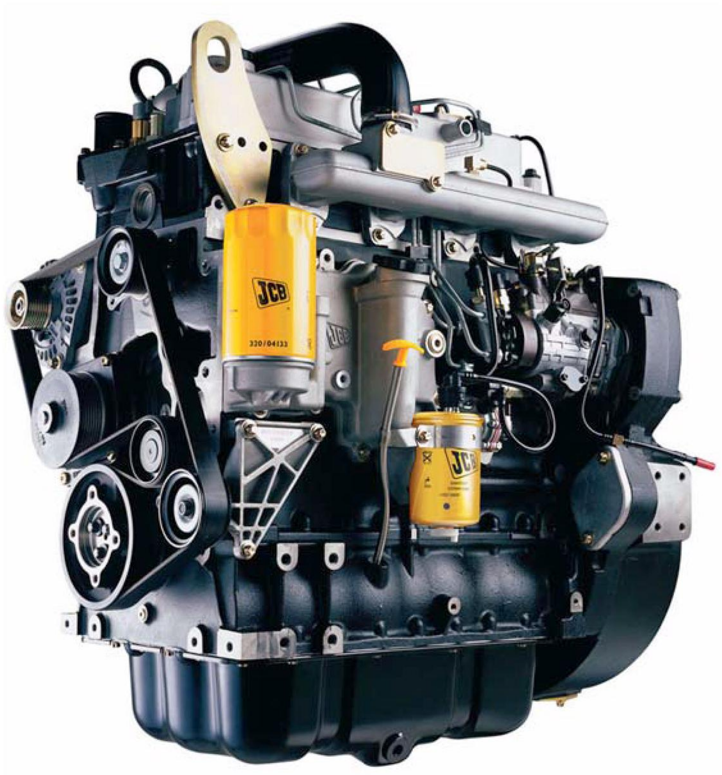
General Information

Service Manual - JCB 444 Mechanical Engine



Publication No.
9806/3000-04

World Class
Customer Support

Issued by JCB Technical Publications, JCB Aftermarket Training, Woodseat, Rocester, Staffordshire, ST14 5BW, England. Tel +44 1889 591300 Fax +44 1889 591400

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Introduction

About this Manual

Using the Service Manual

This publication is designed for the benefit of JCB Distributor Service Engineers who are receiving, or have received, training by JCB Technical Training Department.

These personnel should have a sound knowledge of workshop practice, safety procedures, and general techniques associated with the maintenance and repair of engines.

Renewal of oil seals, gaskets, etc., and any component showing obvious signs of wear or damage is expected as a matter of course. It is expected that components will be cleaned and lubricated where appropriate, and that any opened hose or pipe connections will be blanked to prevent excessive loss of hydraulic fluid, engine oil and ingress of dirt. Finally, please remember above all else **SAFETY MUST COME FIRST**!

The manufacturer's policy is one of continuous improvement. The right to change the specification of the engine without notice is reserved. No responsibility will be accepted for discrepancies which may occur between the specifications of the engine and the descriptions contained in this publication.

Section Numbering

The manual is compiled in sections, the first three are numbered and contain information as follows:

1 **General Information** includes torque settings and service tools.

2 **Care & Safety** includes warnings and cautions pertinent to aspects of workshop procedures etc.

3 **Routine Maintenance**includes service schedules and recommended lubricants.

The remaining sections deal with Descriptions, Fault Finding, Dismantling, Overhaul etc. of specific components, for example:

4 **Systems Descriptions**

5 **Fault Finding** ...etc.

Left Side, Right Side

References to the `left' side and the `right' side of the engine are when viewed from the flywheel end of the engine, as shown at **1A**.

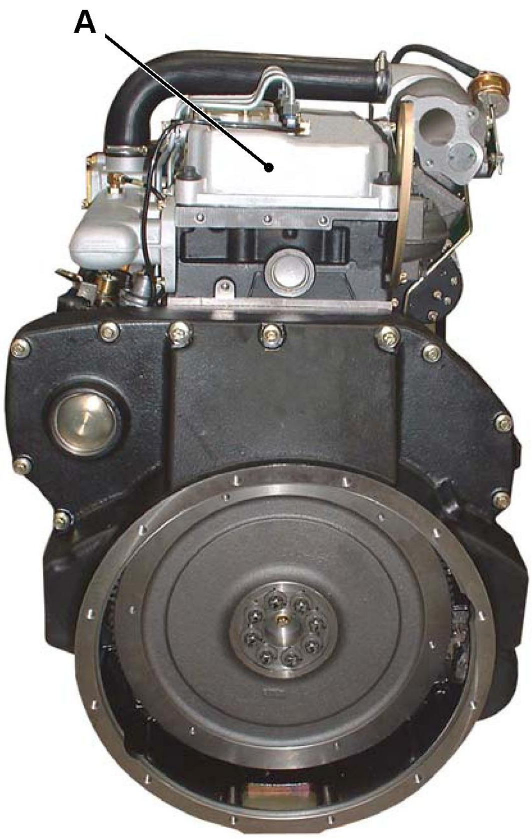


Fig 1.

Units of Measurement

In this manual, the S.I. system of units is used. For example, liquid capacities are given in litres. The imperial units follow in parenthesis () e.g. 28 litres (6 UK gal).

Machine Related Data

The JCB 444 Engine can be fitted to a variety of constructions and agricultural machines. The scope of this publication is limited to the engine, but references to a typical machine installation will be made. Tasks and information specific to a machine installation will be listed in the relevant machine Service Manual, for example engine removal and replacement procedures.

Acronyms and Abbreviations

Some of the following acronyms and abbreviations are used in this service manual. The remainder are used in the automotive industry and are repeated for reference only.

°C	Celsius
°F	Fahrenheit
A/R	As Required
API	American Petroleum Institute
BBDC	Before Bottom Dead Centre
BDC	Bottom Dead Centre
BSFC	Brake Specific Fuel Consumption
BTDC	Before Top Dead Centre
CCV	Crankcase Vent
CID	Cubic inch Displacement
CSA	Cold Start Advance
CSAS	Cold Start Advance Solenoid
cST	Centistokes
ECM	Electronic Control Module
ECS	Emission Control System
EPA	Environmental Protection Agency
ESOS	Electric Shut-Off Solenoid or Engine Shut-Off Solenoid
FAME	Fatty Acid Methyl Esters
FEAD	Front End Accessory Drive
FIE	Fuel Injection Equipment
FIP	Fuel Injection Pump
Hg	Mercury
HP	Horse Power
I/D	Inside Diameter
kg	Kilogram
KPH	Kilometres per hour
Kw	Kilowatt
LH	Left Hand
ltr	Litre
mm	Millimetre
MPH	Miles per Hour
NA	Naturally Aspirated
N/A	Not Applicable/Not Available
Nm	Newton Metre
NSP	Non Serviced Part
O/D	Outside Diameter
OEM	Original Equipment Manufacturer
PPM	Parts per Million
PSI	Pounds per square Inch
PTO	Power Take Off
RH	Right Hand
RME	Rapeseed Methyl Ester
RPM	Revolutions per Minute
SAE	Society of Automotive Engineers
SME	Sunflower Methyl Ester
SOME	Soyabean Methyl Ester
STD	Standard
TBA	To be Advised
TC	Turbocharged
TCA	Turbocharged Aftercooled
TDC	Top Dead Centre
TI	Technical Information
VOME	Vegetable Oil Methyl Esters

Identifying the Engine

Engine Identification Plate

Engine Labels

Each JCB 444 Engine has a unique identification number stamped onto the main engine block, as shown at **2A**. Refer to ⇨ ***Engine Identification Number Explanation (1-5)*** for a full detailed description of the number.

In addition to the identification number, there is an emisssions legislation label **2B**.

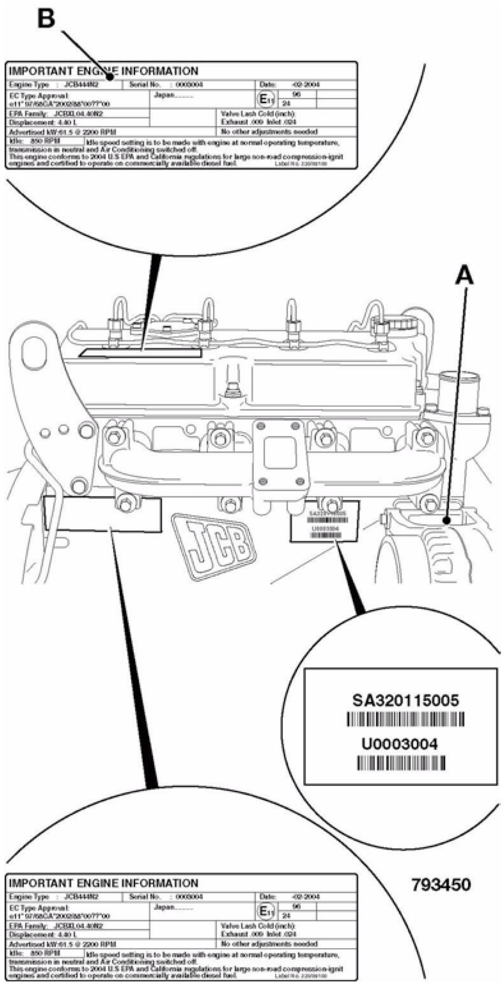


Fig 2.

Component Labels

In addition to the engine labels, some of the machine engine components will also have a label attached, or a part number etched into the casting, these include:

- the starter motor
- the alternator
- the fuel injection pump
- engine bedplate
- engine block
- cylinder head
- Turbo charger

In some instances, it may be necessary to quote the information on these labels, for instance if there is a parts query, or a warranty claim. Make a note of these numbers.

Engine Identification Number Explanation

The full engine number is stamped on the emissions label and the serial number is stamped on the engine block. ⇨ Fig 2. (1-4).

An explanation of the full engine number is detailed below. ⇨ Fig 4. (1-5).

If you need parts or service information for your engine, you must quote the complete engine number.

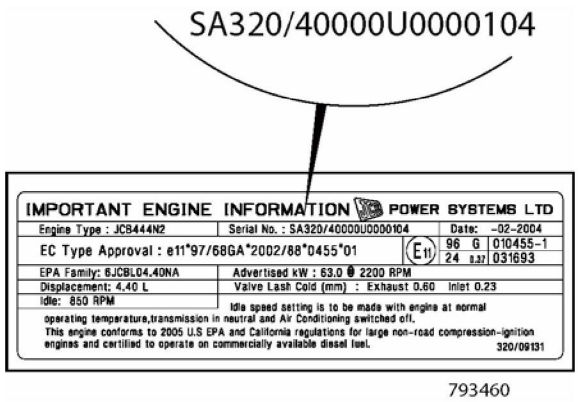


Fig 3.

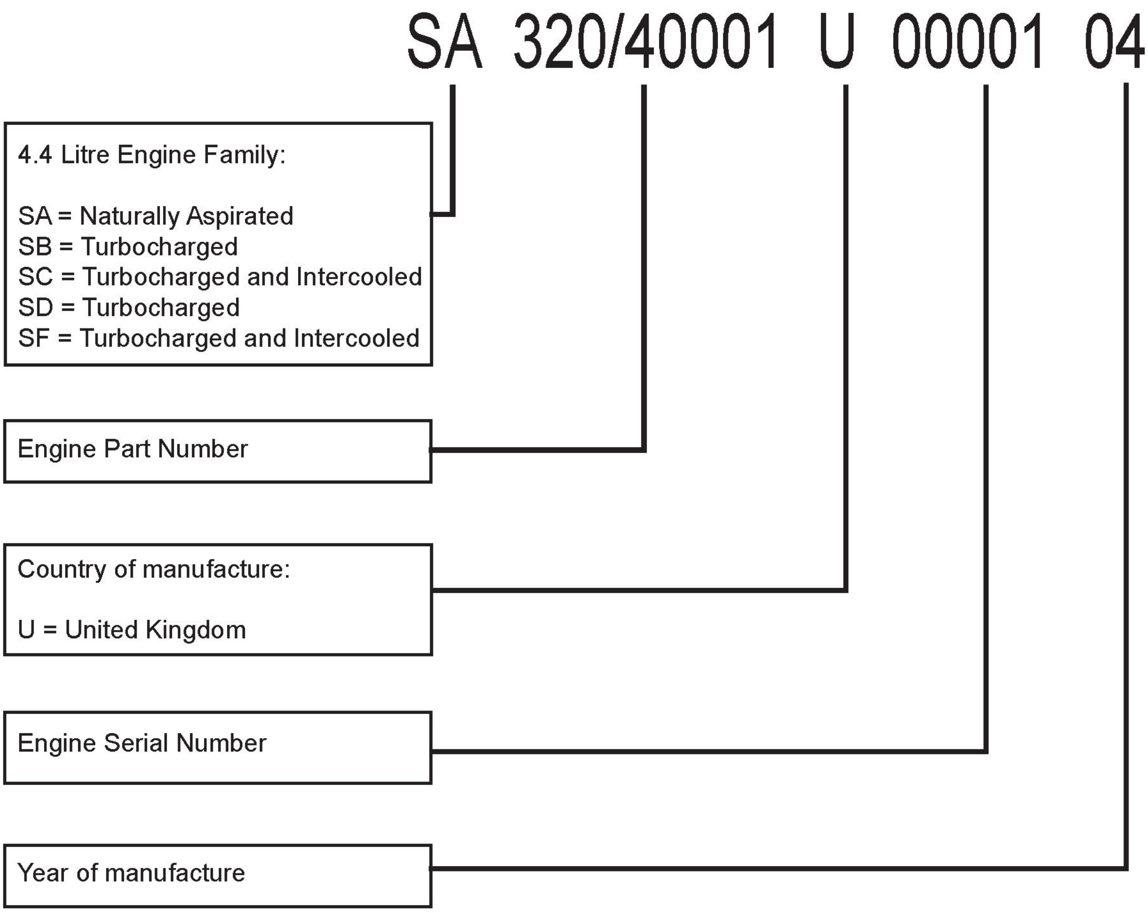


Fig 4.

Engine Component Identification

Table 1. Engine - As viewed on the left hand side.

⇨ *Fig 5. (1-7)*

1	Rocker cover
2	Fuel injectors and high pressure fuel pipes
3	Lubrication oil filler cap
4	Timing gear case
5	Flywheel housing
6	Bed plate
7	Lubrication oil pan (sump)
8	Engine lifting eye
9	Air Inlet manifold
10	Fuel injection pump
11	Fuel lift pump
12	Fuel filter
13	Lubrication oil filler cap
14	Lubrication oil filter
15	Lubrication oil cooler housing
16	Lubrication oil dip stick
17	Low duty PTO (blanking cover if no device is fitted)
18	Water temperature sender (cold start)
19	Low pressure fuel line (to tank)
20	Oil drain plug (sump)
21	Oil pressure switch
22	Inlet manifold induction heater (if fitted)

Engine Component Identification

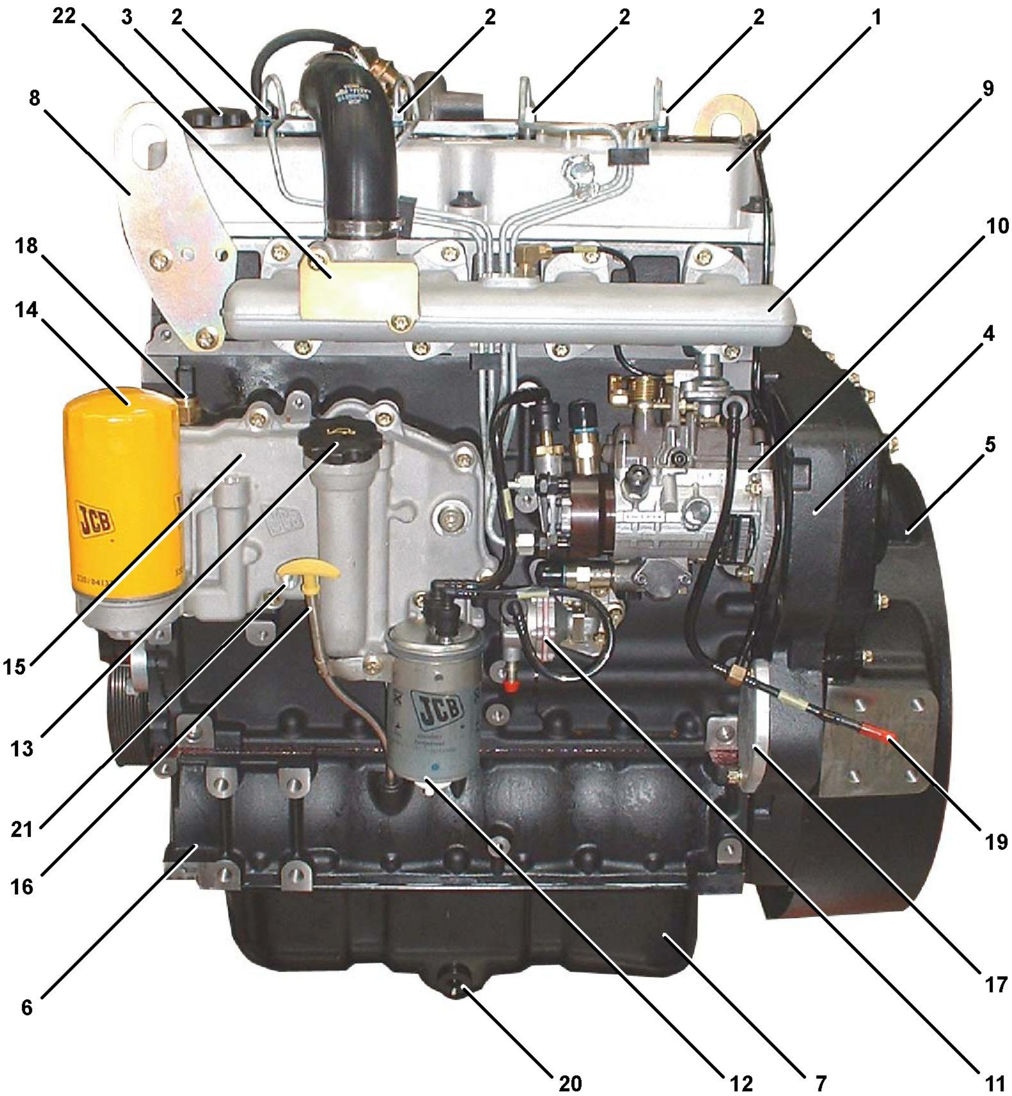


Fig 5. SB Type engine shown

Table 2. Engine - As viewed on the right hand side

⇨ *Fig 6. (1-9)*

1	Rocker cover	11	Exhaust manifold
2	Breather chamber inspection cover	12	Alternator and drive pulley assembly (belt not fitted)
3	Cylinder block	13	Coolant pump drive pulley (belt not fitted)
4	Timing gear case	14	Coolant pump housing (cylinder block)
5	Flywheel housing	15	Coolant inlet/radiator hose connector
6	Bed plate	16	Heavy duty PTO (blanking cover if no device is fitted)
7	Lubrication oil pan (sump)	17	Starter motor assembly
8	Lifting eye	18	Turbocharger oil drain line (turbocharged engine only)
9	Turbocharger (turbocharged engine only)	19	Turbocharger oil feed line (turbocharged engine only)
10	Turbocharger waste gate actuator assembly	20	Oil drain plug (sump)

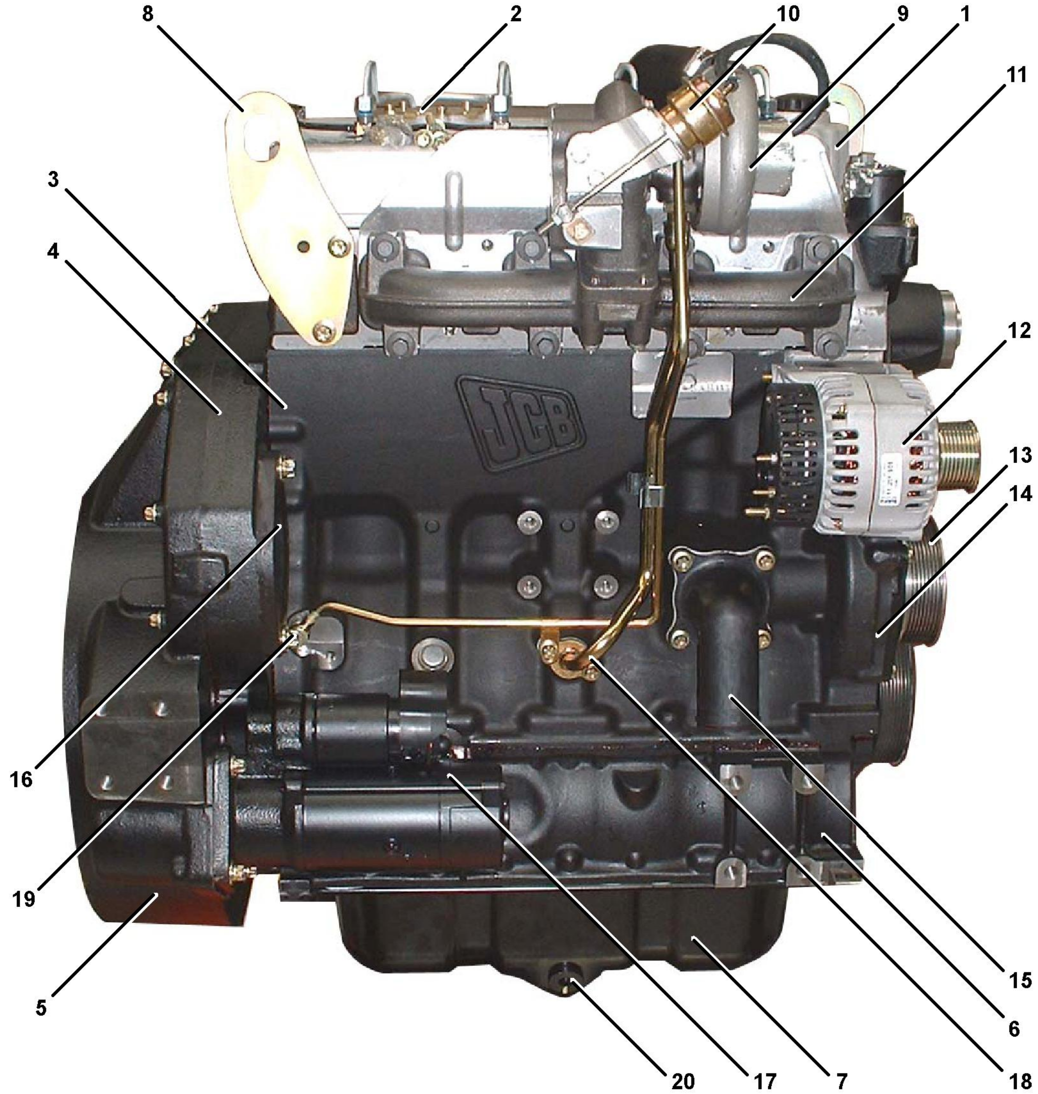


Fig 6. SB Type engine shown

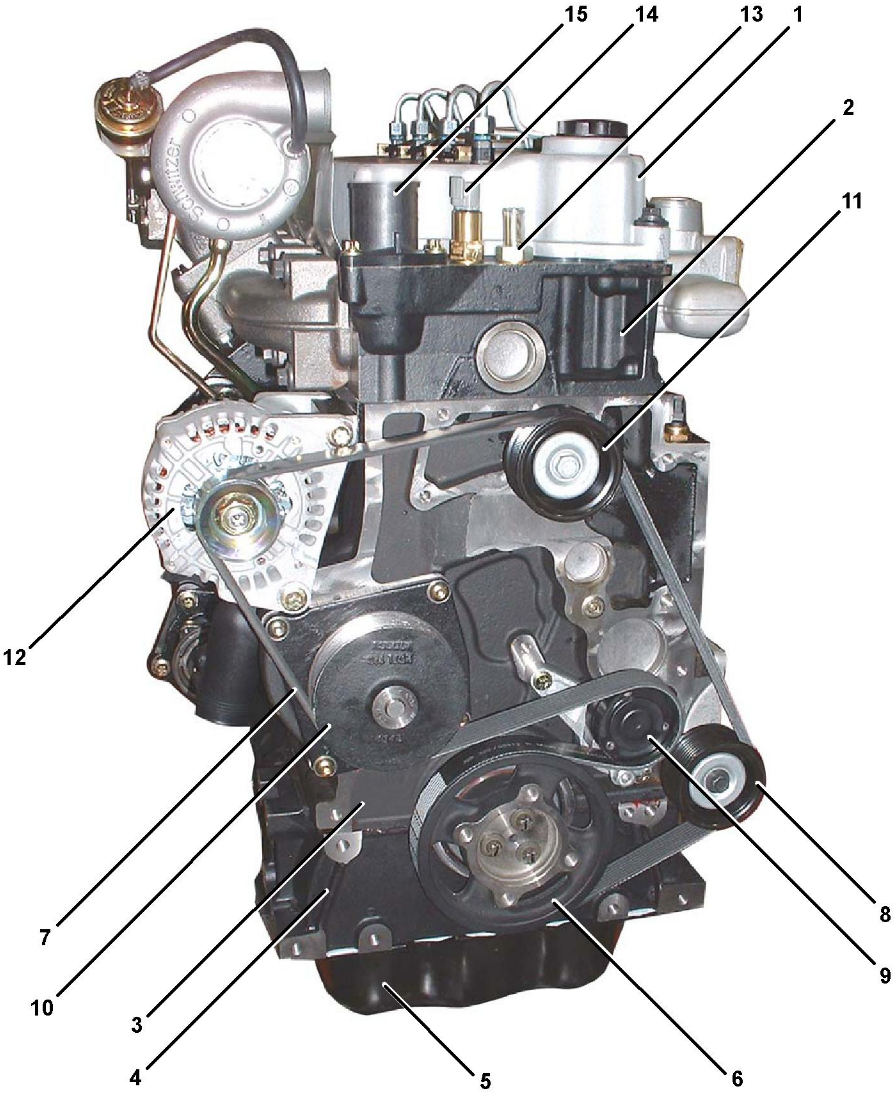


Fig 7. SB Type engine shown

Table 3. Engine - As viewed on the crankshaft pulley (front) end

⇨ *Fig 7. (1-10)*

1	Rocker cover	9	Drive belt tensioner and pulley
2	Cylinder head	10	Coolant pump and drive pulley assembly
3	Cylinder block	11	Idler pulley
4	Bed plate	12	Alternator and drive pulley assembly
5	Lubrication oil pan (sump)	13	Cab heater water hose connector
6	Crankshaft pulley	14	Coolant temperature sender
7	Front end accessory drive belt	15	Coolant thermostat housing/radiator hose connector
8	Idler pulley		

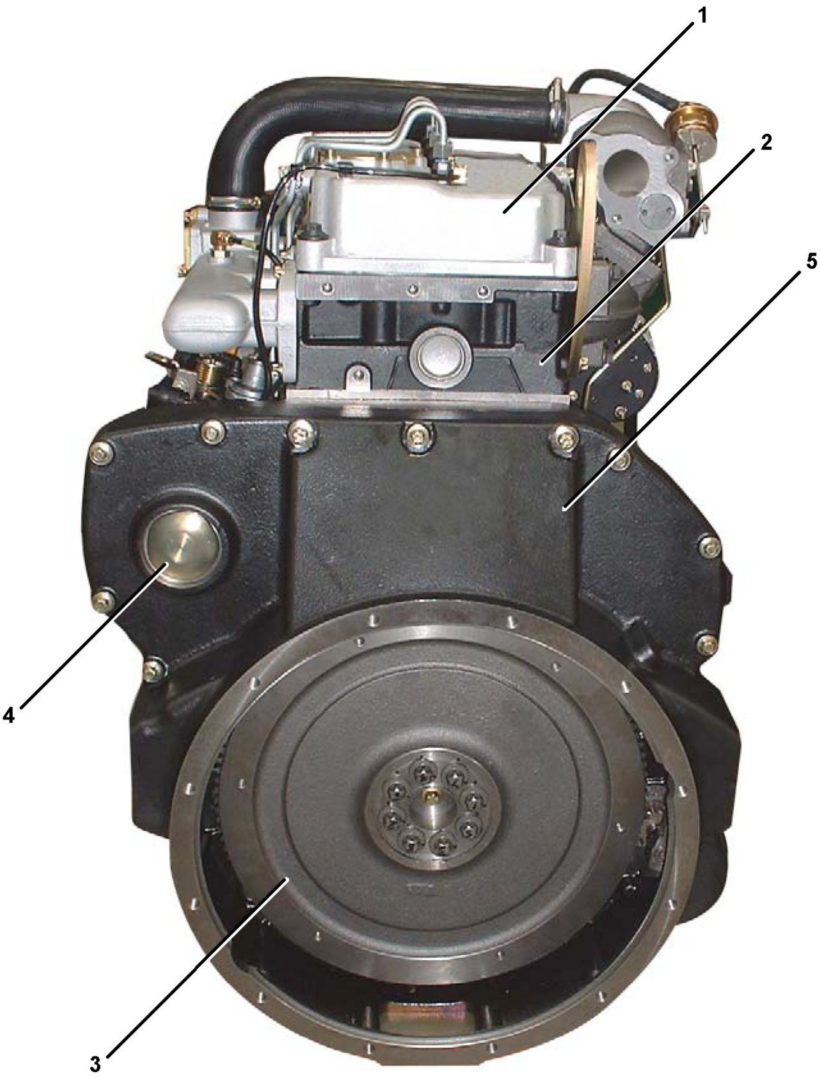


Fig 8. SB Type engine shown

Table 4. Engine - As viewed on the flywheel (rear) end

⇒ Fig 8. (1-11)

1	Rocker cover	4	Fuel injection pump drive gear cover
2	Cylinder head	5	Flywheel housing
3	Flywheel		

Technical Data

Basic Engine Data

Engine Specifications

Engine Type:	
- SA	Naturally Aspirated
- SB	Turbocharged
- SC	Turbocharged with Intercooler
- SD	Turbocharged
- SF	Turbocharged with Intercooler
Rated speed	2200 rpm
Weight (Dry):	
- SA	472 kg (1040 lb)
- SB, SC, SD, SF	477 kg (1052 lb)
Number of cylinders	4
Nominal bore size	103 mm (4.055 in)
Stroke	132 mm (5.16 in)
Cylinder arrangement	In line
Combustion Cycle	4-stroke
Firing order	1-3-4-2
Displacement	4.40 litres
Compression ratio	
- SA	18.6 : 1
- SB	18.3 : 1
- SC	17.5 : 1
- SD, SF	17.2 : 1
Engine Compression	see Note (1)
Direction of rotation (viewed from front {crankshaft pulley} end)	Clockwise
Valves	4 per cylinder
Valve tip clearances (measured cold):	
- SA, SB, SC	Inlet: 0.19 to 0.27 mm (0.007 to 0.011 in)
	Exhaust: 0.56 to 0.64 mm (0.022 to 0.025 in)
- SD, SF	Inlet: 0.35 mm (0.014 in)
	Exhaust: 0.56 to 0.64 mm (0.022 to 0.025 in)
Lubricating oil pressure (2)	4.0 to 4.8 bar (58 to 70 lb in^2)
Combustion system	Direct Injection

Fuel injection pump	Rotary Mechanical

(1) Compression variance between each cylinder should be no greater than 3.5 bar (50 lb in2)
(2) Engine at normal operating temperature and maximum revs.

Engine Block & Bedplate Data

Cylinder bore [1]	103.000 to 103.020 mm (4.055 to 4.046 in)
Main bearing bolts torque [2]	
- first stage	50 Nm (37 lbf ft)
- second stage	115 Nm (85 lbf ft)
- final stage	turn a further 180°
Surface finish for cylinder head joint	Rz < 15um; Rmax < 20um
Diameter of first oversize bore	103.500 to 103.520 mm (4.074 to 4.076 in)
Diameter of second oversize bore	104.00 to 104.020 mm (4.094 to 4.952 in)
Main bearing bore (without bearings)	
- numbers 1 to 4	92.000 to 92.020 mm (3.622 to 3.623 in)
- number 5	105.000 to 105.020 mm (4.134 to 4.135 in)
Main bearing bore (with bearings)	
- numbers 1 to 4	88.047 to 88.090 mm (3.466 to 3.468 in)
- number 5	100.047 to 100.090 mm (3.939 to 3.941 in)
Camshaft bore	
- numbers 1 to 4	60.040 to 60.070 mm (2.364 to 2.365 in)
- number 5 (bush) [3]	60.290 to 60.32 mm (2.374 to 2.375 in)
Permissible wave profile	wt<10m (2.5 distance)

(1) Nominal diameter to be measured 63mm below head face.

(2) Torque information MUST be used in conjunction with recommended procedures contained in this manual. Failure to use the appropriate and correct removal, replacement, dismantle and assembly procedures may result in an engine failure in service. Refer also to the procedures for the correct bolt tightening sequence.

(3) Bush no longer fitted from January 2008.

Cylinder Head Data

Cylinder head distortion (maximum permissible)	
- end to end	0.05 mm (0.002 in)
- side to side	0.03 mm (0.0012 in)
Valve recess depth	
- Inlet	0.85 mm (0.033 in)
- Exhaust	0.85 mm (0.033 in)
Valve seat angle	
- inlet	120 ° (inclusive)
- exhaust	90 ° (inclusive)
Cylinder head bolts torque (1)	
- first stage	40 Nm (30 lbf ft)
- second stage	75 Nm (56 lbf ft)
- third stage	repeat 75 Nm
- fourth stage	torque angle + 90 °
- final stage	torque angle + 180°
Surface finish for cylinder head joint	Rz < 15um; Rmax < 20um
Permissible wave profile	wt < 10um 2.5 distance

(1) Torque information MUST be used in conjunction with recommended procedures contained in this manual. Failure to use the appropriate and correct removal, replacement, dismantle and assembly procedures may result in an engine failure in service. Refer also to the procedures for the correct bolt tightening sequence.

Inlet and Exhaust Valve Data

Max lift inlet	
- SA, SB, SC	9.37 mm @ 101° atdc
- SD, SF	9.64 mm @ 101° atdc
Max lift exhaust	
- SA	9.42 mm @ 110° btdc
- SB, SC	9.42 mm @ 115° btdc
- SD, SF	9.84 mm @ 115° btdc
Inlet opens (top of ramp)	
- SA, SB, SC	10° btdc
- SD, SF	6° btdc
Inlet closes	
- SA, SB, SC	32° abdc
- SD, SF	28° abdc
Exhaust opens	
- SA	50° bbdc
- SB, SC	60° bbdc
- SD, SF	41° bbdc
Exhaust closes	
- SA, SB, SC	10° atdc
- SD, SF	9° atdc
Valve stem diameter	
- SA, SB, SC	Inlet: 6.935 +/-0.0075 mm (0.273 +/-0.0003 in)
	Exhaust: 6.975 +/-0.0075 mm (0.275 +/-0.0003 in)
- SD, SF	Inlet: 6.928 to 6.943 mm (0.2727 to 0.2733 in)
	Exhaust: 6.918 to 6.933 mm (0.2724 to 0.2729 in)
Valve spring free length	40.18 mm (1.581 in)
Valve guide bore diameter	
- min	6.958 mm (0.2739 in)
- max	6.968 mm (0.2743 in)
Valve face angle	
- inlet	60.5 °
- exhaust	45.17 °
Valve length	131.9 to 132.4 mm (5.193 to 5.213 in)
Valve sealing	stem seal with sealing washer
Valve head depth (below cylinder head surface)	
- inlet	0.89 to 1.39 mm (0.035 to 0.055 in)

- exhaust	0.95 to 1.45 mm (0.037 to 0.057 in)
Valve rim thickness	2.98 to 3.38 mm (0.117 to 0.133 in)

Rocker Levers, Rocker Shaft and Tappets Data

Valve tip clearances (measured cold):	
- SA, SB, SC	Inlet: 0.19 to 0.27 mm (0.007 to 0.011 in)
	Exhaust: 0.56 to 0.64 mm (0.022 to 0.025 in)
- SD, SF	Inlet: 0.35 mm (0.014 in)
	Exhaust: 0.56 to 0.64 mm (0.022 to 0.025 in)
Rocker lever bore diameter	
- min	26.046 mm (1.025 in)
- max	26.129 mm (1.029 in)
Rocker shaft diameter	
- min	26.00 mm (1.0236 in)
- max	26.021 mm (1.0244 in)
Tappets stem diameter	
- min	19.987 mm (0.787 in)
- max	19.975 mm (0.786 in)
Tappet bore diameter	
- min	20.00 mm (0.7874 in)
- max	20.021 mm (0.7882 in)
Tappet height (maximum)	55.25 mm (0.0218 in)

Pistons and Connecting Rods Data

Gudgeon pin bore diameter	
- min	40.008 mm (0.015751 in)
- max	40.013 mm (0.015753 in)
Piston ring clearance	
- top ring	keystone ring
- middle ring	0.11 to 0.07 mm (0.0043 to 0.0027 in)
- bottom (oil) ring	0.09 to 0.05 mm (0.0035 to 0.0019 in)
Piston ring gap	
- top ring	0.3 to 0.5 mm (0.118 to 0.019 in)
- middle ring	0.55 to 0.8 mm (0.0216 to 0.0314 in)
- bottom (oil) ring	0.25 to 0.50 mm (0.0098 to 0.0196 in)
Piston height above cylinder block (cold)	0.0375 to 0.3385 mm (0.0014 to 0.013 in)
Piston groove width	
- top ring	3.108 to 3.133 mm (0.122 to 0.123 in)
- middle ring	2.47 to 2.67 mm (0.972 to 0.105 in)
- bottom (oil) ring	4.04 to 4.06 mm (0.1590 to 0.1598 in)
Connecting rod type (1)	Split fracture
Connecting rod bore diameter	77.00 to 77.01 mm (3.0314 to 3.0318 in)
Connecting rod side clearance	
- min	0.05 mm (0.0019 in)
- max	0.40 mm (0.0157 in)
Big end bearings:	
- width	32.5 to 33.00 mm (1.279 to 1.299 in)
- thickness (at centre)	1.990 to 1.981 mm (0.0783 to 0.0779 in)
Small end bearings:	
- inside diameter	40.034 to 40.020 mm (1.5761 to 1.5755 in)

(1) *Split fracture type connecting rods MUST NOT be dot punched, or etched in any way during disassembly - refer to relevant service procedures.*

Crankshaft Data

Main bearing journal diameter (x4)	
- min	87.98 mm (3.460 in)
- max	88.00 mm (3.464 in)
Main rear bearing journal diameter (x 1)	
- min	99.98 mm (3.936 in)
- max	100.00 mm (3.937 in)
Connecting rod bearing journal diameter	
- min	72.98 mm (2.873 in)
- max	73.00 mm (0.2755 in)
Maximum wear and ovality on journals	TBA mm
Crankshaft induction hardness	55 HRc min on surface
Thrust washer width	
- min	2.44 mm (0.096 in)
- max	2.50 mm (0.787 in)
Crankshaft end float	
- min	0.05 mm (0.002 in)
- max	0.28 mm (0.011 in)

Camshaft Data

Camshaft journal diameter	
- 4 off	59.99 to 59.97 mm (2.362 to 2.361 in)
- 1 off	60.25 to 60.22 mm (2.372 to 2.370 in)
Camshaft lobe wear limits	
SA, SB, SC	Inlet: 7.23 +/-0.025 mm (0.285 +/-0.001 in)
	Exhaust: 7.269 +/-0.025 mm (0.286 +/-0.001 in)
SD, SF	Inlet: 7.385 to 7.435 mm (0.291 to 0.293 in)
	Exhaust: 7.545 to 7.595 mm (0.297 to 0.299 in)
Camshaft bush diameter (1)	60.32 to 60.29 mm (2.375 to 2.374 in)
Camshaft Gear (2)	104 teeth

(1) Bush no longer fitted from January 2008.
(2) The camshaft gear is not available as a separate service item. The gear must be heated onto the camshaft in the correct timed position. Specialist fixtures are used during the production process to achieve the correct timing.

Fuel System Data

Acceptable and Unacceptable Fuels

Important: *No warranty liability whatsoever will be accepted for failure of fuel injection equipment where the failure is attributed to the quality and grade of the fuel used.*

Fuel Specification	Applicable Engines	Service Requirements
EN590 Diesel fuel types - Auto/C0/C1/C2/C3/C4	All Dieselmax engines.	Obey the usual routine maintenence schedules and procedures
BS2869 Class A2		
ASTM D975-91 Class 2, US DF1, US DF2, US DFA		
JIS K2204 (1992) Grades 1, 2, 3 and Special Grade 3		
ASTM D975-91 Class 1DA	All Dieselmax engines. **Engines operated with these fuels may have a reduced service life**	Obey the usual routine maintenence schedules and procedures. **Fuel additives are recommended for use with low sulphur fuels** ⇨ *Additives (1-23)*
MIL T38219 XF63		
NATO F63		
French EN590 (RME5) with 5% maximum		
AVCAT FSII, NATO F44, JP5, MIL T5624, DERD 2452, AVTOR	All Dieselmax engines. **Engines operated with these fuels will have a reduced service life**	Obey the usual routine maintenence schedules and procedures. **Fuel additives MUST be used** ⇨ *Additives (1-23)*
NATO F35, JET A1, DEF STAN 91-91, DERD 2494, JP7		
AVCAT, NATO F43 (obsolete), JP5 without additives		
JET A (ASTM D1655)		
ASTM D3699 Kerosene		
B20 Biodiesel - RME content blended with mineral derived diesel (20% maximum) - ASTM D6751, DIN 51606, ISO 14214	**Dieselmax engines manufactured from 2007 on ONLY**(1)	**YOU MUST obey special routine maintenance schedules and procedures**. ⇨ *Service Requirements for use of B20 Biodiesel (1-23)*
AVTAG (obsolete)	**These fuels are NOT ACCEPTABLE with or without additives. Engines MUST NOT be operated with these fuels**	
AVTAG FSII (obsolete), NATO F40, JP4, DERD 2454		
JET B (ASTM D1655)		
BS MA100		
JIS K2203 No.2		
Unmodified vegetable oils		

(1) The year of manufacture is part of the engine serial number. Refer to Identifying the Engine.

Additives

The additives listed below are advertised as being suitable for bringing the lubricity levels of kerosene/low sulphur fuels up to those of diesel fuels. They must be used as specified by your fuel supplier who will understand the concentration level necessary.

– Elf 2S 1750. Dosage 1000-1500 ppm (0.1 - 0.15%), specifically for Indian Superior Kerosene (SKO) but may be applicable to other fuels.
– Lubrizol 539N. Dosage (on Swedish low sulphur fuel) 250 ppm.
– Paradyne 7505 (from Infineum). Dosage 500 ppm (0.05%).

