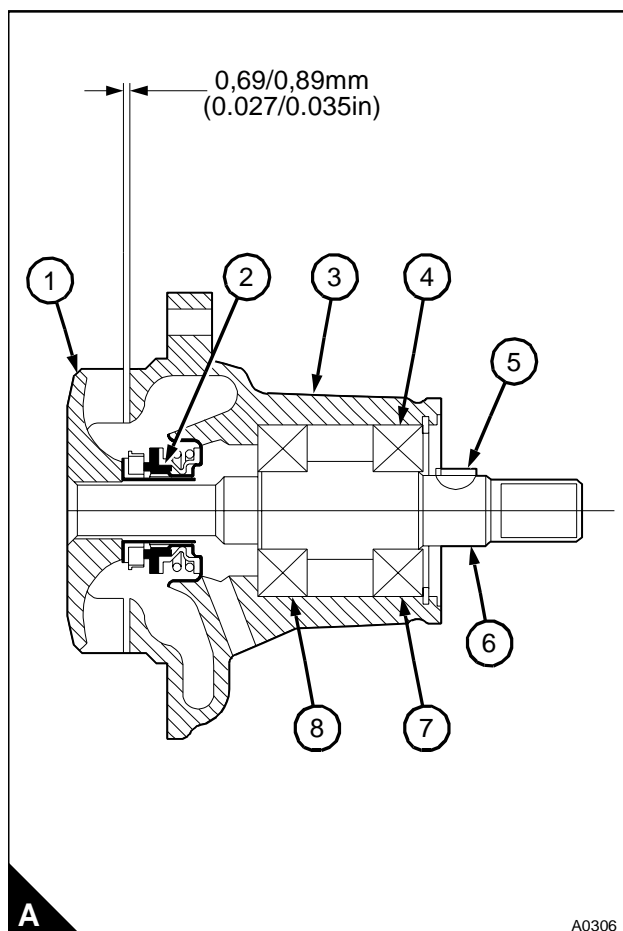
Special tools		Consumable products	
Description	Part number	Description	Part number
Standard bench press	-	POWERPART Retainer (oil tolerant)	21820603

The service kit for the pump contains two bearings, the shaft, a circlip and a coolant seal.

Each bearing is filled with grease and sealed by the bearing manufacturer. The bearings will not need attention during service.

1 Support the impeller end of the pump body. Apply a narrow ring of POWERPART Retainer (oil tolerant) to the face of the outer race of each bearing race. Put the bearing (A8) into position on the pump housing. Use a suitable adaptor on the outer race and press the bearing fully into the back of the bearing housing.

2 Support the inner race of the bearing just fitted from the impeller end of the pump body. Use a suitable adaptor which will allow the shaft (A6) to pass through it. Press the new shaft into the bearing until shoulder of the shaft is fully against the inner race of the bearing. Put the bearing (A7) into position on the pump housing and shaft. Use a suitable adaptor on the inner and outer race to ensure the pressure is applied evenly. Press the bearing onto the shaft and housing until the inner race of the bearing is against the shoulder of the shaft. Remove excess retainer and fit the new circlip (A4).



Continued

3 Fit a new coolant seal (A2) as follows:

Caution: It is important that only the tool, shown in (C), is used to fit the new coolant seal.

The coolant seal is an interference fit on the shaft and a tool will be necessary to fit the seal correctly.

The tool should be made of mild steel bar to the dimensions shown in (C), listed as follows:

- | | | | |
|----------------------------|----------------------------|-----------------------------------|-----------------------------------|
| A 44,0 mm (1.73 in) | C 11,3 mm (0.44 in) | E 16,1 mm (0.63 in) | G 2,00 mm (0.08 in) at 45° |
| B 40,0 mm (1.57 in) | D 37,3 mm (1.47 in) | F 1,00 mm (0.04 in) at 45° | |

The dimensions of the tool to fit the coolant seal, will ensure that the seal is the correct length after it is installed. It will also prevent axial distortion of the seal when it is pressed onto the shaft.

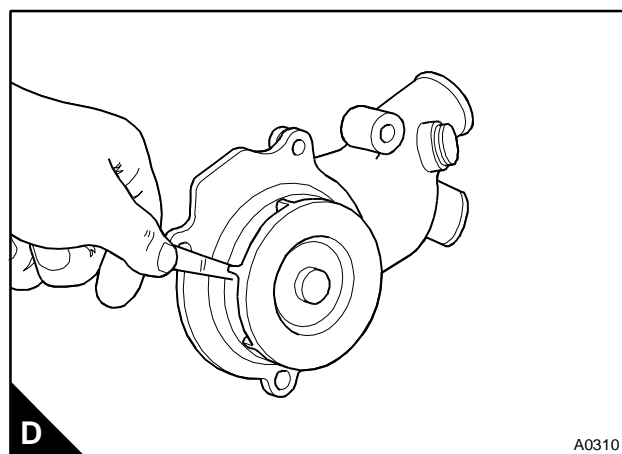
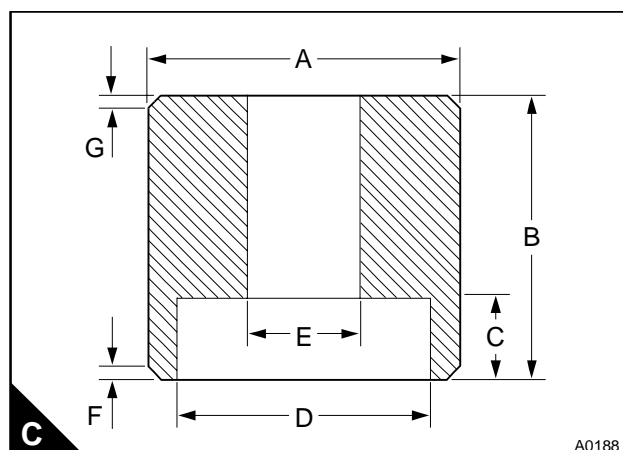
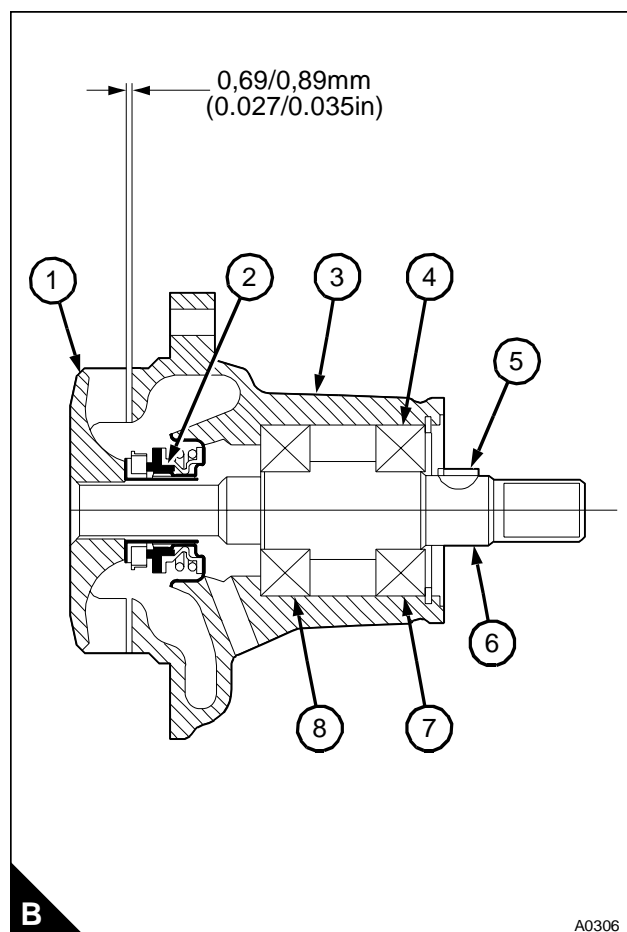
Do not lubricate the seal. It is important that the seal is not contaminated by oil or grease and if it is held in the hand, it should be held by the edge of the flange. Do not damage the ring of green sealant applied to the body of the coolant seal just behind the flange of the seal.