Note: *These products are given as examples only. The information is derived from the manufacturers data. The products are not recommended or endorsed by JCB.*

Service Requirements for use of B20 Biodiesel

– The engine oil must be a grade CH4 as minimum specification.
– Do not leave unused B20 biodiesel in the fuel tank for extended periods (top up each day).
– Make sure that 1 in 5 fuel tank fills use standard diesel to EN590 specification, this will help to prevent `gumming'.
– Make sure regular oil sampling is completed (look for excessive unburnt fuel content, water or wear particles.
– Change the engine oil and filter more frequently (as a minimum half the recommended intervals), or as indicated by oil sampling.
– Change the fuel filters more frequently (as a minimum half the recommended intervals), or if there are engine performance related issues.
– Make sure the fuel is stored correctly, care must be taken to make sure no water enters the machine fuel tank (or the storage tank). Water will encourage mico-bacterial growth.
– Make sure that the fuel pre-filter is drained DAILY (not every week as currently advised).
– Only JCB ENGINES built after Jan. 2007 are applicable (i.e. engines with 07 on the end of their serial number and factory filled with CH4 oil) - this is not approved with other manufacturers.
– Use heater kits in low ambient temperature territories.
– The biodiesel must meet the following standards: ASTM D6751, DIN 51606, ISO 14214

Note: *If necessary use a test kit to confirm the fuel specification. Testing kits are available (not from JCB currently), use the internet as a source for the kits.*

Note: *If performance related issues are to be reported to JCB Service, and the engine has been run on biodiesel, then the fuel system must be filled with standard diesel (at least 2 x tank fills) to EN590 specification and relevant stall speeds recorded prior to making the report.*

Warranty

JCB have shown a commitment to support the enviroment by approving the use of biodiesel blended fuels.

Using a B20 blend of biodiesel requires caution and additional servicing of the engine is required. ⇨ ***Service Requirements for use of B20 Biodiesel (1-23)***

Failure to follow the additional recommended service requirements may lead to a warranty claim being declined.

Failures resulting by the incorrect use of biodiesels or other fuel additives are not defects of the JCB Dieselmax engine workmanship and therefore will not be supported by JCB Warranty.

Fuel Types

Note: *The information that follows does not indicate types of fuel that are acceptable or unacceptable.* ***⇨ Acceptable and Unacceptable Fuels (1-22)***.

Any fuel purchased for operation of the JCB Dieselmax engine must be purchased from reputable oil producers/ outlets and stored in accordance with the manufacturers recommendations. ***⇨ Effects of Fuel Contaminates (1-27)***

1 Diesel - mineral derived, hydrocarbon fuels to European standard EN590 or equivalent.

2 Low Sulphur Diesel - mineral derived, hydrocarbon fuels to EN590 or equivalent. This fuel has totally replaced automotive (road use) diesel in the European Union since October 1996 and has sulphur limited to a maximum of 0.05% by weight.

3 Ultra Low Sulphur Diesel - Reformulated mineral derived, hydrocarbon fuels to EN590 or equivalent. Now widely available in the UK, mainland Europe and some parts of the USA. Sulphur limited to a maximum of 0.005% by weight or lower. ***⇨ Sulphur Content (1-26)***

4 Vegetable Oil -unmodified. Certain pure vegetable oils (sunflower oil, rapeseed oil etc.)

5 Biodiesel - chemically modified vegetable oil. By chemically modifying vegetable oils, methyl esters of that oil are produced. These are collectively known as "Fatty Acid Methyl Esters" (FAME) or "Vegetable Oil Methyl Esters" (VOME).

Note: *Refer also to additional information.* ***⇨ Usage and Effects of Fuels (1-25)***.

Usage and Effects of Fuels

Note: *The information that follows does not indicate types of fuel that are acceptable or unacceptable.* ***⇨ Acceptable and Unacceptable Fuels (1-22)***.

1 Low Sulphur Diesel

In its basic form because of the process of reducing sulphur by removal of sulphur containing compounds (which contribute to mechanical lubrication) an increase in the wear rate of the fuel injection equipment could occur. In view of this, the major fuel producers add suitable lubricity improvers to enable the FIE to run satisfactorily, with no acceleration in wear rate. They must ensure that the lubricity improvers do not themselves create residual deposits that could block the fuel system e.g. filter, injectors etc.

In addition to the lubrication effect there can also be a further reduction in the aromatic content of the fuel which can lead to shrinking/cracking of traditionally nitrile rubber seals throughout the fuel injection equipment that has previously been exposed to higher sulphur level fuels. The major fuel producers tend to maintain the total aromatic content to an acceptable level (15% by volume).

2 Ultra Low Sulphur Diesel

Also known as `city diesel'. Available throughout the UK and some parts of Europe since March 1999. This fuel has a maximum sulphur content of 0.005% by weight and a further reduction in the natural lubricity and aromatic content than experienced with low sulphur diesel. Major oil producers will add lubrication improvers and also maintain the total aromatic content to an acceptable level.

3 Unmodified Vegetable Oils

Burned in diesel engines neat or used as an extender to mineral derived fuel. When these are subjected to heat in the fuel injection system they form sticky deposits that can be found inside the fuel pump and a hard lacquer in the injectors where exposure to even higher temperatures takes place.

4 Chemically Modified Vegetable Oils (FAME/VOME)

These fuels have been derived from a wide range of vegetable oils and animal fats, resulting in better stability, viscosity and cetane number than those produced from unmodified vegetable oils, but it is recognised that there are potential problems associated with the finished fuel characteristics. These oils are less stable than mineral oil derived fuels when stored and they will readily degrade producing fatty acids, methanol and water, none of which are desirable in the FIE. These effects are known to be accelerated when the fuel is stored in the presence of air and water together.

An extract `common statement' from the FIE manufactures specifies that "The fuel injection equipment manufacturers can accept no liability whatsoever for failure attributable to operating their products with fuels for which the products were not designed, and no warranties or representations are made as to the possible effects of running these products with such fuels".

The three most common Fame types are RME - Rapeseed methyl ester (preferred crop in Europe), SME - Soyabean methyl ester (preferred crop in USA). Less common FAME's can be derived from animal fats (e.g. modified beef extracts) and reclaimed cooking oils.

5 B20 Biodiesel

Biodiesel refers to pure fuel before it is blended with diesel fuel ***⇨ Chemically Modified Vegetable Oils (FAME/VOME) (1-25)***. When biodiesel is blended with diesel fuel it is referred to as B5, B20 etc, where the number indicates the percentage of biodiesel in the fuel, for example B5 contains 5% biodiesel.

Biodiesel has different characteristics than mineral based fuels in that it is able to mix with water and therefore will have a high water retention capacity - this could lead to seals swelling, fuel system corrosion and seal damage.

Biodiesels will `cloud' at higher temperatures than mineral based fuels. To explain Cloud Point - the lowest temperature at which fluid can flow and performs its functions is referred to as Pour Point. Just prior to reaching its Pour Point the diesel fluid becomes `cloudy' due to crystallization of waxy constituents - this is know as Cloud Point. Using diesel at temperature below its cloud point can result in filter clogging. To prevent this happening pre-heating will be required.

Using B20 biodiesel can result in unburnt fuels accumulating in the engine oil, ultimately this can affect the engine oil efficiency and lead to engine damage (with standard diesel any unburnt fuel evaporates off the lubricating oil).Biodiesels must be stored to exclude water absorption and oxidation.

The natural properties of biodiesel make it a good medium for micro bacterial growth, these microbes can cause fuel system corrosion and early fuel filter blocking. It will be necessary to consult and seek advice from your fuel supplier, the effectiveness of conventional antibacterial additives when used in biodiesel is still being investigated in the fuel industry.A high percentage biodiesel mixture (>20%) can lead to fuel gelling and filter blocking in low temperature operation, it may also effect the power and performance of the engine.

To minimise the risk of engine damage when using a B20 mix, there are additional service requirements. ⇨ *Service Requirements for use of B20 Biodiesel (1-23)*

If the recommended actions are not taken there may be the following consequences:- low temperature filter clogging- injectors lacquering / sticking- deterioration of seals and rubber hoses- corrosion of metal parts in the fuel system- engine performance problemsThese risks will be increased if the fuel has been poorly stored, that is deteriorated through oxidation and / or water absorption.

Sulphur Content

High sulphur content can cause engine wear. (High sulphur fuel is not normally found in North America, Europe or Australia.) If you have to use high sulphur fuel you must change the engine oil more frequently. ⇨ *Table 5. Sulphur Content (1-26)*.

Low sulphur fuels must have the appropriate fuel lubricity additives, these lubricity improvers must not create residual deposits that block the fuel system, e.g. injectors, filters etc. Contact your fuel Supplier.

CAUTION

A combination of water and sulphur will have a corrosive chemical effect on fuel injection equipment. It is essential that water is eradicated from the fuel system when high sulphur fuels are used.

ENG-3-2

Table 5. Sulphur Content

Percentage of sulphur in the fuel (%)	Oil Change Interval
Less than 0.5	Normal
0.5 to 1.0	0.75 of normal
More than 1.0	0.50 of normal

Effects of Fuel Contaminates

The effect of dirt, water and other contaminants in diesel can be disastrous for injection equipment:

– Dirt - A severely damaging contaminant. Finely machined and mated surfaces such as delivery valves and distributor rotors are susceptible to the abrasive nature of dirt particles - increased wear will almost inevitably lead to greater leakage, uneven running and poor fuel delivery.
– Water - water can enter fuel through poor storage or careless handling, and will almost inevitably condense in fuel tanks. The smallest amounts of water can result in effects that are just as disastrous to the fuel injection pump as dirt, causing rapid wear, corrosion and in severe cases, even seizure. It is vitally important that water is prevented from reaching the fuel injection equipment. The filter/water trap must be drained regularly.
– Wax - Wax is precipitated from diesel when the ambient temperature falls below that of the fuel's cloud point, causing a restriction in fuel flow resulting in rough engine running. Special winter fuels may be available for engine operation at temperatures below 0°C (32°F). These fuels have a lower viscosity and limit wax formation.

Lubrication System Data

Filter type	Screw-on canister (with drain facility)
Pressure to open by-pass valve	1.6 bar (23 lb/in^2)
Oil pressure relief valve setting	4.5 bar (65 lb/in^2)
Oil pressure switch setting	0.6 bar falling (9 lb/in^2)
Oil pump (1)	Integral unit with relief valve

(1) The oil pump is a non-serviceable part.

Cooling System Data

Radiator cap pressure setting	1 bar (14.5 lb/in^2)
Thermostat	Wax element with by-pass blanking
Thermostat operating temperature:	
- nominal temperature	88°C (190°F)
- start to open temperature	86 - 90°C (187 - 194°F)
- full open temperature	102°C (216°F)
- travel (fully open)	9 mm (0.354 in.)
Fan belt type	Front end accessory drive (FEAD)
Fan belt (FEAD) adjustment	Automatic belt tensioner
Fan belt (FEAD) type	Multigroove belt
Coolant Temperature Switch/Sender range	see ⇨ ***Electrical Equipment Data (1-30)***
Water pump (1)	Bolt on, belt driven unit

(1) *The water pump is a non-serviceable part.*

Electrical Equipment Data

Alternator	
Make	Iskra - AAK
Rating	
- option 1	14V, 95 Amp
- option 2	28V, 55 Amp
Cooling	Internal Fan
W-terminal	For engine speed indication
Alternator speed	2.8 x engine speed
Starter Motor (1)	
Make	Iskra - AZF 45
Rating	
- option 1	12V, 4.2 kW
- option 2	24V, 4.2 kW
Operating range	-30 to +120°C (-22 to 248°F)
Number of pinion teeth	11

(1) Never operate the starter motor longer than 20 seconds. Allow at least 2 minutes for cooling and battery recovery before operating again. Overheating caused by excessive operation will seriously damage the starter motor.

Switches	
Cold start advance switch	
- set temperature	55°C rising (131°F)
- switch mode	Normally closed
- tightening torque	16 Nm max (12 lb ft)
- thread diameter	M12 x 1.5
Coolant temperature switch/sender	Dual function switch/sender
- set temperature (switch)	112°C +/-3°C (234 +/-5.4°F)
- mode (switch)	Normally open
- tightening torque	16 Nm max (12 lb ft)
- thread diameter	M12 x 1.5
- Temperature v resistance table	
Temperature °C (°F)	Resistance - Ohms +/- 10%
25 (77)	500
50 (122)	197.4
100 (212)	41.9
110 (230)	32

Oil pressure switch	
- set pressure	0.6 bar falling (9 lb/in^2)
- switch mode	Normally closed
- max pressure	27.5 bar (398 lb/in^2)
- max working pressure	13.8 bar (200 lb/in^2)
- tightening torque	16 Nm max (12 lb ft)
- thread diameter	M10 x 1.5

Torque Settings

Zinc Plated Fasteners and Dacromet Fasteners

T11-002

Introduction

Some external fasteners on JCB machines are manufactured using an improved type of corrosion resistant finish. This type of finish is called Dacromet and replaces the original Zinc and Yellow Plating used on earlier machines.

The two types of fasteners can be readily identified by colour and part number suffix. ⇨ ***Table 6. Fastener Types (1-32)***.

Table 6. Fastener Types

Fastener Type	**Colour**	**Part No. Suffix**
Zinc and Yellow	Golden finish	'Z' (e.g. 1315/3712Z)
Dacromet	Mottled silver finish	'D' (e.g. 1315/3712D)

Note: *As the Dacromet fasteners have a lower torque setting than the Zinc and Yellow fasteners, the torque figures used must be relevant to the type of fastener.*

Note: *A Dacromet bolt should not be used in conjunction with a Zinc or Yellow plated nut, as this could change the torque characteristics of the torque setting further. For the same reason, a Dacromet nut should not be used with a Zinc or Yellow plated bolt.*

Note: *All bolts used on JCB machines are high tensile and must not be replaced by bolts of a lesser tensile specification.*

Note: *Dacromet bolts, due to their high corrosion resistance are used in areas where rust could occur. Dacromet bolts are only used for external applications. They are not used in applications such as gearbox or engine joint seams or internal applications.*

Bolts and Screws

Use the following torque setting tables only where no torque setting is specified in the text.

Note: *Dacromet fasteners are lubricated as part of the plating process, do not lubricate.*

Torque settings are given for the following conditions:

Condition 1

– Un-lubricated fasteners
– Zinc fasteners
– Yellow plated fasteners

Condition 2

– Zinc flake (Dacromet) fasteners
– Lubricated zinc and yellow plated fasteners
– Where there is a natural lubrication. For example, cast iron components

Verbus Ripp Bolts

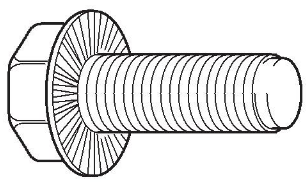


Fig 9.

Torque settings for these bolts are determined by the application. Refer to the relevant procedure for the required settings.

Zinc Plated Fasteners and Dacromet Fasteners

Table 7. Torque Settings - UNF Grade 'S' Fasteners

Bolt Size		Hexagon (A/F)	Condition 1			Condition 2		
in.	mm	in.	Nm	kgf m	lbf ft	Nm	kgf m	lbf ft
1/4	6.3	7/16	11.2	1.1	8.3	10.0	1.0	7.4
5/16	7.9	1/2	22.3	2.3	16.4	20.0	2.0	14.7
3/8	9.5	9/16	40.0	4.1	29.5	36.0	3.7	26.5
7/16	11.1	5/8	64.0	6.5	47.2	57.0	5.8	42.0
1/2	12.7	3/4	98.00	10.0	72.3	88.0	9.0	64.9
9/16	14.3	13/16	140.0	14.3	103.2	126.0	12.8	92.9
5/8	15.9	15/16	196.0	20.0	144.6	177.0	18.0	130.5
3/4	19.0	1 1/8	343.0	35.0	253.0	309.0	31.5	227.9
7/8	22.2	1 15/16	547.0	55.8	403.4	492.0	50.2	362.9
1	25.4	1 1/2	814.0	83.0	600.4	732.0	74.6	539.9
1 1/8	31.7	1 7/8	1181.0	120.4	871.1	1063.0	108.4	784.0
1 1/4	38.1	2 1/4	1646.0	167.8	1214.0	1481.0	151.0	1092.3

Table 8. Torque Settings - Metric Grade 8.8 Fasteners

Bolt Size		Hexagon (A/F)	Condition 1			Condition 2		
ISO Metric Thread	mm	mm	Nm	kgf m	lbf ft	Nm	kgf m	lbf ft
M5	5	8	5.8	0.6	4.3	5.2	0.5	3.8
M6	6	10	9.9	1.0	7.3	9.0	0.9	6.6
M8	8	13	24.0	2.4	17.7	22.0	2.2	16.2
M10	10	17	47.0	4.8	34.7	43.0	4.4	31.7
M12	12	19	83.0	8.5	61.2	74.0	7.5	54.6
M16	16	24	205.0	20.9	151.2	184.0	18.8	135.7
M20	20	30	400.0	40.8	295.0	360.0	36.7	265.5
M24	24	36	690.0	70.4	508.9	621.0	63.3	458.0
M30	30	46	1372.0	139.9	1011.9	1235.0	125.9	910.9
M36	36	55	2399.0	244.6	1769.4	2159.0	220.0	1592.4

Zinc Plated Fasteners and Dacromet Fasteners

Table 9. Metric Grade 10.9 Fasteners

Bolt Size		Hexagon (A/F)	Condition 1			Condition 2		
ISO Metric Thread	mm	mm	Nm	kgf m	lbf ft	Nm	kgf m	lbf ft
M5	5	8	8.1	0.8	6.0	7.3	0.7	5.4
M6	6	10	13.9	1.4	10.2	12.5	1.3	9.2
M8	8	13	34.0	3.5	25.0	30.0	3.0	22.1
M10	10	17	67.0	6.8	49.4	60.0	6.1	44.2
M12	12	19	116.0	11.8	85.5	104.0	10.6	76.7
M16	16	24	288.0	29.4	212.4	259.0	26.4	191.0
M20	20	30	562.0	57.3	414.5	506.0	51.6	373.2
M24	24	36	971.0	99.0	716.9	874.0	89.1	644.6
M30	30	46	1930.0	196.8	1423.5	1737.0	177.1	1281.1
M36	36	55	3374.0	344.0	2488.5	3036.0	309.6	2239.2

Table 10. Metric Grade 12.9 Fasteners

Bolt Size		Hexagon (A/F)	Condition 1			Condition 2		
ISO Metric Thread	mm	mm	Nm	kgf m	lbf ft	Nm	kgf m	lbf ft
M5	5	8	9.8	1.0	7.2	8.8	0.9	6.5
M6	6	10	16.6	1.7	12.2	15.0	1.5	11.1
M8	8	13	40.0	4.1	29.5	36.0	3.7	26.5
M10	10	17	80.0	8.1	59.0	72.0	7.3	53.1
M12	12	19	139.0	14.2	102.5	125.0	12.7	92.2
M16	16	24	345.0	35.2	254.4	311.0	31.7	229.4
M20	20	30	674.0	68.7	497.1	607.0	61.9	447.7
M24	24	36	1165.0	118.8	859.2	1048.0	106.9	773.0
M30	30	46	2316.0	236.2	1708.2	2084.0	212.5	1537.1
M36	36	55	4049.0	412.9	2986.4	3644.0	371.6	2687.7

Table 11. Torque Settings - Rivet Nut Bolts/Screws

Bolt Size				
ISO Metric Thread	mm	Nm	kgf m	lbf ft
M3	3	1.2	0.1	0.9
M4	4	3.0	0.3	2.0
M5	5	6.0	0.6	4.5
M6	6	10.0	1.0	7.5
M8	8	24.0	2.5	18.0
M10	10	48.0	4.9	35.5
M12	12	82.0	8.4	60.5

Table 12. Torque Settings - Internal Hexagon Headed Cap Screws (Zinc)

Bolt Size			
ISO Metric Thread	Nm	kgf m	lbf ft
M3	2.0	0.2	1.5
M4	6.0	0.6	4.5
M5	11.0	1.1	8.0
M6	19.0	1.9	14.0
M8	46.0	4.7	34.0
M10	91.0	9.3	67.0
M12	159.0	16.2	117.0
M16	395.0	40.0	292.0
M18	550.0	56.0	406.0
M20	770.0	79.0	568.0
M24	1332.0	136.0	983.0

Hydraulic Connections

T11-003

'O' Ring Face Seal System

Adaptors Screwed into Valve Blocks

Adaptor screwed into valve blocks, seal onto an 'O' ring which is compressed into a 45° seat machined into the face of the tapped port.

Table 13. Torque Settings - BSP Adaptors

BSP Adaptor Size	Hexagon (A/F)			
in.	mm	Nm	kgf m	lbf ft
1/4	19.0	18.0	1.8	13.0
3/8	22.0	31.0	3.2	23.0
1/2	27.0	49.0	5.0	36.0
5/8	30.0	60.0	6.1	44.0
3/4	32.0	81.0	8.2	60.0
1	38.0	129.0	13.1	95.0
1 1/4	50.0	206.0	21.0	152.0

Table 14. Torque Settings - SAE Connections

SAE Tube Size	SAE Port Thread Size	Hexagon (A/F) mm	Nm	kgf m	lbf ft
4	7/16 - 20	15.9	20.0 - 28.0	2.0 - 2.8	16.5 - 18.5
6	9/16 - 18	19.1	46.0 - 54.0	4.7 - 5.5	34.0 - 40.0
8	3/4 - 16	22.2	95.0 - 105.0	9.7 - 10.7	69.0 - 77.0
10	7/8 - 14	27.0	130.0 - 140.0	13.2 - 14.3	96.0 - 104.0
12	1 1/16 - 12	31.8	190.0 - 210.0	19.4 - 21.4	141.0 - 155.0
16	1 5/16 - 12	38.1	290.0 - 310.0	29.6 - 31.6	216.0 - 230.0
20	1 5/8	47.6	280.0 - 380.0	28.5 - 38.7	210.0 - 280.0

Hoses Screwed into Adaptors

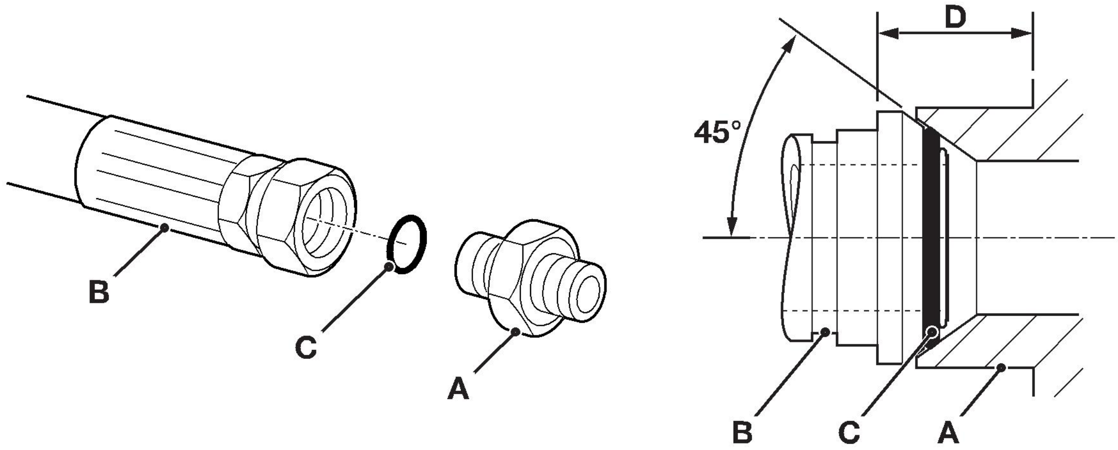


Fig 10.

Hoses **10-B** screwed into adaptors **10-A** seal onto an `O' ring **10-C** which is compressed into a 45° seat machined into the face of the adaptor port.

Note: *Dimension* ***10-D*** *will vary depending upon the torque applied.*

Table 15. BSP Hose - Torque Settings

BSP Hose Size	Hexagon (A/F)			
in.	**mm**	**Nm**	**kgf m**	**lbf ft**
1/8	14.0	14.0 - 16.00	1.4 - 1.6	10.3 - 11.8
1/4	19.0	24.0 - 27.0	2.4 - 2.7	17.7 - 19.9
3/8	22.0	33.0 - 40.0	3.4 - 4.1	24.3 - 29.5
1/2	27.0	44.0 - 50.0	4.5 - 5.1	32.4 - 36.9
5/8	30.0	58.0 - 65.0	5.9 - 6.6	42.8 - 47.9
3/4	32.0	84.0 - 92.0	8.6 - 9.4	61.9 - 67.8
1	38.0	115.0 - 126.0	11.7 - 12.8	84.8 - 92.9
1 1/4	50.0	189.0 - 200.0	19.3 - 20.4	139.4 - 147.5
1 1/2	55.0	244.0 - 260.0	24.9 - 26.5	180.0 - 191.8

Adaptors into Component Connections with Bonded Washers

Table 16. BSP Adaptors with Bonded Washers - Torque Settings

BSP Size			
in.	**Nm**	**kgf m**	**lbf ft**
1/8	20.0	2.1	15.0
1/4	34.0	3.4	25.0
3/8	75.0	7.6	55.0
1/2	102.0	10.3	75.0
5/8	122.0	12.4	90.0
3/4	183.0	18.7	135.0
1	203.0	20.7	150.0
1 1/4	305.0	31.0	225.0
1 1/2	305.0	31.0	225.0

'Torque Stop' Hose System

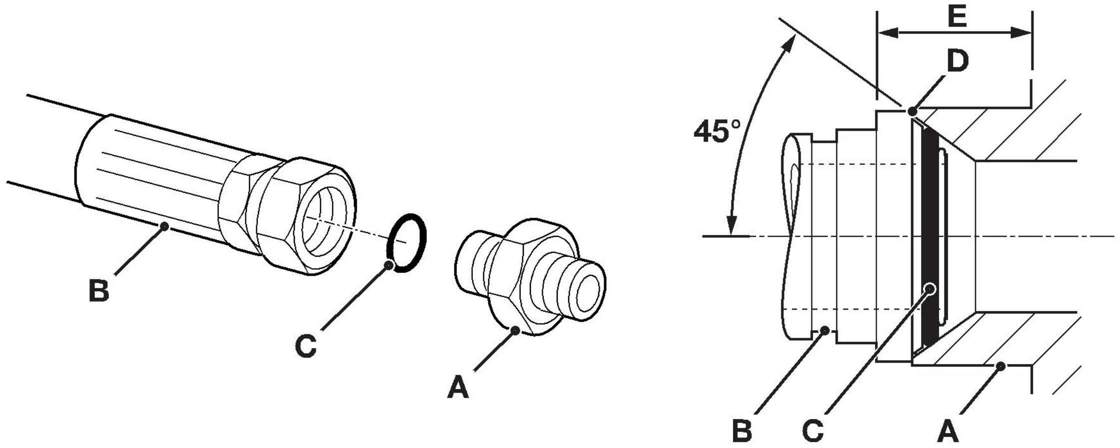


Fig 11.

`Torque Stop' Hoses **11-B** screwed into adaptors **11-A** seal onto an 'O' ring **11-C** which is compressed into a 45° seat machined in the face of the adaptor port. To prevent the 'O' ring being damages as a result of over tightening, 'Torque Stop' Hoses have an additional shoulder **11-D**, which acts as a physical stop.

Note: *Minimum dimension **11-E** fixed by shoulder **11-D**.*

Table 17. BSP `Torque Stop' Hose - Torque Settings

BSP Hose Size	Hexagon (A/F)			
in.	mm	Nm	kgf m	lbf ft
1/8	14.0	14.0	1.4	10.0
1/4	19.0	27.0	2.7	20.0
3/8	22.0	40.0	4.1	30.0
1/2	27.0	55.0	5.6	40.0
5/8	30.0	65.0	6.6	48.0
3/4	32.0	95.0	9.7	70.0
1	38.0	120.0	12.2	89.0
1 1/4	50.0	189.0	19.3	140.0
1 1/2	55.0	244.0	24.9	180.0

Torque + Angle Explanation

Insufficient preload of a bolted joint can cause major problems, such as cylinder head warp, leaking gasket joints etc. There are several methods of achieving an accurate preload of a bolted joint, the two main methods used on the JCB 444 engine are:

1) Torque Control Tightening

2) Angle Control Tightening

1 Torque Control Tightening

Using a torque meter to control the torque is the most popular means of controlling preload, and in the majority of instances this method is adequate. It should be noted that with this process, the majority of the torque is used to overcome friction, therefore slight variations in the frictional conditions can lead to large changes in the bolt preload.

2 Angle Control Tightening

Where a more precise preload is required, the `torque + angle' tightening method is used. The bolt is tightened to a predetermined torque (this may be done in stages), and then as a final sequence, the bolt is tightened to a predetermined angle - this method of tightening the bolts results in a smaller variation in the final preload.

It is critical that the predetermined tightening angle is accurately achieved, failure to tighten accurately to the specified angle could result in the bolt preload being incorrect - this will lead to eventual failures. It is good practice to replace all bolts that have been tightened using the torque + angle procedure.

Torque + Angle Tightening Procedure

The following example explains the recommended torque + angle procedure. A torque angle gauge should be used for accuracy, but as a visual check, the bolts can be match marked as described below.

1 Tighten the bolt to the specified torque (specified torque values will be detailed in the relevant sections).

2 Mark a line across the centre of the bolt, and a second line on the part to be clamped - the two lines should be aligned, as shown at **A**.

3 Mark a third line at the specified torque angle - in this instance the additional torque angle is 90°. This line must be marked the specified angle in a clockwise direction (to further tighten the bolt), as shown at **B**.

4 In some instances, angle torque tightening can be specified in two stages, for instance in this example, the first angle quoted is 90° (shown at **B**), and then a second angle of 180°. The additional 180° angle is from the LAST tightened position - as shown at **C**.

5 Tighten the bolt so that the line on the bolt aligns with the angle(s) marked on the item to be clamped - remember, to ensure complete accuracy an angle gauge should be used.

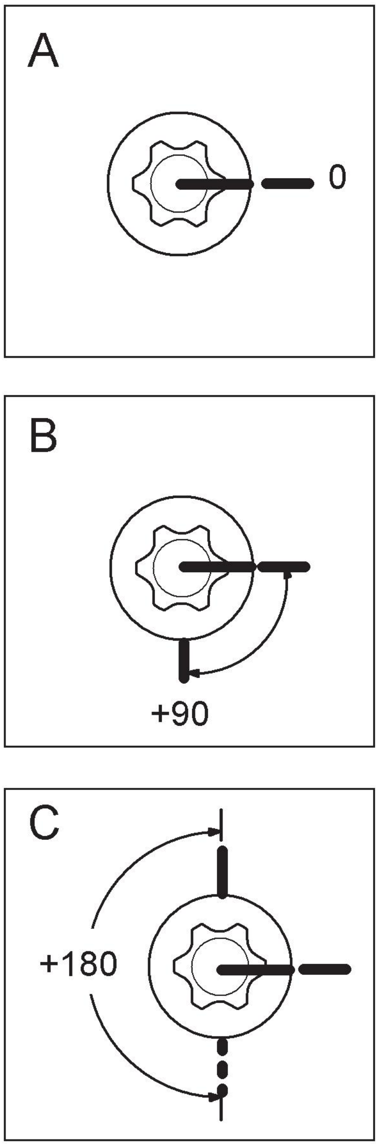


Fig 12.

Engine Torque Figures

This section details all the torque figures to be used on the JCB 444 Engine. Some of the torques MUST be used in conjunction with the recommended procedures contained in this manual, for instance if the torques need to be applied in a specific sequence. For convenience, the list below is arranged in alphabetical order to help you quickly locate the item.

Item

Item

Table 18. Cylinder Head Bolts

Item	Nm	lbf ft	Angle
Cylinder head to block bolts[1] x 12			
- first stage torque	40	30	-
- second stage torque	75	56	-
- third stage torque	75	56	-
- fourth stage torque	-	-	+ 90°
- final stage torque	-	-	+ 180°

Note[1]: Torque information MUST be used in conjunction with recommended procedures contained in this manual.

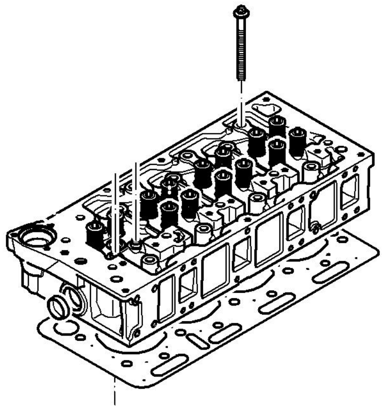


Fig 13.

Table 19. Injector Sleeve

Item	Nm	lbf ft	Angle
Injector Sleeve	36-42	27-31	-

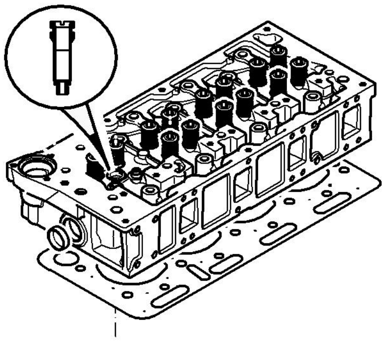


Fig 14.

Table 20. Bedplate Bolts

Item	Nm	lbf ft	Angle
Bedplate to block[1]			
Bolts A - initial snug torque	50	37	-
Bolts B	24	18	-
Bolts A - second stage	115	85	-
Bolts A - final stage angle torque	-	-	+ 180°

Note[1]: Torque information MUST be used in conjunction with recommended procedures contained in this manual.

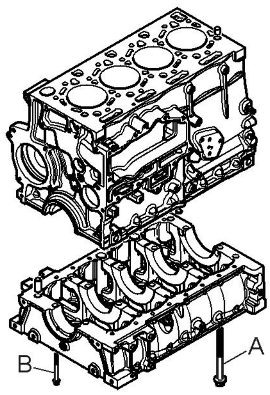


Fig 15.

Table 21. Fuel Pump Retaining Nuts

Item	Nm	lbf ft	Angle
Fuel pump retaining nuts	22-26	16-19	-

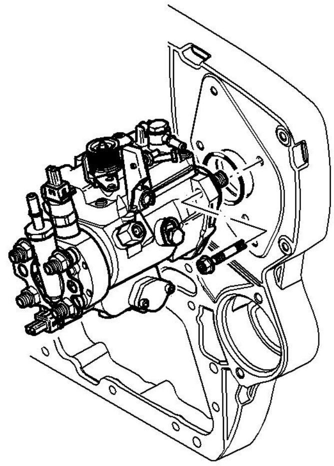


Fig 16.

Table 22. Gear Case to Cylinder Bolts

Item	Nm	lbf ft	Angle
Gear case to cylinder block bolts	31-35	23-26	-

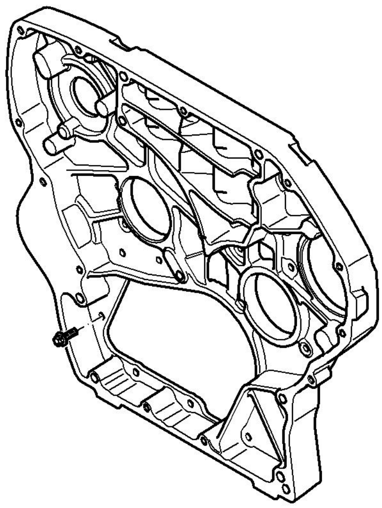


Fig 17.

Table 23. Oil Pump Bolts

Item	Nm	lbf ft	Angle
Oil pump bolts	22-26	16-19	-

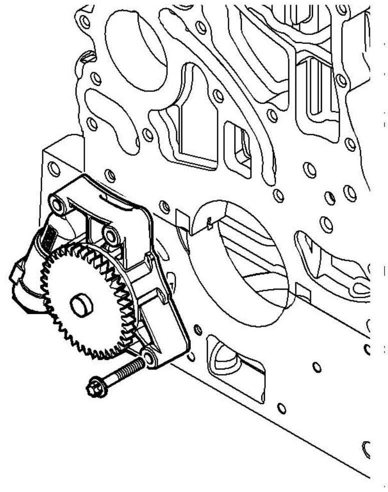


Fig 18.

Table 24. Idler Blanking Plug

Item	Nm	lbf ft	Angle
Idler blanking plug	17-19	13-14	-

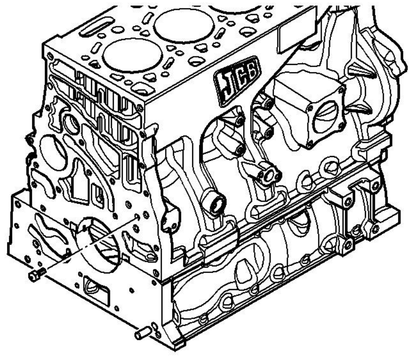


Fig 19.

Table 25. Idler Gear Hub Assembly Bolts

Item	Nm	lbf ft	Angle
Idler gear hub assembly bolts	60-70	44-52	-

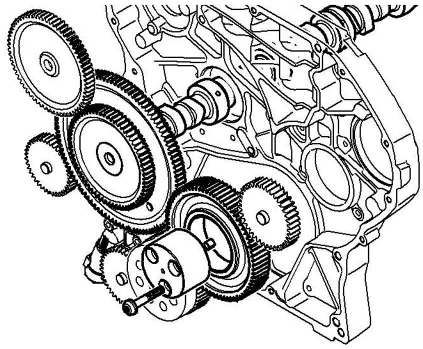


Fig 20.

Table 26. Flywheel Hub to Crank Bolts

Item	Nm	lbf ft	Angle
Flywheel hub to crank gear bolts	43-51	32-38	-

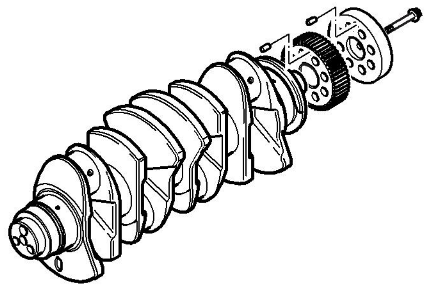


Fig 21.

Table 27. Flywheel Housing Bolts

Item	Nm	lbf ft	Angle
Flywheel housing to gearcase bolts			
- M10 bolts (x 6)	43-51	32-38	-
- M8 bolts (x 12)	22-26	16-19	-

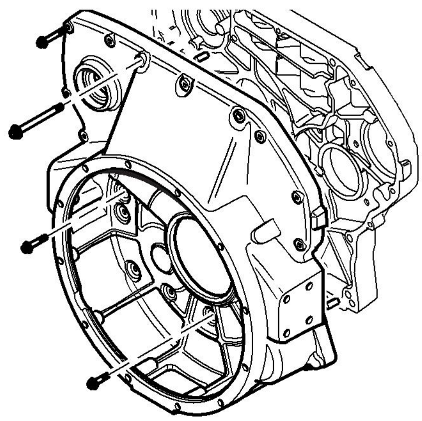


Fig 22.

Table 28. Piston Conrod End Cap Bolts

Item	Nm	lbf ft	Angle
Piston conrod end cap bolts(1)			
- first stage torque	35	26	-
- second stage torque	65	48	-
- third stage angle torque			+ 90°

Note(1): Torque information MUST be used in conjunction with recommended procedures contained in this manual.

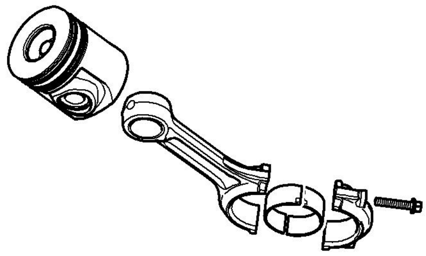


Fig 23.

Table 29. Fan Belt Tensioner Bolts

Item	Nm	lbf ft	Angle
Fan belt tensioner retaining bolts	22-26	16-19	-

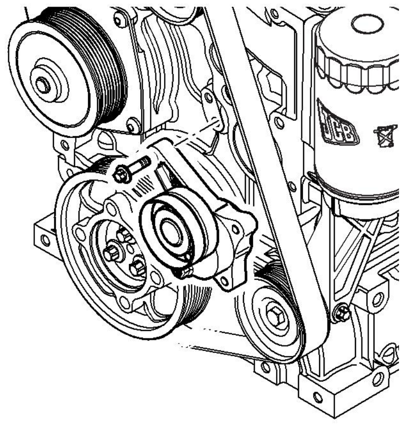


Fig 24.

Table 30. Oil Sump Retaining Bolts

Item	Nm	lbf ft	Angle
Oil sump retaining bolts **A**	22-26	16-19	-
Oil sump plug **B**	40-60	30-44	-

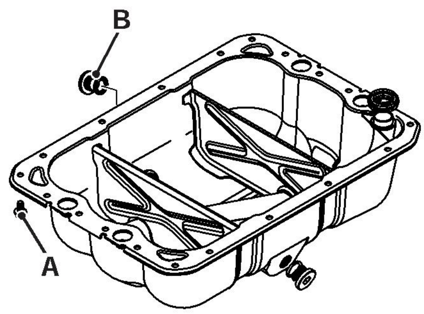


Fig 25.

Table 31. Injection Pump Lock Pin

Item	Nm	lbf ft	Angle
Injection pump lock pin	12	9	-

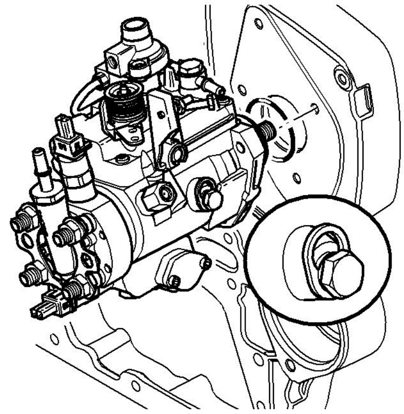


Fig 26.

Table 32. Injection Pump Gear Nut

Item	Nm	lbf ft	Angle
Injection pump gear retaining nut[1]			
- first stage torque	25	18.5	-
- second stage torque	90	67	-

Note[1]: Torque information MUST be used in conjunction with recommended procedures contained in this manual.

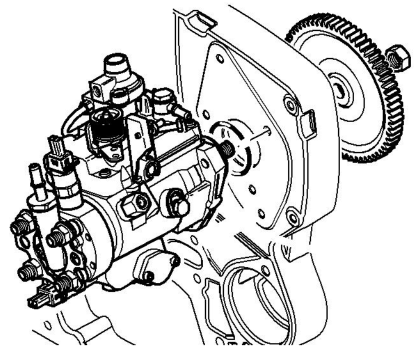


Fig 27.

Table 33. Rocker Shaft Bolts

Item	Nm	lbf ft	Angle
Rocker shaft to cylinder head bolts **A**	22-26	16-19	-

Note: The valve lash adjusting screw **B** must have a minimum turning torque of 12Nm. If the turning torque is less than 12Nm, then a new adjusting screw must be fitted.

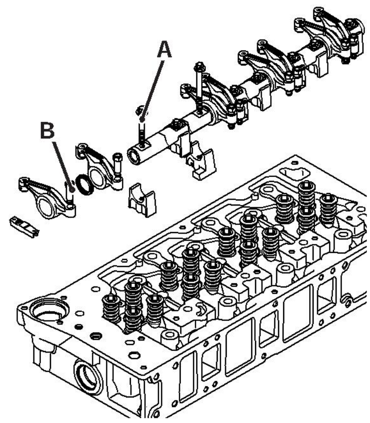


Fig 28.