Support the pulley end of the shaft, ensure that there are no sharp edges on the edge of the shaft and put the seal into position on the end of the shaft. Ensure that the ring of sealant is towards the bearings. Use the tool to press the seal onto the shaft until the bottom of the seal flange is in complete contact with the pump body. Continue to apply force for approximately ten seconds to ensure that the seal remains in position when the force is released.

4 Support the pulley end of the shaft and press the new impeller (B1) onto the shaft until the clearance between the impeller blades and the pump body is 0,69/0,89 mm (0.027/0.035 in) (B). The clearance can be checked with a feeler gauge (D). The minimum clearance with end float is 0,19 mm (0.007 in).

Rotate the shaft to ensure that the impeller is free.

5 Fit the coolant pump to the engine, see Operation 12-4.



Fan

To remove and to fit

Operation 12-7

To remove

- 1 Release the setscrews and remove the fan.
- 2 If necessary, fit the setscrews to retain the fan extension and the pulley to the hub.

To fit

- 1 Clean thoroughly the rear of the fan where it fits onto the fan extension. Also ensure that all paint is removed from this area.
- 2 Put the pulley into position on the hub and the fan extension onto the pulley. Clean the front face of the fan extension.
- 3 Fit the fan and tighten the setscrews to the torque shown in "Recommended torque settings" on page 28.

Lubricating oil cooler

To remove and to fit (canister type)

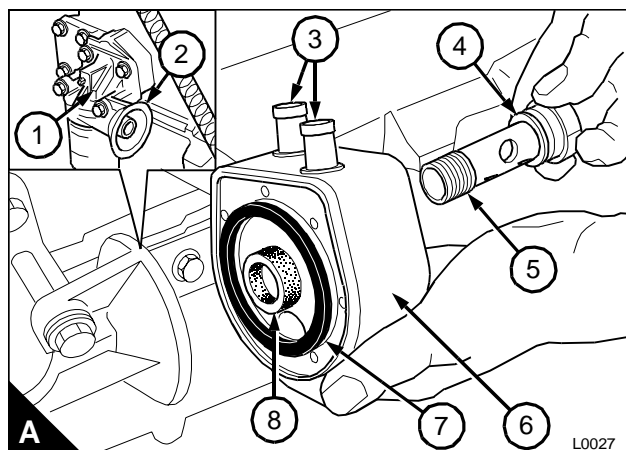
Operation 12-8

To remove

- 1 Drain the cooling system.
- 2 Release the hose clips of the coolant pipes at the oil cooler (A3). Release the threaded adaptor (A5) from the lubricating oil cooler and pull the oil cooler (A6) from the hose connections and the filter head (A1).

To fit

- 1 Clean the joint face of the filter head (A2).
- 2 Check the Washer (A4) and the seals (A7) and (A8) for damage and renew the washer and the seals if they are damaged or worn. Lightly lubricate the seals with clean lubricating oil.
- 3 Push the hose connections for the coolant pipes onto the lubricating oil cooler. Hold the oil cooler in position against the filter head and fit the threaded adaptor. Tighten the threaded adaptor to 37 Nm (27 lbf ft) 3,8 kgf m. Ensure that the hose connections are fitted correctly and tighten the hose clips.
- 4 Fill the cooling system.



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13

Flywheel and flywheel housing

General description

The steel flywheel is fitted with a hardened starter ring. Generally the starter rings have 126 teeth, but certain starter rings have 132 teeth.

The flywheel housing is normally made of cast iron, but certain flywheel housings are made of aluminium alloy.

Flywheel

To remove and to fit

Operation 13-1

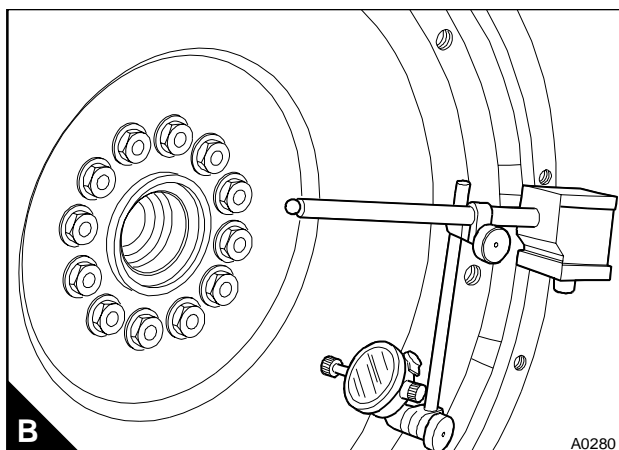
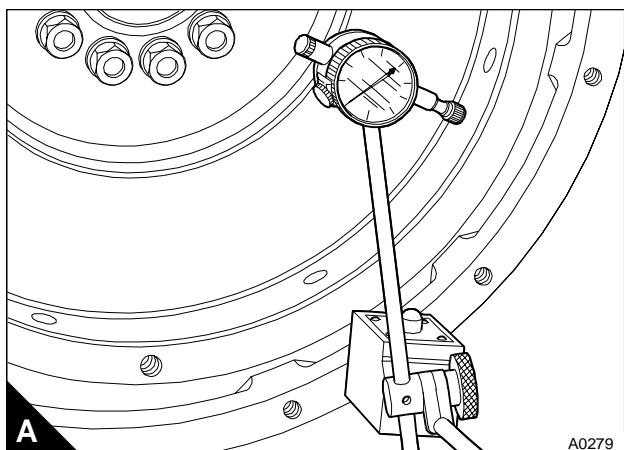
Warning! The flywheel is heavy, use lift equipment or get help to assist with the lift operation before removal of the flywheel fasteners.

To remove

- 1 Remove two opposite setscrews from the flywheel and fit temporarily two guide studs to ensure safety when the flywheel is removed and fitted.
- 2 Remove the remainder of the setscrews and washers and remove the flywheel.
- 3 Check the flywheel and ring gear for damage and renew, if necessary.

To fit

- 1 Ensure that the location faces of the crankshaft and the flywheel are clean and free from damage.
- 2 Fit the flywheel over the guide studs. Fit four setscrews and their washers. Remove the guide studs and fit the remainder of the setscrews and the washers. Tighten the setscrews to 105 Nm (77 lbf ft) 10,7 kgf m.
- 3 Check the flywheel run-out with a dial test indicator (A). This must be less than 0,30 mm (0.012 in) total indicator reading.
- 4 Check the alignment of the flywheel face (B). The error in alignment must not be more than 0,03 mm (0.001 in) total indicator reading for every 25 mm (1.0 in) of the flywheel radius from the crankshaft axis to the indicator plunger. During this check, keep the crankshaft pressed toward the front to remove the effect of crankshaft end-float.



Ring gear

To remove and to fit

Operation 13-2

To remove

Warning! wear eye protection during this operation.

Before the ring gear is removed, check the position of the chamfer on the teeth. To remove the ring gear use a hammer and a chisel to break the ring.

Caution: Ensure that the flywheel is not damaged during this operation.

To fit

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). Ensure that the chamfer on the teeth of the gear is in the correct direction.

Flywheel housing

To remove and to fit

Operation 13-3

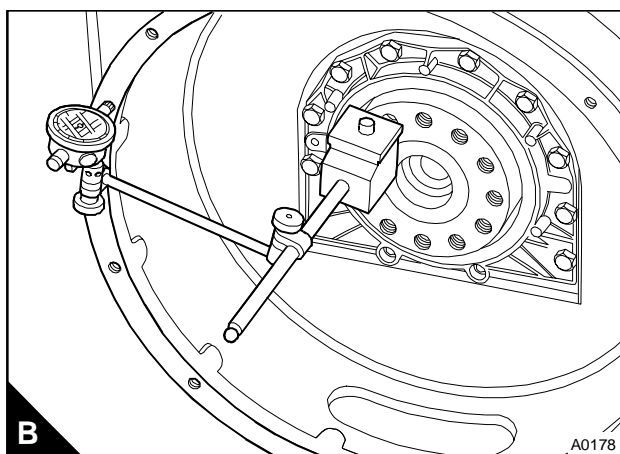
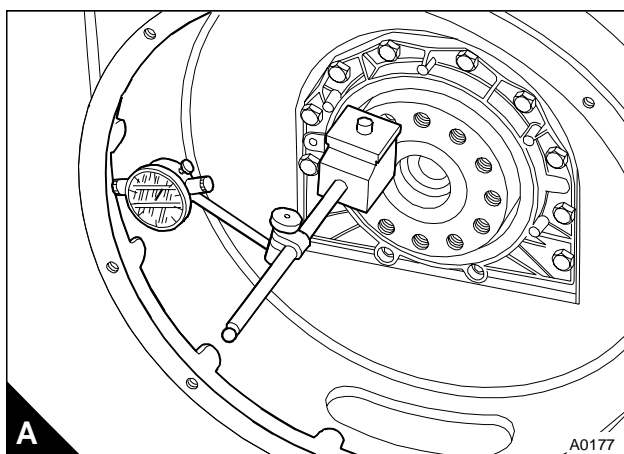
Warning! The flywheel housing is heavy, use lift equipment or get help to assist with the lift operation before removal of the flywheel housing fasteners.

To remove

- 1 Remove the starter motor, see Operation 14-5, and the flywheel, see Operation 13-1.
- 2 Release the housing setscrews and with a soft face hammer, hit carefully the housing to remove it from the dowels.

To fit

- 1 Ensure that the rear face of the cylinder block and the faces of the housing are clean and free from damage. Ensure that the location dowels are fitted correctly. If a felt seal is fitted to the rear flange of the sump, renew the seal.
- 2 Fit the housing onto the dowels and tighten lightly the setscrews.
- 3 Check the housing concentricity with a dial test indicator (A). The run-out limit is given in the relevant Data and dimensions for the "Flywheel and flywheel housing" on page 27. If any adjustment is necessary, it must be made on the housing and the concentricity checked again.
- 4 Tighten the setscrews to the torque recommended in "Recommended torque settings" on page 28.
- 5 Check the housing alignment (B). The maximum tolerance is given in the relevant Data and dimensions for the "Flywheel and flywheel housing" on page 27. Any necessary adjustment must be made on the housing and not on the cylinder block.
- 6 Fit the flywheel, see Operation 13-1 and the starter motor, see Operation 14-5.



14

Electrical equipment

Alternators

General description

The alternator is driven from the crankshaft pulley by a single belt.

Precautions

To prevent damage to the diodes and to the resistors, the precautions given below must be followed:

- 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 correct polarity and voltage.
- Do not check for current flow with a spark contact as damage can be caused to the transistors.