Table 34. Injector Clamp Bolts

Item	Nm	lbf ft	Angle
Injector clamp bolts	22-26	16-19	-

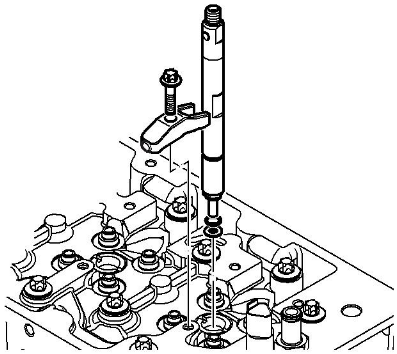


Fig 29.

Table 35. Rocker Cover Bolts

Item	Nm	lbf ft	Angle
Rocker cover retaining bolts	20-24	16-19	-

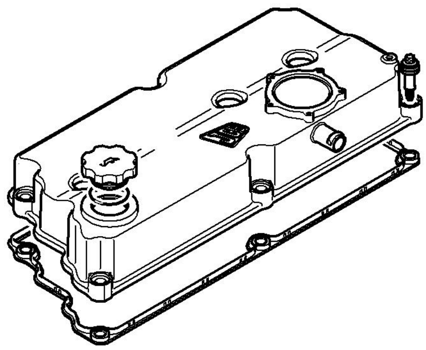


Fig 30.

Table 36. Oil Cooler To Cylinder Block

Item	Nm	lbf ft	Angle
Oil cooler housing to cylinder block bolts **A**	22-26	16-19	-
Oil cooler matrix to oil cooler housing bolts **B**	21-25	15-18	-
Oil filter drain plug **C**	35-40	26-29	-

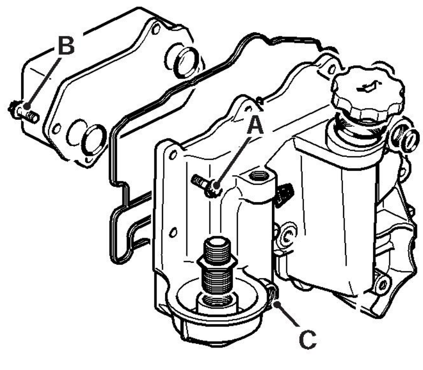


Fig 31.

Table 37. Fuel Injection Pump Cap

Item	Nm	lbf ft	Angle
FIP tamper-proof cap	65-75	48-56	-

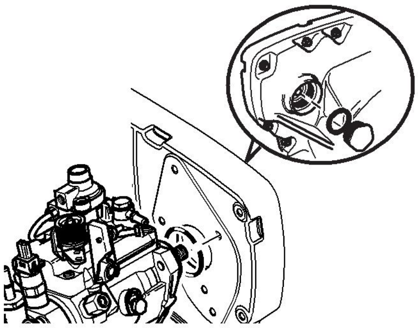


Fig 32.

Table 38. Thermostat Housing Bolts

Item	Nm	lbf ft	Angle
Thermostat housing retaining bolts	22-26	16-19	-

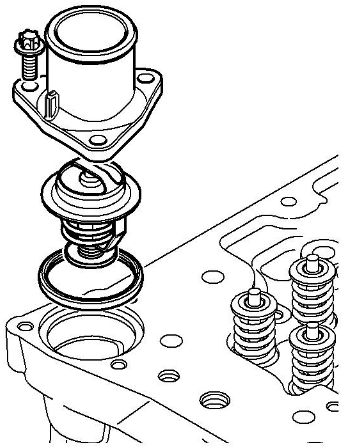


Fig 33.

Table 39. Water Inlet Connector Bolts

Item	Nm	lbf ft	Angle
Water inlet connector retaining bolts	22-26	16-19	-

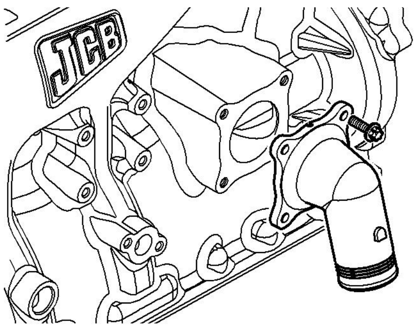


Fig 34.

Table 40. Water Heater Outlet Connector

Item	Nm	lbf ft	Angle
Water heater outlet connector	25-30	19-22	-

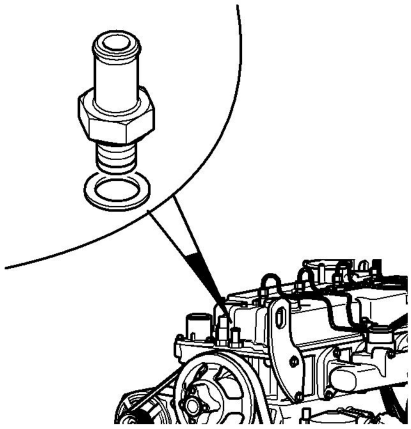


Fig 35.

Table 41. Water Pump Bolts

Item	Nm	lbf ft	Angle
Water pump retaining bolts	22-26	16-19	-

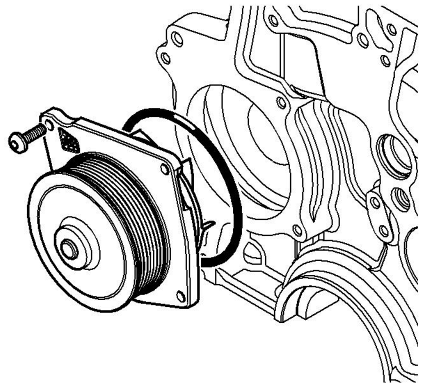


Fig 36.

Table 42. Water Temperature Sender/Switch

Item	Nm	lbf ft	Angle
Water temperature sender/switch	16	12	-

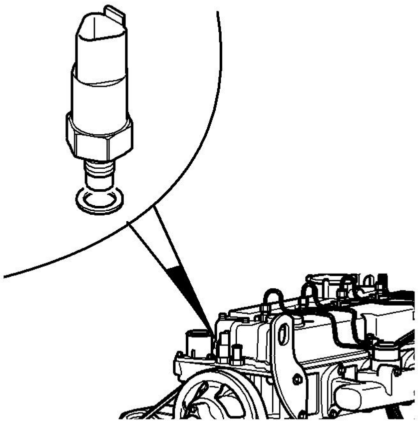


Fig 37.

Table 43. Cold Start Advance Switch

Item	Nm	lbf ft	Angle
Cold start advance switch	16	12	-

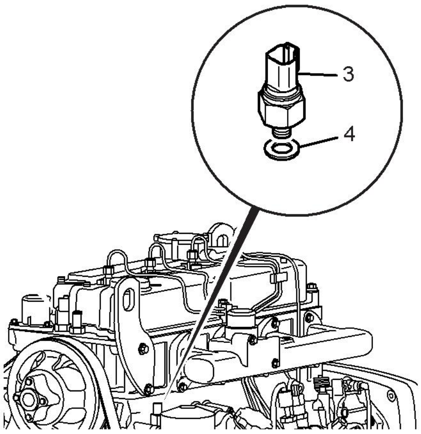


Fig 38.

Table 44. Fuel Lift Pump Bolts

Item	Nm	lbf ft	Angle
Fuel lift pump retaining bolts	22-26	16-19	-

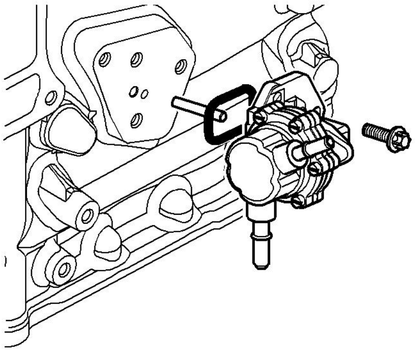


Fig 39.

Table 45. Exhaust Manifold Bolts

Item	Nm	lbf ft	Angle
Exhaust manifold retaining bolts			
- first stage	25	19	-
- final stage angle torque			+ 90°

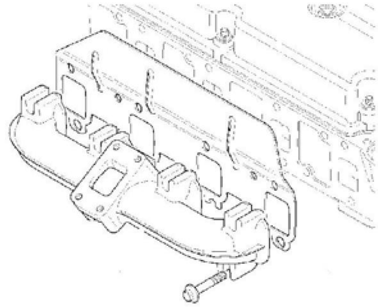


Fig 40.

Table 46. Inlet Manifold Bolts

Item	Nm	lbf ft	Angle
Inlet manifold retaining bolts	22-26	16-19	-

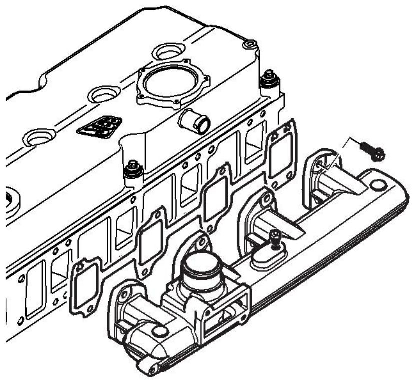


Fig 41.

Table 47. High Pressure Fuel Pipes

Item	Nm	lbf ft	Angle
High pressure fuel pipes	25-29	19-22	-

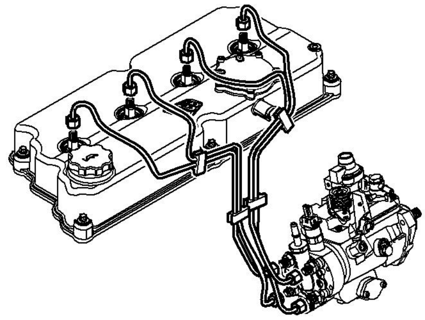


Fig 42.

Table 48. Turbo Charger to Exhaust Manifold Nuts

Item	Nm	lbf ft	Angle
Turbo charger to exhaust manifold retaining nuts	22-26	16-19	-

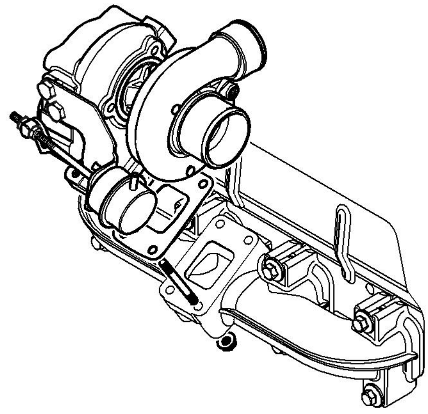


Fig 43.

Table 49. Power Take Off (PTO) Pump Bolts

Item	Nm	lbf ft	Angle
Power take off (PTO) pump bolts			
- SAE `A' - M10 bolts	43-51	32-38	-
- SAE `B' - M12 bolts	73-89	54-66	-

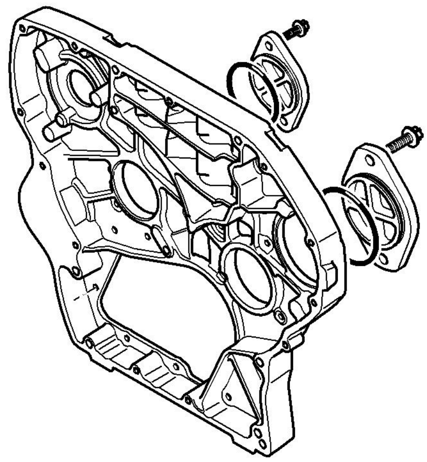


Fig 44.

Table 50. Flywheel to Crankshaft Hub Bolts

Item	Nm	lbf ft	Angle
Flywheel to crankshaft hub retaining bolts[(1)]			
- first stage torque	40	30	-
- second stage torque	120	89	-
- final stage angle torque	-	-	+ 120°

Note[(1)]: Torque information MUST be used in conjunction with recommended procedures contained in this manual.

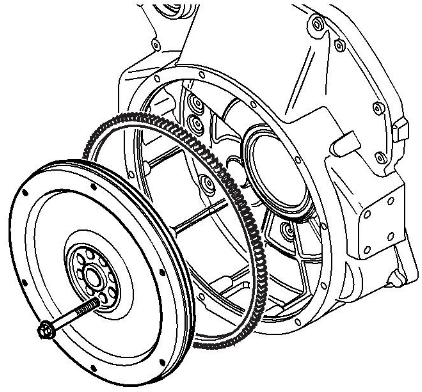


Fig 45.

Table 51. Front Pulley to Crankshaft Bolts

Item	Nm	lbf ft	Angle
Front pulley to crankshaft retaining bolts[(1)]			
- first stage torque	30	22	-
- second stage torque	75	56	-
- final stage angle torque	-	-	+ 180°

Note[(1)]: Torque information MUST be used in conjunction with recommended procedures contained in this manual.

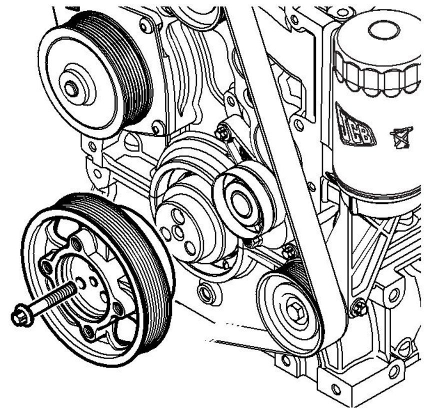


Fig 46.

Table 52. Lifting Bracket Bolts

Item	Nm	lbf ft	Angle
Lifting bracket retaining bolts	43-51	32-38	-

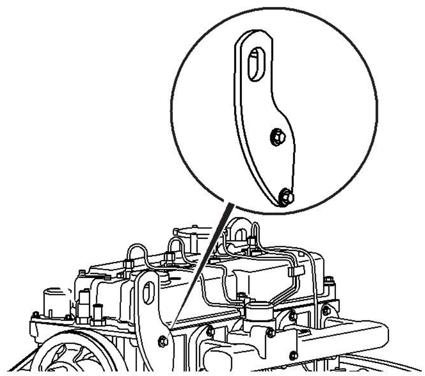


Fig 47.

Table 53. Starter Motor Bolts

Item	Nm	lbf ft	Angle
Starter motor retaining bolts	43-51	32-38	-

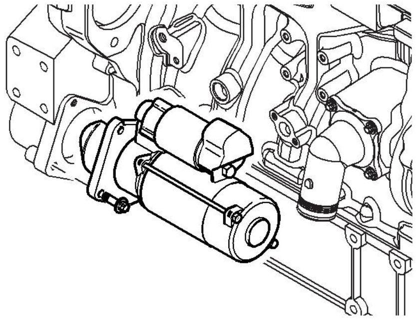


Fig 48.

Lubricants and Capacities

Engine Lubricating Oil

New engines DO NOT require a running-in period. The engine/machine should be used in a normal work cycle immediately, glazing of the piston cylinder bores, resulting in excessive oil consumption, could occur if the engine is gently run-in. Under no circumstances should the engine be allowed to idle for extended periods; (e.g. warming up without load).

A minimum API CF4 grade oil must be used. Superior grade oils may be more appropriate for heavy duty applications (such as sustained high loads and operation at elevated temperatures).

The choice of lubricant viscosity should be made based on the lowest ambient temperature at which the machine will be started and the maximum ambient temperature at which it will operate.

The following table provides guidance as to the temperature range that can be accommodated by standard oil viscosities and can be used to select an appropriate grade. ⇨ Table 54. (1-57).

Table 54.

Oil Viscosity	Minimum Temperature °C (°F)	Maximum Temperature °C (°F)
SAE 0W30	- 40 (-40)	+ 30 (86)
SAE 0W20	- 40 (-40)	+ 10 (50)
SAE 5W20	- 30 (-22)	+ 10 (50)
SAE 5W40	- 30 (-22)	+ 40 (104)
SAE 10W30	- 20 (-4)	+ 40 (104)
SAE 15W40	- 15 (-5)	+ 50 (122)

Recommended Oils

Table 55.

Engine Oil	Specification
JCB High Performance(1)	ACEA E2:B2:A2, API CF4/SG(1)
JCB Extreme Performance	ACEA E5/B3/A3, API CH-4/SJ

(1) Not suitable for generator set applications.

Engine Oil Capacity

Choose the grade of oil to suit the temperature range as detailed. ⇨ Table 54. (1-57). The engine oil capacity, including filter and clean sump is 12 litres MIN and 15 litres MAX mark on the dipstick.

Table 56.

Item	Capacity litres (UK Gal)	
	Minimum	Maximum
Engine	12 (2.6)	15 (3.3)

Coolant Mixtures

WARNING

Antifreeze can be harmful. Obey the manufacturer's instructions when handling full strength or diluted antifreeze.

7-3-4-4_1

The protection provided by JCB Four Seasons Antifreeze and Summer Coolant is shown below. If any other anti-freeze is used, refer to the manufacturer's instructions and ensure that a corrosion inhibitor is included. DO NOT use solutions of more than 60% or less than 50% or damage to the cooling system will occur.

55% Solution - Maintains circulation down to -36 deg C (-33 deg F), protects against damage down to -41 deg C (-42 deg F)

The strength of the anti-freeze solution must be checked at least once a year, preferably at the beginning of the cold period. It is an advantage to leave the anti-freeze in all the year round as it gives continued protection against corrosion. Always renew the anti-freeze every two years. A 50% anti-freeze mixture must be used even if frost protection is not needed. This gives protection against corrosion and raises the coolant's boiling point.

It should be noted that serious damage to the cooling system can occur if corrosion inhibitors are not used.

Service Aids

Sealing, Retaining and Care Compounds

Part Number	Description and Application
4102/3800	RTV silicone sealant - oil pan to bedplate
320/00831	Anaerobic sealant - bedplate to block
	Anaerobic sealant - gear case to block
	Anaerobic sealant - flywheel housing to gear case
320/00829	Rubber lubricant Gel - injector Sleeve O-ring
	Rubber lubricant Gel - rear crankshaft oil seal
	Rubber lubricant Gel - front crankshaft oil seal
320/00812	Anaerobic Adhesive - all core plugs
4102/3500	Anaerobic retaining adhesive - injector sleeve threads
4104/1557	Cleaner and degreaser - for degreasing components prior to use of anaerobic sealant.
4104/2900	Degreaser
4104/3200	Gasket remover

Service Tools

General Engine Tools

The following `general' service tools are recommended to perform safe and correct engine repair procedures.

When applicable, the JCB part number will be shown immediately below the tool title.

If there is no part number, the tool is not available from JCB Service. In this instance, the tool can be purchased from any good tool store.

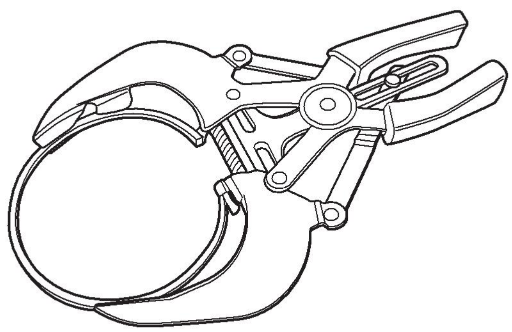


Fig 49. Piston Ring Expander Tool

Use to install piston rings on to the piston. Ensures the rings are fitted without damage or distortion.

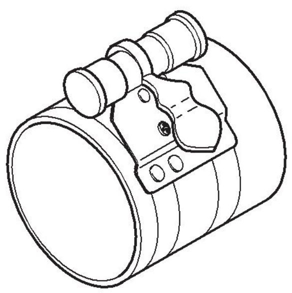


Fig 50. Piston Ring Compressor Tool

Use to compress the piston rings in preparation for fitting the piston assembly into the cylinder bore.

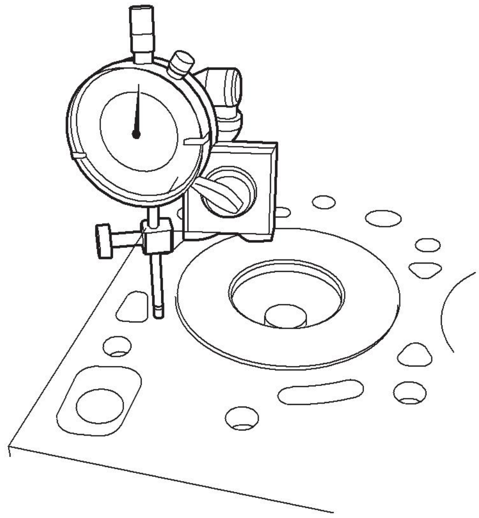


Fig 51. Dial Test Indicator

Use in a number of applications where it is necessary to measure accurate dimensions.

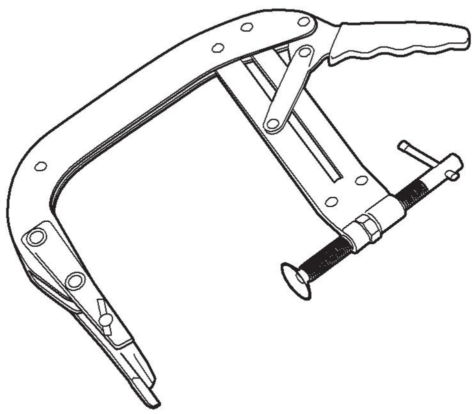


Fig 52. Valve Spring Compressor Tool

Use to install and remove valve spring collets.

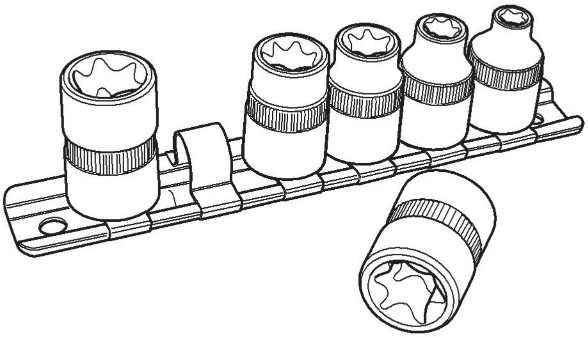


Fig 53. Star Drive (Torx®) Heavy Duty Set

Use to loosen and tighten all star drive fasteners. Use in conjunction with a good quality, calibrated torque wrench.

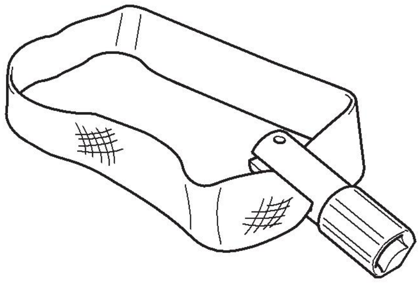


Fig 54. 892/00292 Oil Filter Wrench

Use to install or remove spin-on filter canister.

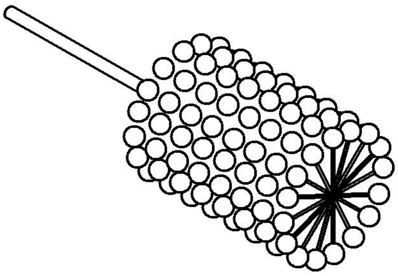


Fig 55. 892/00041 Bore De-Glazing Tool

De-glazing tool for cylinder bores (to assist bedding-in of new piston rings).

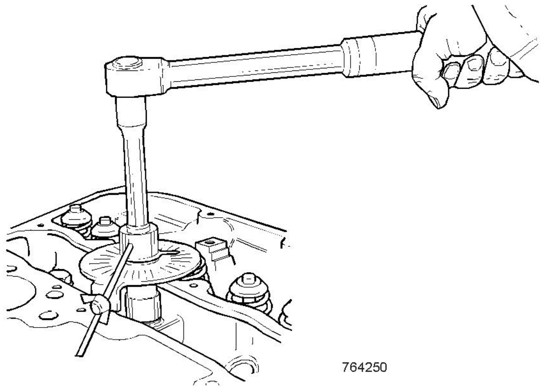


Fig 56. Torque + Angle Tool

Use to accurately torque bolts. The torque + angle method is used extensively on the JCB 444 Engine.

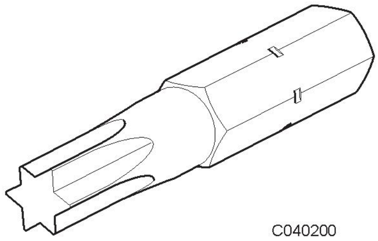


Fig 57. Star Drive (Torx®) Heavy Duty Socket Bit (T40 size)

Use to loosen and tighten the coolant pump retaining bolts.Use in conjunction with a good quality, calibrated torque wrench.

Specialist Engine Tools

The following `specialist' service tools are required to perform safe and correct engine repair procedures.

The tools can be ordered using the tool part number detailed.

For reference, a copy of the tool drawings is included in section 10. If the tools are to be made locally, the correct grade of material must be used.

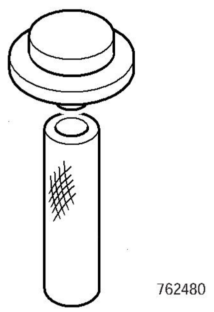


Fig 58. 892/01146 Cylinder Block Core Plug Fitting Tool

Use to correctly fit cylinder block core plugs. Tool includes handle and different size cups to suit various size core plugs.

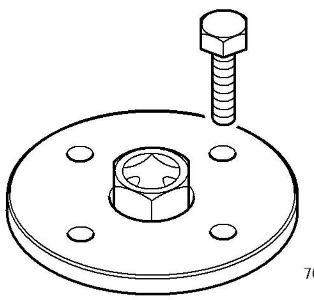


Fig 59. 892/01147 Crankshaft Turning Tool

Use to manually turn the crankshaft, for instance when setting top dead centre (TDC). 4 x mounting holes to suit crankshaft pulley.

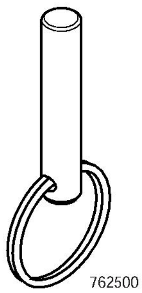


Fig 60. 892/01148 Timing Pin (Crankshaft)

Use to correctly align the crankshaft at top dead centre (TDC).

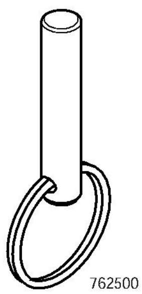


Fig 61. 892/01148 Timing Pin (Camshaft)

Use to align the camshaft in the correct timed position when removing/fitting the fuel injection pump.

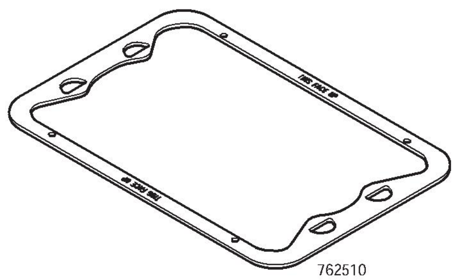


Fig 62. 892/01149 Template For Application Of Oil Sump Sealant

Use to ensure correct sealant application.

Note: *Correct positioning of the sealant is critical to prevent leaks.*

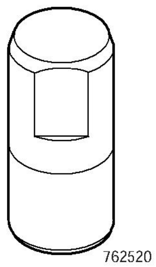


Fig 63. 892/01150 Oil Sump Location Dowels (2 off required)

Use to correctly align the sump, prevent sump movement during fitting.

Note: *Correct positioning of the sump is critical to ensure a good joint and prevent leaks.*

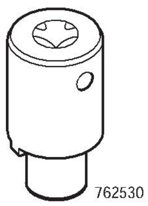


Fig 64. 892/01151 Injector Sleeve Fitting/Removing Tool

Use to fit and remove the injector sleeves. The sleeves are pre-fitted on cylinder head assemblies.

Fig 65. 892/01152 Valve Stem Seals Fitting Tool

Use to ensure positive engagement of the valve stem seals.

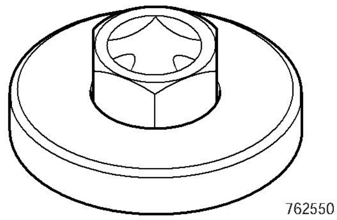


Fig 66. 892/01154 Fuel Injection Pump, Tool For Removing The Tamper-proof Cover

Use to gain access to the FIP gear retaining locknut. The tool is used to remove the tamper proof cover.

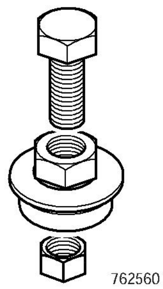


Fig 67. 892/01155 Fuel Injection Pump Gear Removal Tool

Use to remove the gear from the fuel injection pump shaft.

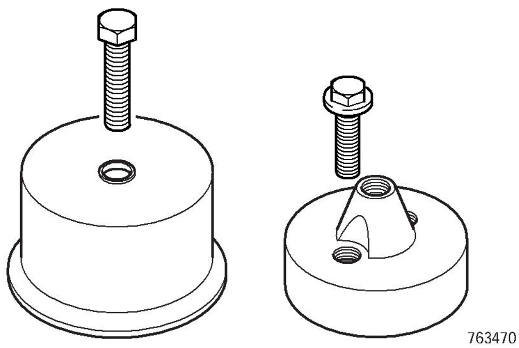


Fig 68. 892/01157 Crankshaft Front Oil Seal Fitting Tool

Use to correctly fit the crankshaft front oil seal.

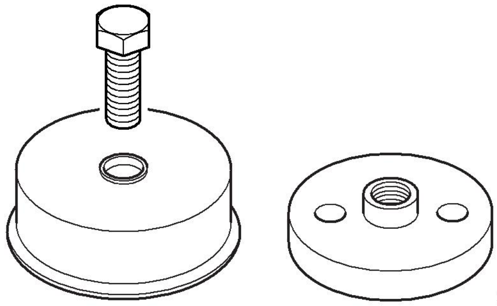

763480

Fig 69. 892/01156 Crankshaft Rear Oil Seal Fitting Tool

Use to correctly fit the crankshaft rear oil seal.

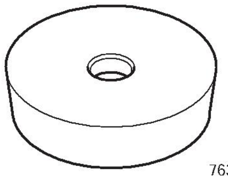

763490

Fig 70. 892/01158 Crankshaft Rear Oil Seal Alignment Tool

Use to position the crankshaft rear oil seal before using fitting tool 892/01156. This tool must be used to position the seal, otherwise the lip of the seal may be `inverted' during the fitting process - leading to potential oil leak.

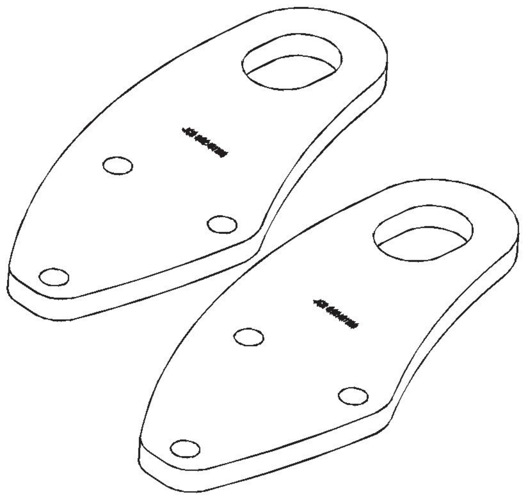


Fig 71. 892/01160 (x 2) Lifting Brackets

Use to safely lift and lower the engine, lifting brackets are purposed designed.

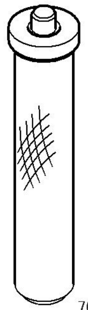

762610

Fig 72. 892/01159 Rocker Cover Injector Seals Fitting Tool

Use to correctly set and fit the rocker cover injector seals.

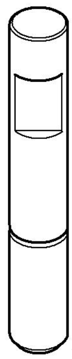

762620

Fig 73. 892/01168 Dummy Injector

Use in place of the injector to check engine compression. End drilled and tapped 1/8-28BSP to accept universal adaptor fitting.

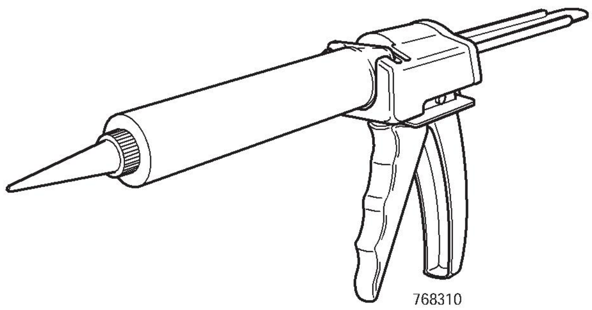


Fig 74. 892/01173 Sealant Applicator

Use to apply the anaerobic and silicone sealant evenly and correctly.

Note: *For reference use the following sealant bead sizes: 1.5 mm bead for anaerobic sealant, 4.0 mm bead for silicone sealant .*

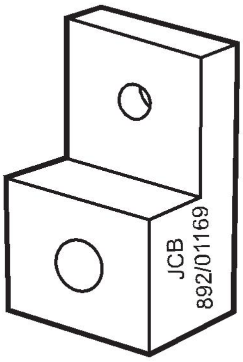


Fig 75. 892/01169 Top Dead Centre (TDC) Setting Tool

Use to correctly set the No. 1 piston to TDC (firing) when removing and replacing the fuel injection pump.

Fig 76. 892/01179 `C' Shaped Ring Spanner

Use to access the inner mounting nut of the fuel injection pump.

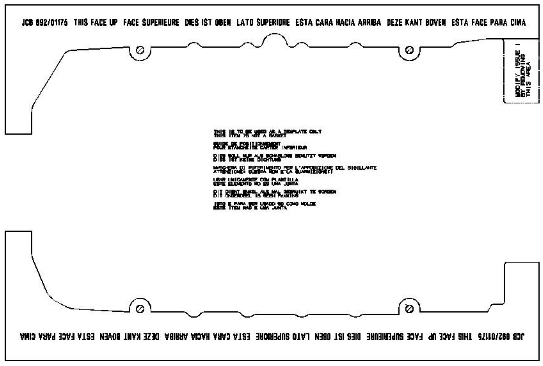


Fig 77. 892/01175 Template For Application Of Bedplate To Engine Block Anaerobic Sealant

Use to ensure correct sealant application.

Note: *Correct positioning of the sealant is critical to ensure joint integrity.*

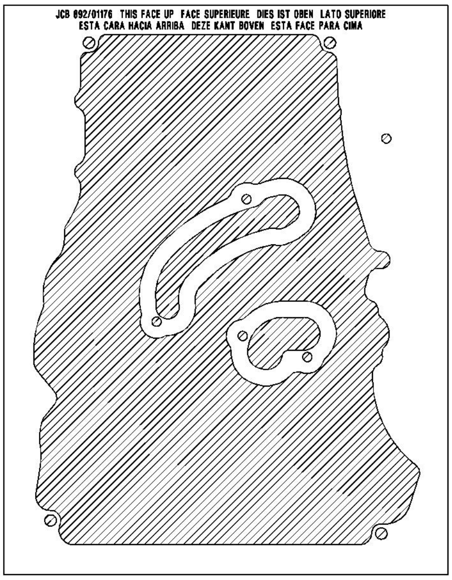


Fig 78. 892/01176 Template For Application Of Gear Case To Engine Block Anaerobic Sealant

Use to ensure correct sealant application.

Note: *Correct positioning of the sealant is critical to ensure joint integrity.*

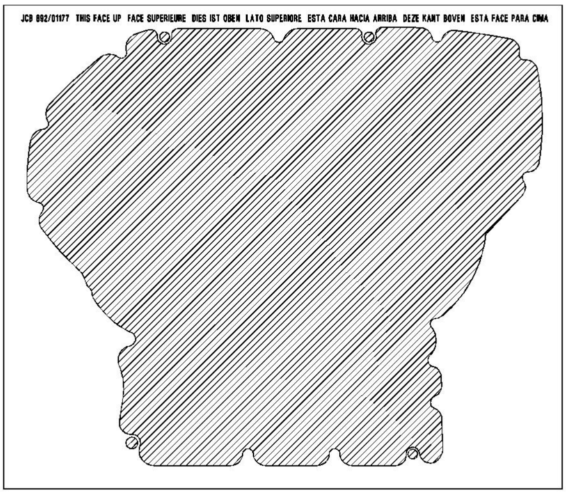


Fig 79. 892/01176 Template For Application Of Flywheel Housing To Gear Case Anaerobic Sealant

Use to ensure correct sealant application.

Note: *Correct positioning of the sealant is critical to ensure joint integrity.*

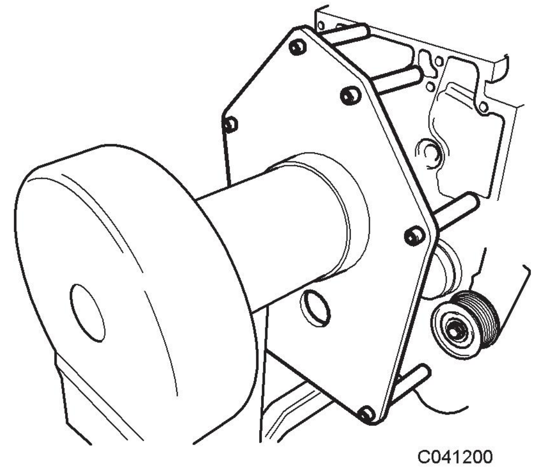


Fig 80. Engine Mounting Frame

For use with a suitable engine stand. Manufacture locally. ⇨ ***Service Tool Drawings (1-67)***

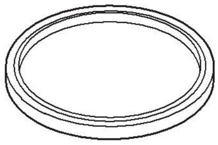


Fig 81. 892/01259 Crankshaft Rear Oil Seal Spacer Ring

For use with specific engine builds only - See parts catalogue.

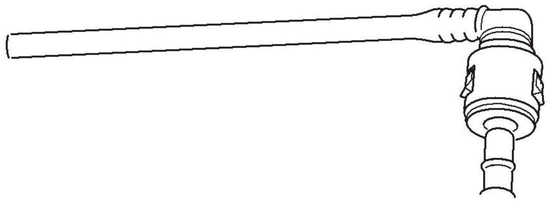
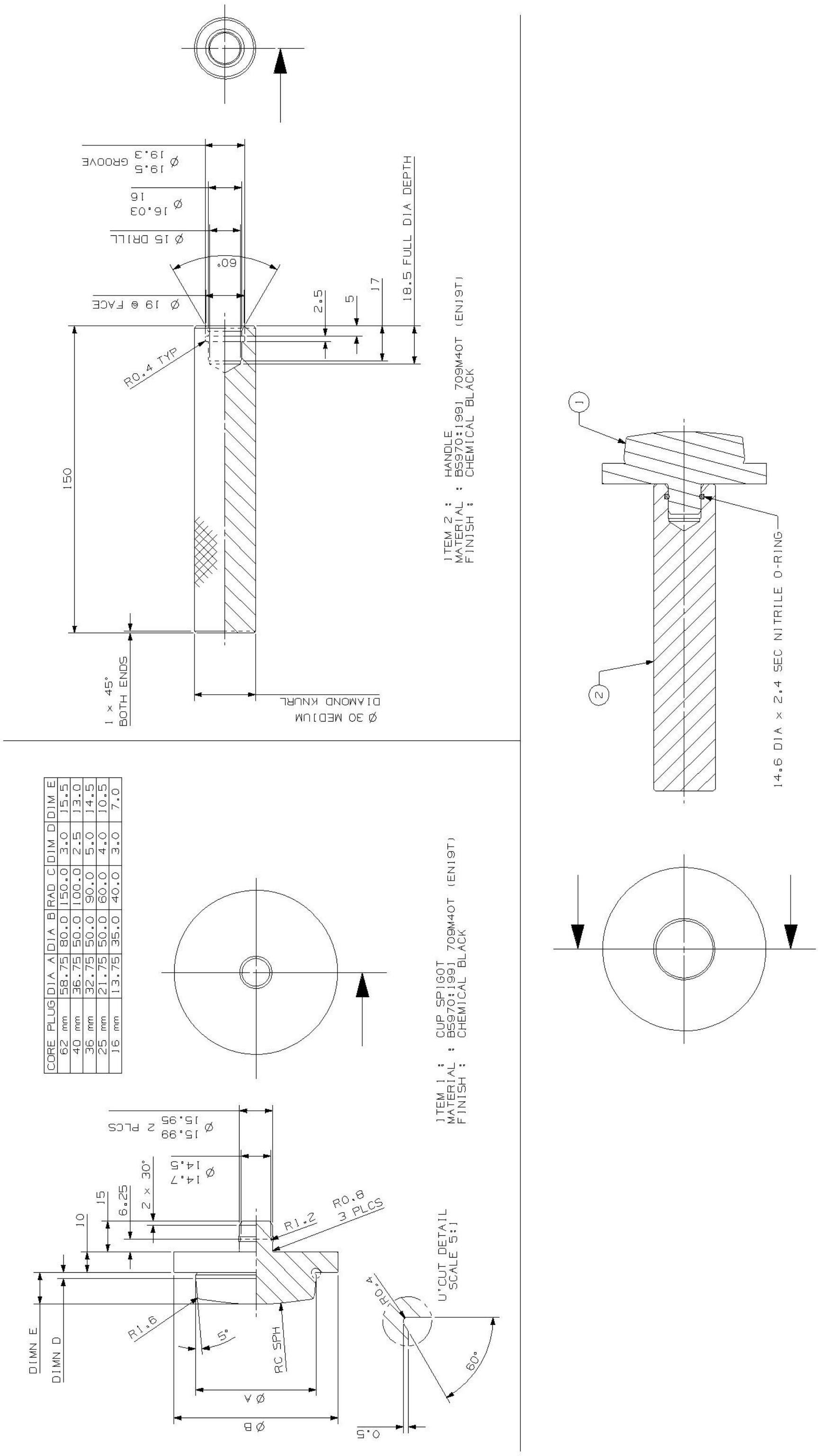


Fig 82. 320/07182 Fuel Return Line Tubing (Clear)

For diagnosing air ingress into the fuel system.

Service Tool Drawings

892/01146 - Core Plug Fitting Tool



CORE PLUG	DIA A	DIA B	RAD C	DIM D	DIM E
62 mm	58.75	80.0	150.0	3.0	15.5
40 mm	36.75	50.0	100.0	2.5	13.0
36 mm	32.75	50.0	90.0	5.0	14.5
25 mm	21.75	50.0	60.0	4.0	10.5
16 mm	13.75	35.0	40.0	3.0	7.0

Fig 83.