To check and to adjust drive belt tension

Operation 14-1

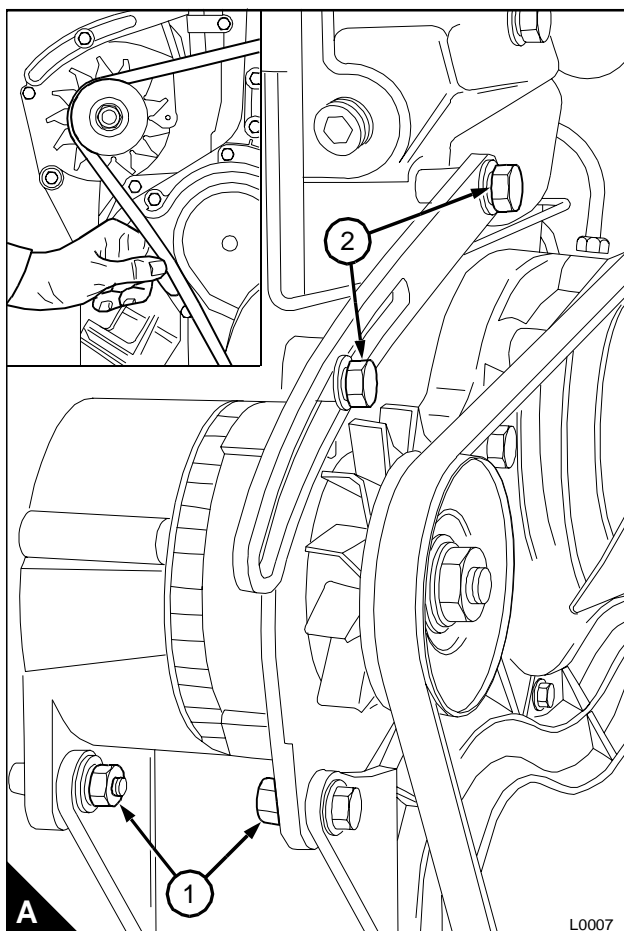
To check

- 1 Renew the belt if it is worn or damaged.
- 2 To check the belt tension: Press down the belt with the thumb at the centre of the longest free length and check the deflection (A). With moderate thumb pressure - 45 N (10 lbf) 4,5 kgf - the correct deflection of the belt is 10 mm ($\frac{3}{8}$ in).

To adjust tension

- 1 Loosen the pivot fasteners (A1) of the alternator and the adjustment link fasteners (A2).
- 2 Change the position of the alternator to give the correct tension. Tighten the pivot fasteners of the alternator and the adjustment link fasteners.
- 3 Check the belt tension again to ensure that it is still correct.

Note: If a new belt is fitted, the belt tension must be checked again after the first 20 hours of operation.

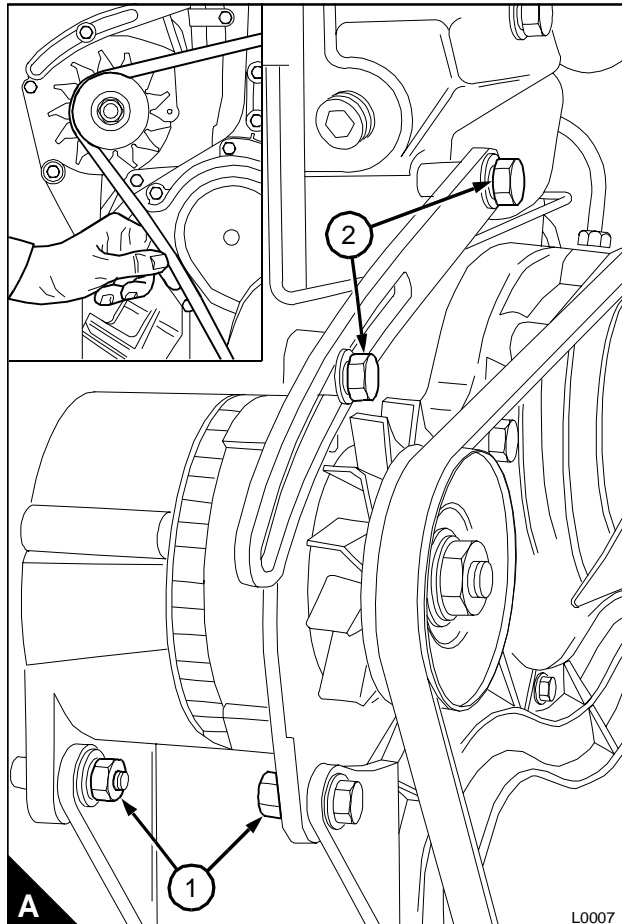


To remove and to fit the drive belt

Operation 14-2

- 1 Loosen the pivot fasteners (A1) of the alternator and the adjustment link fasteners (A2).
- 2 Release all of the tension from the belt and remove the belt.
- 3 Fit the new belt and adjust the tension, see Operation 14-1.

Note: The belt tension must be checked again after the first 1000 km (600 miles) or 20 hours of operation.



To remove and to fit the alternator

Operation 14-3

To remove

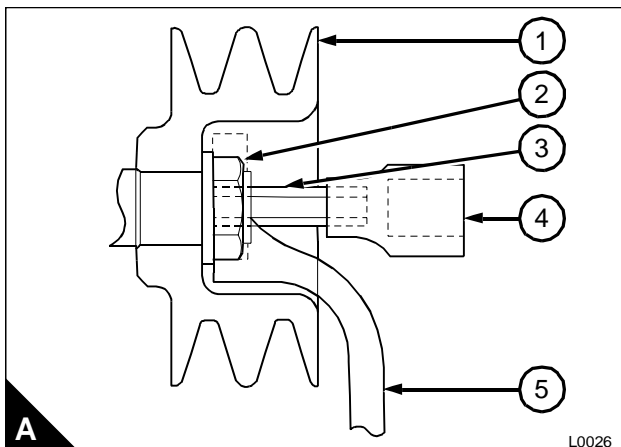
- 1 Disconnect the electrical connection.
- 2 Loosen the pivot fasteners of the alternator and the fasteners of the adjustment link.
- 3 Release all the belt tension and remove the belt.
- 4 Remove the adjustment link from the alternator and remove the pivot bolt. Make a note of the position of the washers and distance pieces to ensure that they are fitted correctly. Remove the alternator.

To fit

- 1 Put the alternator in position and assemble loosely the pivot fasteners and the adjustment link and its fasteners. Ensure that the washers and the distance pieces are fitted in their correct positions and that the alternator pulley (A1) is aligned to the crankshaft pulley within $\pm 2,4 \text{ mm}$ ($3/32 \text{ in}$).

Note: Before the nut for the shaft of the A127 alternator pulley can be tightened the shaft must be held in position by an 8 mm allen key (A3) and socket wrench (A4). Torque is then applied to the nut (A2) by a torque spanner (A5), see "Recommended torque settings" on page 28 for the correct torque.

- 2 Fit the drive belt(s), see Operation 14-2, and adjust the drive belt tension, see Operation 14-1. Tighten the fasteners and check the tension again.
- 3 Connect the electrical connection.



To maintain the alternator

Operation 14-4

- 1 Ensure that the drive belts are not worn and that the belt tension is correct.
- 2 Keep the alternator clean. To clean the alternator, use a material which is damp with kerosene or 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.

Alternator fault diagnosis

The alternator is designed in such a way that a flow of current (indicated by no light at the warning light or a reading shown on an ammeter) shows that the system is in correct operation. If the system is in correct operation, no open circuit, voltage or current output checks need to be done on the installation unless:

- The warning light does not show when the alternator is stationary and the switch is in the "on" position or it shows a light when the alternator is in operation.
- No charge current is shown on the ammeter.
- The battery is discharged.
- The battery is hotter than normal which is an indication of loss of voltage control.

If one or more of the above symptoms occur, the procedure indicated below should be applied.

- 1 Ensure that the battery is fully charged.
 - 2 Connect a moving-coil voltmeter of good quality, with a range of 0-50 volts, across the positive and negative terminals of the alternator. If an ammeter is not fitted in the electrical circuit, fit a moving-coil ammeter of good quality, with a range of 0-100 ampere, in the wire between the alternator and the positive terminal of the battery.
 - 3 Turn the warning light switch to the "on" position (main switch on instrument panel); the warning light should be illuminated.
 - 4 Switch on a 10-15 ampere load, for example, lights, fans, etc.
 - 5 Start the engine and operate it at a fast idle speed; either the warning light should be extinguished or the ammeter indicates a small change in the current in relationship to the engine speed.
 - 6 Increase the engine speed for a moment to near maximum speed, when the charge current should be approximately equal to the rating for the alternator, refer to the relevant Data and dimensions for the "Alternators" on page 27.
 - 7 Operate the alternator at approximately half speed (engine speed approximately 1500 rev/min) and remove the electrical load. The voltage should go up to 14 volts for a 12 volt system or 28 volts for a 24 volt system and then remain constant. At the same time the current reading should show a reduction.
- Any change in the above data can indicate a fault and the procedure that follows should be used before any components are disconnected. This procedure is not suitable for A127 alternators and, if a fault is found, the alternator should be removed for test by a specialist.

The regulator is a sealed unit and a repair is not possible. If there is a regulator fault, the regulator must be renewed.

If the warning light is not illuminated when the switch is in the "on" position:

Check the bulb. If no fault:

Check all the connections at the regulator, at the alternator and at the battery.

If no fault:

Turn the switch to the "off" position. Disconnect the wire from the "F" terminal on the alternator and connect a wire between the "F" terminal and the negative terminal on the alternator. Turn the switch to the "on" position.

If the warning light shows, the fault is in the regulator.

If the warning light does not show, the fault is in the alternator.

Continued

If the warning light continues to show and the ammeter shows no output when the alternator is in operation:

Check all the connections at the regulator, alternator and battery.

If no fault:

Turn the switch to the "off" position. Disconnect the wire from the "F" terminal on the alternator and connect a wire between the "F" terminal and the negative terminal on the alternator. Turn the switch to the "on" position and operate the engine at fast idle.

If there is no output, there is a fault in the alternator.

If there is an output, there is a fault in the regulator.

If the warning light continues to show when the alternator is in operation and the ammeter shows a reduced output with maximum output only at maximum engine speed or if the warning light does not show, but there is a reduced output from the alternator with maximum output only at maximum engine speed:

There is a fault in the alternator.

If there is an intermittent light from the warning light and the ammeter needle is not stationary when the battery is charged fully and no load is applied:

Check for a higher than normal resistance in the negative control wire of the regulator.

If the resistance is normal, there is a fault in the regulator.

If the battery charge is too high and the ammeter indicates high or maximum output at all times:

Check the positive control wire and its connection at the regulator.

If the wire and its connection are correct, there is a fault in the regulator.

Starter motors

General description

Magneti Marelli M127 and Bosch JF starter motors are fitted to these engines.

If a Delco Remy starter motor is fitted, a distance piece is fitted between the starter motor flange and the flywheel housing.

To remove and to fit

Operation 14-5

Special requirements

Consumable products	
Description	Part number
POWERPART Hylosil	1861108

To remove

If the engine has a flywheel housing which is oil filled, drain the flywheel housing before the starter motor is removed.

- 1 Disconnect the battery.
- 2 Disconnect the starter motor cables.
- 3 Release the fasteners and remove the starter motor and, if fitted, the distance piece.

To fit

- 1 If one is fitted, put the distance piece in position with its location lip to the flywheel housing. Fit the starter motor and tighten the fasteners.
- 2 Connect the starter motor cables. If the engine has a flywheel housing which is oil filled, the starter motor must be sealed before it is fitted. Clean the flange face of the starter motor and the face of the flywheel housing. Apply a 2,0 mm (0.080 in) continuous bead of POWERPART Hylosil to the flange face of the starter motor near to the spigot.
- 3 Connect the battery.

To test on the engine

Operation 14-6

Ensure that the battery is fully charged.

Turn on the lights and operate the starter switch. If no lights are fitted to the machine, connect a voltmeter across the battery terminals and operate the starter switch.

If the starter does not operate but the lights keep their power or there is no voltage drop across the battery, check the switch and all the connections and wires. Slow action of the starter can be caused by faulty connections.

Failure to engage smoothly between the starter and the flywheel can be caused, on some types of starter motor, by dirt on the helical grooves of the starter motor drive, which can prevent free pinion movement. Clean the shaft thoroughly with gasolene, or a fluid made especially for the purpose, and apply a small quantity of Aero Shell 6B or its equal.

Starting aid

General description

There are two types of electrical starting aid in use: The fuelled starting aid and the port heater.

The fuelled starting aid is a device which is operated electrically and ignites a controlled amount of diesel fuel in the induction manifold to heat the induction air. A heater coil in the body expands a valve holder to allow fuel to flow into the device. The fuel is ignited by the hot coil and the heated air enters the induction manifold when the starter motor is operated.

The port heater has an electrically heated coil that heats the air as it enters the induction manifold. Port heaters are used in a group of two or three.