892/01147 - Crankshaft Turning Tool

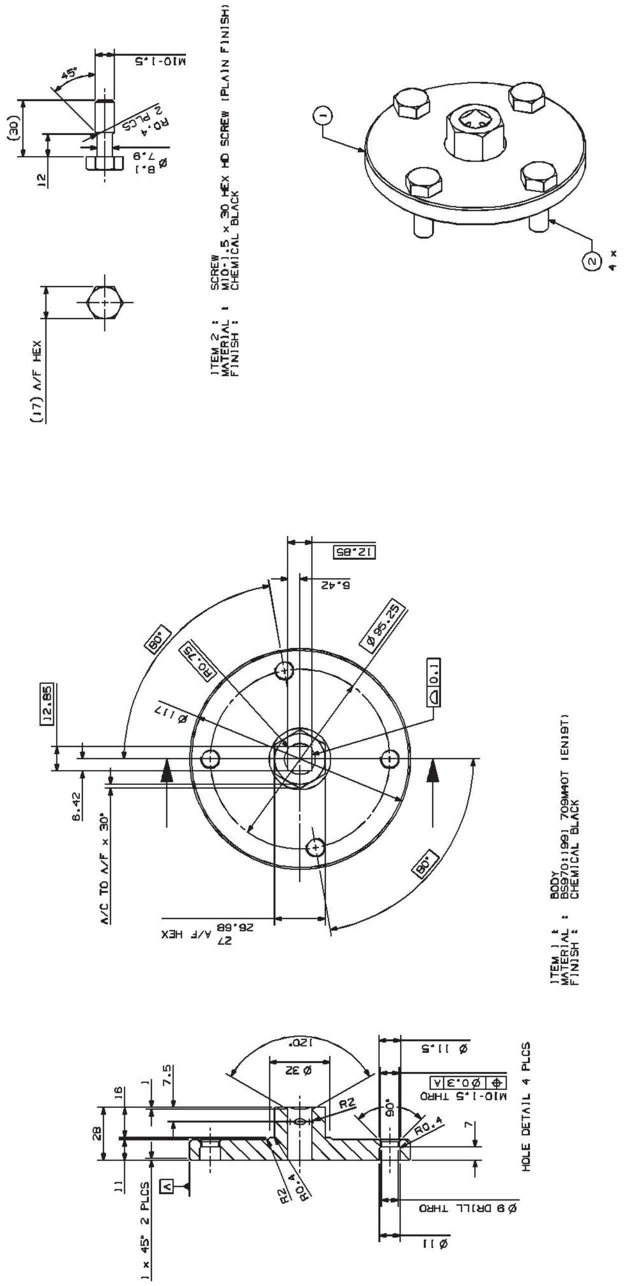


Fig 84.

892/01148 - Timing Pin

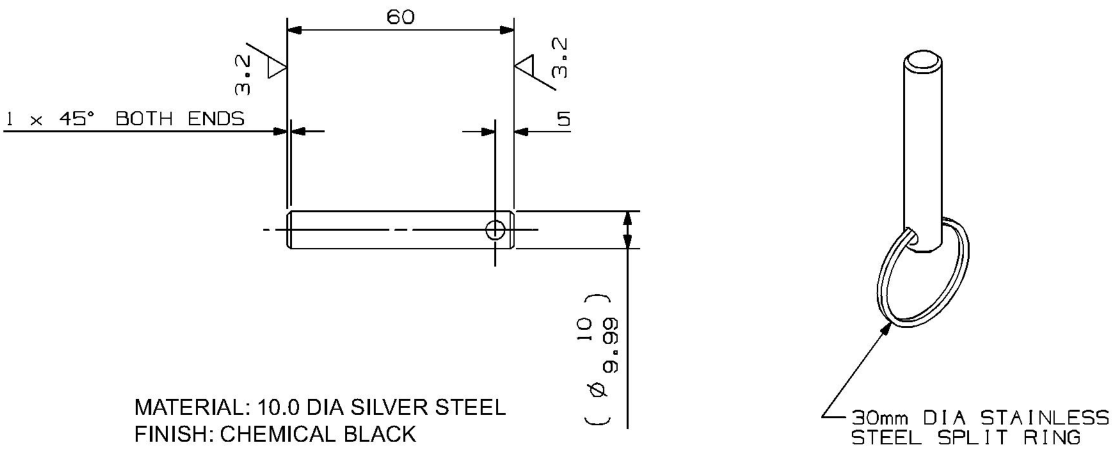


Fig 85.

892/01149 - Sump Sealant Template

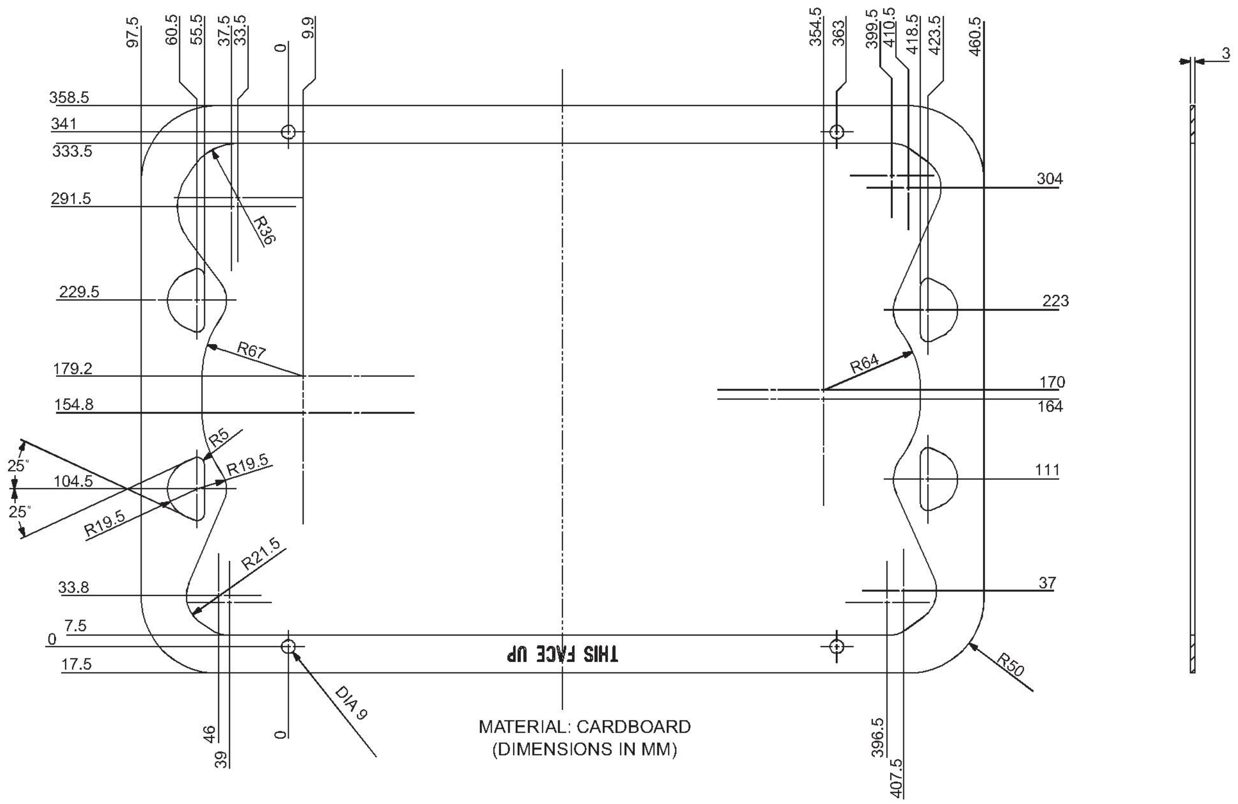


Fig 86.

892/01150 - Oil Sump Location Dowel

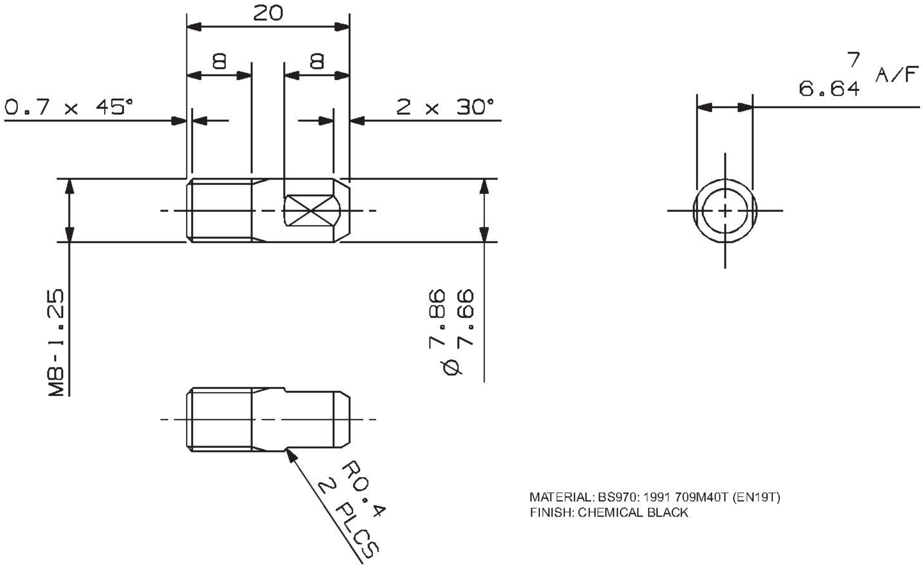


Fig 87.

892/01151 - Injector Sleeve Removal Tool

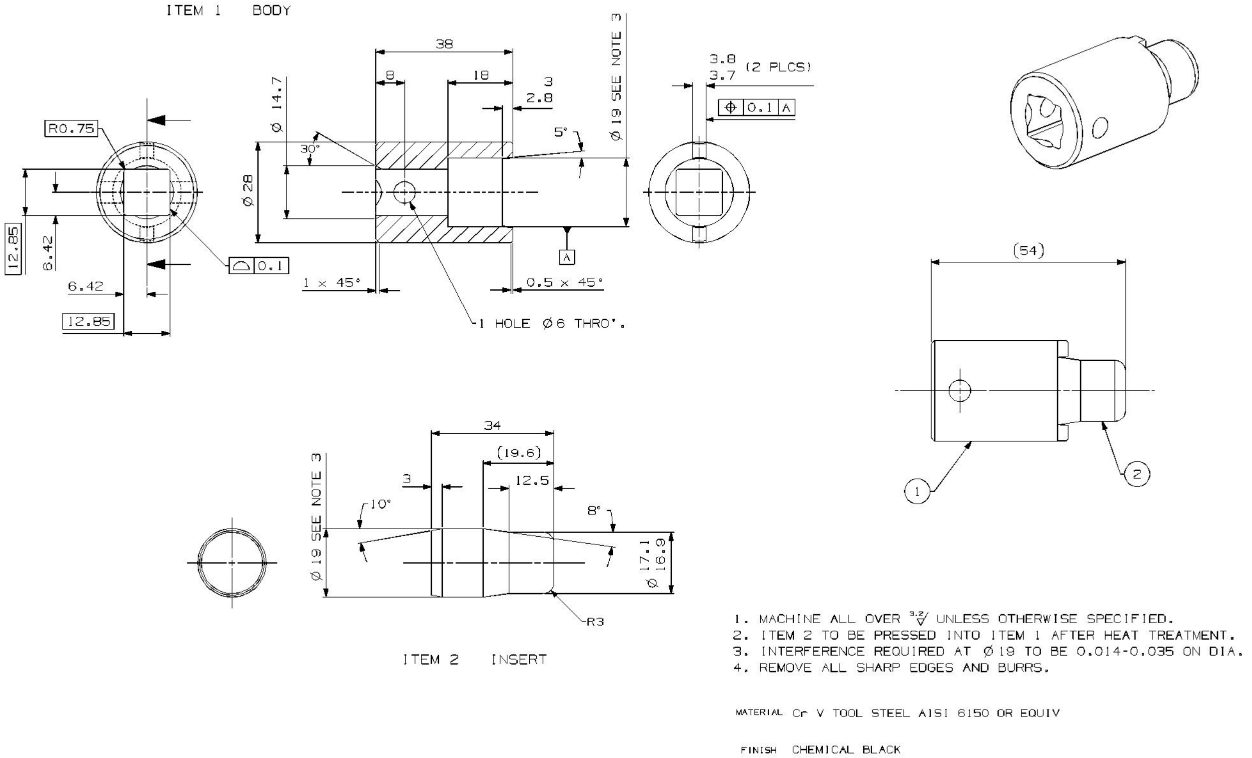


Fig 88.

892/01152 - Valve Stem Seal Fitting Tool

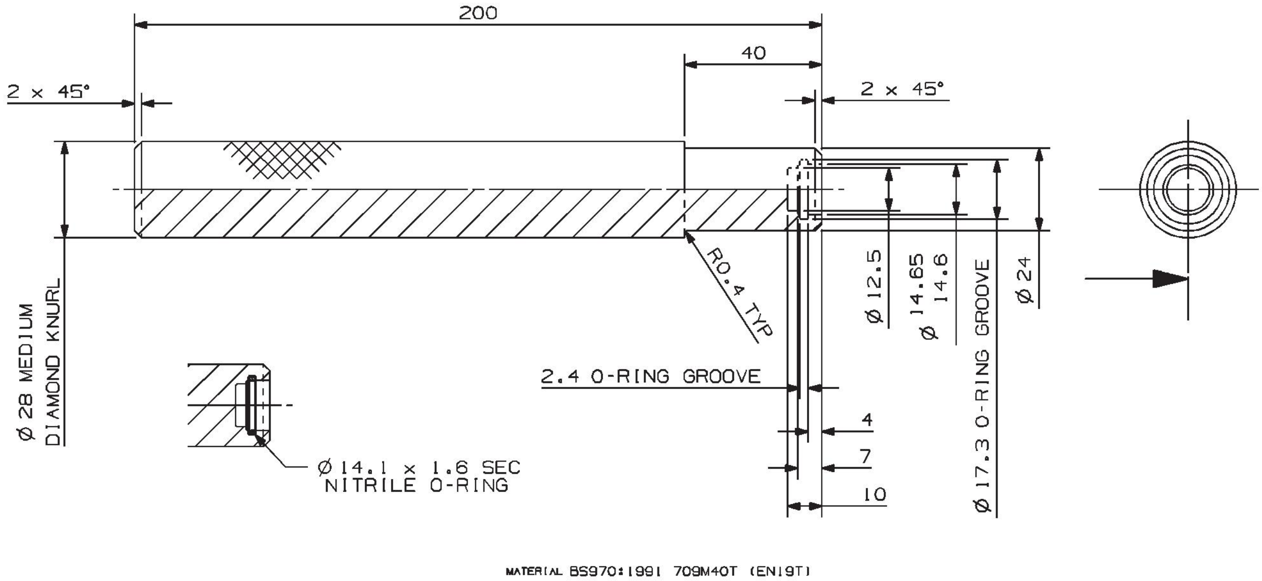


Fig 89.

892/01154 - FIP Cover Removal Tool

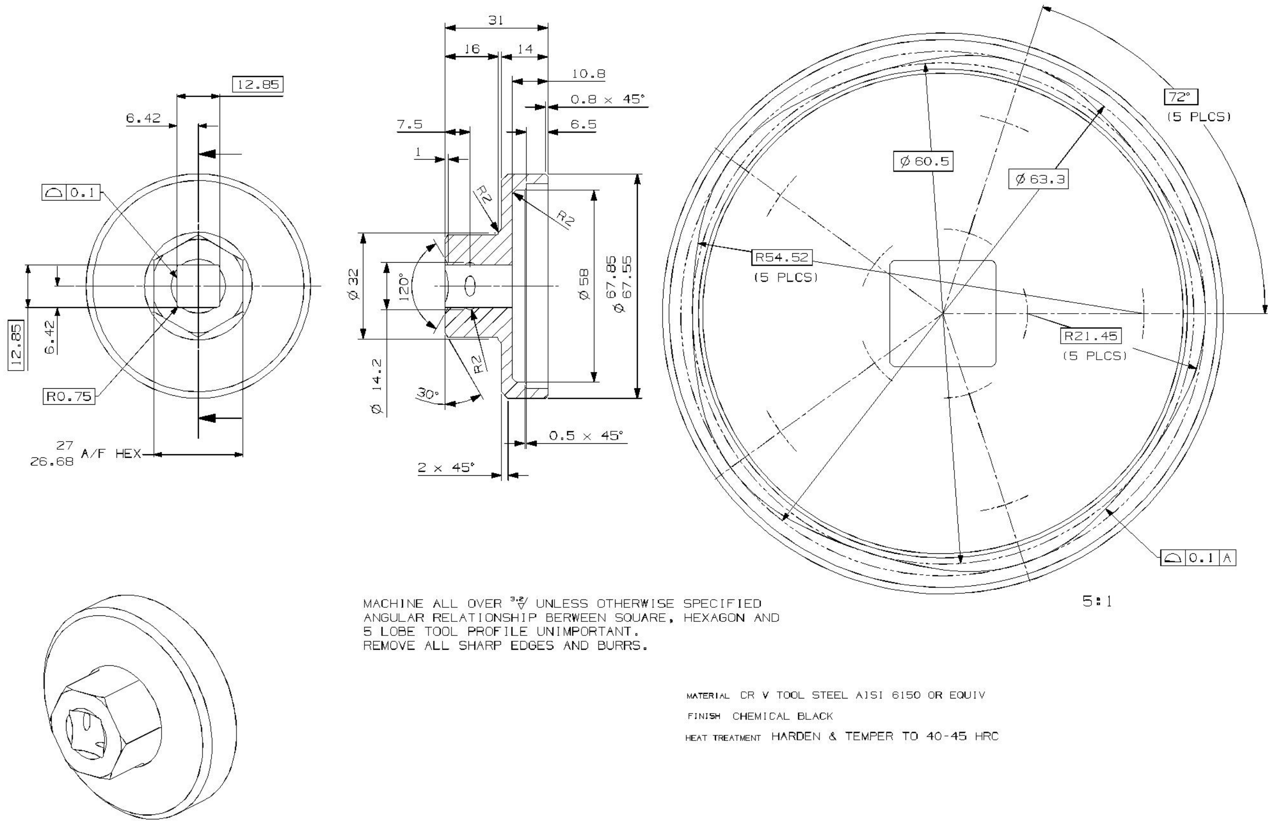


Fig 90.

892/01155 - FIP Gear Removal Tool

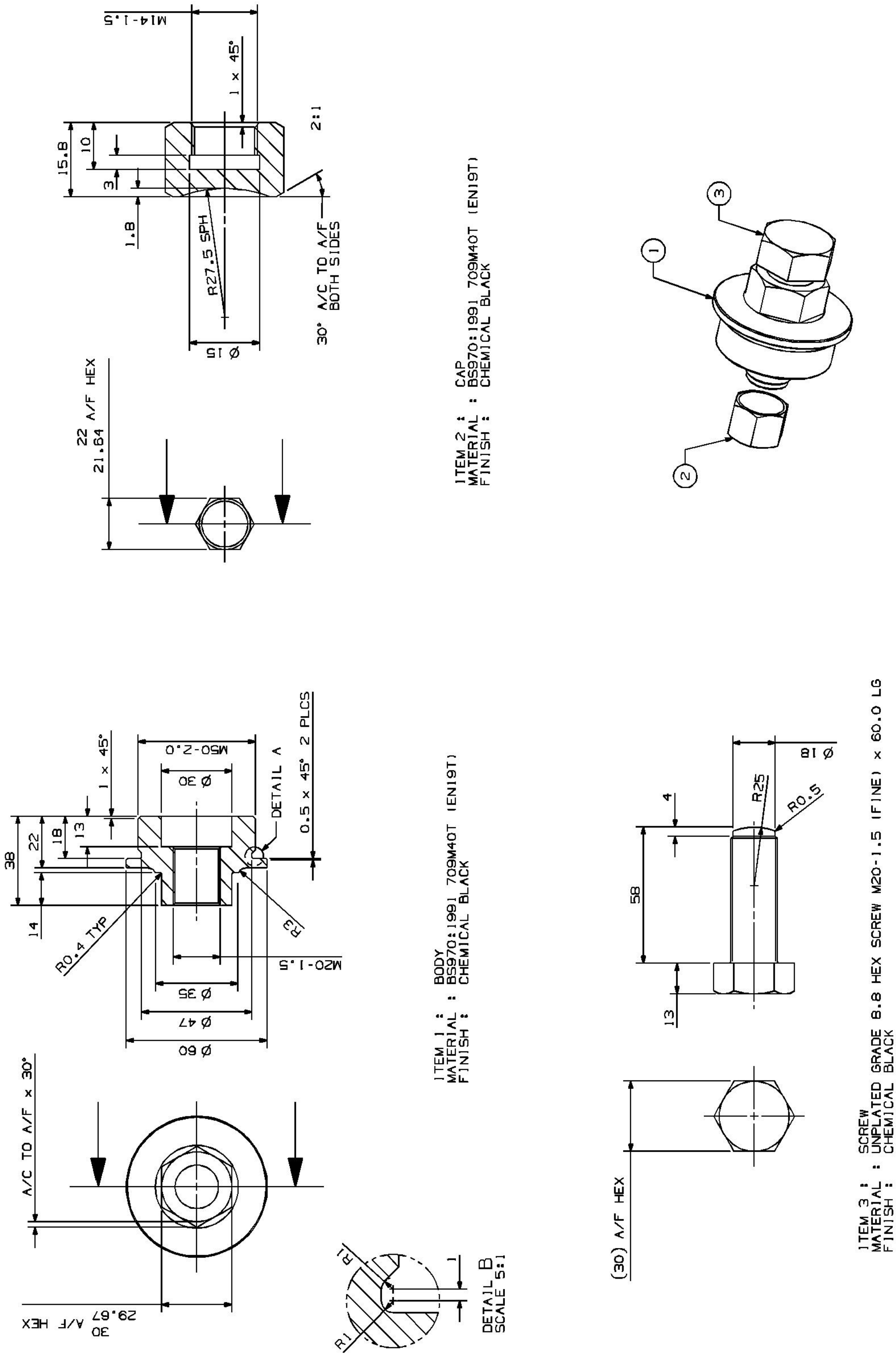


Fig 91.

892/01157 - Crankshaft Front Seal Fitting Tool

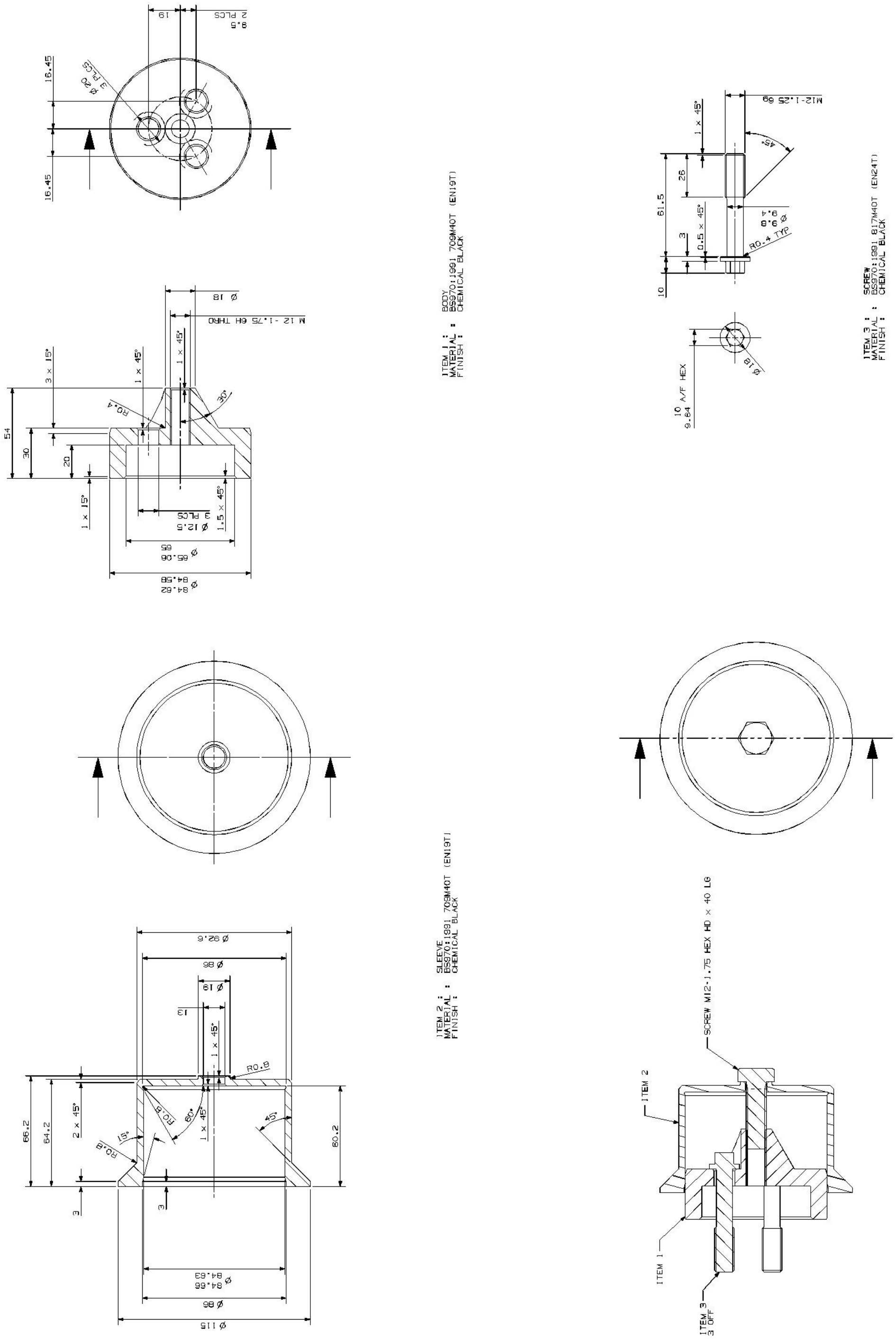


Fig 92.

892/01156 - Crankshaft Rear Seal Fitting Tool

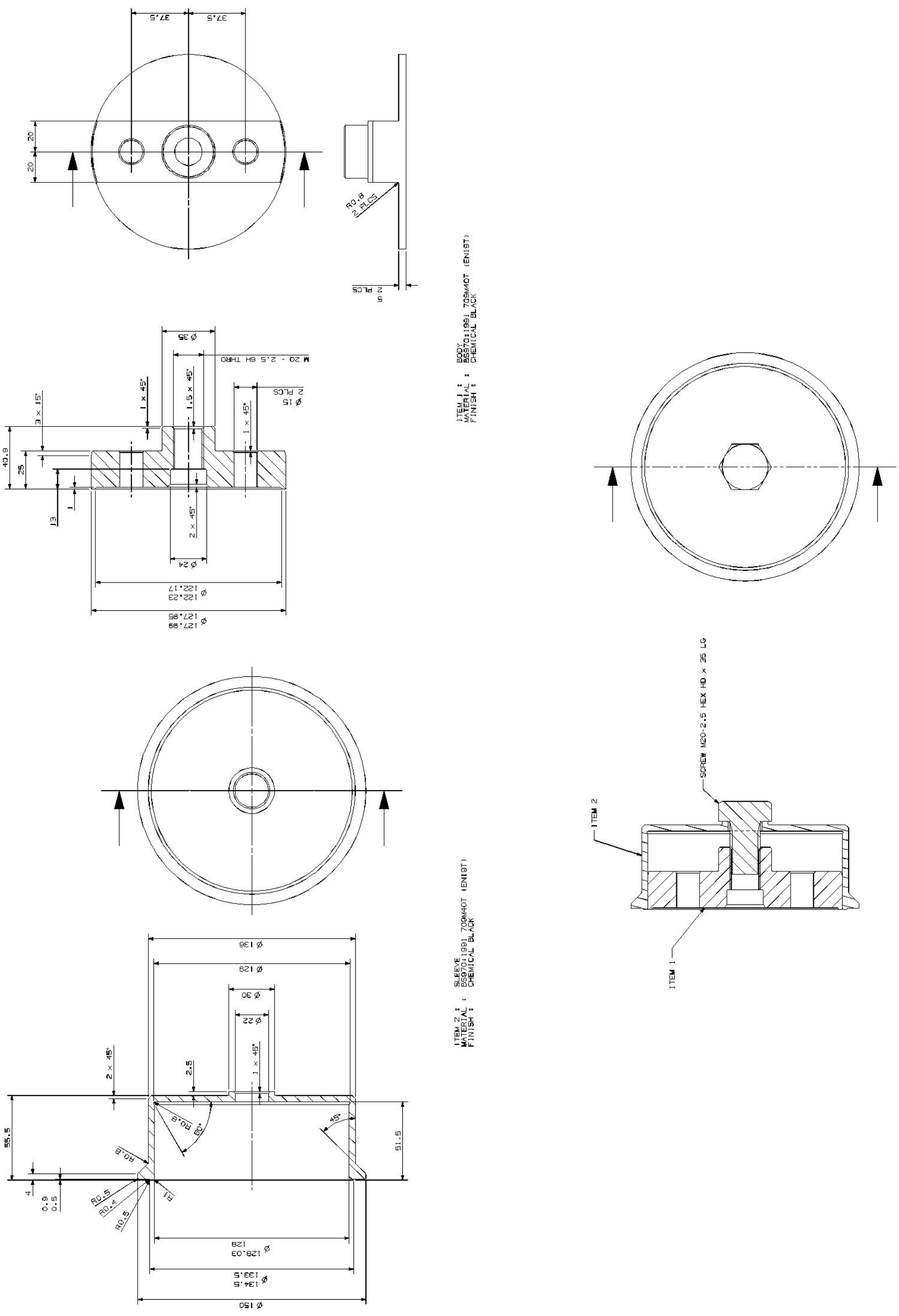


Fig 93.

892/01158 - Crankshaft Rear Seal Alignment Tool

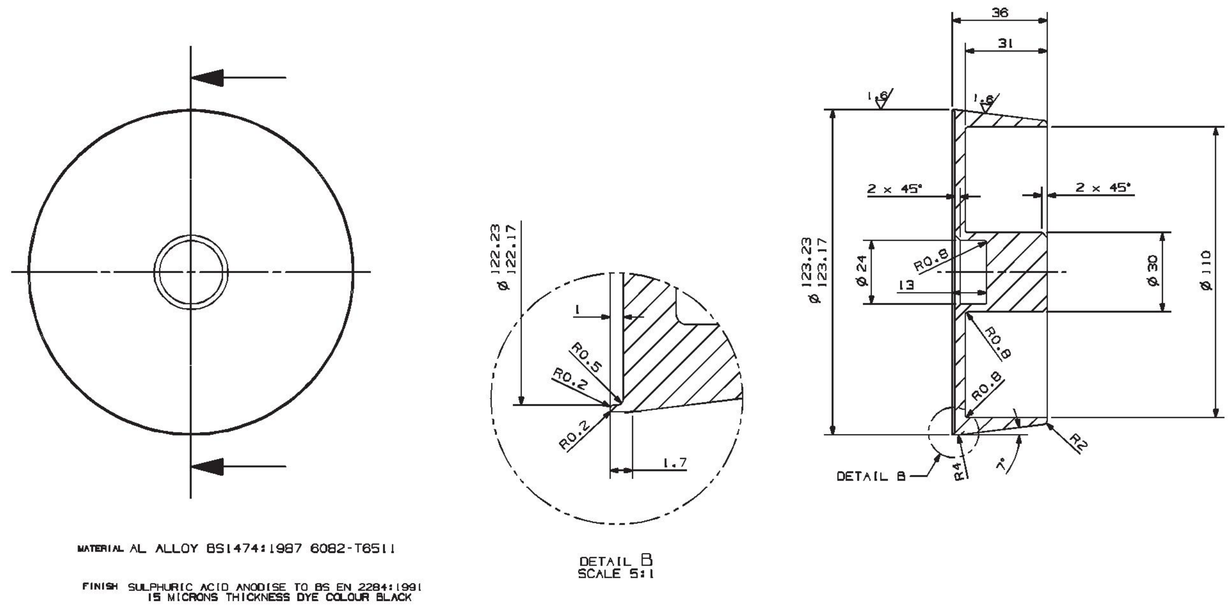


Fig 94.

892/01159 - Injector Seal Fitting Tool

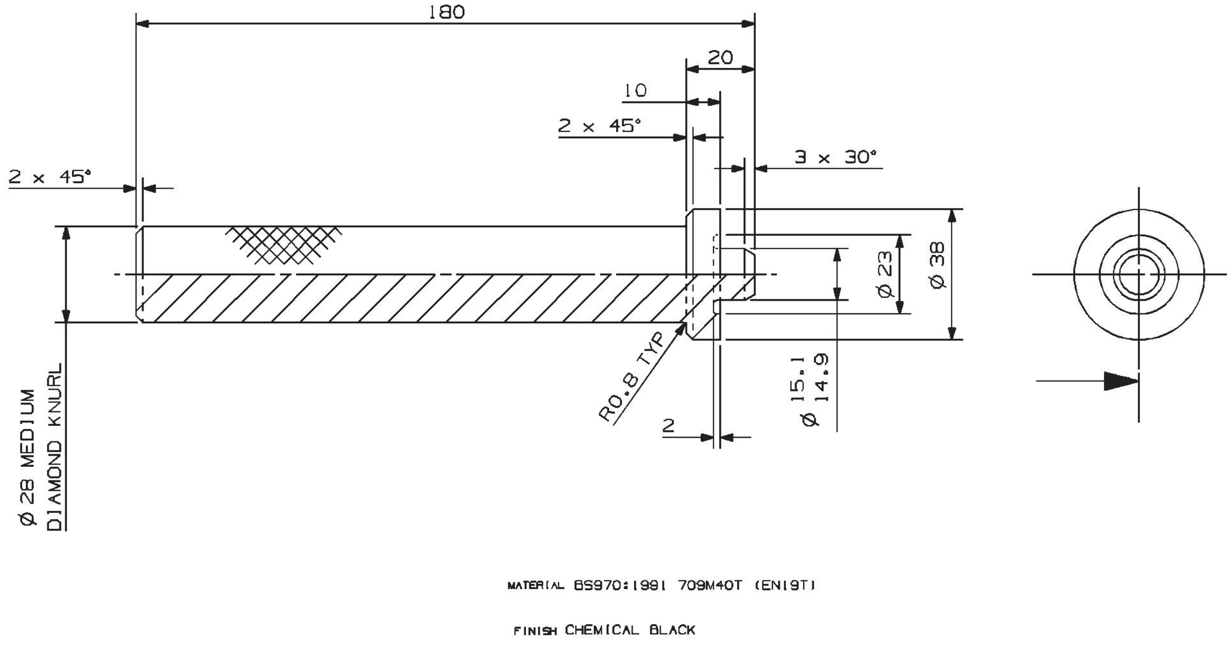


Fig 95.

892/01168 - Dummy Injector

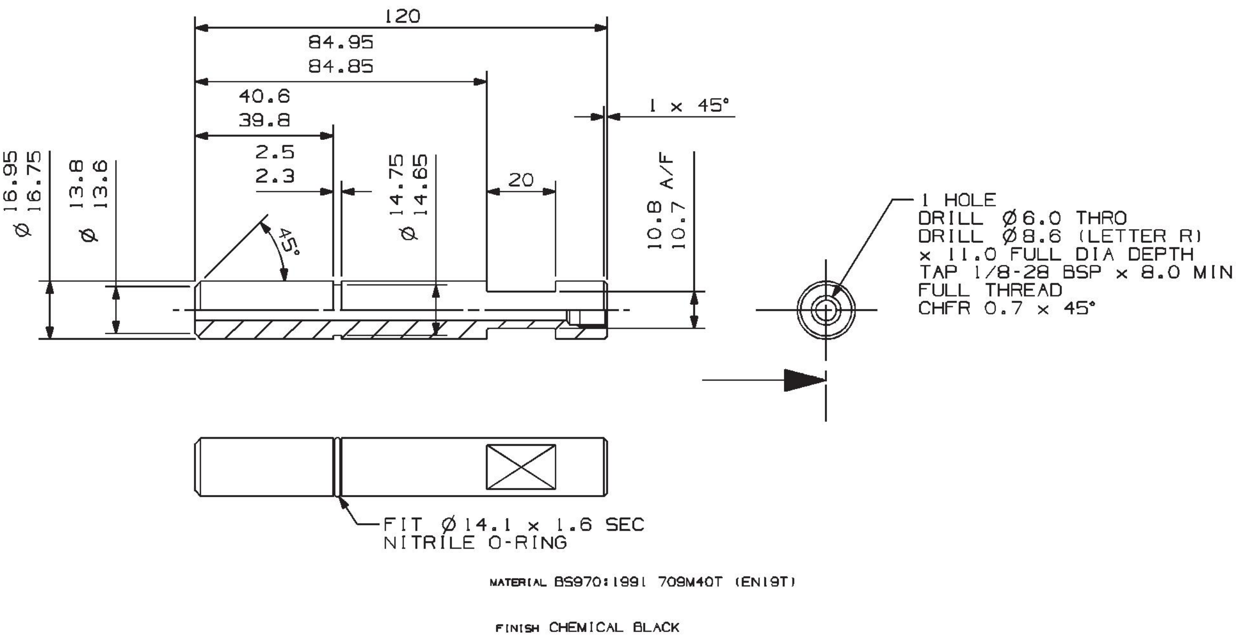
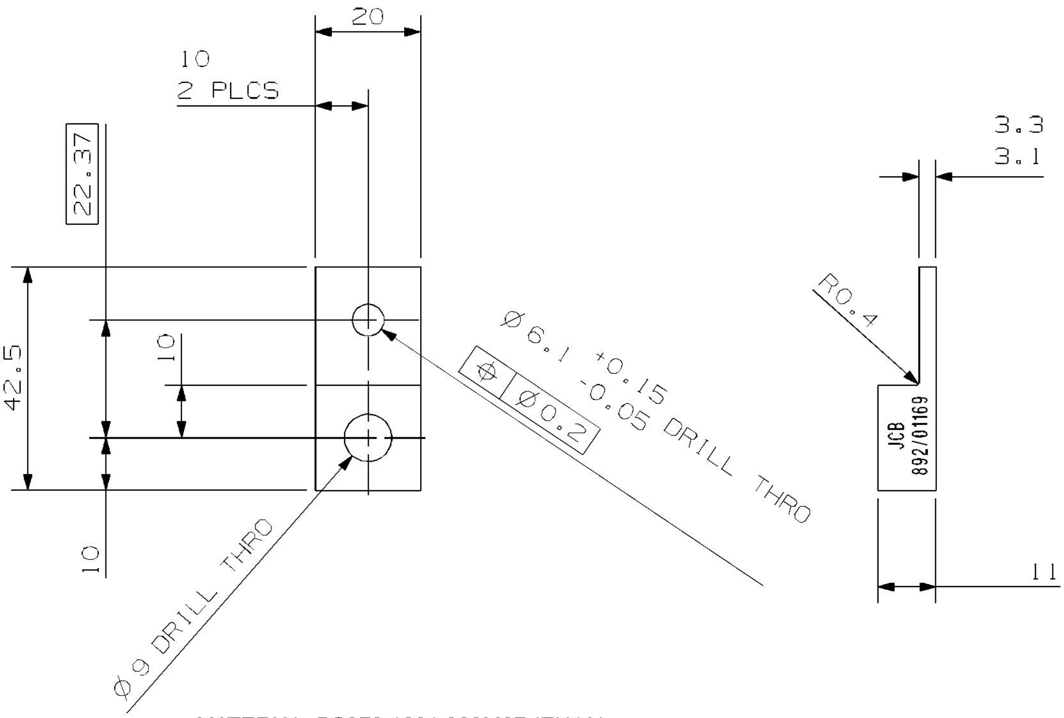


Fig 96.

892/01169 - Top Dead Centre (TDC) Setting Tool



MATERIAL: BS970:1991 230M07 (EN1A)

Fig 97.

Engine Mounting Frame

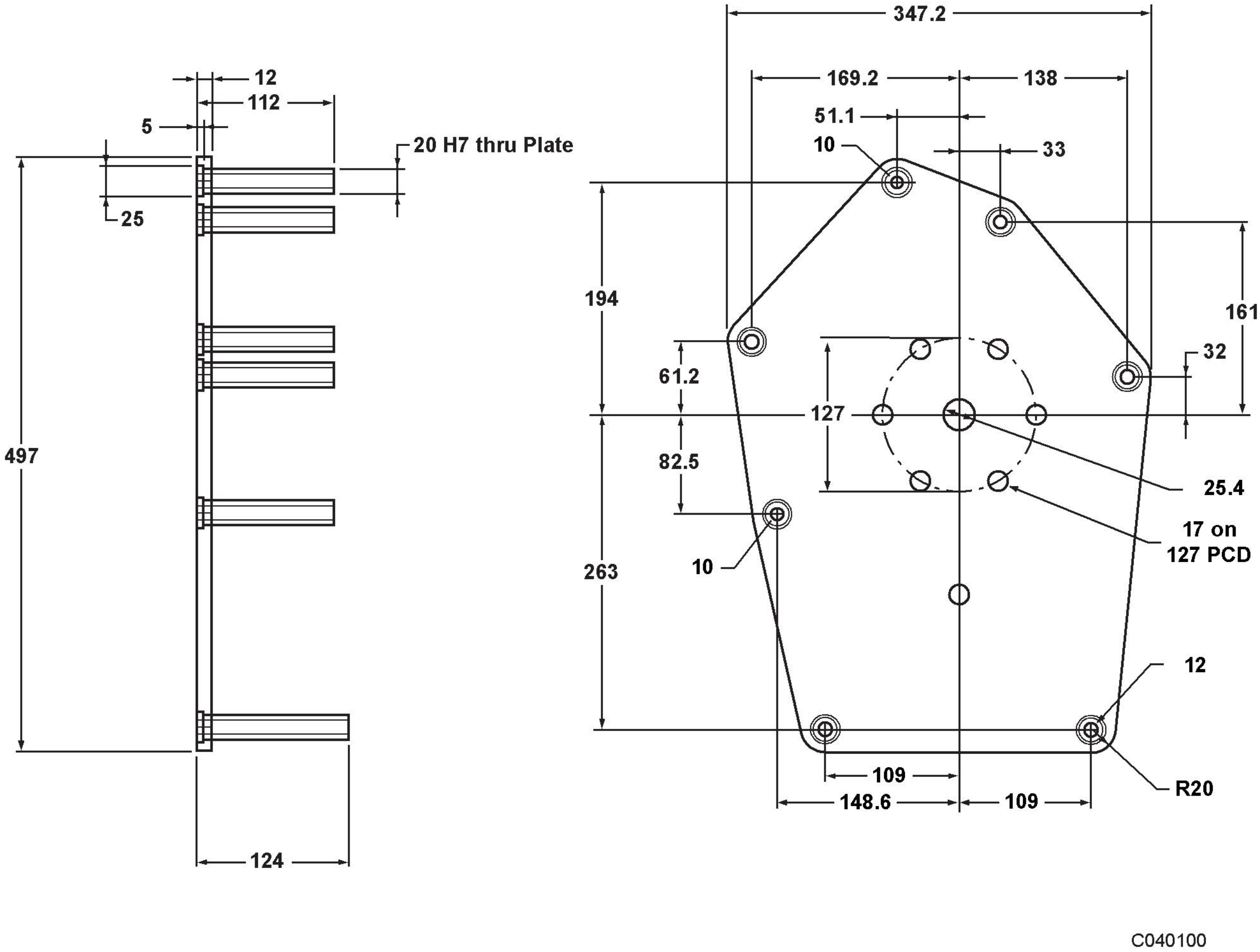


Fig 98.

Service Parts and Repair Kits

Engine Repair Parts and Kits Identification

➩ *Engine Repair Parts and Kits Identification (1-82)* detail the repair parts and kits available from JCB Service. When applicable, the removal and replacement, or dismantling and assembly procedures contained in this manual will make a reference to the parts and kits on these pages.