To remove and to fit a fuelled starting aid

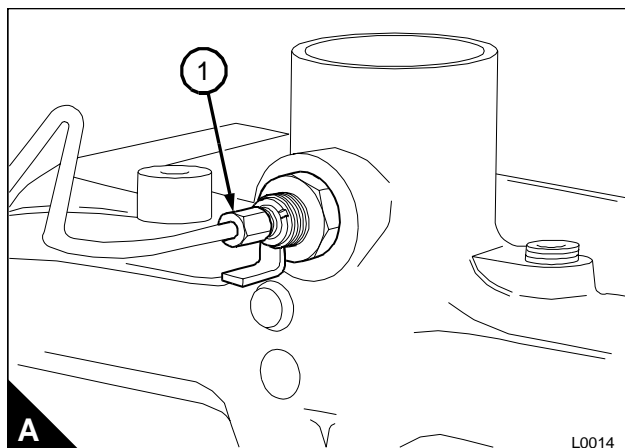
Operation 14-7

To remove

- 1 Disconnect the fuel pipe (A1) and the electrical connection (A2).
- 2 Remove the starting aid.

To fit

- 1 Ensure that the contact faces of the manifold and the starting aid are clean. Put the sealing washer into position and fit the starting aid. Tighten the starting aid to 31 Nm (23 lbf ft) 3,2 kgf m.
- 2 Check the fuel pipe and, if it is still full of fuel, connect it to the starting aid. If the fuel has drained from the pipe, eliminate the air from the pipe as shown in step of Operation 11-13.
- 3 Connect the electrical connection (A2).



To check the fuelled starting aid

Operation 14-8

If the inside of the induction manifold is wet, check that there is not a fuel leak from the fuelled starting aid.

- 1** Disconnect the fuel pipe and the electrical connection at the starting aid. Remove the starting aid from the manifold and fit a suitable plug in the manifold.
- 2** Connect the fuel pipe to the starting aid, but leave the connection loose. Do not fit the electrical connection, but ensure that the connector has a suitable insulator fitted. Operate the priming lever of the fuel lift pump until fuel free of air comes from the connection. Tighten the connection.
- 3** Start the engine and operate it at low speed.

Check that there is no fuel leakage from the valve of the starting aid.

- 4** If there is no leakage, remove the plug from the induction manifold and fit the starting aid. Connect the fuel pipe to the starting aid and remove the air from the pipe as shown above. Connect the electrical connection. If there is a leak from the valve of the starting aid, fit a new starting aid.

15

Auxiliary equipment

Power take-off adaptors (adaptor for a hydraulic pump)

To remove and to fit

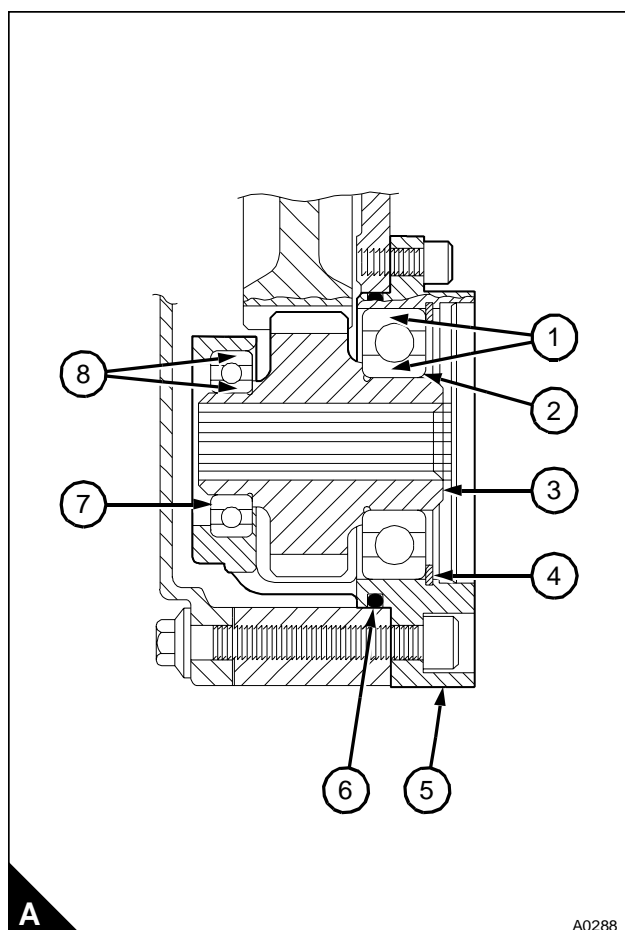
Operation 15-1

To remove

- 1 Release the cap screws and remove the adaptor assembly from the rear of the timing case.
- 2 Check the gear, the spline and the bearings for wear and other damage and renew the components as necessary.

To fit

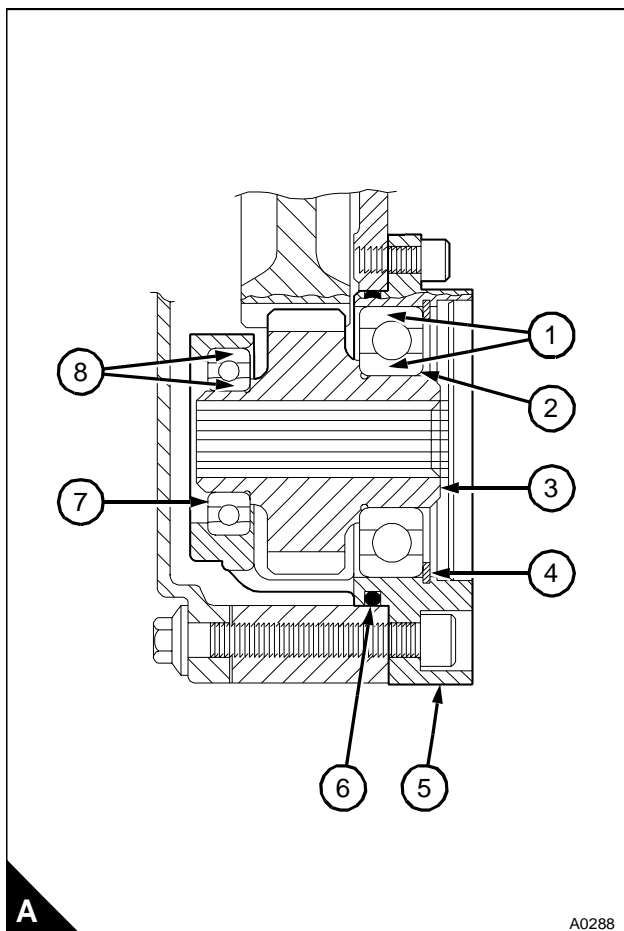
- 1 Fit a new "O" ring (A6) in its recess in the housing (A5) and lightly lubricate it with clean engine lubricating oil.
- 2 Lubricate the bearings (A2) and (A7) with clean engine lubricating oil. Fit the adaptor assembly to the timing case and tighten the cap screws.