For instance, ***Rocker Cover - Removal and Replacement - Section 12*** details the rocker cover removal and replacement procedure. On this page, there is a sub-heading termed **`Service Parts'**, listed under this heading are items available as replacement parts. The items are identified exactly as listed in the following pages, eg, item 1 - Rocker Cover Gasket Kit, item 1.1 - Rocker Cover Gasket, etc.

The kits are identified for your reference, when applicable a complete kit can be ordered, or the individual parts. Refer to the engine parts catalogue for the relevent part numbers.

For convenience, the kit titles and page cross references are identified as follows.

Item	Description	Qty
1	Rocker cover gasket kit	1
1.1	Rocker cover seal	1
1.2	Injector seal	4
1.3	Injector cap	4
1.4	Fuel pipe cap	8
1.5	O-ring leak-off rail	4
1.6	O-ring oil filler cap	1

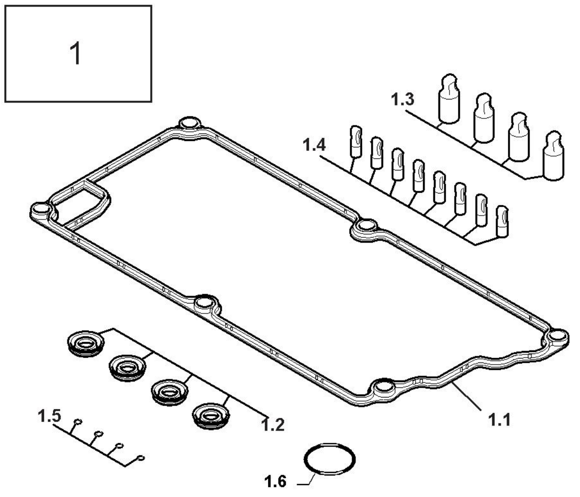


Fig 99.

Item	Description	Qty
2	Crankshaft assy kit	1
2.1	Crankshaft - machining	1
2.2	Crankshaft gear assy - HCR	1
2.3	Hub - flywheel	1
2.4	Zero leak plug	1
2.5	Screw	1
14	Main bearing kit std	1
15	Thrust washer kit std	1

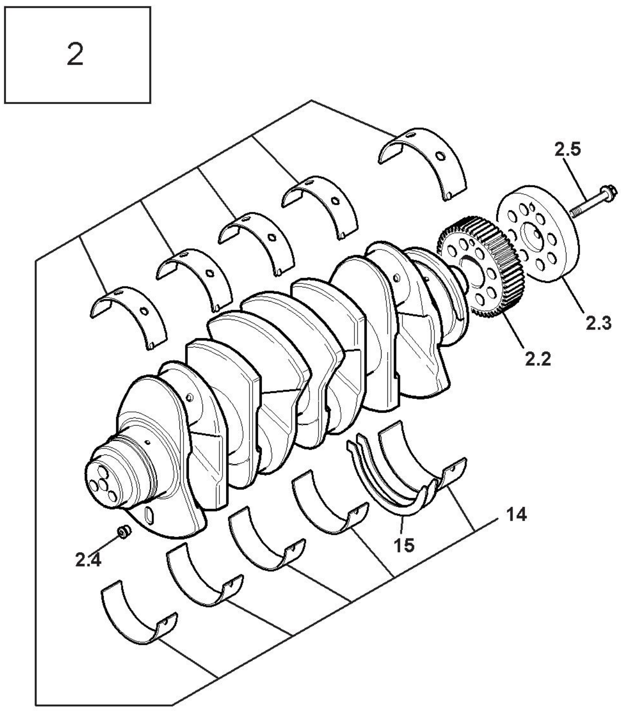


Fig 100.

Item	Description	Qty
3	Piston kit NA	1
3.1	Piston assy NA (NSP)	1
3.2	Piston ring kit std	1
3.3	Retainer - piston pin	1

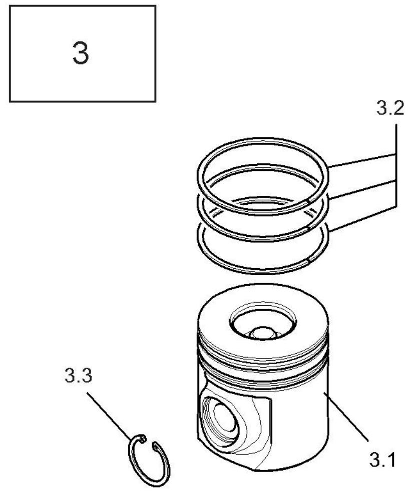


Fig 101.

Item	Description	Qty
4	Piston kit TC	1
4.1	Piston assy TC (NSP)	1
4.2	Piston ring kit std	1
4.3	Retainer - piston pin	1

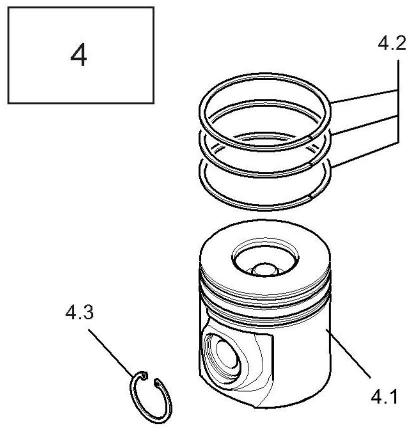


Fig 102.

Engine Repair Parts and Kits Identification

Item	Description	Qty
5	Piston kit TCA	1
5.1	Piston assy TCA (NSP)	1
5.2	Piston ring kit std	1
5.3	Retainer - piston pin	1

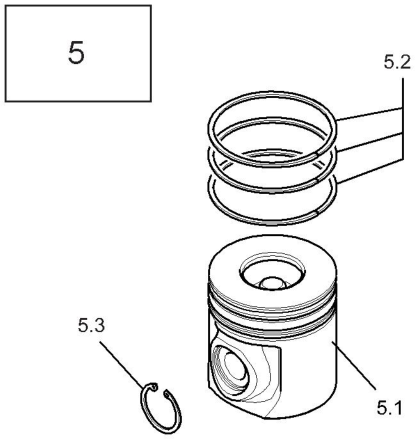


Fig 103.

Item	Description	Qty
6	Top gasket kit NA	1
6.1	Cylinder head gasket	1
6.2	Valve stem seal	16
6.3	Thermostat hsg c-seal	1
6.4	Gasket inlet manifold	1
6.5	Gasket exhaust manifold NA	1
6.6	Intake heater gasket	1
6.7	Cooler cover gasket	1
6.8	Gasket - water inlet pipe	1
6.9	Washer - fuel injector	4
6.10	Seal - fuel injector	4
6.11	O-ring - plugs, oil cooler housing	2
6.12	O-ring - oil cooler matrix	2
6.13	O-ring - fuel lift pump	1
6.14	Bonded seal - oil pressure sender, cold start switch	2
6.15	Bonded seal - temperature sender switch	1
6.16	Bonded seal - water outlet connector	1
1.1	Rocker cover seal	1
1.2	Injector seal	4
1.3	Injector cap	4
1.4	Fuel pipe cap	8
1.5	O-ring leak-off rail	4
1.6	O-ring filler cap	1

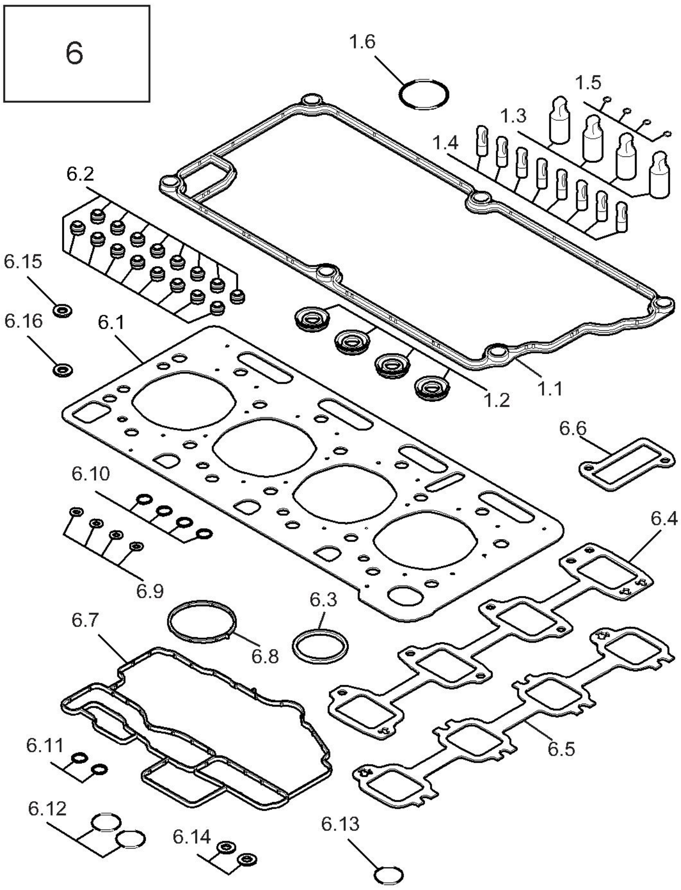


Fig 104.

Item	Description	Qty
7	Top gasket kit TC/TCA	1
7.1	Gasket / heat-shield	1
7.2	Gasket t/c to manifold	1
7.3	Copper washer	4
7.4	O-ring	1
7.5	Sealing washer - oil drain	1
1.1	Rocker cover seal	1
1.2	Injector seal	4
1.3	Injector cap	4
1.4	Fuel pipe cap	8
1.5	O-ring leak-off rail	4
1.6	O-ring - filler cap	1
6.1	Piston assy TCA (NSP)	1
6.2	Piston ring kit std	16
6.3	Retainer - piston pin	1
6.4	Gasket inlet manifold	1
6.5	Gasket exhaust manifold NA	1
6.6	Intake heater gasket	1
6.7	Cooler cover gasket	1
6.8	Gasket - water inlet pipe	1
6.9	Washer - fuel injector	4
6.10	Seal - fuel injector	4
6.11	O-ring - plugs, oil cooler housing	2
6.12	O-ring - oil cooler matrix	2
6.13	O-ring - fuel lift pump	1
6.14	Bonded seal - oil pressure sender, cold start switch	2
6.15	Bonded seal - temperature sender switch	1
6.16	Bonded seal - water outlet connector	1

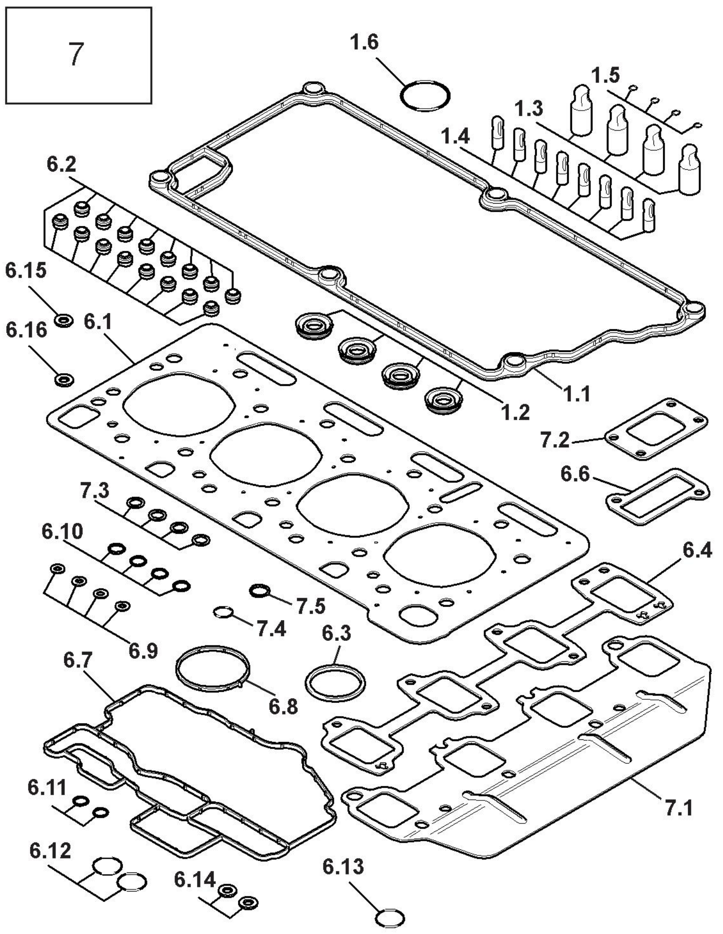


Fig 105.

Item	Description	Qty
8	Bottom gasket kit	1
8.1	Water pump gasket	1
8.2	Oil seal front	1
8.3	Oil seal rear	1
8.4	Oil pan sealant	1
8.5	Sealant template oil pan	1
8.6	Sealant	1
8.7	Oil drain plug o-ring	2
8.8	Gasket t/c oil drain	1
8.9	O-ring	1
8.10	Seal FIP	1
8.11	O-ring	1
8.12	O-ring	1
8.13	Seal - oil pick up	1

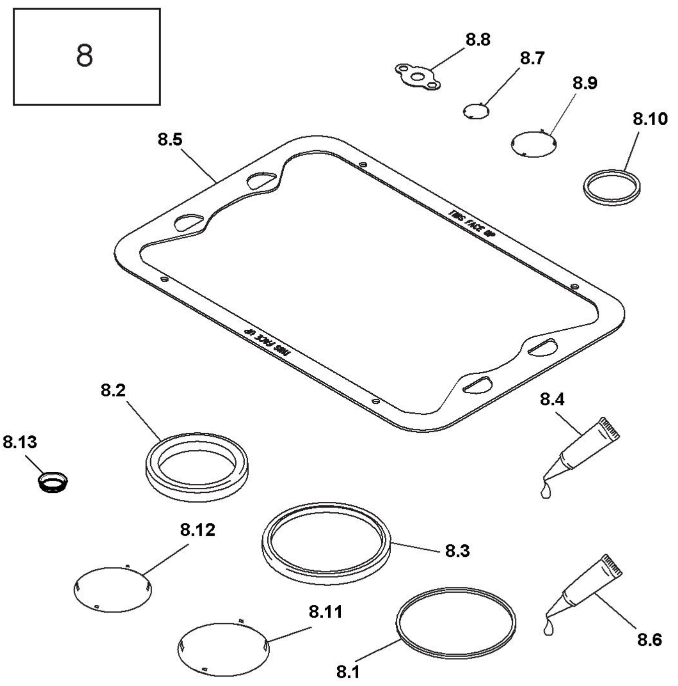


Fig 106.

Item	Description	Qty
9.0	Oil pan sealant kit	1
8.4	Oil pan sealant	1
8.5	Sealant template oil pan	1
8.7	O-ring - drain plug	1
8.13	Seal - oil pick up	1

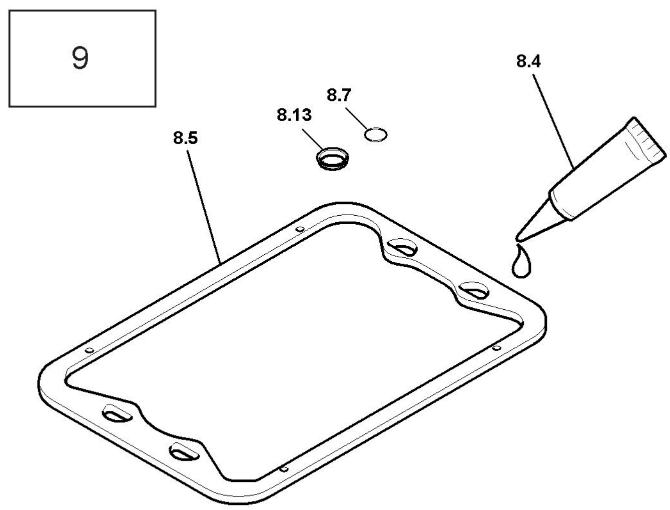


Fig 107.

Item	Description	Qty
10	Cylinder head Kit NA/TC	1
10.1	Cylinder Head Machining(1)	1
10.2	GA Valves Inlet	8
10.3	GA Valves Exhaust	8

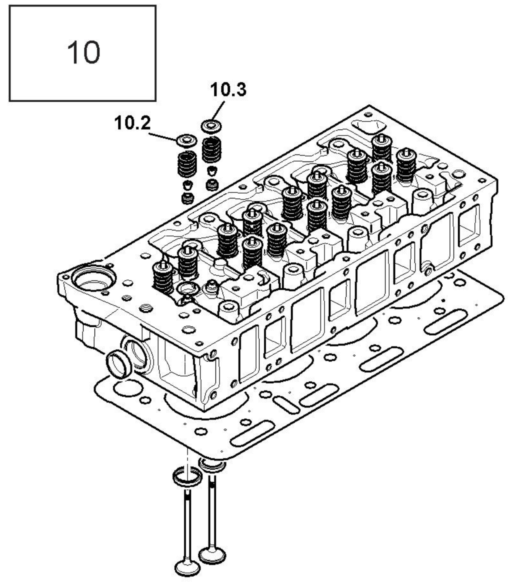


Fig 108.

(1) Refer to Technical Data, Section 1, for machining information and tolerances.

Item	Description	Qty
11	Cylinder head Kit TCA	1
11.1	Cylinder Head Machining(1)	1
10.2	GA Valves Inlet	8
10.3	GA Valves Exhaust	8

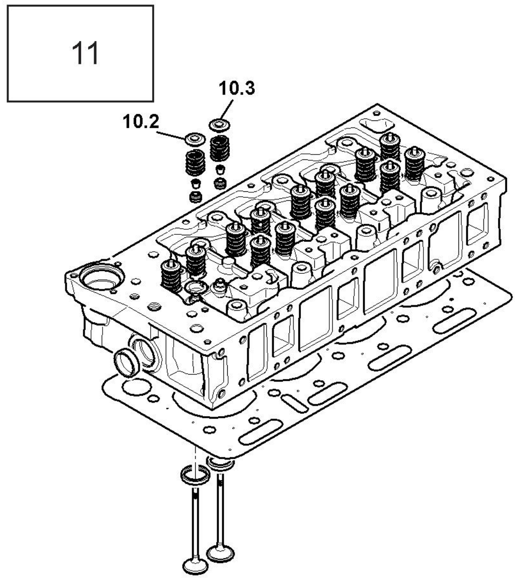


Fig 109.

(1) Refer to Technical Data, Section 1, for machining information and tolerances.

Item	Description	Qty
12	Cylinder head gasket kit +0.25	1
12.1	Cylinder head gasket +0.25	1

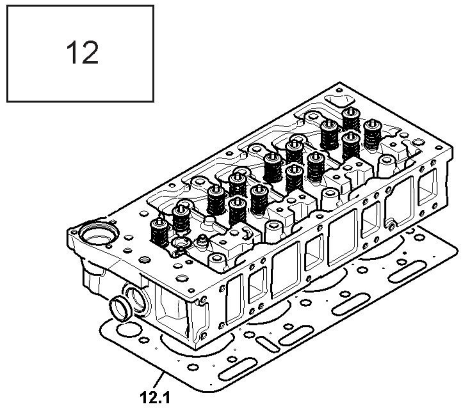


Fig 110.

Item	Description	Qty
13	Cylinder head gasket kit +0.50	1
13.1	Cylinder head gasket +0.50	1

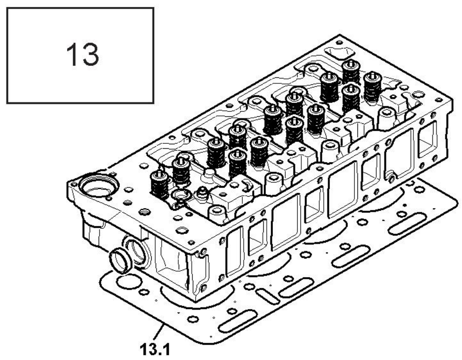


Fig 111.

Item	Description	Qty
14	Main bearing kit std	1
14.1	Bearing - Main Upper std(1)	4
14.2	Bearing - Main Lower std(1)	4
14.3	Bearing - Main Upper Rear std(1)	1
14.4	Bearing - Main Lower Rear std(1)	1

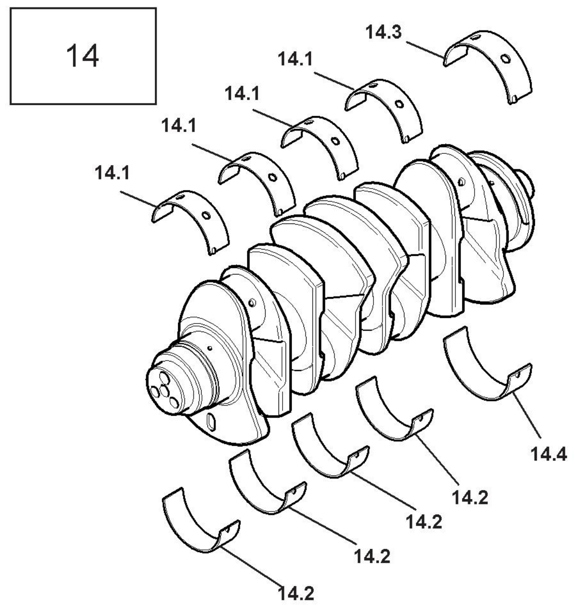


Fig 112.

(1) Items not available separately, part of kit item 14.

Item	Description	Qty
15	Thrust washer kit std	1
15.1	Bearing - Main Thrust Washer	2

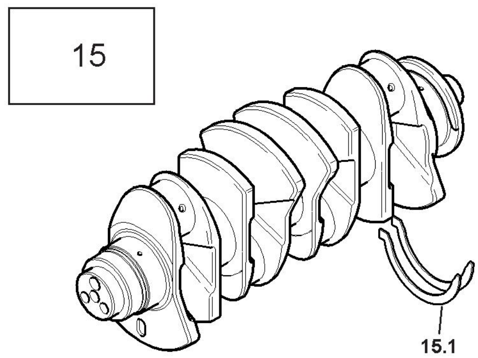


Fig 113.

Item	Description	Qty
16	Big-end bearing kit std	1
16.1	Bearing - Big-end std	8

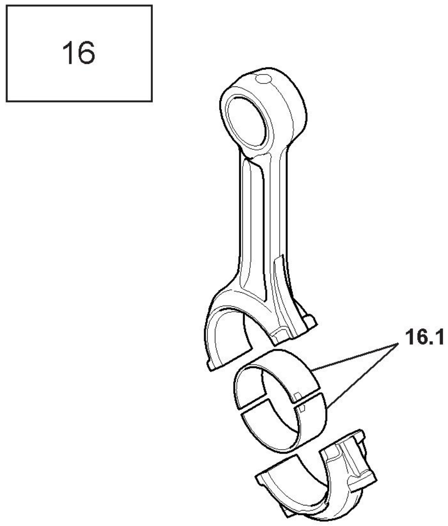


Fig 114.

Engine Repair Parts and Kits Identification

Item	Description	Qty
17	Engine overhaul kit NA std	1
17.1	Bolt - M8 x 57 Con. Rod	8
3	Piston kit NA	4
6	Top gasket kit	1
8	Bottom gasket kit	1

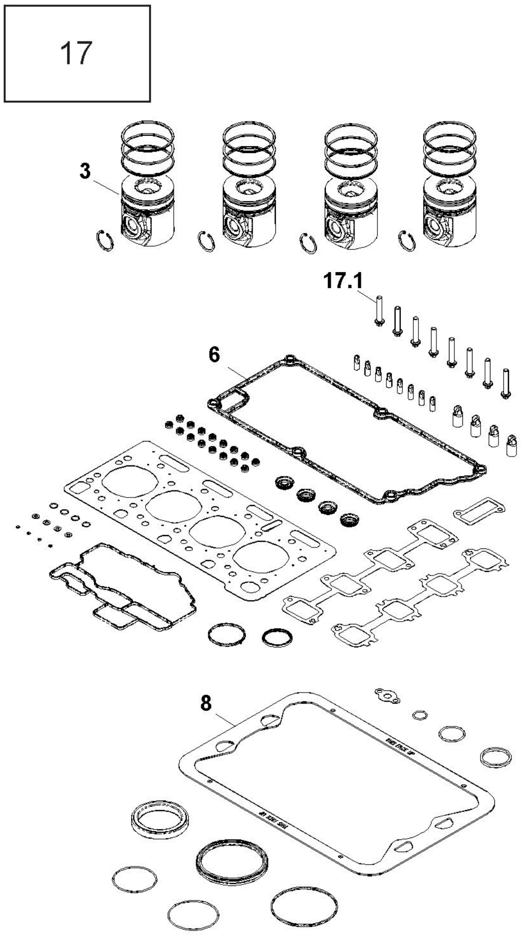


Fig 115.

Item	Description	Qty
18	Engine overhaul kit TC std	1
17.1	Bolt - M8 x 57 Con. Rod	8
4	Piston kit TC	4
6	Top gasket kit	1
8	Bottom gasket kit	1

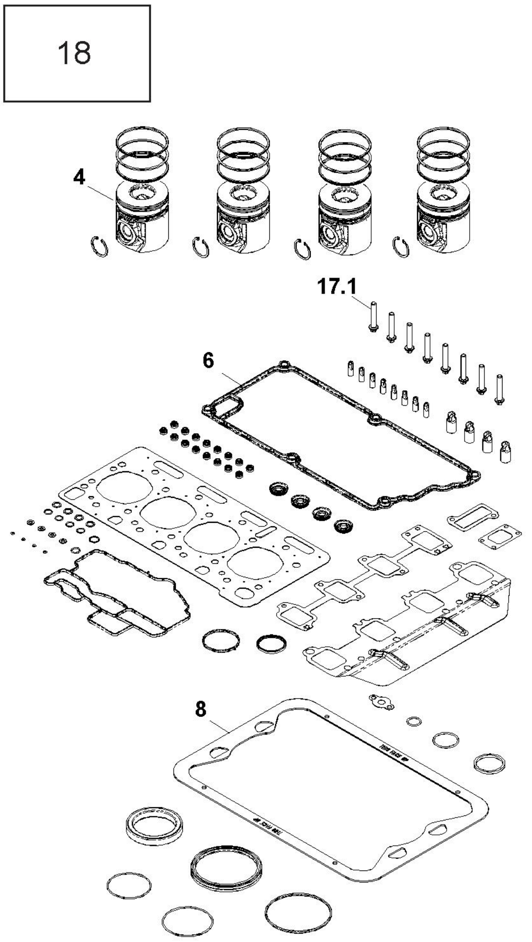


Fig 116.

Item	Description	Qty
19	Engine overhaul kit TCA std	1
17.1	Bolt - M8 x 57 Con. Rod	8
5	Piston kit TCA	4
6	Top gasket kit	1
8	Bottom gasket kit	1

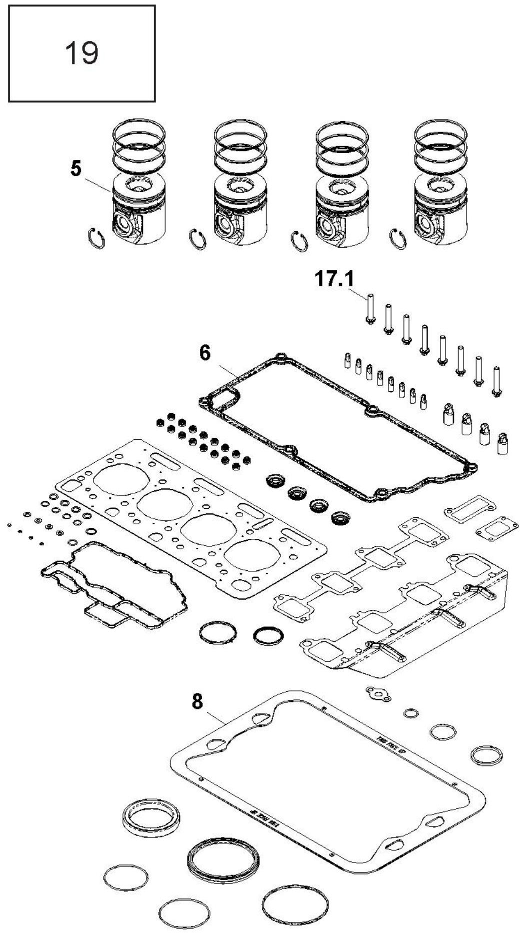


Fig 117.

Engine Repair Parts and Kits Identification

Item	Description	Qty
50	Starter motor kit	1
50.1	Starter solenoid	1
50.2	Sundry parts kit (bolts, o-ring)	1
50.3	Brush holder assembly	1
50.4	Brush kit	1

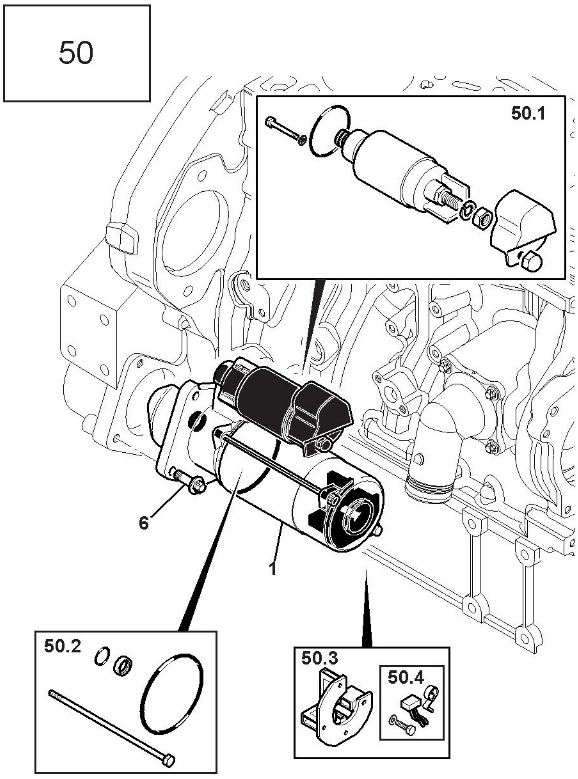


Fig 118.

Item	Description	Qty
60	Alternator kit	1
60.1	Thru bolt kit	1
60.2	Pulley	1
60.3	Nut and spacer	1
60.4	Regulator and brush box assembly	1

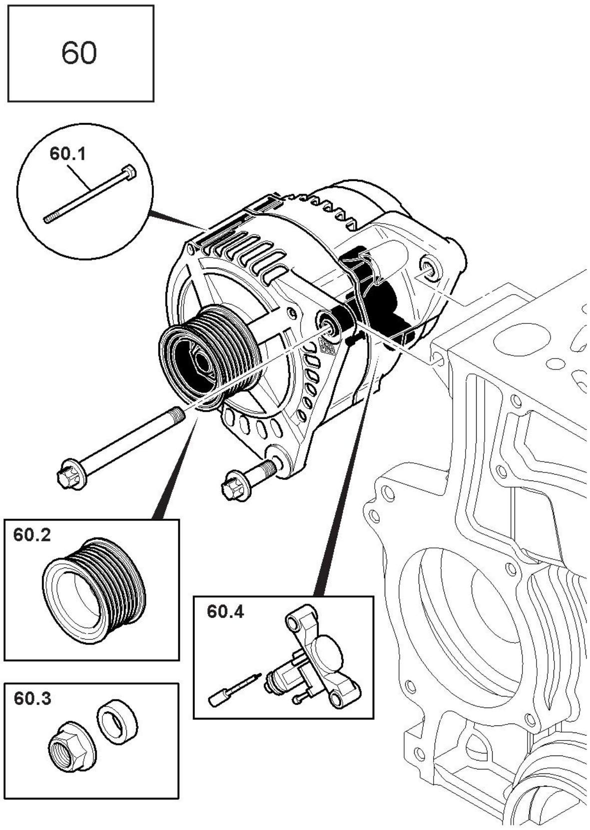


Fig 119.

Engine Lifting

Lifting Information

Refer to the ***Technical Data*** section for the various engine weights.

The lifting equipment used must be an approved type and capable of lifting the engine safely. The recommended lifting equipment is shown at **120-B**.

Never attempt to manually lift heavy components such as the cylinder head, crankshaft etc on your own. Always use lifting equipment, or obtain the help of an assistant.

Inspect the lifting brackets **120-A** for signs of damage. The brackets must be correctly torqued to the engine block, the correct torque figure for the bracket retaining bolts is 43-51Nm.

Make sure the lifting equipment does not damage any of the engine dressing and the rocker cover.

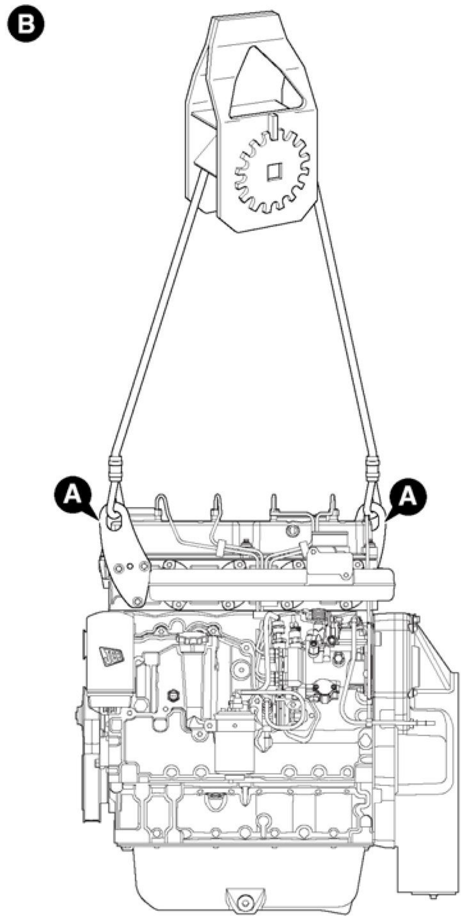


Fig 120.

Operating Procedures

Starting the Engine

Pre-Start Notes

⚠ WARNING

On turbo-charged machines, do not keep the accelerator pedal fully depressed when the engine has started. Do not race the engine until the oil pressure low light has gone out. Racing the engine too soon could damage the turbo-charger due to insufficient lubrication.

16-2-4-1

Several factors will influence the starting performance of the engine, these include:

– The ambient temperatures
– The condition of the battery
– The viscosity of the engine oil
– The condition of the starter motor

The engine does not require any cold starting aids for temperatures down to -18°C.

If the engine is operating in temperatures below -18°C, then a pre-heater is available. The heater fits in the inlet manifold as shown, and is linked into the machine's electrical system.

In severe cold climate conditions, a block heater can be installed.

Make sure that all the necessary machine pre-start checks have been completed, these will include:

– engine oil level
– engine coolant level
– battery connections
– fuel tank has sufficient fuel
– fuel pre-filters drained
– the machine is safe and ready to start

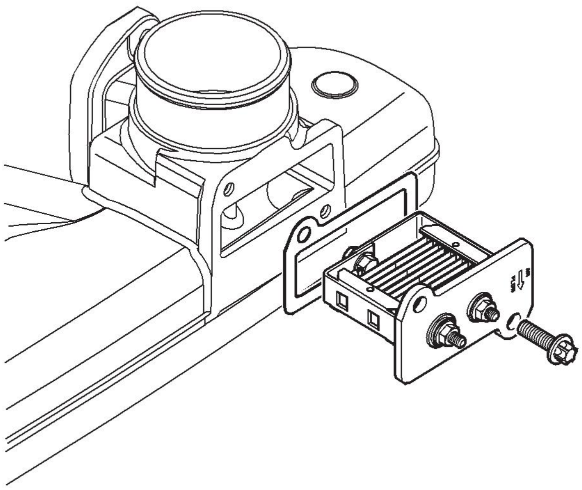


Fig 121.

Start Procedure

1 Make sure that all machine controls are in the `neutral' position.

2 If a pre-heater is fitted, turn the starter key **A** to the to the pre-heat position **II**. If applicable to your equipment, the warning light on the instrument cluster will extinguish when pre-heat is complete.

CAUTION

Do not operate the starter motor for more than 20 seconds at one time. Let the starter motor cool for at least 2 minutes.

0124

3 Turn the starter key to the starter engage position **III** and hold it there until the engine starts. Do not operate the starter for more than 20 seconds.

Note: *If the engine does not start at the first attempt, return the key to the off (**O**) position and allow the starter to cool for a few minutes and then repeat steps **2** and **3**.*

4 As soon as the engine starts, release the key which will return to the run position.

5 ⇨ ***Engine Checks After Start-up (1-101)***.

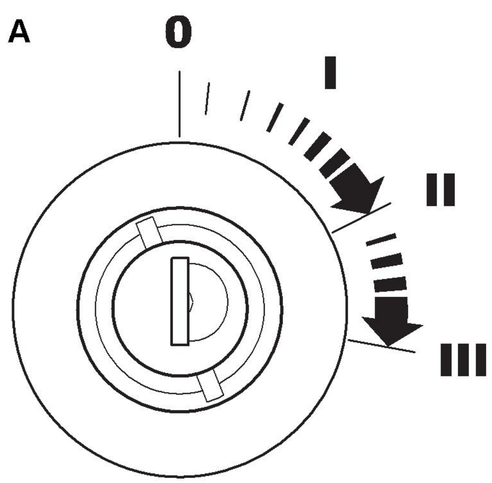


Fig 122.

Engine Checks After Start-up

⚠ WARNING

On turbo-charged machines, do not keep the accelerator pedal fully depressed when the engine has started. Do not race the engine until the oil pressure low light has gone out. Racing the engine too soon could damage the turbo-charger due to insufficient lubrication.

16-2-4-1

⚠ WARNING

Stop the engine and investigate the cause if any of the following conditions occur:

1. **The warning lights fail to go off when the engine has been started.**
2. **The alarm is still sounding when the engine has been started.**
3. **The warning lights illuminate and the alarm sounds when the engine is running.**

16-2-4-2

Check the following items after the engine has been started.

1. Make sure that all the engine instrumentation warning lights have extinguished.
2. Do not over accelerate the engine until the `oil pressure low' warning light has extinguished.
3. If any warning indicator fails to extinguish, or if they illuminate while the engine is running, make the machine safe, stop the engine and investigate the cause.
4. Listen for engine noise, any abnormal noise must be investigated to determine the cause.
5. Check the exhaust smoke colour, generally after the engine has reached operating temperature, the exhaust colour should be as detailed:

- colourless or light blue	- normal
- black	- abnormal
- white	- abnormal

6. Check for any lubricating oil leakage, particularly around joints and connectors.
7. Check the fuel injection pump circuit for leakage, including fuel lines, fuel filter(s) and injection pump.
8. Check the coolant system for signs of leakage, particularly around the radiator and hose connections.

Engine Running-in Procedure

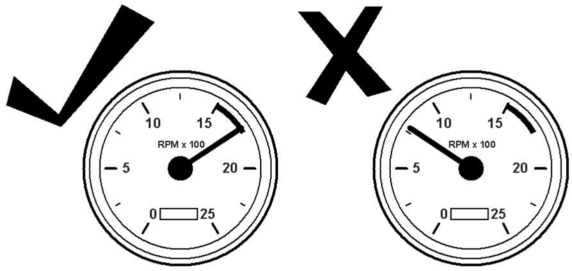
New engines DO NOT require a running-in period. The engine/machine should be used in a normal work cycle immediately.

Glazing of the piston cylinder bores, resulting in excessive oil consumption, could occur if engine duty is too light from new.

Under no circumstances should the engine be allowed to idle for extended periods; (e.g. warming up without load).

A minimum API CF4 grade oil must be used. Superior grade oils may be more appropriate for heavy duty applications (such as sustained high loads and operation at elevated temperatures).

Refer also to ***Lubricants and Capacities, Section 1.***



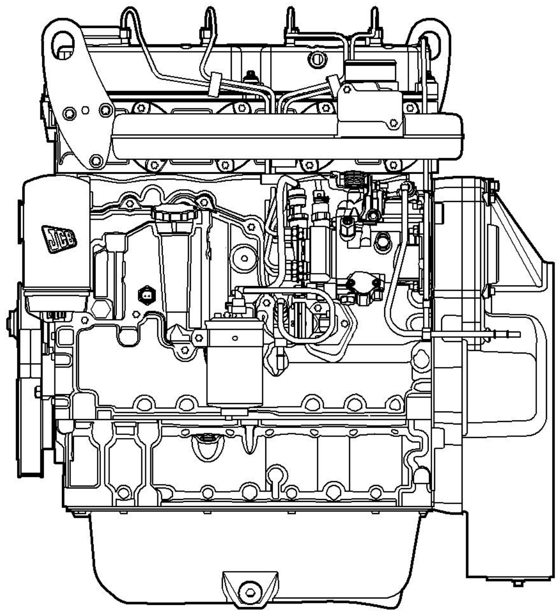


Fig 123.

Stopping the Engine

1 Make sure that all machine controls are in the `neutral' position.

CAUTION

Allow turbocharged engines to run at approximately 1000 rpm and reduced load for 2 to 3 minutes before shut down. This will allow the turbocharger to cool. Failure to follow this procedure could result in turbocharger damage.

ENG-1-6

2 It is recommended that turbocharged engines are run at 1000 RPM (approximately) and reduced load for 2 - 3 minutes before shut down. This will allow the turbocharger to cool and return to idle speed while engine oil pressure is still available for lubrication.

3 Turn the starter key to the OFF (**O**) position, as shown at **A**.

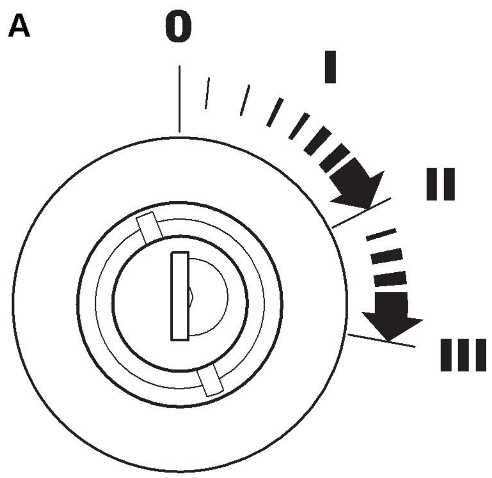


Fig 124.

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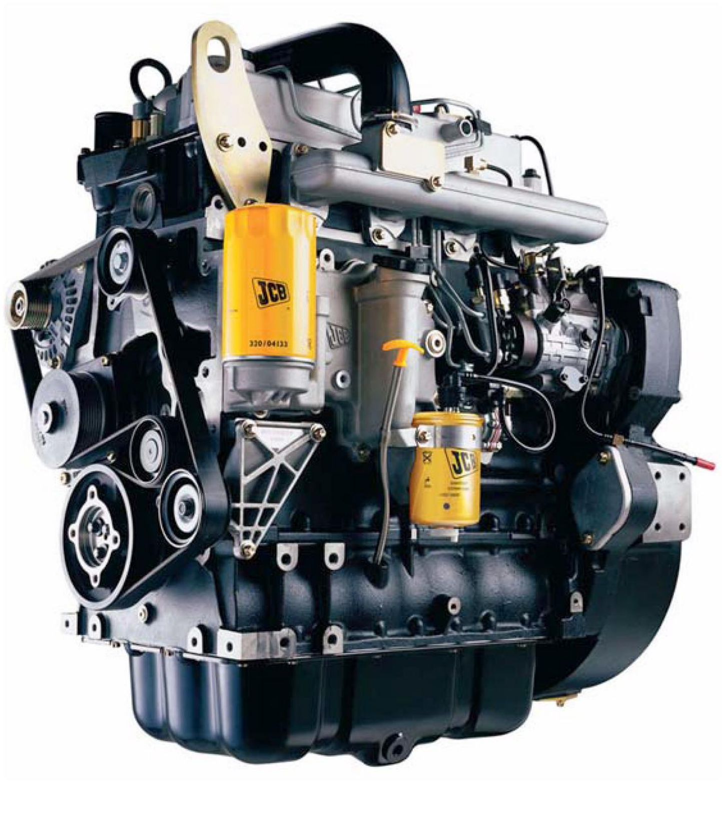
Section 3

Routine Maintenance

Service Manual - JCB 444 Mechanical Engine



Publication No.

9806/3000-04

World Class
Customer Support

Issued by JCB Technical Publications, JCB Aftermarket Training, Woodseat, Rocester, Staffordshire, ST14 5BW, England. Tel +44 1889 591300 Fax +44 1889 591400

Notes:

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Routine Maintenance

Routine Maintenance

Introduction

Maintenance Procedures

The following Routine Maintenance section refers to the engine only.

General references will be made to the machine

WARNING

Machinery utilizing the engine must be correctly parked and prepared, for example safety strut fitted, prior to completing maintenance tasks on the engine.

Maintenance must be completed by suitably qualified personnel.

You or others could be killed or seriously injured if the machine is not correctly prepared and maintained.

ENG-1-5

When the engine is installed in a machine, it will be necessary to make sure that the machine is correctly parked and prepared to safely complete the routine maintenance tasks. Refer to the machine's documentation.

To obtain the best performance from your engine, make sure that the service tasks are completed at the recommended period - see Service Schedules.

If the machine/engine is working in adverse conditions, then the service intervals should be reduced, examples of adverse conditions are:

– operating in a very dusty environment
– operating continuously at high engine load
– operating in an environment with lots of chaff
– operating in an extremely hot and cold environment
– operating continuously on slopes
– operating continuously at high altitude
– operating in an environment with high humidity
– operating with a low quality fuel

Note: *See **Technical Data, Fuel Specifications, Section 1**, for more information relating to recommended fuels.*

All maintenance procedures must be completed by suitably qualified personnel.

Cleaning the Engine

Do not attempt to clean any part of the engine while it is running. Stop the engine and allow it to cool for at least one hour. Disconnect the machine battery.

Use an approved water soluble degreaser to soften any oil deposits. Wash with clean water and allow the engine to dry.

High Pressure Cleaning

CAUTION

The engine or certain components could be damaged by high pressure washing systems; special precautions must be taken if the engine is to be washed using a high pressure system.

Ensure that the alternator, starter motor and any other electrical components are shielded and not directly cleaned by the high pressure cleaning system.

ENG-3-3

Special precautions must be taken if the engine is to be washed using a high pressure cleaning system as follows:

1 Do not aim the jet wash directly at the fuel injector seals (shown at **A**).

2 Do not wash any part of the:

- fuel injection pump
- cold start device
- electrical shut off solenoid (ESOS)
- electrical connections

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

4 Ensure that the alternator, starter motor and any other electrical components are shielded and not directly cleaned by the high pressure cleaning system.

The engine or certain components could be damaged by pressure washing systems.

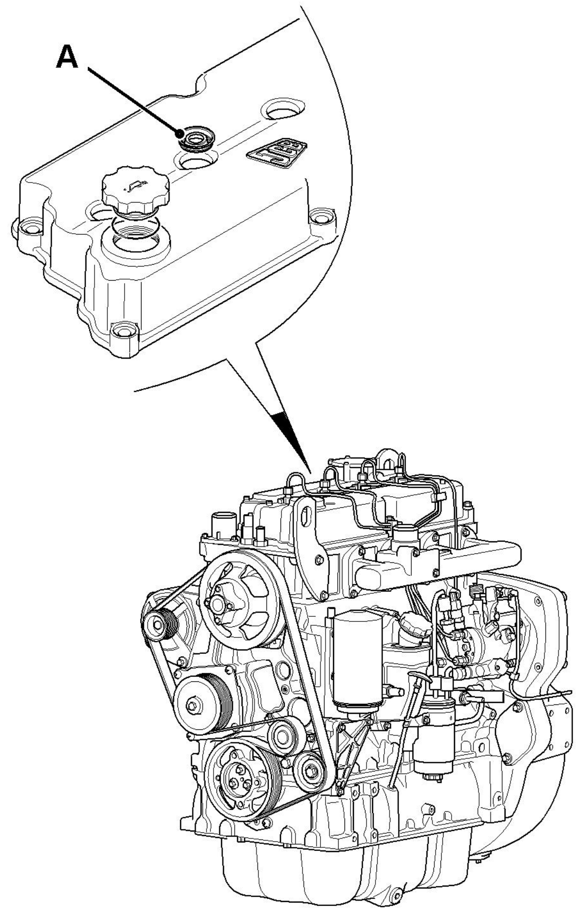

Fig 1.

Lubricants - Health and Safety

It is most important that you read and understand this information and the publications referred to. Make sure all your colleagues who are concerned with lubricants read it too.

Hygiene

JCB lubricants are not a health risk when used properly for their intended purposes.

However, excessive or prolonged skin contact can remove the natural fats from your skin, causing dryness and irritation.

Low viscosity oils are more likely to do this, so take special care when handling used oils, which might be diluted with fuel contamination.

Whenever you are handling oil products you should maintain good standards of care and personal and plant hygiene. For details of these precautions we advise you to read the relevant publications issued by your local health authority, plus the following.

Storage

Always keep lubricants out of the reach of children.

Never store lubricants in open or unlabelled containers.

Waste Disposal

⚠ CAUTION

It is illegal to pollute drains, sewers or the ground. Clean up all spilt fluids and/or lubricants.

Used fluids and/or lubricants, filters and contaminated materials must be disposed of in accordance with local regulations. Use authorised waste disposal sites.

INT-3-2-14

All waste products should be disposed of in accordance with all the relevant regulations.

The collection and disposal of used oil should be in accordance with any local regulations. Never pour used engine oil into sewers, drains or on the ground.

New Oil

There are no special precautions needed for the handling or use of new oil, beside the normal care and hygiene practices.

Used Oil

Used engine crankcase lubricants contain harmful contaminants.

Here are precautions to protect your health when handling used engine oil:

1. Avoid prolonged, excessive or repeated skin contact with used oil.
2. Apply a barrier cream to the skin before handling used oil.
3. Note the following when removing engine oil from skin:
   - **a** Wash your skin thoroughly with soap and water.
   - **b** Using a nail brush will help.
   - **c** Use special hand cleansers to help clean dirty hands.
   - **d** Never use petrol, diesel fuel, or paraffin for washing.
4. Avoid skin contact with oil soaked clothing.
5. Don't keep oily rags in pockets.
6. Wash dirty clothing before re-use.
7. Throw away oil-soaked shoes.

First Aid - Oil

Eyes

In the case of eye contact, flush with water for 15 minutes. If irritation persists, get medical attention.

Swallowing

If oil is swallowed do not induce vomiting. Get medical advice.

Skin

In the case of excessive skin contact, wash with soap and water.

Spillage

Absorb on sand or a locally approved brand of absorbent granules. Scrape up and remove to a chemical disposal area.

Fires

Extinguish with carbon dioxide, dry chemical or foam. Fire-fighters should use self-contained breathing apparatus.

Service Schedules

A badly maintained engine is a danger to the operator and the people working around him. Make sure that the regular maintenance and lubrication jobs listed in the service schedules are done to keep the engine in a safe and efficient working condition.

WARNING

Machinery utilizing the engine must be correctly parked and prepared, for example safety strut fitted, prior to completing maintenance tasks on the engine.

Maintenance must be completed by suitably qualified personnel.

You or others could be killed or seriously injured if the machine is not correctly prepared and maintained.

ENG-1-5

Apart from the daily jobs, the schedules are based on machine running hours. Keep a regular check on the hourmeter readings to correctly gauge service intervals. Do not use a machine which is due for a service. Make sure any defects found during the regular maintenance checks are rectified immediately.

Calendar equivalents:

10 Hours = Daily 50 Hours = Weekly 500 Hours = Six Months 1000 Hours = Yearly 2000 Hours = 2 Years 6000 Hours = 6 Years

The tick boxes indicate the frequency, for example, 'Oil and Filter Change' is indicated every 500 hours. The first change would therefore be at 500 hours,then the next change at 1000 hours, then 1500 hours etc.

Service schedules differ depending on engine application. Make sure you refer to the correct schedule as follows:

⇨ *Table 1. All Applications Except Generator Set Applications (3-6)*

⇨ *Table 2. Generator Set Applications Only (3-7)*

Table 1. All Applications Except Generator Set Applications

Pre-start Cold Checks Service Points and Fluid Levels	Operation	10 Hr	50 Hr	500 Hr	1000 Hr	2000 Hr	6000 Hr
ENGINE							
Oil level	- Check	☐					
Coolant Quality/ level	- Check	☐					
Coolant or Oil Leaks	- Check	☐					
Fuel Filter and Water Sedimentor	- Check for Contamination and Drain		☐				
Oil and Filter (1) (2)(3)	- Change			☐			
Fuel Filter (4)	- Change				☐		
All Hoses - Condition	- Check			☐			
Radiator (5)	- Clean			☐			
Front End Accessory Drive (FEAD) Belt Condition	- Check			☐			
Air Cleaner Outer Element (5)	- Change				☐		
Air Cleaner Inner Element	- Change					☐	
Valve Clearances	- Check and Adjust					☐	
Breather Gauze (6)	- Clean					☐	
Oil Filler and Dipstick O-rings	- Change					☐	
Low Idle Speed	- Check and Adjust					☐	
Cooling system	- Drain and Fill					☐	
Rocker Cover Seal and Injector Seals	- Change					☐	
Front End Accessory Drive (FEAD) Belt	- Change						☐
Injectors	- Change						☐
Injector(s) Leak-Off Rail	- Change						☐
High Pressure Fuel Lines	- Inspect						☐

(1) If operating under arduous conditions, change the engine oil and filter every 250 hours.
(2) The oil service interval will be affected if there is a high sulphur content in the fuel. Refer to Technical Data, Fuel System Data, for more information.
(3) If Dieselmax engines are operated with B20 Biodiesel, change the oil and filter every 250 hours. A minimum specification of CH4 oil must be used. Only Dieselmax engines manufactured from 2007 are suitable for operation with B20 Biodiesel. Other service requirements apply, refer to Technical Data, Fuel System Data, for more information.
(4) Check the machine's operator handbook for the fuel sedimenter filter change frequency.
(5) If operating in dusty adverse working environments, more frequently.
(6) SA, SB, SC engines only.

Table 2. Generator Set Applications Only

Pre-start Cold Checks Service Points and Fluid Levels	Operation	10 Hr	50 Hr	500 Hr	1000 Hr	2000 Hr	6000 Hr
ENGINE							
Oil level	- Check	☐					
Coolant Quality/ level	- Check	☐					
Coolant or Oil Leaks	- Check	☐					
Fuel Filter and Water Sedimentor	- Check for Contamination and Drain		☐				
Oil and Filter (1) (2)(3)	- Change			☐			
Fuel Filter (4)	- Change			☐			
All Hoses - Condition	- Check			☐			
Radiator (5)	- Clean			☐			
Front End Accessory Drive (FEAD) Belt Condition	- Check			☐			
Air Cleaner Outer Element (5)	- Change				☐		
Air Cleaner Inner Element	- Change					☐	
Valve Clearances	- Check and Adjust					☐	
Breather Gauze (6)	- Clean					☐	
Oil Filler and Dipstick O-rings	- Change					☐	
Low Idle Speed	- Check and Adjust					☐	
Cooling system	- Drain and Fill					☐	
Rocker Cover Seal and Injector Seals	- Change					☐	
Front End Accessory Drive (FEAD) Belt	- Change						☐
Injectors	- Change						☐
Injector(s) Leak-Off Rail	- Change						☐
High Pressure Fuel Lines	- Inspect						☐

(1) *If operating under arduous conditions, change the engine oil and filter every 250 hours.*
(2) *The oil service interval will be affected if there is a high sulphur content in the fuel. Refer to Technical Data, Fuel System Data, for more information.*
(3) *If Dieselmax engines are operated with B20 Biodiesel, change the oil and filter every 250 hours. A minimum specification of CH4 oil must be used. Only Dieselmax engines manufactured from 2007 are suitable for operation with B20 Biodiesel. Other service requirements apply, refer to Technical Data, Fuel System Data, for more information.*
(4) *Check the machine's operator handbook for the fuel sedimenter filter change frequency.*
(5) *If operating in dusty adverse working environments, more frequently.*
(6) *SA, SB, SC engines only.*

Engine Oil and Filter

⚠ CAUTION

It is illegal to pollute drains, sewers or the ground. Clean up all spilt fluids and/or lubricants.

Used fluids and/or lubricants, filters and contaminated materials must be disposed of in accordance with local regulations. Use authorised waste disposal sites.

INT-3-2-14

⚠ WARNING

Oil

Oil is toxic. If you swallow any oil, do not induce vomiting, seek medical advice. Used engine oil contains harmful contaminants which can cause skin cancer. Do not handle used engine oil more than necessary. Always use barrier cream or wear gloves to prevent skin contact. Wash skin contaminated with oil thoroughly in warm soapy water. Do not use petrol, diesel fuel or paraffin to clean your skin.

INT-3-2-3

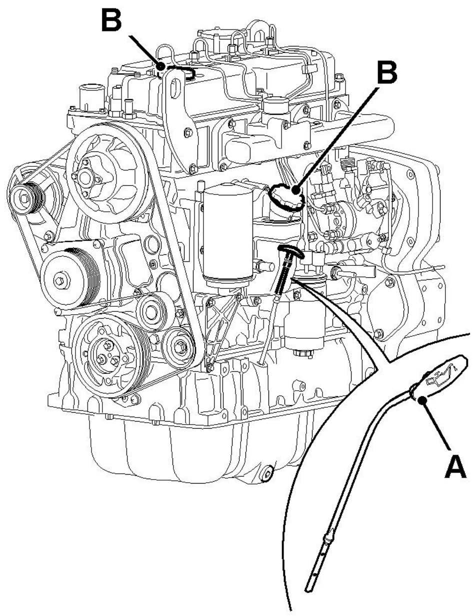

Fig 2.

Checking the Oil Level

Engine oil and oil filter change must be completed in accordance with the service schedules. Failure to change the oil and filter at the recommended interval could cause serious engine failure.

1 Park and make the machine safe in accordance with the machine handbook instructions.

2 Check that the oil level is between the two marks on the dipstick **2-A**.

3 If necessary, add recommended oil through one of the the filler points **2-B**.

Changing the Oil and Filter

Drain the oil when the engine is warm as contaminants held in suspension will then be drained with the oil.

1 Place a container of suitable size beneath the drain plug **3-C**.

⚠ CAUTION

Oil will gush from the hole when the drain plug is removed. Hot oil and engine components can burn you. Keep to one side when you remove the plug.

13-3-1-15

2 Remove drain plug **3-C** and its 'O' ring **3-D**. Let the oil drain out, then clean and refit the drain plug with a new 'O' ring. Torque tighten the plug to 40 - 60 Nm (30 - 44 lbf ft).

3 Loosen and remove filter housing drain plug **3-E**. Let the oil fully drain. Refit the plug. Torque tighten the plug to 40 - 60 Nm (30 - 44 lbf ft).

4 Unscrew the filter canister **3-F**, using a chain wrench if necessary.

5 Clean the seal face of the filter head **3-G**.

6 Smear the seal **3-H** on the new filter canister with clean engine oil.

7 Screw in the new filter canister - hand tight only.

⚠ CAUTION

It is illegal to pollute drains, sewers or the ground. Clean up all spilt fluids and/or lubricants.

Used fluids and/or lubricants, filters and contaminated materials must be disposed of in accordance with local regulations. Use authorised waste disposal sites.

INT-3-2-14

8 Through one of the filler points **3-B**, fill the engine with the recommended oil to the MAX mark on the dipstick **3-A**. Wipe off any spilt oil, refit the filler cap and make sure it is secure.

9 Operate the engine until the oil pressure low warning light has extinguished. Check for oil leakage. When the oil has cooled, check the oil level again, and if necessary top up with clean engine oil.

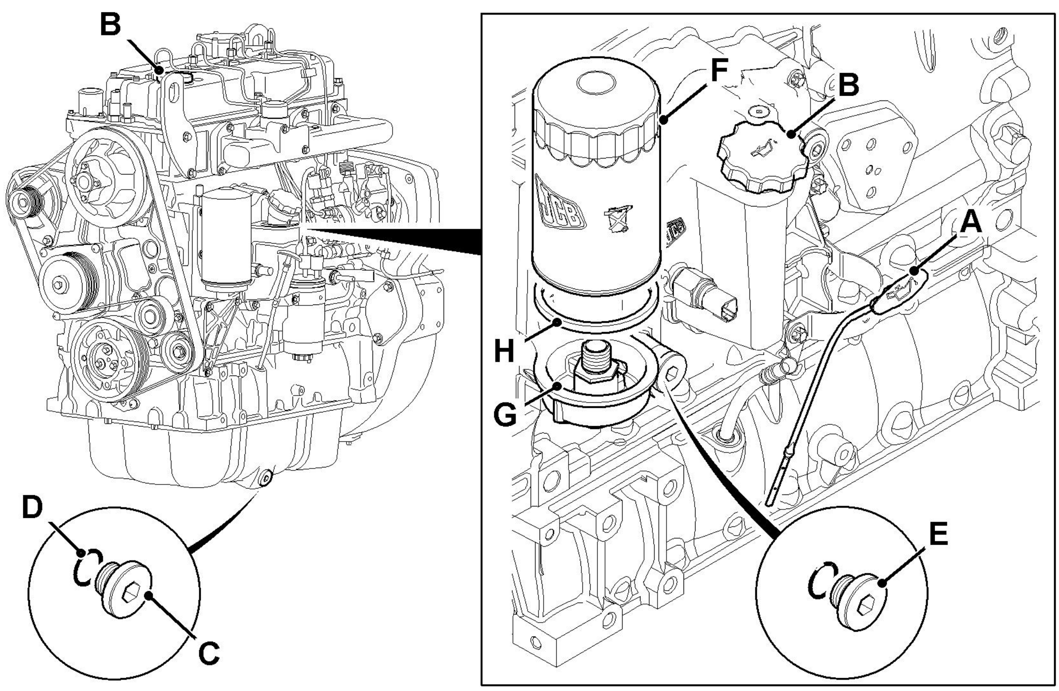

Fig 3.

Engine Cooling System

Coolant Mixtures

The protection provided by JCB Four Seasons Anti-freeze and Summer Coolant is shown below. If any other anti-freeze is used, refer to the manufacturer's instructions and ensure that a corrosion inhibitor is included.

DO NOT use solutions of more than 50% or damage to the engine may occur.

Solution	Maintains circulation down to:	Protects against damage down to:
50%	-33°C (-27°F)	-45°C (-49°F)

The strength of the anti-freeze solution must be checked at least once a year, preferably at the beginning of the cold period.

It is an advantage to leave the anti-freeze in all the year round as it gives continued protection against corrosion. Always renew the anti-freeze every two years.

A 50% anti-freeze mixture must be used even if frost protection is not needed. This gives protection against corrosion and raises the coolant's boiling point.

WARNING

Antifreeze can be harmful. Obey the manufacturer's instructions when handling full strength or diluted antifreeze.

7-3-4-4_1

Checking the Coolant Level

The procedures below describes a typical coolant package installation.

WARNING

The cooling system is pressurised when the coolant is hot. When you remove the cap, hot coolant can spray out and burn you. Make sure that the engine is cool before you work on the cooling system.

9-3-3-1_2

1 Park and make the machine safe in accordance with the machine handbook instructions.

2 Check the level of coolant in the expansion bottle **4-A**. If necessary remove the filler cap and top up to the level indicated.

3 Refit the filler cap and make sure it is tight.

4 Run the engine for a while to raise the coolant to working temperature and pressure. Stop the engine and check for leaks.

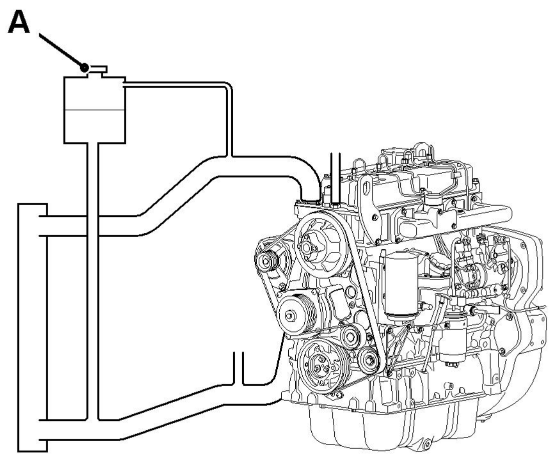

Fig 4.

Changing the Coolant

The procedures below describes a typical coolant package installation.

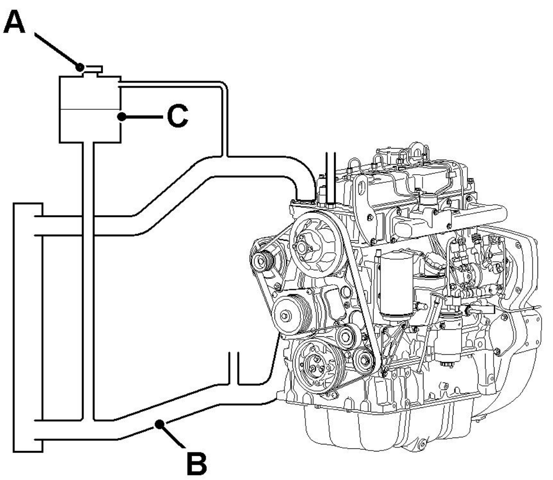

Fig 5.

WARNING

The cooling system is pressurised when the coolant is hot. When you remove the cap, hot coolant can spray out and burn you. Make sure that the engine is cool before you work on the cooling system.

9-3-3-1_2

1. Park and make the machine safe in accordance with the machine handbook instructions. Stop the engine and let it cool down.

2. Carefully loosen cap **5-A** just enough to let any pressure escape. Remove the cap when all pressure is released.

3. Disconnect the bottom radiator hose at **5-B** and allow the coolant to drain.

4. Flush the system by pouring clean water into filler port **5-A**.

5. Reconnect the radiator hose.

6. Fill the expansion bottle **5-C**, using the necessary anti-freeze solution, to the level indicated.

7. Check for leaks.

8. Run the engine for a while to raise the coolant to working temperature and pressure. Stop the engine and check for leaks. Check the level in the expansion bottle and top up if necessary.

Front End Accessory Drive (FEAD) Belt

A spring loaded tensioning unit **6-A** ensures that the front end accessory drive belt (FEAD) **6-B** is kept at the correct tension.

⚠ WARNING

Make sure the engine cannot be started. Disconnect the battery before doing this job.

2-3-3-5

⚠ WARNING

Turning the Engine

Do not try to turn the engine by pulling the fan or fan belt. This could cause injury or premature component failure.

0094

Front End Accessory Belt (FEAD) Inspection

At the recommended service interval, visually inspect the belt for damage.

1. Park and make the machine safe in accordance with the machine handbook instructions. Stop the engine and let it cool down.
2. Renew the belt if it has cracks or if it is frayed or has pieces of material missing (as shown at **6-C**).

If the belt does need replacing follow the procedures described below:

Front End Accessory Belt (FEAD) Replacement

1. Park and make the machine safe in accordance with the machine handbook instructions. Stop the engine and let it cool down.
2. Use a 16mm socket located on the hexagon spigot nut **6-D**, carefully rotate the tensioner against spring force in the direction shown. Do not use excessive force or the tensioner will be damaged.
3. Keep holding the tensioner against the spring force and lift the belt off the drive tensioner pulley.
4. Slowly release the spring force by rotating the tensioner unit in the opposite direction.
5. Before fitting the new belt, check that the tensioner roller and the fan pulley rotate smoothly and that there is no play in the bearings.
6. Fit the new belt using a reversal of the above procedures.

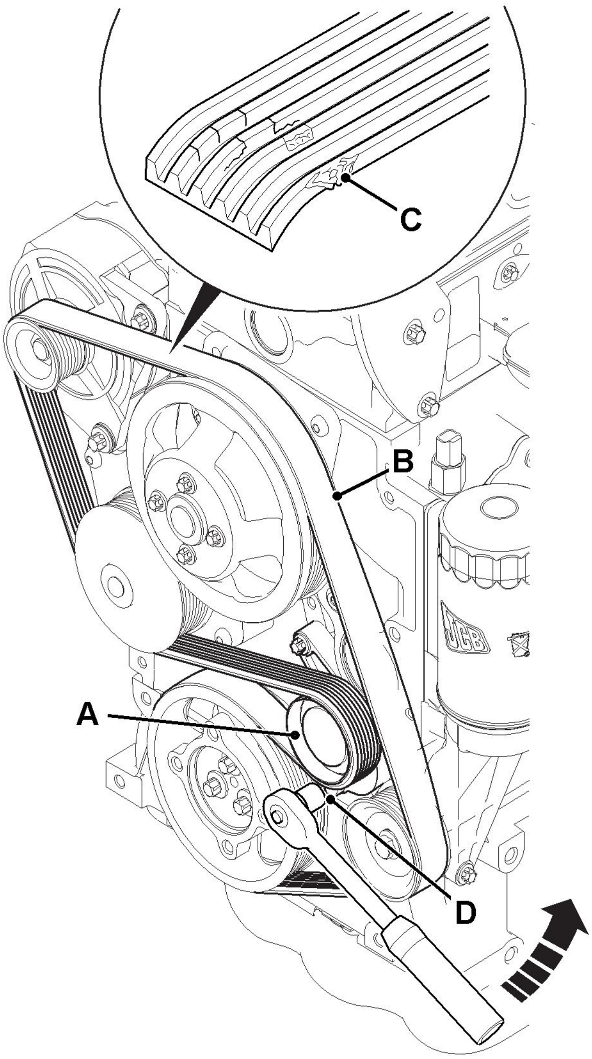

Fig 6.

Engine Fuel System

Draining the Water Separator and Fuel Filter

⚠ CAUTION

It is illegal to pollute drains, sewers or the ground. Clean up all spilt fluids and/or lubricants.

Used fluids and/or lubricants, filters and contaminated materials must be disposed of in accordance with local regulations. Use authorised waste disposal sites.

INT-3-2-14

1. Park and make the machine safe in accordance with the machine handbook instructions.
2. Drain off any water in the element **7A** by turning tap **7B**.
3. Drain off any water in the water separator bowl **7A** by turning tap **7B**. DO NOT disconnect the water in fuel electrical connector **7C**.
4. If there is sediment in the bowl after draining, support the bowl and release the locking ring **7D**.
5. Wash the bowl in clean fuel.
6. Refit the bowl, secure in position with locking ring **7D**.
7. Make sure that the water in fuel electrical connector **7C** is correctly fitted.

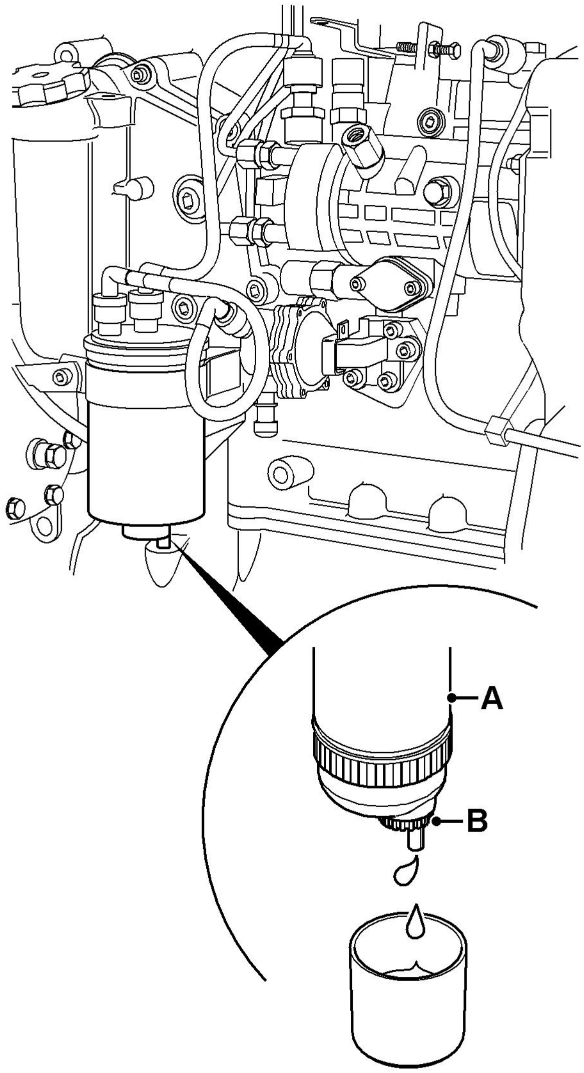

Fig 7.

Changing the Filter Element

1 Park and make the machine safe in accordance with the machine handbook instructions.

⚠ CAUTION

Do not allow dirt to enter the fuel system. Before disconnecting any part of the fuel system, thoroughly clean around the connection. When a component has been disconnected, for example a fuel pipe, always fit protective caps and plugs to prevent dirt ingress.

Failure to follow these instructions will lead to dirt entering the fuel system. Dirt in the fuel system will seriously damage the fuel injection equipment and could be expensive to repair.

ENG-1-7

2 Thoroughly clean the outside of the filter housing and around the filter head.

3 Loosen the drain tap **8B** and allow the water/fuel to drain into a suitable container.

4 Remove the low pressure fuel lines **8C**. Mark the pipes prior to removal to ensure they are refitted in the correct position.

5 Release the filter strap retaining screw **8D** and lift the filter clear.

Note: *Some installations have a washer fitted between the strap and the cooler housing - keep the washer to reuse.*

6 Install new filter element **8A**. Make sure that the black dot is aligned with the locating hole in the strap. Torque tighten the filter strap retaining screw **8D** to 24 Nm (17.7 lbf ft).

7 Reconnect the fuel lines **8C** and **8E**.

Note: *Some engine configurations have a dipstick retaining bracket located at the filter strap retaining screw. When tightening the filter strap screw ensure that the dipstick bracket does not foul the filter element.*

8 Bleed the fuel system. ⇨ ***Priming the Fuel System (3-16)***

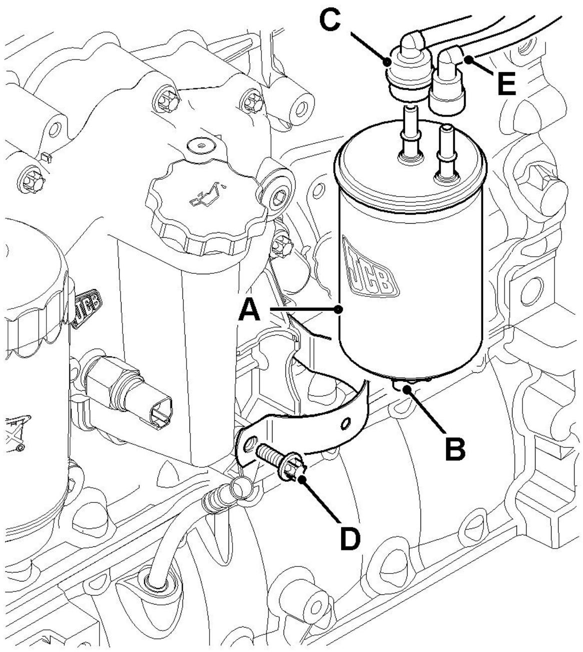

Fig 8.

Changing the Water Separator Pre- Filter

Note: *Refer to the machine handbook for information relating to the location of the pre-filter and water separator.*

1 Park and make the machine safe in accordance with the machine handbook instructions.

CAUTION

Do not allow dirt to enter the fuel system. Before disconnecting any part of the fuel system, thoroughly clean around the connection. When a component has been disconnected, for example a fuel pipe, always fit protective caps and plugs to prevent dirt ingress.

Failure to follow these instructions will lead to dirt entering the fuel system. Dirt in the fuel system will seriously damage the fuel injection equipment and could be expensive to repair.

ENG-1-7

2 Drain and remove the water separator bowl **9C**. ⇨ *Draining the Water Separator and Fuel Filter (3-13)*.

3 To remove the filter element **9A**, release locking ring **9B** and discard element.

4 Fit new element and secure in position with locking ring **9B**.

5 Refit water separator bowl **9C**.

6 Make sure that the water in fuel electrical connector **9D** is correctly fitted.

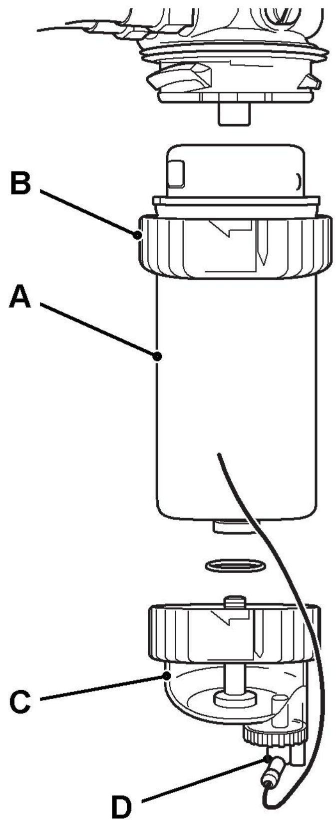

Fig 9.

Priming the Fuel System

⚠ CAUTION

Running the engine with air in the system could damage the fuel injection pump. After maintenance, the system must be bled to remove any air.

2-3-3-11

⚠ WARNING

Fine jets of fluid at high pressure can penetrate the skin. Keep face and hands well clear of pressurised fluid and wear protective glasses. If fluid penetrates your skin, get medical help immediately.

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The entry of air into the fuel system can cause problems such as difficult engine starting and unstable engine running.

Typically, the source of the air is often through leaks in the low pressure side of the fuel system (the fuel feed lines to the fuel injection pump). Air can enter the fuel system if the following occurs:

- A fuel system component has been disconnected. For example, when renewing the fuel filter.
- A leak in the low pressure side of the fuel system during engine operation, or the low pressure pipes have been disconnected.
- The fuel tank is allowed to drain during normal operation.
- Draining of the water separator pre-filter and not priming afterwards.
- The fuel filter seals are leaking.
- The fuel lift pump is faulty (split diaphragm or loose stub pipes).
- The high pressure fuel pipes have been disconnected.

1 Disconnect the fuel feed line **10A** at the fuel injection pump.

2 Operate the fuel lift pump priming lever **10B** or **10C** until air free fuel exits from the fuel line.

Note: *If no fuel is moved when the fuel lift pump priming lever **10B** is operated, then the pump diaphragm may have rested in a 'maximum lift' position. To move the diaphragm, use the starter key to turn the engine, then try the priming lever again.*

3 Reconnect the fuel feed line **10A**.

4 Run the engine at idle and operate the throttle between idle and half speed (1200 rpm) repeatedly for 2 minutes.

Note: *The engine should never be run at full speed or full load until the fuel system has been properly purged of air.*

5 If the engine runs smoothly for a short time, and then begins to run roughly or stops, check for air in the fuel system. Use the method below to help diagnose air ingress into the system:

Any air in the fuel system will pass through the fuel injection pump and be expelled via the fuel return line.

a Disconnect the fuel return line (line to tank) at the engine connection **10X**. In its place, connect a length of clear plastic fuel line tubing (see ***Service Tools***). Allow the other end of the tubing to drain into a suitable clean container.

b Start the engine and run at idle for 3 minutes.

c Run the engine at half speed for 3 minutes.

d Examine the clear tubing for signs of air bubbles.

If no bubbles are present, then air is not being drawn into the fuel system.

If there are air bubbles, check all seals and connections. Tighten or replace each item in the low pressure side of the system.

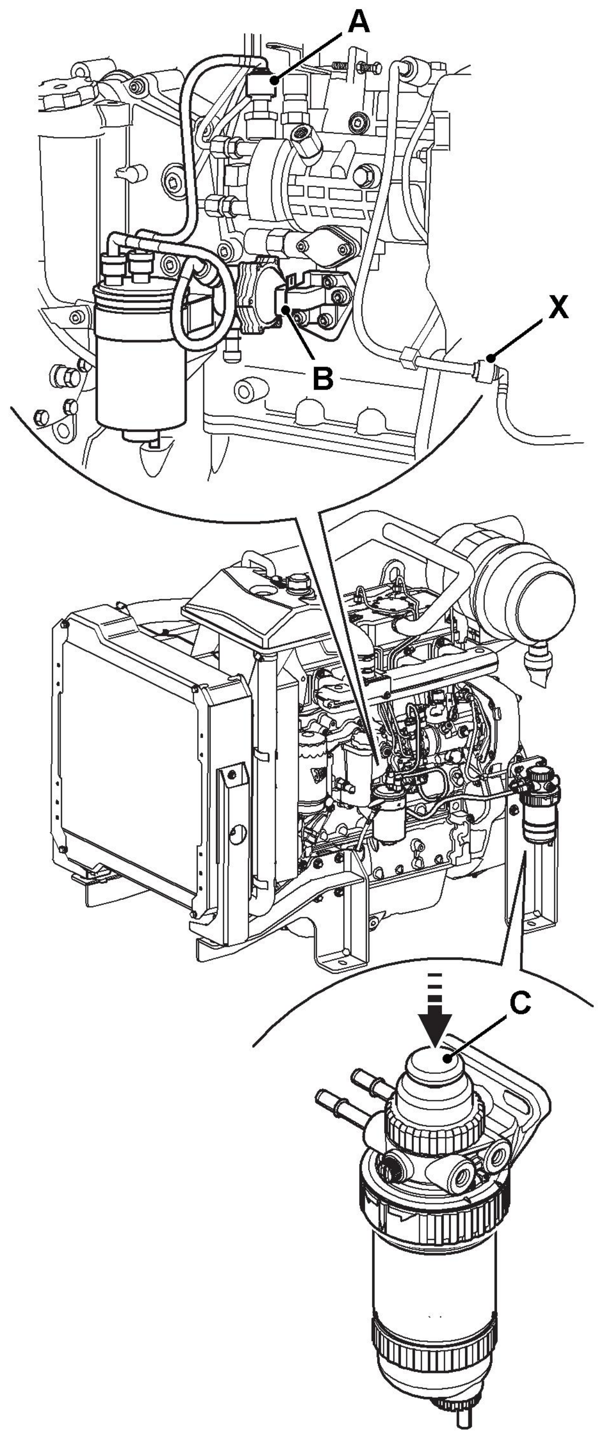

Fig 10.

Air Intake System

Engine performance and durability will be severely affected if the quality of the air intake is poor.

A dirty and blocked air cleaner element will reduce the amount of air entering the combustion chamber which can cause engine mis-firing, black smoke and low output power.

A dirty and blocked air filter can also lead to abrasion of the cylinder bores and valves (referred to as `dusting'). This will cause excessive oil consumption, black smoke, low output power and a reduced engine life.

Refer to the machine's operator handbook for the air filter element removal and replacement procedures.

Inspect hoses and fittings for splits and poor clamping which may allow unfiltered air to enter the engine.

In hostile environments, change the air filter elements more frequently.

In some applications, an air filter pre-cleaner can be fitted.

A typical air filter installation is shown, **11-A** is the outer element and **11-B** is the inner element. Item **11-C** shows a potential problem as the hose has split allowing dirty unfiltered air to enter the engine.

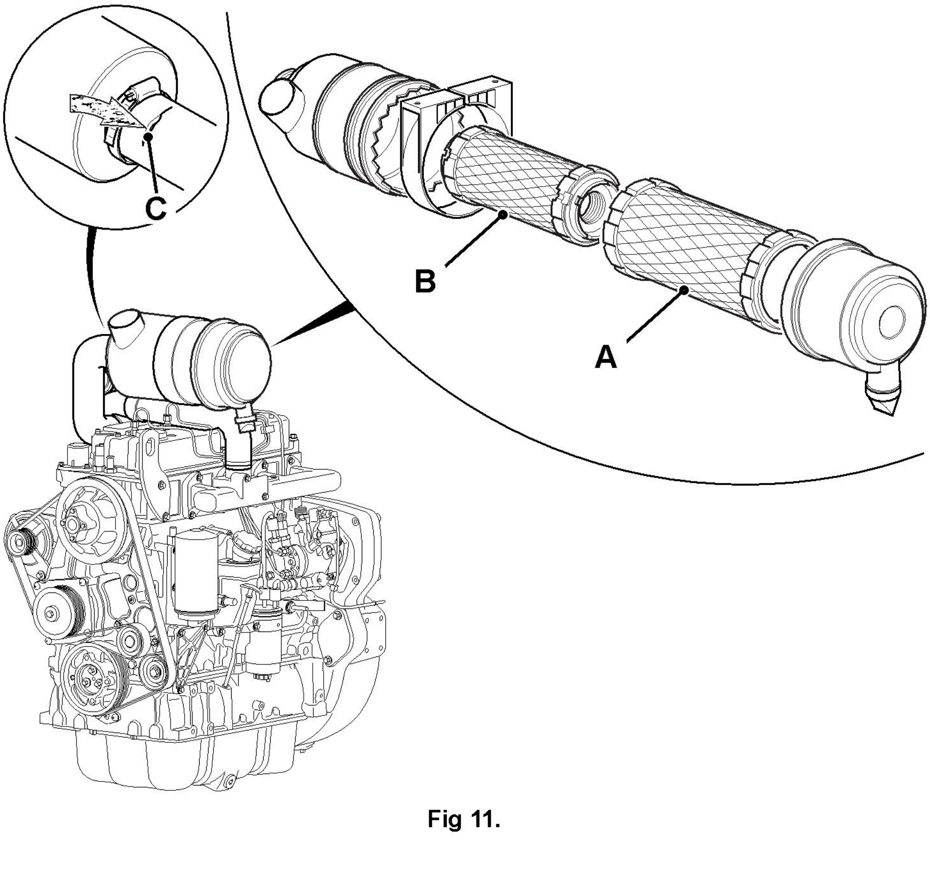

Fig 11.

Engine Breather

Cleaning the Engine Breather Gauze

The breather gauze is located inside the rocker cover as shown at **12A**. It should be cleaned or changed at the recommended interval - ⇨ ***Service Schedules (3-5)***.

1 Park the machine safe in accordance with the machine handbook instructions.

2 Remove the rocker cover, refer to ***Rocker Cover, Section 12***.

3 Loosen and remove the filter gauze cover retaining screws **12B**.

4 Remove the filter gauze cover **12C** and the filters **12D**.

5 Using a suitable and safe cleaning solvent clean the filters (or fit new filters), make sure any residual oil has been fully removed.

6 Make sure the filters are fully dried before refitting.

7 Fit the gauze filters. Apply JCB Threadlocker to screws **12B**. Make sure that the tapped holes in the rocker cover are clean and free from excessive oil. Torque tighten the screws **12B** to 8-10 Nm (6-7 lbf ft).