To dismantle

Operation 15-2

- 1 Remove the hydraulic pump.
- 2 Remove the adaptor assembly, see Operation 15-1.
- 3 Remove the circlip (A4). Provide a support for the flange face of the housing (A5). Use a suitable adaptor on the front bearing (A7) to press the gear and bearings out of the housing.
- 4 Remove the bearings from the gear (A3) with a suitable gear puller.



Special requirements

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

1 Apply a narrow ring of POWERPART Retainer (oil tolerant) to the outer face of the front bearing (A7) in the position shown (A1). Provide a support for the front face of the housing. Use a suitable adaptor on the outer ball guide of the bearing to press the front bearing onto the shoulder in the housing. Remove excess retainer (oil tolerant).

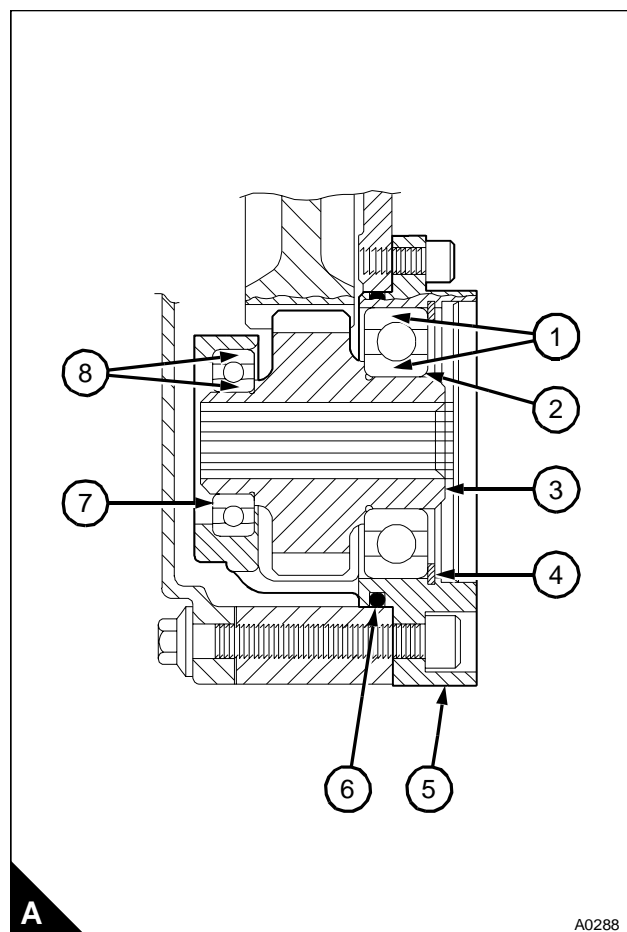
2 Apply a narrow ring of POWERPART Retainer (oil tolerant) to the inner face of the front bearing in the position shown (A1). Provide a support for the bearing. With the small diameter of the gear toward the bearing, press the gear into the bearing until the gear is onto its shoulder.

3 Apply a narrow ring of POWERPART Retainer (oil tolerant) to the outer face and to the inner face of the rear bearing (A2) in the positions shown (A1). Ensure that the support is under the front bearing. Use a suitable adaptor on the outer ball guide of the bearing to press the bearing into the housing and onto the shoulder on the gear. Remove excess retainer. Fit the circlip into its groove in the housing.

4 Check the backlash between the power take-off gear and the idler gear: Power take-off gears are identified by the part number stamped on the gear face.

The backlash for gears with part numbers 3117C111, 3117C112 or 3117C113, is 0,08 mm (0.003 in) minimum.

The backlash for gears with part numbers 3117C114, 3117C115 and 3117C116 is 0,18/0,25 mm (0.007/0.010 in) minimum.



Exhauster

To remove and to fit

Operation 15-4

To remove

- 1 Disconnect the lubricating oil and vacuum pipes from the exhauster and fit covers to the open ends of the pipes.
- 2 Release the setscrews and remove the exhauster.

To fit

- 1 Ensure that the joint faces of the exhauster and the timing case are clean and renew the joint. Fit the exhauster to the timing case and tighten the setscrews.
- 2 Remove the covers from the open ends of the pipes and connect the oil pipe and the vacuum pipe to the exhauster.

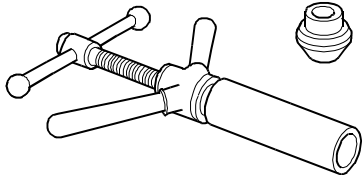
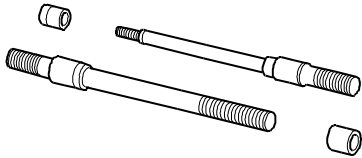
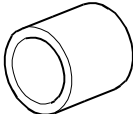
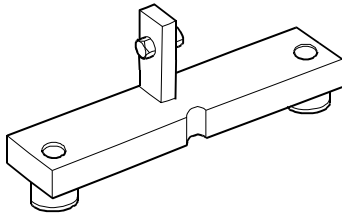
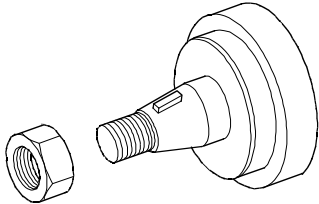
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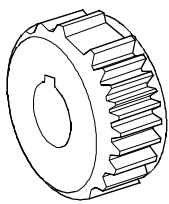
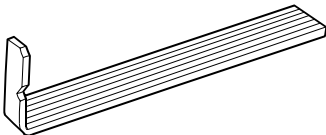
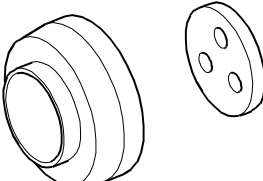
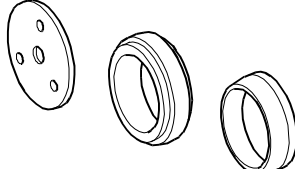
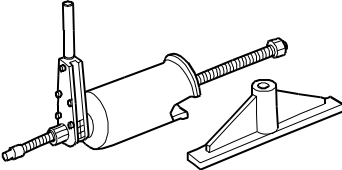
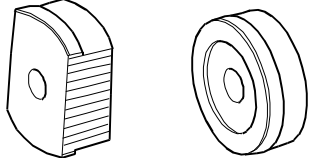
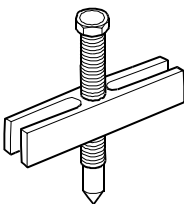
Special tools

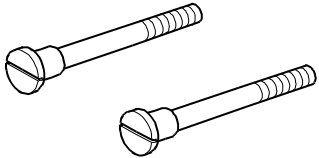
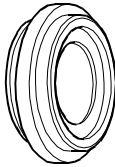
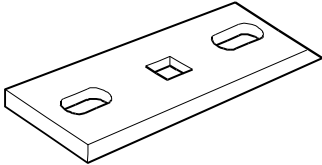
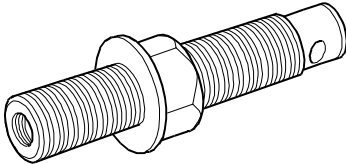
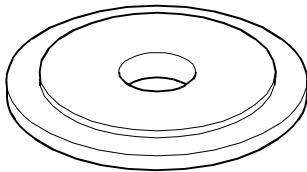
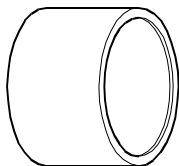
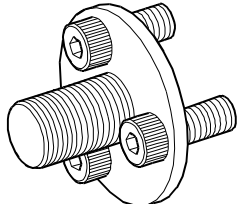
List of special tools

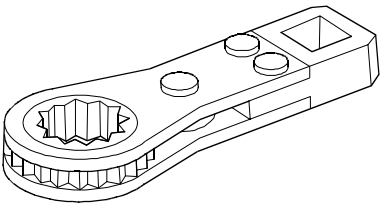
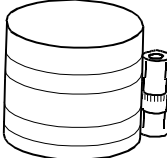

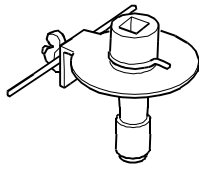
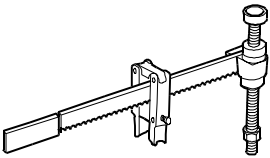
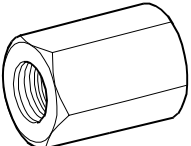

These tools are available through your local Perkins Distributor. If you cannot obtain the correct tool locally contact:

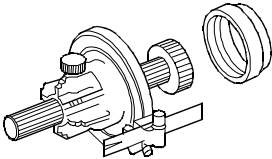
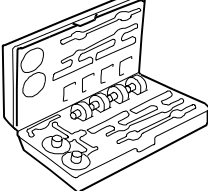
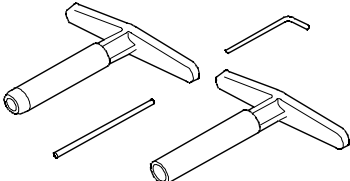
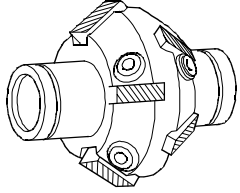
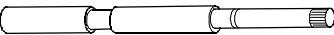
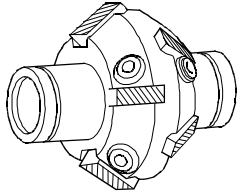
The Perkins Service Department, Peterborough, PE1 5NA, England, UK. Tel 01733 583000, Fax 01733 582240, Telex 32501 PERKEN G.

Number	Description	Illustration
PD.1D	Remover/replacer for valves guides (main tool) Part number 21825478	
PD.1D-1A	Adaptor for use with PD.1D Part number 21825479	
PD.1C-6	Adaptor for use with PD.1D and PD.1D-1A Part number 21825482	
PD.41D	Gauge for piston height, valve depth and cylinder liner flange; for use with PD.208. Part number 21825496	
PD.67-2	Drive adaptor for use with MS.67B. Part number 21825512	

Number	Description	Illustration
PD.67-3	Gear adaptor for use with MS.67B. Part number 21825513	
PD.67-4	Pointer for use with MS.67B. Part number 21825514	
PD.162B	Centralising tool for timing case cover (four cylinder engines) Part number 21825936	
PD.145D	Replacer tool for crankshaft rear seal. Part number 21825540	
PD.150B	Remover/replacer for cylinder liner (main tool). Part number 21825543	
PD.150-7B	Adaptors for use with PD.150B. Part number 21825551	
PD.155C	Basic puller for camshaft and fuel pump gears. Part number 21825565	

Number	Description	Illustration
PD.155B-5	Adaptors for use with PD.155C. Part number 21825568	
PD.170-4	Adaptor for standard seal for use with PD.170. Part number 21825581 (PD.170-4)	
PD.165B	Crankshaft rotation adaptor for use with a 12,7 mm (0.5 in) square drive. Part number 21825576	
PD.170	Replacer tool for seal of timing case cover (main tool). Part number 21825577	
PD.170-1	Pressure plate for use with PD.170. Part number 21825578	
PD.170-2	Sleeve for use with PD.170. Part number 21825579	
PD.170-3	Fastener plate for use with PD.170. Part number 21825580	

Number	Description	Illustration
PD.239	Spanner for flange nuts of fuel injection pump. Part number 21825964	
PD.206	Replacer tool for pistons. Part number 21825491	
PD.208	Dial gauge for use with PD.41D. Part number 21825617	
PD.198 (MS.1531)	Angle gauge to tighten cylinder head setscrews. Part number 21825607	
PD.6118B	Valve spring compressor. Part number 21825666	
PD.6118-7	Stud adaptor for use with PD.6118B. Part number 21825672	
PD.6118-8	Setscrew adaptor for use with PD.6118B. Part number 21825673	

Number	Description	Illustration
MS.67B	Universal timing gauge. Part number 21825610	
MS.76A	Set of adjustable cutters for valve seats. Part number 21825518	
MS.76B	Handle set for valve seat cutters (also included in MS.76A). Part number 21825619	
MS.281	Cutter for inlet valve seats (also included in MS.76A). Part number 21825632	
MS.150-9.5	Adjustable pilot for valve seat cutters (also included in MS.76A). Part number 21825655	
MS.275	Cutter for exhaust valve seats (also included in MS.76A). Part number 21825631	

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