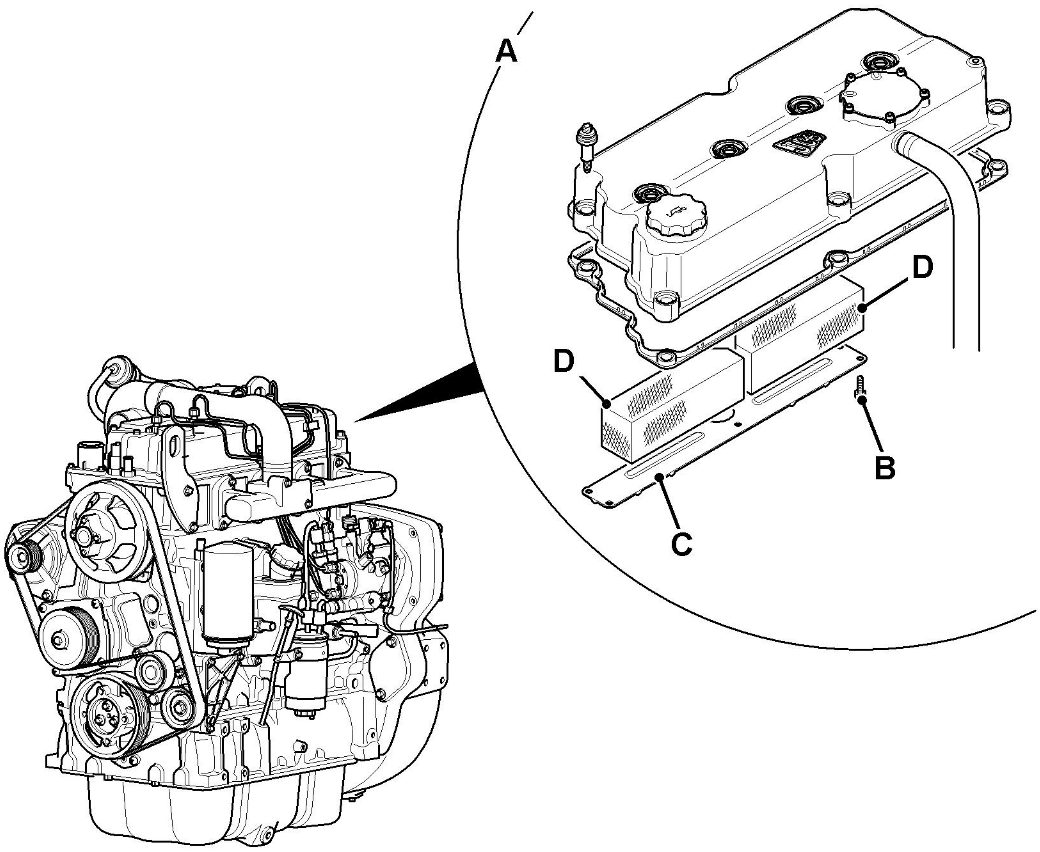

Fig 12.

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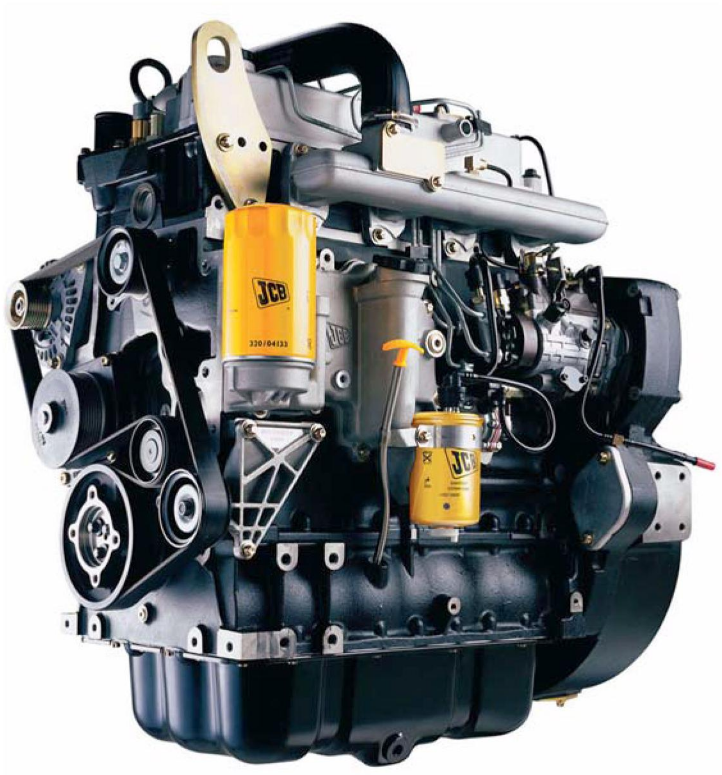
Section 4

Systems Description

Service Manual - JCB 444 Mechanical Engine



Publication No.
9806/3000-04

World Class
Customer Support

Issued by JCB Technical Publications, JCB Aftermarket Training, Woodseat, Rocester, Staffordshire, ST14 5BW, England. Tel +44 1889 591300 Fax +44 1889 591400

Notes:

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Engine Overview

Component Identification

External

The following identifies the main components of a typical engine assembly visible from the exterior. Some variants may differ in detail.

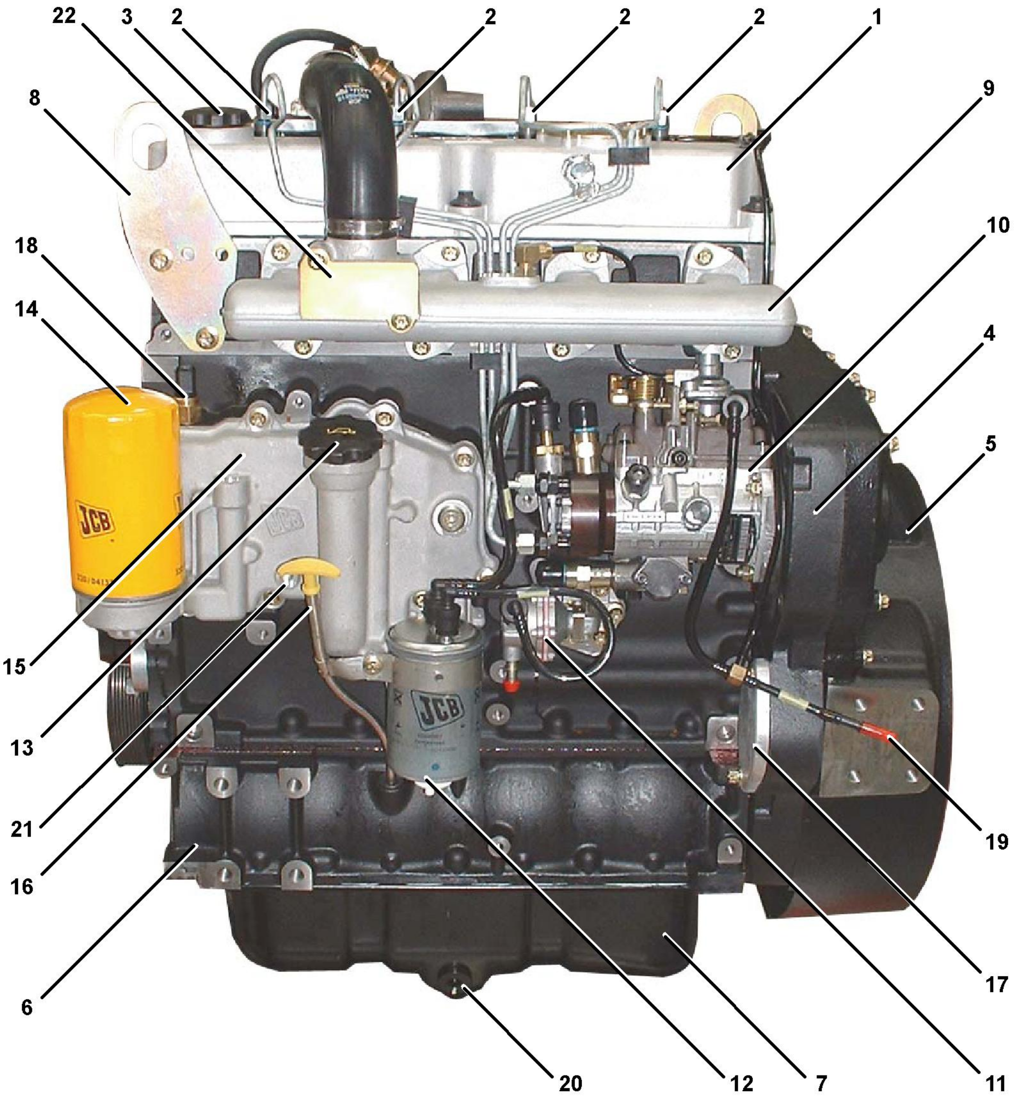


Fig 1. SB Type engine shown

⇨ *Table 1. (4-2)*

Component Identification

Table 1. Engine - As viewed on the left hand side

⇨ *Fig 1. (4-1)*.

1	Rocker cover	12	Fuel filter
2	Fuel injectors and high pressure fuel pipes	13	Lubrication oil filler cap
3	Lubrication oil filler cap	14	Lubrication oil filter
4	Timing gear case	15	Lubrication oil cooler housing
5	Flywheel housing	16	Lubrication oil dip stick
6	Bed plate	17	Low duty PTO (blanking cover if no device is fitted)
7	Lubrication oil pan (sump)	18	Water temperature sender (cold start)
8	Engine lifting eye	19	Low pressure fuel line (to tank)
9	Air Inlet manifold	20	Oil drain plug (sump)
10	Fuel injection pump	21	Oil pressure switch
11	Fuel lift pump	22	Inlet manifold induction heater (if fitted)

Component Identification

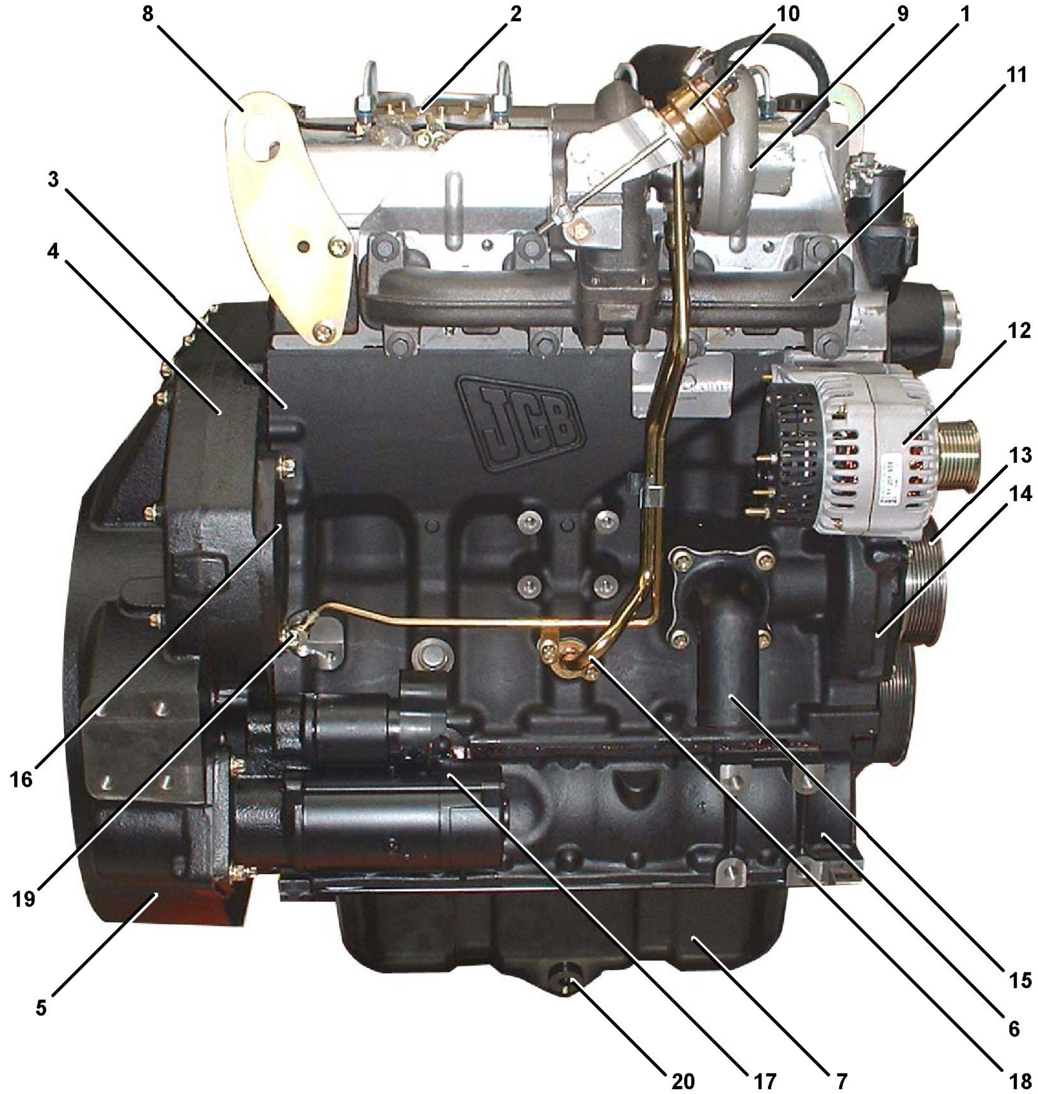


Fig 2. SB Type engine shown

⇨ *Table 2. (4-4)*

Table 2. Engine - As viewed on the right hand side

⇨ *Fig 2. (4-3)*

1	Rocker cover	11	Exhaust manifold
2	Breather chamber inspection cover	12	Alternator and pulley assembly (drive belt not fitted)
3	Cylinder block	13	Coolant pump drive pulley (drive belt not fitted)
4	Timing gear case	14	Coolant pump housing (cylinder block)
5	Flywheel housing	15	Coolant inlet/radiator hose connector
6	Bed plate	16	Heavy duty PTO (blanking cover if no device is fitted)
7	Lubrication oil pan (sump)	17	Starter motor assembly
8	Engine lifting eye	18	Turbocharger oil drain line (turbocharged engines only)
9	Turbocharger (turbocharged engines only)	19	Turbocharger oil feed line (turbocharged engines only)
10	Turbocharger waste gate actuator assembly	20	Oil drain plug (sump)

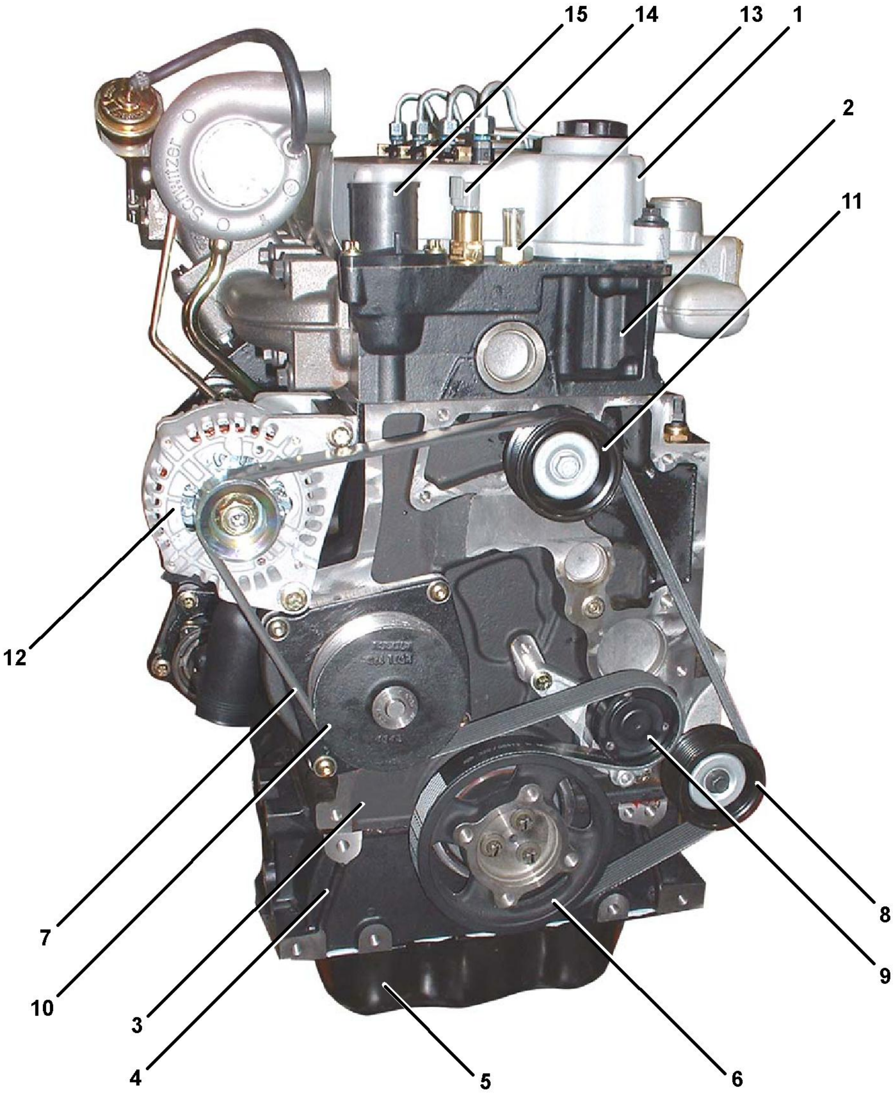


Fig 3. SB Type engine shown

Table 3. Engine - As viewed on the crankshaft pulley (front) end

⇨ *Fig 3. (4-5)*

1	Rocker cover	9	Drive belt tensioner and pulley
2	Cylinder head	10	Coolant pump and drive pulley assembly
3	Cylinder block	11	Idler pulley
4	Bed plate	12	Alternator and drive pulley assembly
5	Lubrication oil pan (sump)	13	Cab heater water hose connector
6	Crankshaft pulley	14	Coolant temperature sender
7	Front end accessory drive belt	15	Coolant thermostat housing/radiator hose connector
8	Idler pulley		

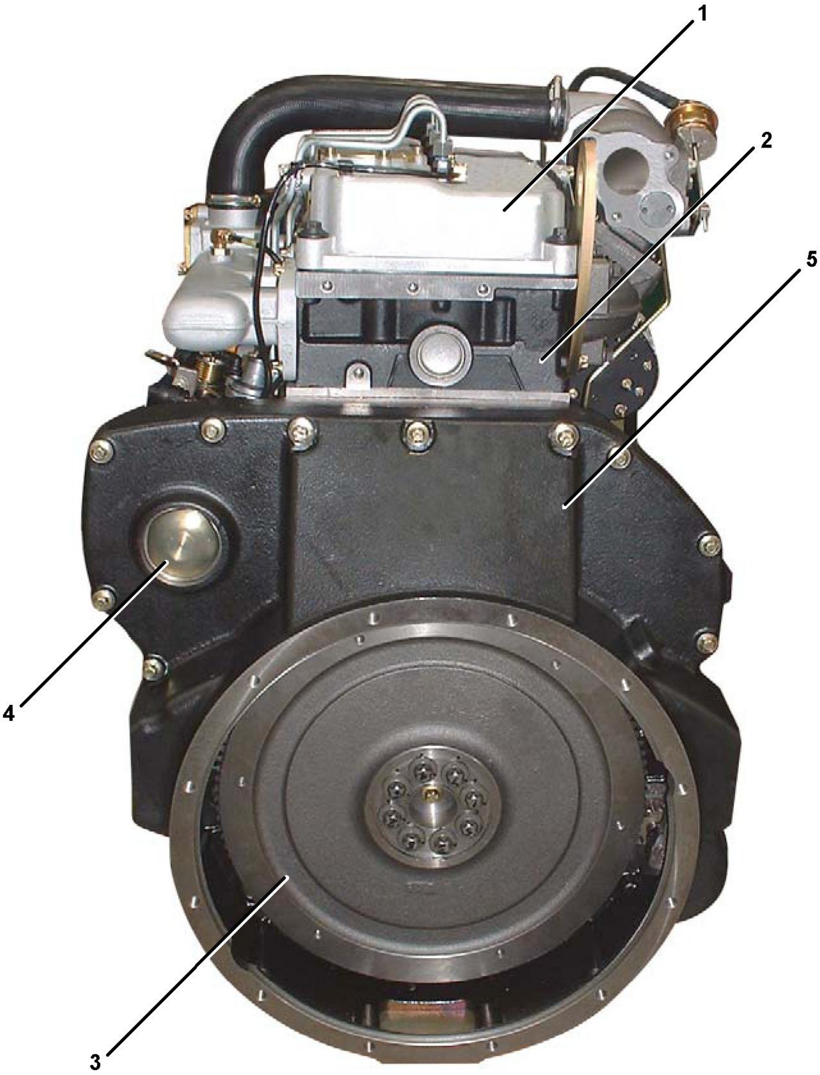


Fig 4. SB Type engine shown

Table 4. Engine - As viewed on the flywheel (rear) end

⇒ Fig 4. (4-6)			
1	Rocker cover	4	Fuel injection pump drive gear cover
2	Cylinder head	5	Flywheel housing
3	Flywheel		

Internal

The following indentifies the main internal components of a typical engine assembley. Some variants may differ in detail.

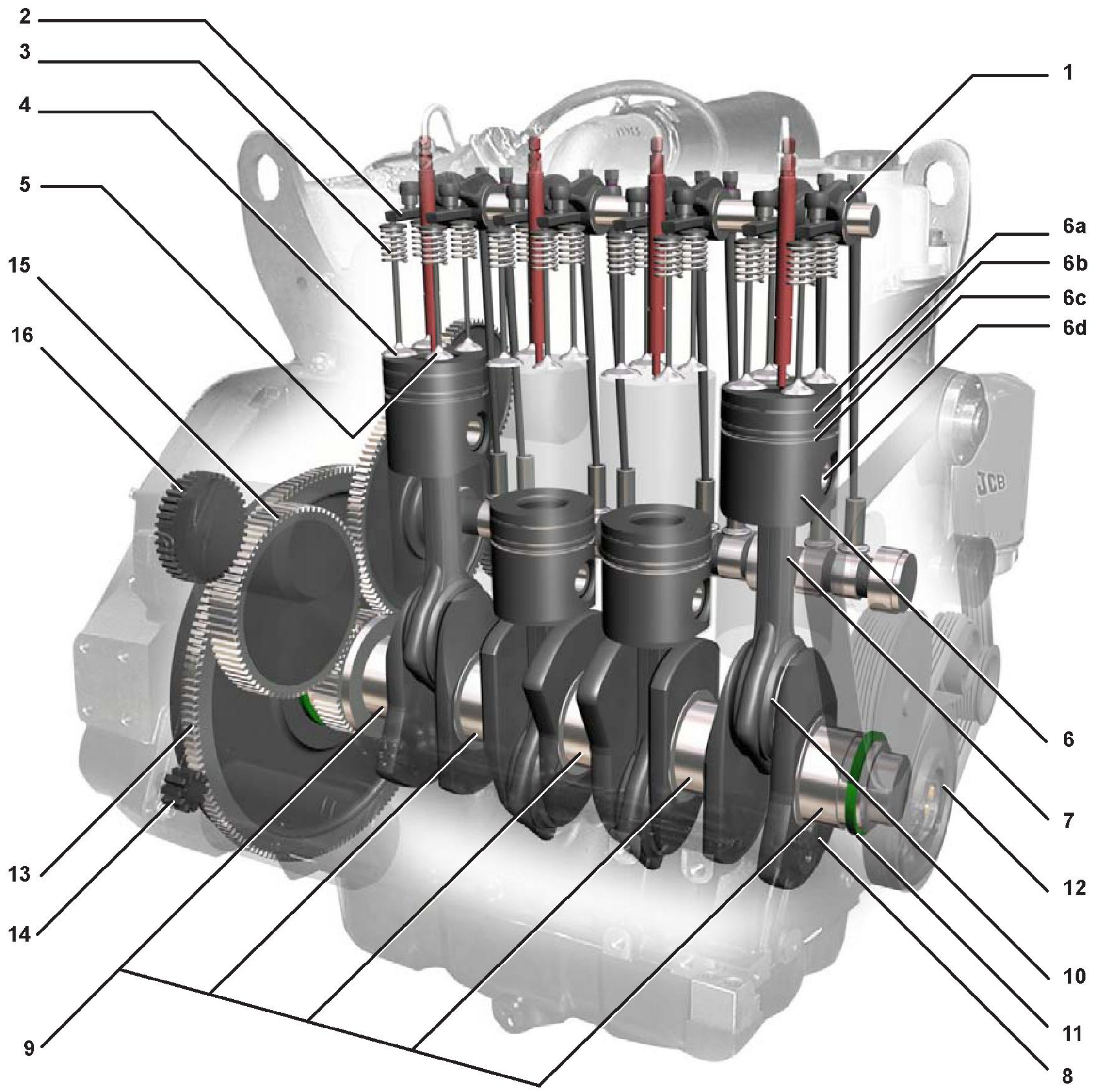


Fig 5. Engine - As viewed on the front right side

⇨ *Table 5. (4-8)*

Table 5. Engine - As viewed on the front right side

⇒ Fig 5. (4-7)			
1	Rocker assembly	7	Connecting rod assembly (4 off)
2	Valve bridge piece (8 off)	8	Crankshaft
3	Valve spring (16 off)	9	Main bearing - crankshaft (5 off)
4	Inlet valve (8 off)	10	Big end bearing - crankshaft/connecting rod (4 off)
5	Exhaust valve (8 off)	11	Front crankshaft oil seal
6	Piston assembly (4 off)	12	Front end drive belt pulley
6a	Piston ring - top compression (4 off)	13	Flywheel
6b	Piston ring - 2nd compression (4 off)	14	Starter motor pinion
6c	Piston ring - oil control (4 off)	15	High duty P.T.O. idler gear (if fitted)
6d	Gudgeon pin (4 off)	16	High duty P.T.O. device drive gear (if fitted)

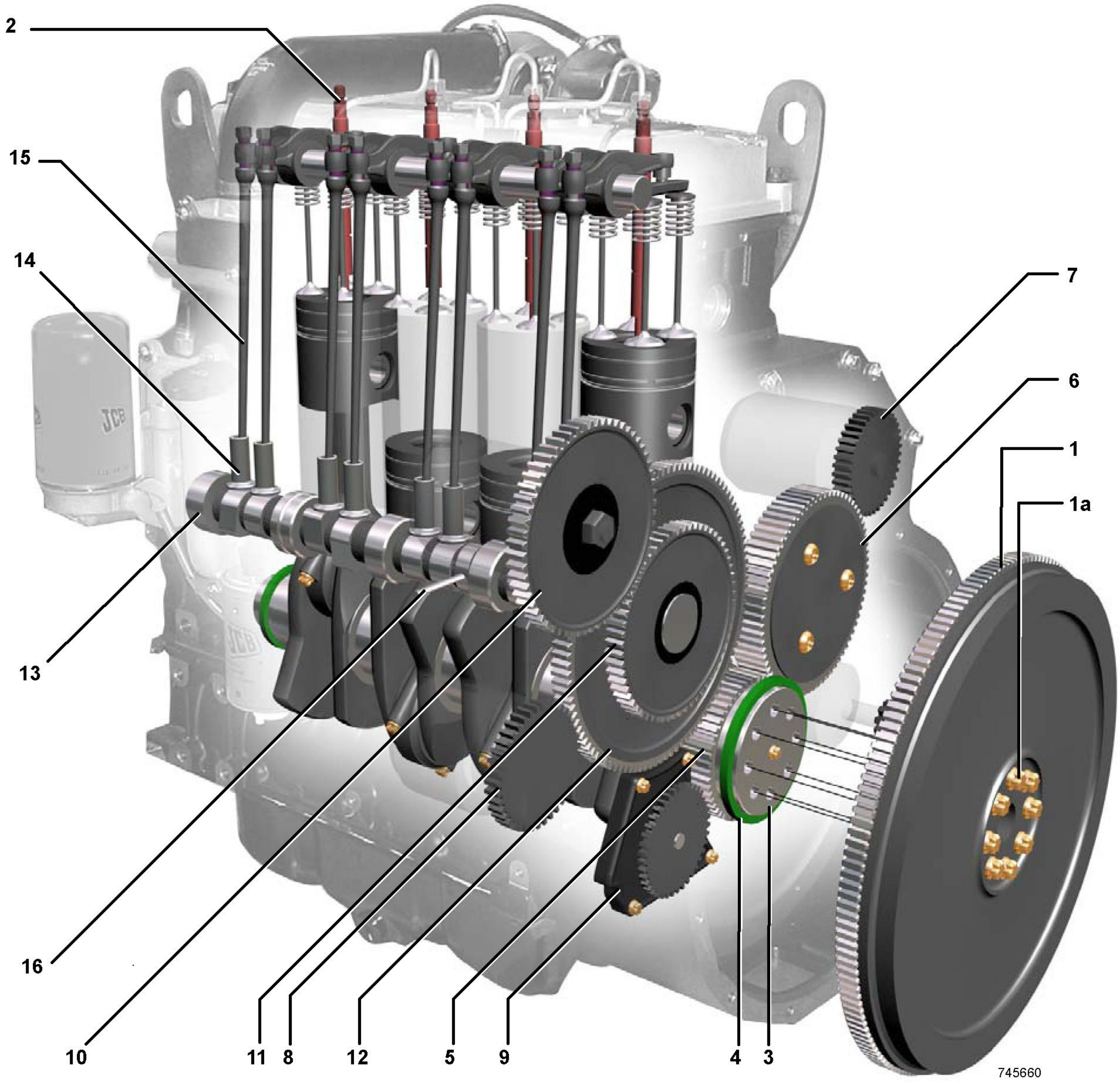


Fig 6. Engine - As viewed on the rear left side

⇨ *Table 6. (4-10)*

Table 6. Engine - As viewed on the rear left side

⇨ Fig 6. (4-9)

1	Flywheel	9	Lubrication oil pump
1a	Flywheel - crankshaft fixing bolts (8 off)	10	Fuel injection pump drive gear
2	Fuel injector (atomiser) (4 off)	11	Camshaft compound gear - drive to item 10
3	Flywheel hub	12	Camshaft drive gear
4	Rear crankshaft oil seal	13	Camshaft
5	Crankshaft drive gear	14	Tappet (8 off)
6	High duty P.T.O. idler gear (if fitted)	15	Push rod (8 off)
7	High duty P.T.O. device drive gear (if fitted)	16	Fuel lift pump actuator pin
8	Low duty P.T.O. device (if fitted)		

Basic Description

The JCB 444 engine is a 4 cylinder diesel engine in which the fuel is ignited by compression ignition (C.I.). The engine operates on a four stroke cycle, ⇨ *The Four Stroke Cycle (4-14)*.

The engine is started by electric starter motor **7-1**. The motor turns the engine via a pinion and teeth on the engine flywheel **7-2**.

When the engine runs the crankshaft **7-3** drives the camshaft **7-4** via gears. The camshaft opens and closes the inlet and exhaust valves **7-5** and **7-6** via push rods **7-7** in time with the four stroke cycle. The engine has 16 valves, 2 inlet and 2 exhaust valves for each cylinder.

The crankshaft also drives a mechanical fuel injection pump **7-8** via gears. The pump injects fuel via injectors, or atomisers **7-9** into each cylinder in time with the four stroke cycle. Fuel is pumped from a fuel tank to the injection pump by means of a lift pump **7-10** driven by cam lobes on the camshaft.

Air is drawn into the engine via inlet manifold **7-11** and exhaust gasses exit via exhaust manifold **7-12**. On turbocharged engines an exhaust driven turbocharger **7-13** pressurises air at the inlet manifold.

A mechanical lubrication oil pump **7-14** is driven by the crankshaft via gears. The pump pressurises and circulates oil for engine lubrication and cooling purposes.

A drive belt **7-15** again driven by the crankshaft, drives a coolant circulation pump, alternator, radiator cooling fan and other ancilliaries such as an air conditioning compressor.

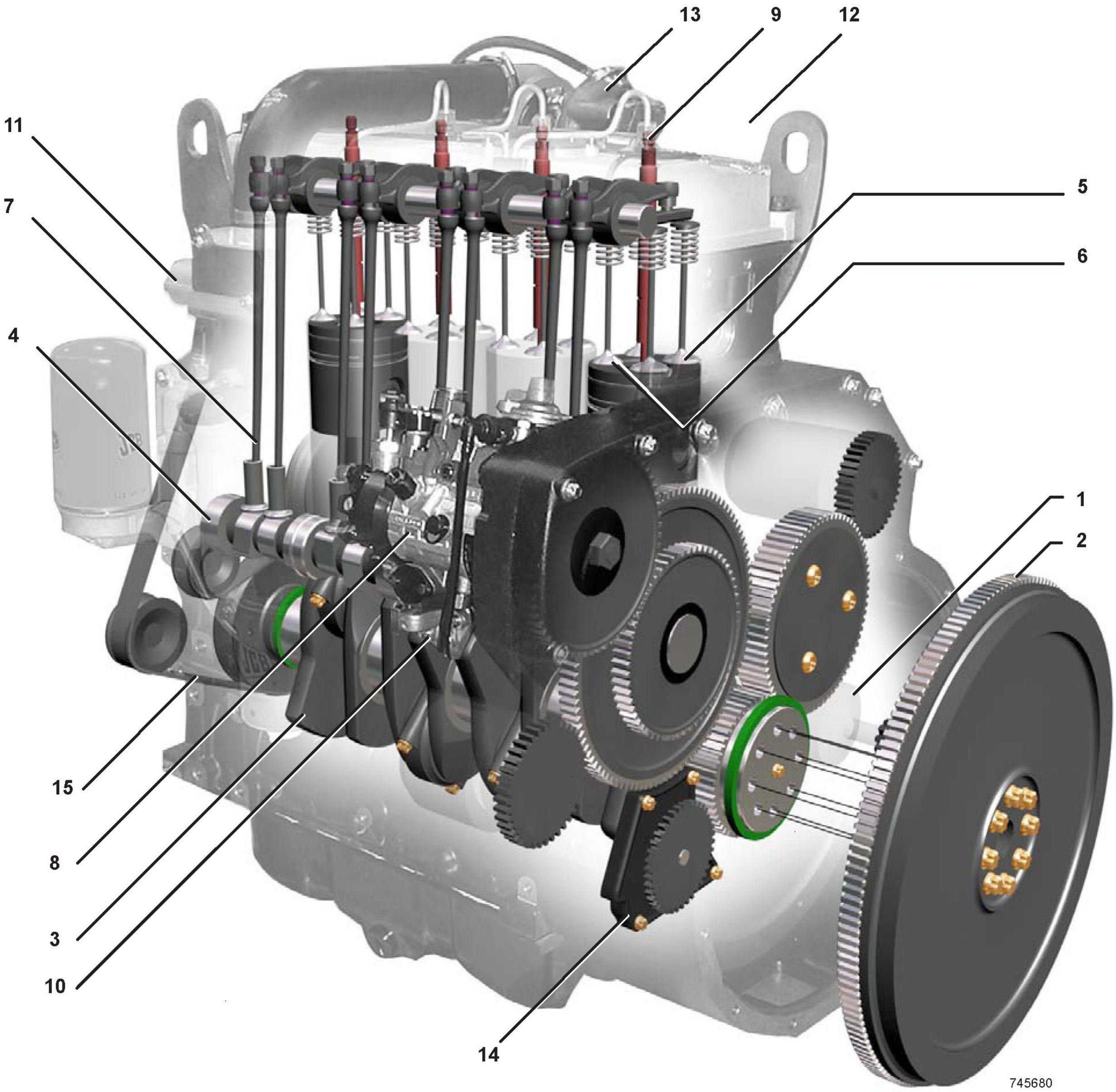


Fig 7.

⇨ *Table 7. (4-13)*

Table 7. Engine - As viewed on the rear left side

⇨ Fig 7. (4-12)

1	Starter motor	9	Fuel injectors (4 off)
2	Flywheel	10	Fuel lift pump
3	Crankshaft	11	Inlet manifold
4	Camshaft	12	Exhaust manifold
5	Inlet valves (8 off)	13	Turbocharger
6	Exhaust valves (8 off)	14	Lubrication oil pump
7	Push rods (8 off)	15	Front end drive belt
8	Fuel injection pump		

The Four Stroke Cycle

1 Induction

As the piston travels down the cylinder it draws filtered air at atmospheric pressure and ambient temperature through an air filter and inlet valves into the cylinder.

2 Compression

When the piston reaches the bottom of its stroke the inlet valves close. The piston then starts to rise up the cylinder compressing the air trapped in the cylinder. This causes the temperature and pressure of the air to rise. Fuel is injected into the cylinder when the piston is near to top dead centre.

3 Power

The piston continues to rise after the start of fuel injection causing a further increase in pressure and temperature. The temperature rises to a point at which the fuel/air mixture ignites. A cylinder is said to be `firing' when the fuel/air mixture ignites.

This combustion causes a very rapid rise in both temperature and pressure. The high pressure generated propels the piston downward turning the crankshaft and producing energy.

4 Exhaust

Once the piston has reached the bottom of its travel, the exhaust valves open and momentum stored in the flywheel forces the piston up the cylinder expelling the exhaust gases.

In a running engine these four phases are continuously repeated. Each stroke is half a revolution of the crankshaft, thus, in one cycle of a four stroke engine, the crankshaft revolves twice.

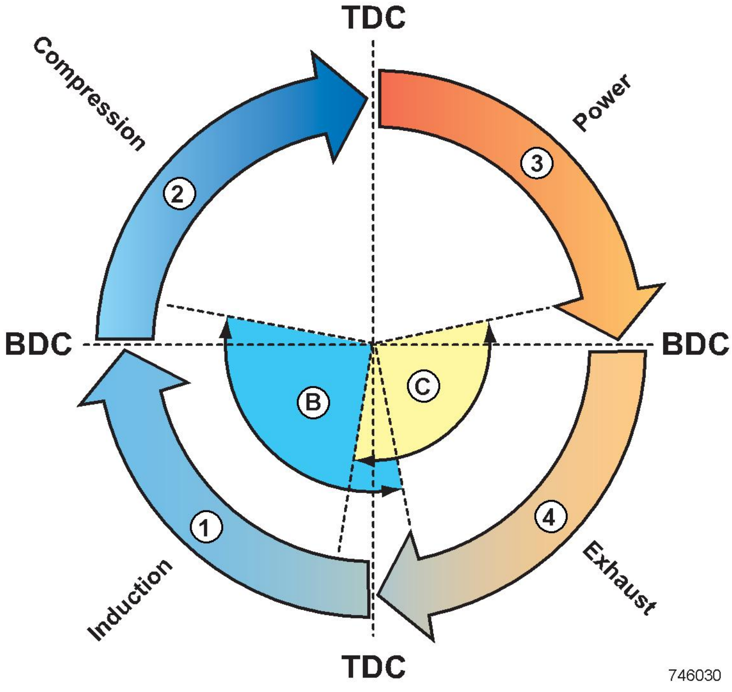


Fig 8.

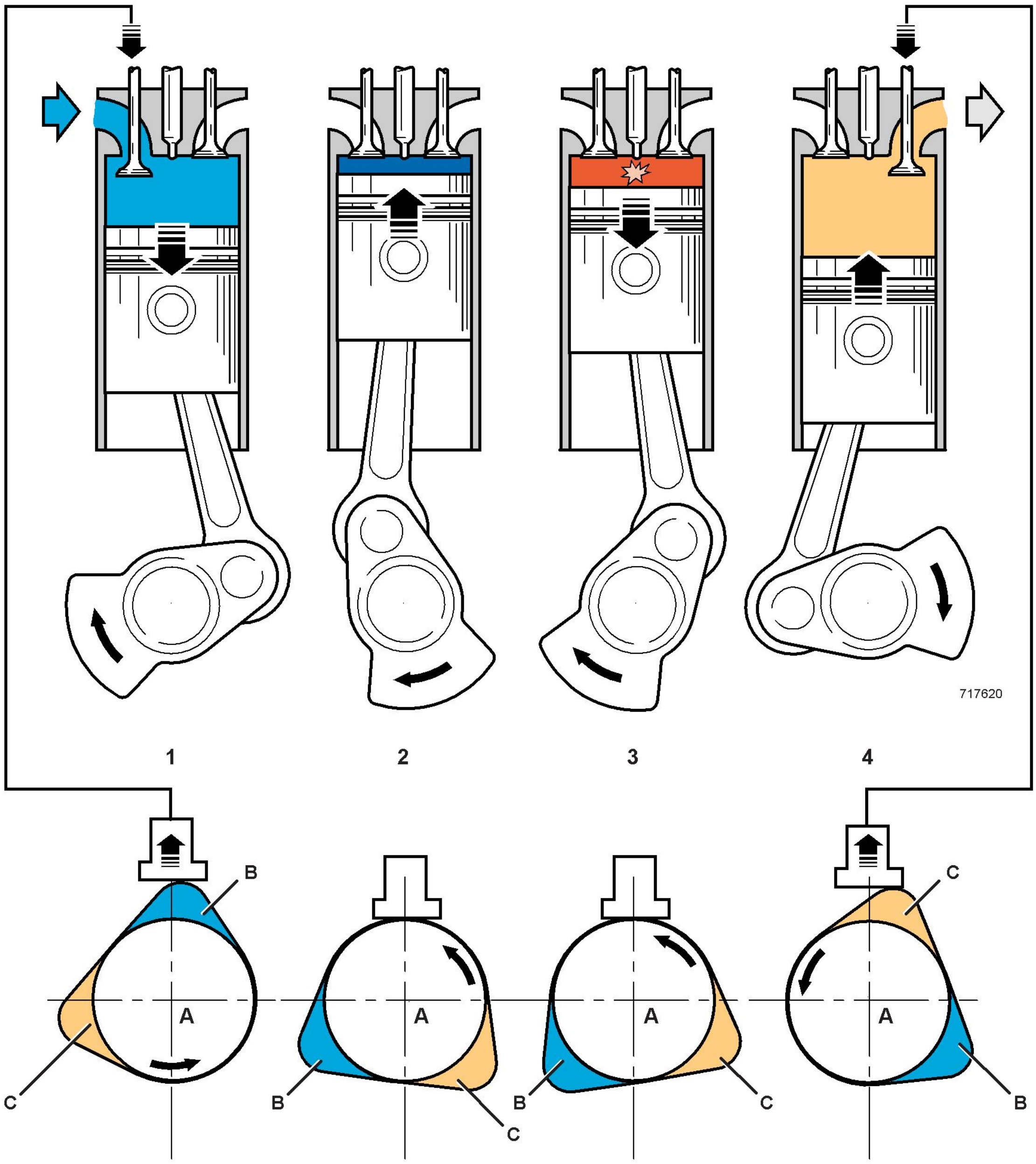


Fig 9.

1	Induction stroke	**A**	Camshaft
2	Compression stroke	**B**	Camshaft lobe - Inlet valve operation
3	Power stroke	**C**	Camshaft lobe - Exhaust valve operation
4	Exhaust stroke	**BDC**	Bottom dead centre
		TDC	Top dead centre

Camshaft and Valve Operation

As the crankshaft rotates the camshaft also rotates, driven by a gear on the crankshaft. The inlet and exhaust valves are opened by lobes on the camshaft in time with the cycle. The diagrams show the position of the camshaft at each part of the four stroke cycle. It can be seen that for a complete cycle the camshaft revolves once. Since the crankshaft revolves twice during the cycle it follows that the camshaft is driven at half crankshaft (engine) speed.

The Four Cylinder Cycle - JCB 444 Engine

The four stroke cycle of the JCB 444 engine is as described in The Four Stroke Cycle ⇨ *The Four Stroke Cycle (4-14)*. This section describes the cycle sequence for the 4 cylinders of the engine.

⇨ *Fig 10. (4-18)*

With the crankshaft positioned as shown the pistons in numbers 1 and 4 cylinders are at top dead centre and pistons in numbers 2 and 3 cylinders are at bottom dead centre.

It is important to note that number 1 cylinder is `firing' and about to start its **Power** stroke. Rotating the crankshaft a further 360 degrees would position the pistons as described but the engine would be at a different stage in its four stroke cycle, with number 1 cylinder about to start its **Induction** stroke.

The stages in the four stroke cycle for each cylinder are as follows:

Cylinder Number 1 - The piston is at the top of its **Compression** stroke and is about to start its Power stroke.	Valve Operation Inlet and exhaust valves closed
Cylinder Number 2 - The piston is at the bottom of its **Power** stroke and is about to start its Exhaust stroke.	Valve Operation Inlet valves closed, exhaust valves about to open
Cylinder Number 3 - The piston is at the bottom of its Induction stroke and is about to start its **Compression** stroke.	Valve Operation Exhaust valves closed, inlet valves about to close
Cylinder Number 4 - The piston is at the top of its **Exhaust** stroke and is about to start its **Induction** stroke.	Valve Operation Exhaust valves about to close, inlet valves about to open

Firing Order

A cylinder is said to be `firing' when the fuel/air mixture ignites and the piston is about to start its power stroke.

From the stages described it can be seen that number 1 cylinder will be next to fire. Number 3 cylinder is starting its compression stroke and is next in the cycle, followed by cylinders 4 and 2.

The firing order is therefore; **1, 3, 4, 2**.

Table 8. Key

⇨ *Fig 10. (4-18)*

CYL1	Cylinder number 1	**A**	Camshaft
CYL2	Cylinder number 2	**B**	Camshaft lobe - Inlet valve operation
CYL3	Cylinder number 3	**C**	Camshaft lobe - Exhaust valve operation
CYL4	Cylinder number 4	**F**	Front of engine

1	Exhaust valves
2	Inlet valves
3	Crankshaft
4	Crankshaft gear
5	Camshaft drive gear

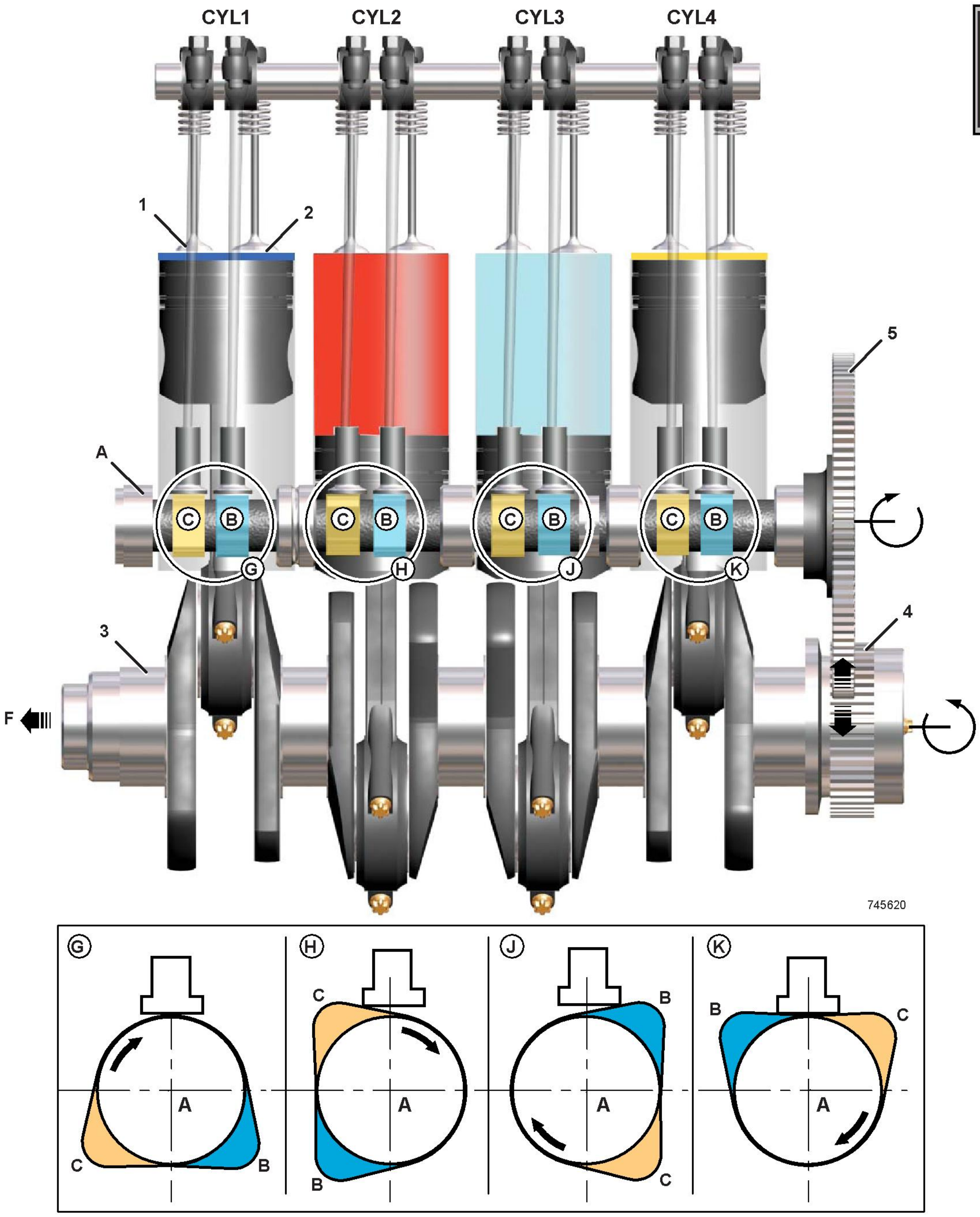


Fig 10.

⇨ Table 8. (4-17)

Timing Gears

The timing gears are located inside a casing at the flywheel end of the engine.

⇨ *Fig 11. (4-20)*

All the gears are driven via the crankshaft gear **11-A** as follows:

1 **Camshaft gear 11-B**. The camshaft is driven at half crankshaft speed.

2 **Fuel injection pump gear 11-C**. The fuel injection pump is driven via compound gear **11-D** fitted to the camshaft. The pump rotates at half crankshaft speed

3 **Oil pump gear 11-E**. The lubrication oil pump is driven directly by the crankshaft gear.

4 **Heavy Duty PTO Gear 11-F** (if fitted). The PTO is driven by the crankshaft gear via idler gear **11-G**.

5 **Low Duty PTO Gear 11-H** (if fitted). The PTO is driven by the camshaft gear **11-B**.

Timing

The engine must be `timed' so that the camshaft operates the valves and the fuel injection pump injects the fuel at the correct times relative to the crankshaft position.

Valve timing is achieved by ensuring that the camshaft drive gear **B** is meshed to the crankshaft gear **A** at their correct angular positions, ⇨ *The Four Stroke Cycle (4-14)* for more information about valve timing.

Timing of the fuel injection pump is not dependent on drive gear meshing. The pump drive shaft is supplied locked at the correct angular position relative to crankshaft/camshaft position. With the crank and camshaft positioned correctly (using temporary locking pins), the pump is fitted to drive gear **11-C** and its drive shaft unlocked.

Table 9. Key

⇨ *Fig 11. (4-20)*			
A	Crankshaft gear	E	Oil pump gear
B	Camshaft gear	F	Heavy duty PTO device gear (if fitted)
C	Fuel injection pump gear	G	Heavy duty PTO idler gear (if fitted)
D	Compound camshaft gear	H	Low duty PTO device gear (if fitted)

A

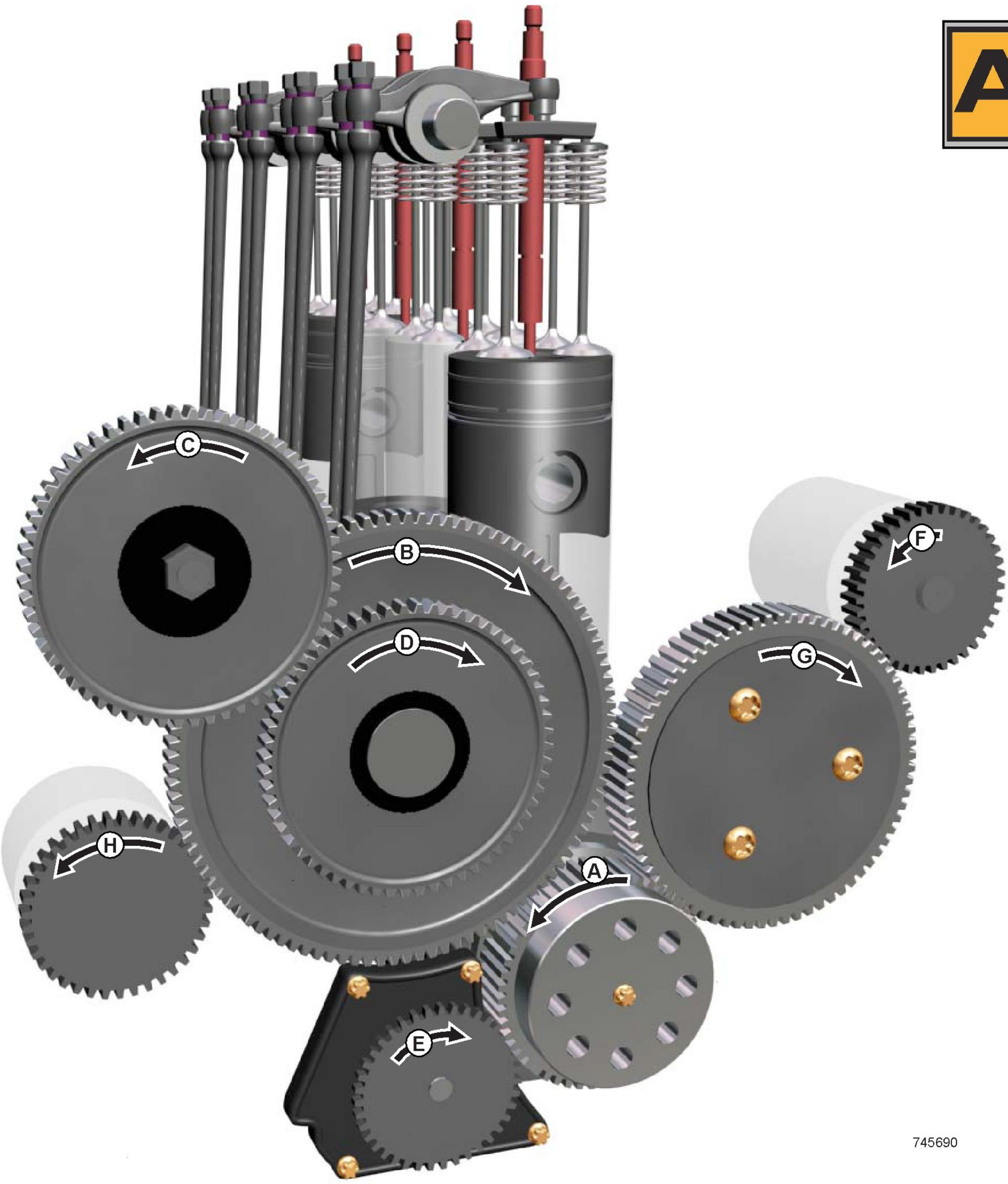


Fig 11.

⇨ Table 9. (4-19)

Valve Train

The valve train system opens and closes the valves with correct timing in relation to the piston movements.

⇨ Fig 12. (4-22), ⇨ Fig 13. (4-23)

The camshaft drive gear **13-1** is driven by the crankshaft gear **13-2** at half the speed of the crankshaft. Camshaft lobes **13-3a**, two for each cylinder, (operating exhaust and inlet valves) actuate the valve tappets **13-4**.

Each push rod **13-5** has one end in a valve tappet and the other end under a rocker arm, **13-6a** or **13-6b** as applicable. Adjusting screw **13-6c** has a ball shaped end that locates in the push rod.

The adjusting screw is used for setting the valve clearance.

When the camshaft **13-3** rotates the cam lobes act on the tappets. The push rods act on the rockers which pivot on shaft **13-7**, depressing two valves at once via the bridge piece **13-9**.

The screw is self locking in the rocker by means of a tapered thread. Wave washers **13-8** act like springs to keep the rockers in their correct positions along the shaft **13-7** and prevent them contacting one another. The rockers incorporate a swivel tip **13-6d**, ensuring alignment with the bridge piece **13-9**. This prevents excessive wear.

Each valve has a compression spring **13-10**. The function of the spring is to close the valve and at the same time return the rocker arm and push rod ensuring that the tappets follow the camshaft lobes. The spring is located on the valve stem **13-17** by a retainer **13-11** and split collets **13-12**.

The valves extend through the cylinder head. There are no sleeves or valve guides in the cylinder head. The valves are made from a special metal to provide a long service life. Damaged or worn valves cannot be lapped or re-ground and must be replaced with new ones. Each valve stem has an oil seal **13-13**.

Valve seat inserts **13-14** are pressed into the cylinder head. The seat inserts are also made from a special metal to provide for a long service life. Damaged or worn seat inserts can be removed and replaced with new ones.

Table 10. Component Identification

⇨ Fig 12. (4-22), ⇨ Fig 13. (4-23)			
1	Camshaft drive gear	**8**	Wave washers (8 off)
2	Crankshaft gear	**9**	Bridge pieces (8 off)
3	Camshaft	**10**	Valve springs (16 off)
3a	Lobes	**11**	Retainer (16 off)
4	Tappets (8 off)	**12**	Collets (32 off)
5	Push rods (8 off)	**13**	Oil seal - valve stems (16 off)
6a	Rockers - inlet (4 off)	**14**	Valve seat inserts (16 off)
6b	Rockers - exhaust (4 off)	**15**	Inlet valves (8 off)
6c	Adjusting screws (8 off)	**16**	Exhaust valves (8 off)
6c	Swivel tip - rockers	**17**	Valve stem
7	Rocker shaft		

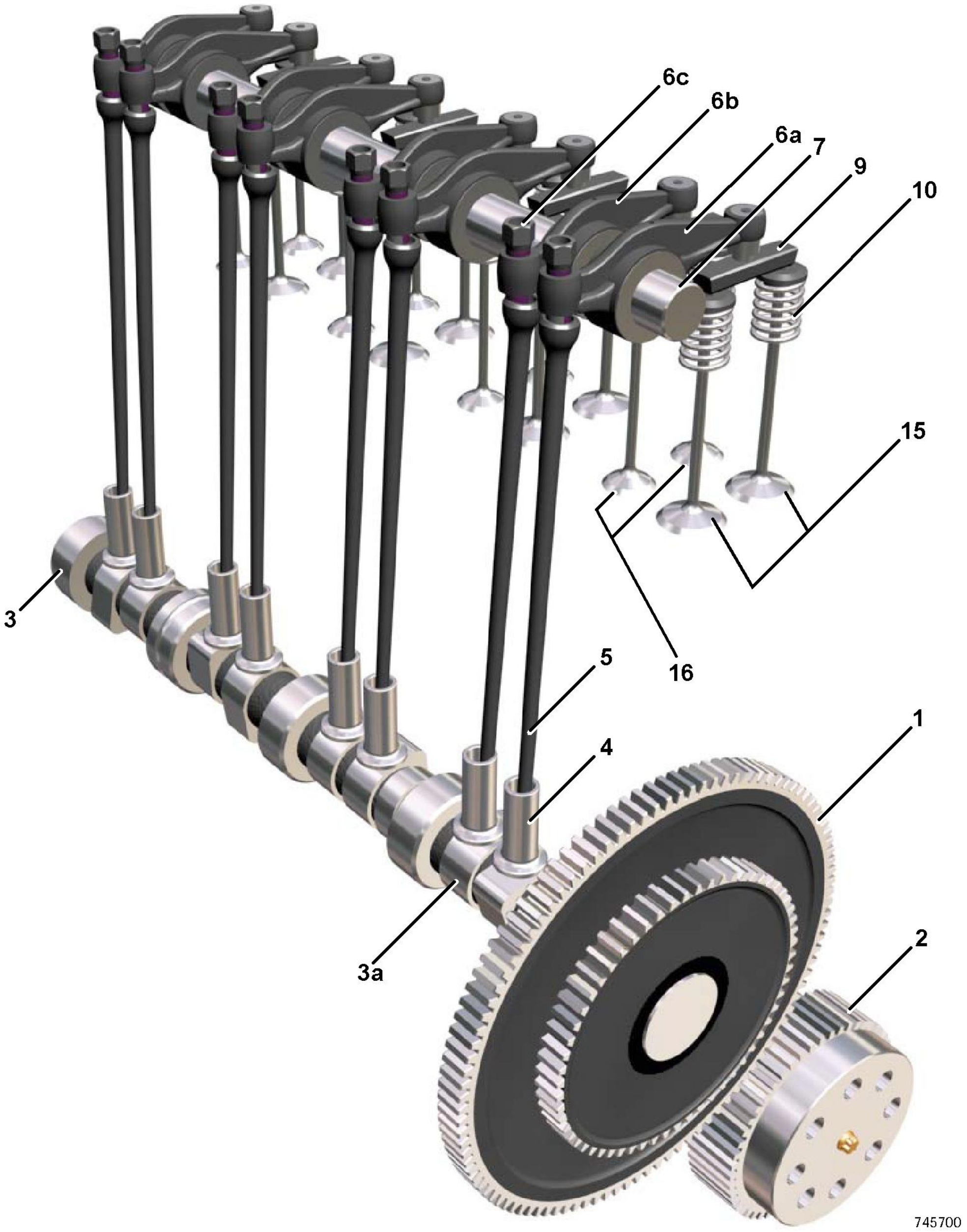


Fig 12.

⇨ Table 10. (4-21)

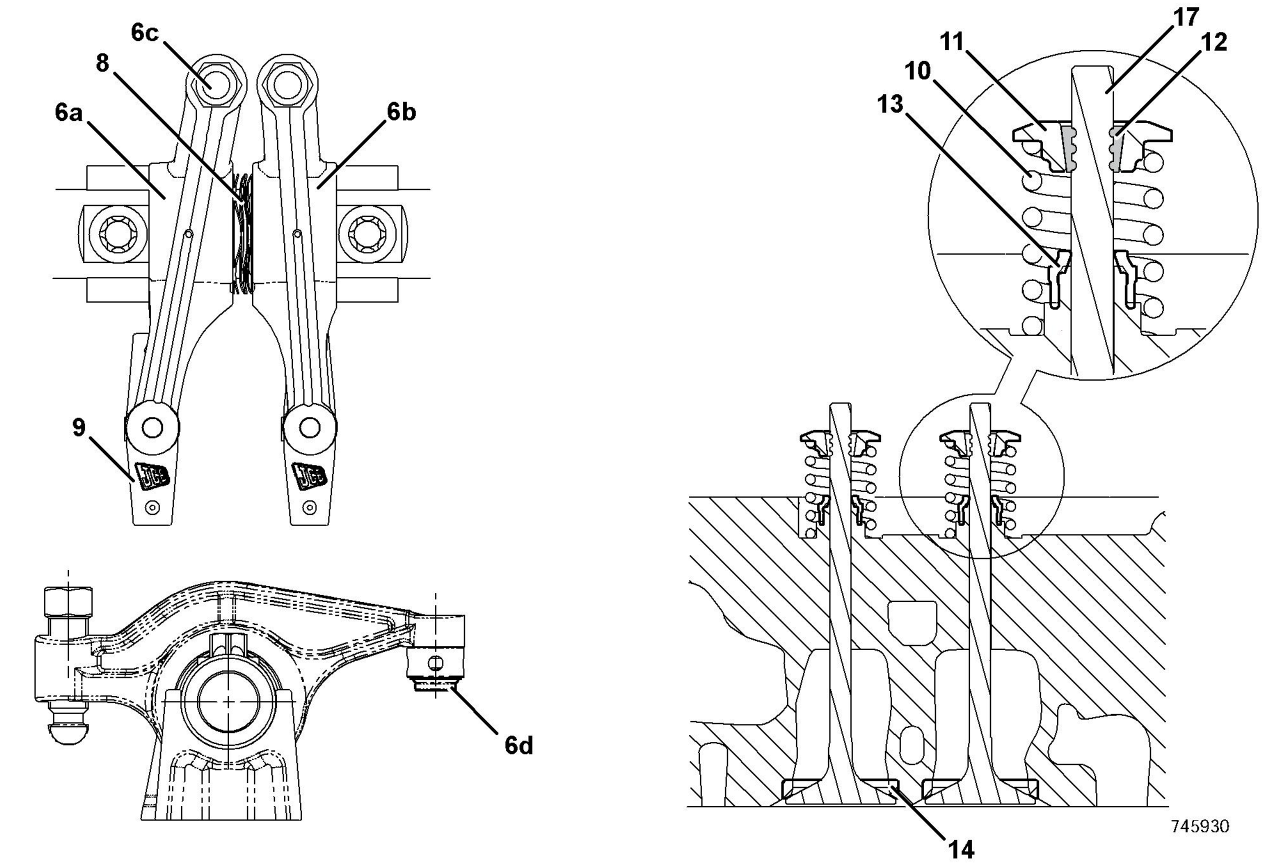


Fig 13.

⇨ Table 10. (4-21)

Front End Accessory Drive (FEAD) Belt System

The crankshaft pulley is used to drive the coolant pump via a drive belt. In addition to the coolant pump the drive belt can also be configured to drive engine mounted accessories including:

Alternator Cooling fan Air conditioning compressor

The belt is maintained at a constant tension by a spring loaded tensioner. To achieve the necessary belt/pulley contact area the belt is routed around idler wheels as required. The configuration varies depending on the accessories fitted.

Drive belt configurations

A	⇨ *With air conditioning compressor, no cooling fan (4-25)*
B	⇨ *Without air conditioning compressor, no cooling fan (4-25)*
C	⇨ *With air conditioning compressor, cooling fan pulley fitted (4-26)*
D	⇨ *Without air conditioning compressor, cooling fan pulley fitted (4-26)*

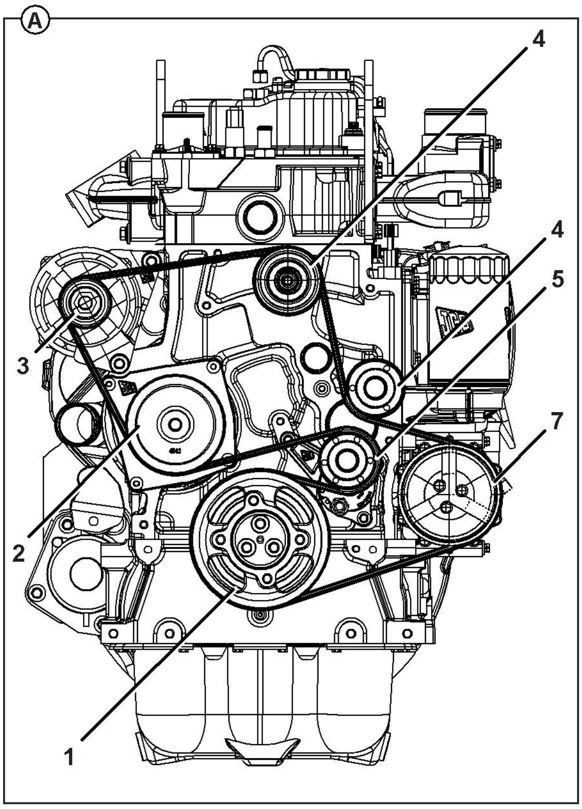


Fig 14. With air conditioning compressor, no cooling fan

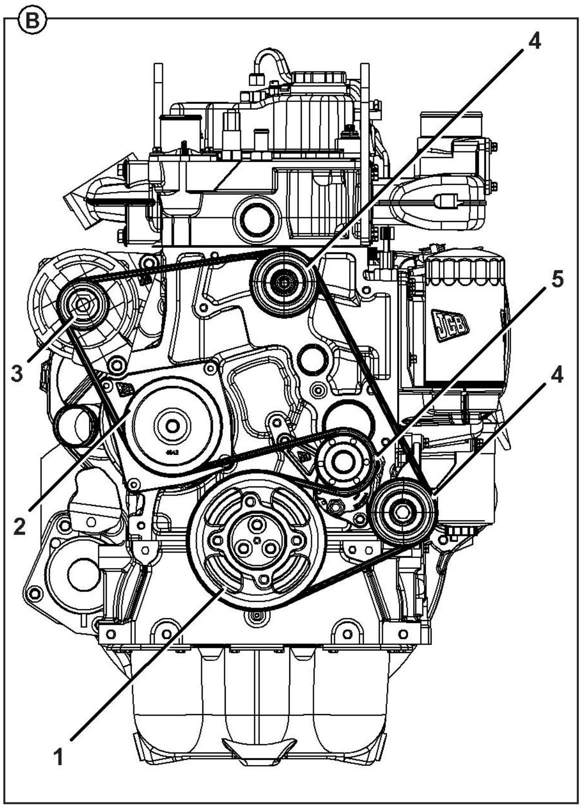


Fig 15. Without air conditioning compressor, no cooling fan

Table 11. Key

⇨ Fig 14. With air conditioning compressor, no cooling fan (4-25) , ⇨ Fig 15. Without air conditioning compressor, no cooling fan (4-25)	
1	Crankshaft drive pulley
2	Coolant pump drive pulley
3	Alternator drive pulley
4	Idler pulley
5	Tensioner pulley
7	Air conditioning compressor drive pulley

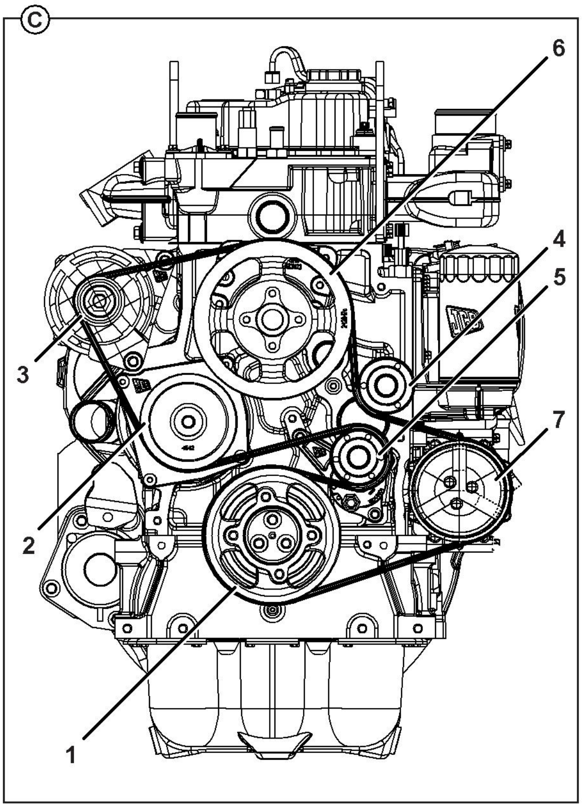


Fig 16. With air conditioning compressor, cooling fan pulley fitted

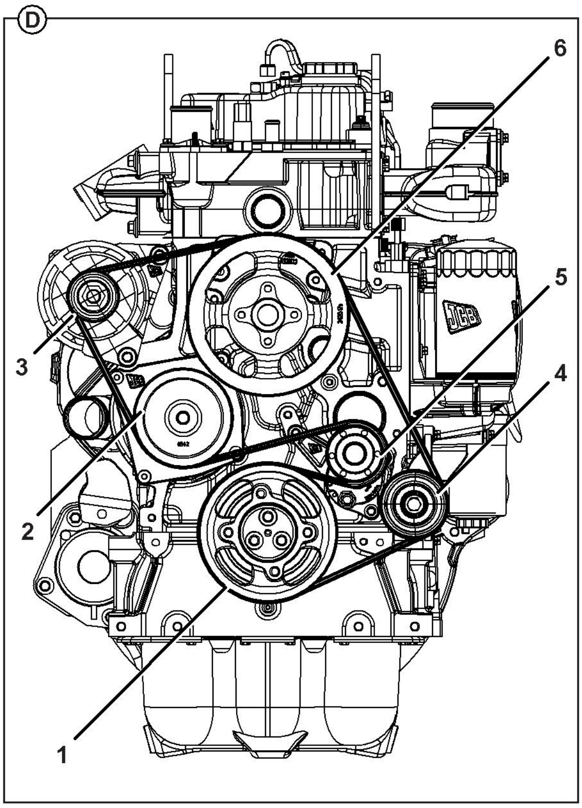


Fig 17. Without air conditioning compressor, cooling fan pulley fitted

Table 12. Key

⇒ *Fig 14. With air conditioning compressor, no cooling fan (4-25)* , ⇒ *Fig 15. Without air conditioning compressor, no cooling fan (4-25)*, ⇒ *Fig 16. (4-26)*, ⇒ *Fig 17. (4-26)*	
1	Crankshaft drive pulley
2	Coolant pump drive pulley
3	Alternator drive pulley
4	Idler pulley(1)
5	Tensioner pulley
6	Cooling fan drive pulley(2)
7	Air conditioning compressor drive pulley

(1) Idler pulley positions differ slightly depending on the size of the fan pulley fitted.
(2) Different fan pulley size options are available. This enables a choice of fan/engine speed ratios.

Lubrication System

Basic Description

The lubrication system distributes oil around the engine by a system of galleries and drillings in the cylinder block and cylinder head. The oil lubricates and seals the moving parts of the engine, reducing friction and wear. In addition the oil plays an important role in cooling the engine by carrying heat from the engine to the cooler. A piston cooling jet sprays oil onto the underside of the pistons to keep them cool, ⇨ ***Piston Cooling and Small End Bearing Lubrication (4-36)***

Oil is drawn from the oil pan (sump) **18-1** by the integral oil pump **18-3** via the strainer **18-2**. The strainer prevents any large particles of debris passing through, which may damage the pump.

The oil passes from the outlet side of the pump through a relief valve which limits the maximum oil pressure by venting oil back to the inlet side of the pump, ⇨ ***Oil Pump (4-29)***.

From the pump the oil passes through the cooler **18-4** and filter **18-5**, ⇨ ***Oil Cooler and Filter (4-31)***. After cooling and filtering, oil passes into the main oil gallery **18-11**. An oil pressure switch **18-12** senses oil pressure. From the main gallery oil is delivered, via drillings **18-7**, to the crankshaft main bearings, rocker assembly (drilling **18-8**) , camshaft (drilling **18-6**) and timing gears (drilling **18-9**). Note that drilling **18**-8 is through the cylinder block and cylinder head.

When the high pressure oil has passed through the bearings it reverts to sump pressure and `splash' lubricates internal components such as rocker tips, cam lobes and timing gear teeth. Gravity drains the oil via galleries in the cylinder head and block, back into the oil pan (sump). A drain slot allows oil to drain from the timing case back to the oil pan.

Table 13. Key

⇨ ***Fig 18. (4-28)***

1	Oil pan (sump)
2	Suction strainer
3	Oil pump
4	Oil cooler
5	Filter
6	Camshaft - high pressure oil feed
7	Crankshaft main bearings - high pressure oil feed
8	Rocker assembly - high pressure oil feed
9	PTO idler gear bearing/timing case - high pressure oil feed
10	External high pressure oil feed connection (engine block) - Turbo charger (if fitted)
11	Main high pressure oil feed gallery (engine block)

Table 14. Colour Key

⇨ ***Fig 18. (4-28)***

Green	Oil at sump pressure
Red	Oil at high pressure
Pink	Oil at lower pressure but higher than sump pressure

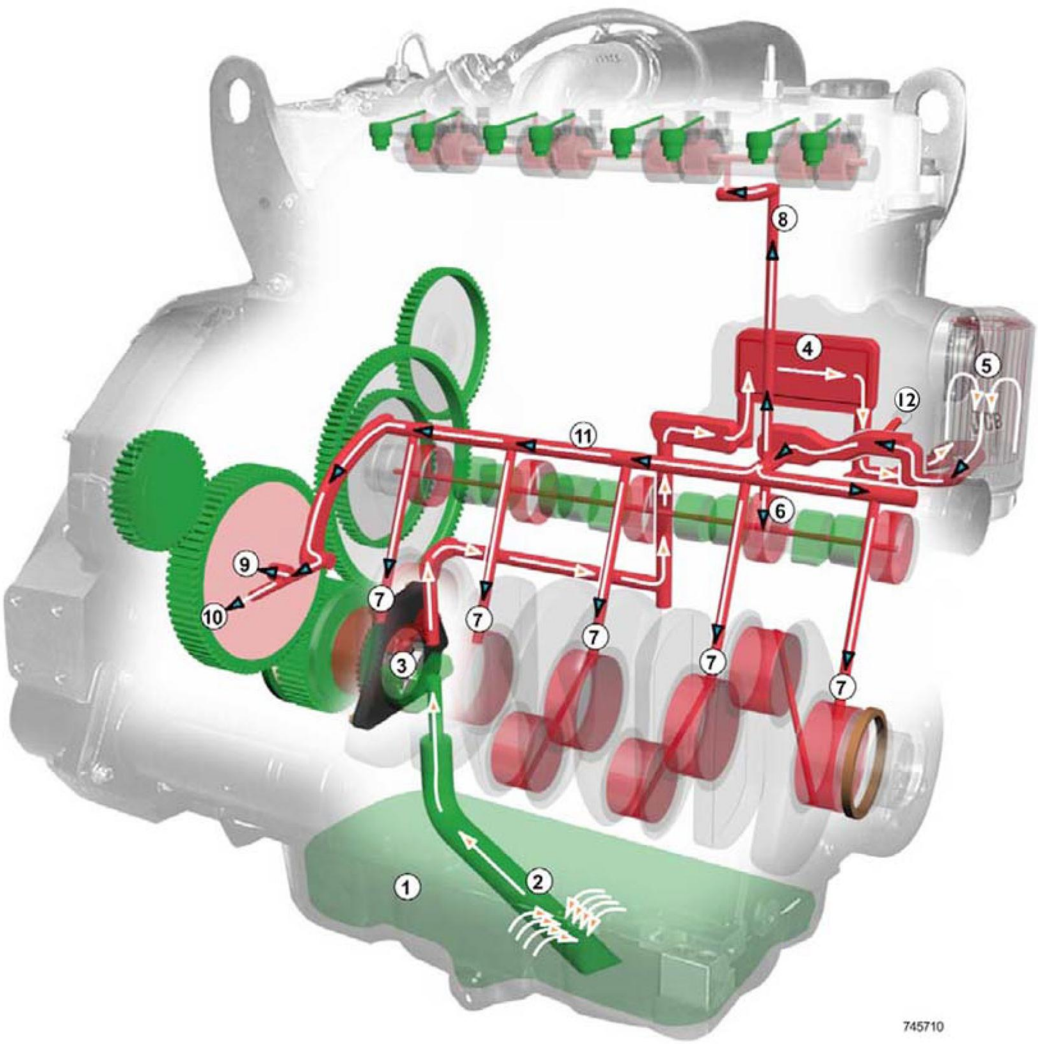


Fig 18.

Oil Pump

⇒ Fig 19. (4-30)

The oil pump **19-1** is a rotor type located inside the timing gear case. The pump is driven by gears via the crankshaft.

The pump consists of two rotors, one running inside the other. The outer rotor **19-2** has one more lobe than the inner rotor **19-3** and turns on a different axis.

When rotated the gap between the inner and outer rotor lobes increases, drawing oil in through the inlet port **19-4**. After a half rotation the gap reaches a maximum, the inlet port is closed and the outlet port **19-5** opened.

Further rotation causes the gap between the lobes to diminish, forcing the oil out through the outlet port.

A pressure relief valve assembly **19-6** is integral with the pump body. As oil pressure increases it acts on a spool **19-8** to overcome the pressure of spring **19-7**. As the spool moves it uncovers a port allowing pressurised oil directly back to the inlet port **19-4**. In practice the spool is continually opening and closing to maintain the correct oil pressure value. The valve is not adjustable.

Table 15. Key

⇒ Fig 19. (4-30)

1	Oil pump
2	Outer rotor
3	Inner rotor
4	Inlet port
5	Outlet port
6	Relief valve assembly
7	Relief valve spring
7a	Relief valve port - return to inlet port **4**
8	Relief valve spool
8a	Relief valve pressure port - connected to port **5**
9	Oil pump connecting ports - engine bed plate

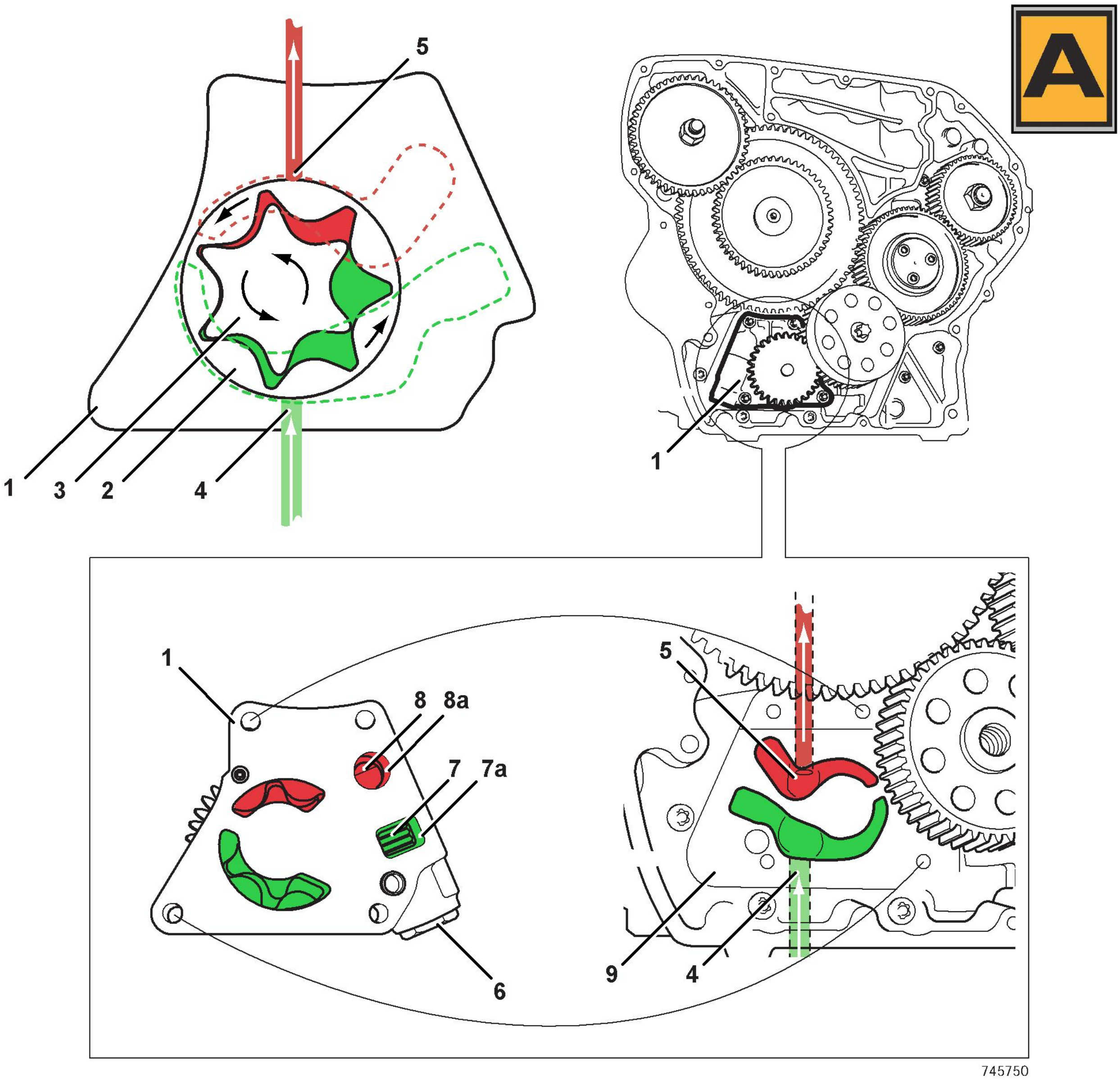


Fig 19.

Oil Cooler and Filter

⇨ Fig 20. (4-32)

The oil cooler and filter are incorporated in a housing **20-1** bolted to the side of the cylinder block. The housing allows transfer of lubricating oil from the cylinder block to the oil cooler **20-5** and filter head **20-3**. Coolant also transfers to the housing and passes over the oil cooler matrix **20-5** causing heat to exchange from the oil to the coolant.

Cooled and filtered oil then passes back into the main oil gallery in the block via port **20-10**.

An engine oil filler point is also included via cap **20-2** and port **20-11** which aligns with a port in the block.

Oil Cooler Matrix

Although the cooler matrix **20 -5** is a separate component, it is a non serviceable part and must not be removed from the housing. The housing/cooler assembly is leak tested during manufacture to minimise the risk of cross contamination of coolant and lubricating oil.

Oil Filter

The oil filter **20-13** is a `spin on' type which screws on and off the filter head **20-3**.

Engine running - shown at **20-A**. The oil pump delivers oil at pressure to the filter via port **20 -9**. The lip seal **20-15** is forced off its seat and oil flows through a large area paper element **20-14**. Filtered oil enters the inner part of the filter and forces down the valve plate **20-16** against spring **20-17**. Oil then leaves the filter and filter head via port **20-10**.

Engine stopped - shown at **20-B**. With the engine stopped oil pressure in the galleries and filter decays. As it does so, valve plate **20-16** is pushed on its seat under the action of spring **20-17**, preventing oil draining down from the engine galleries. Lip seal **20-15** also falls on its seat and oil is prevented from draining from the filter assembly. These features help protect the engine from oil starvation on start up.

Table 16. Key

⇨ Fig 20. (4-32)	
1	Oil cooler and filter housing
2	Oil filler cap
3	Oil filter head
4	Oil filter drain down plug
5	Oil cooler matrix
6	Sealing gasket - housing to cylinder block
7	Coolant gallery
8	Oil gallery - from pump to cooler
9	Oil gallery - from cooler to filter head
10	Oil gallery - from filter head to main oil gallery
11	Oil fill port
12	Oil pressure switch
13	Oil filter
14	Filter element
15	Lip seal
16	Valve plate
17	Spring

A	Oil filter state - engine running
B	Oil filter state - engine stopped

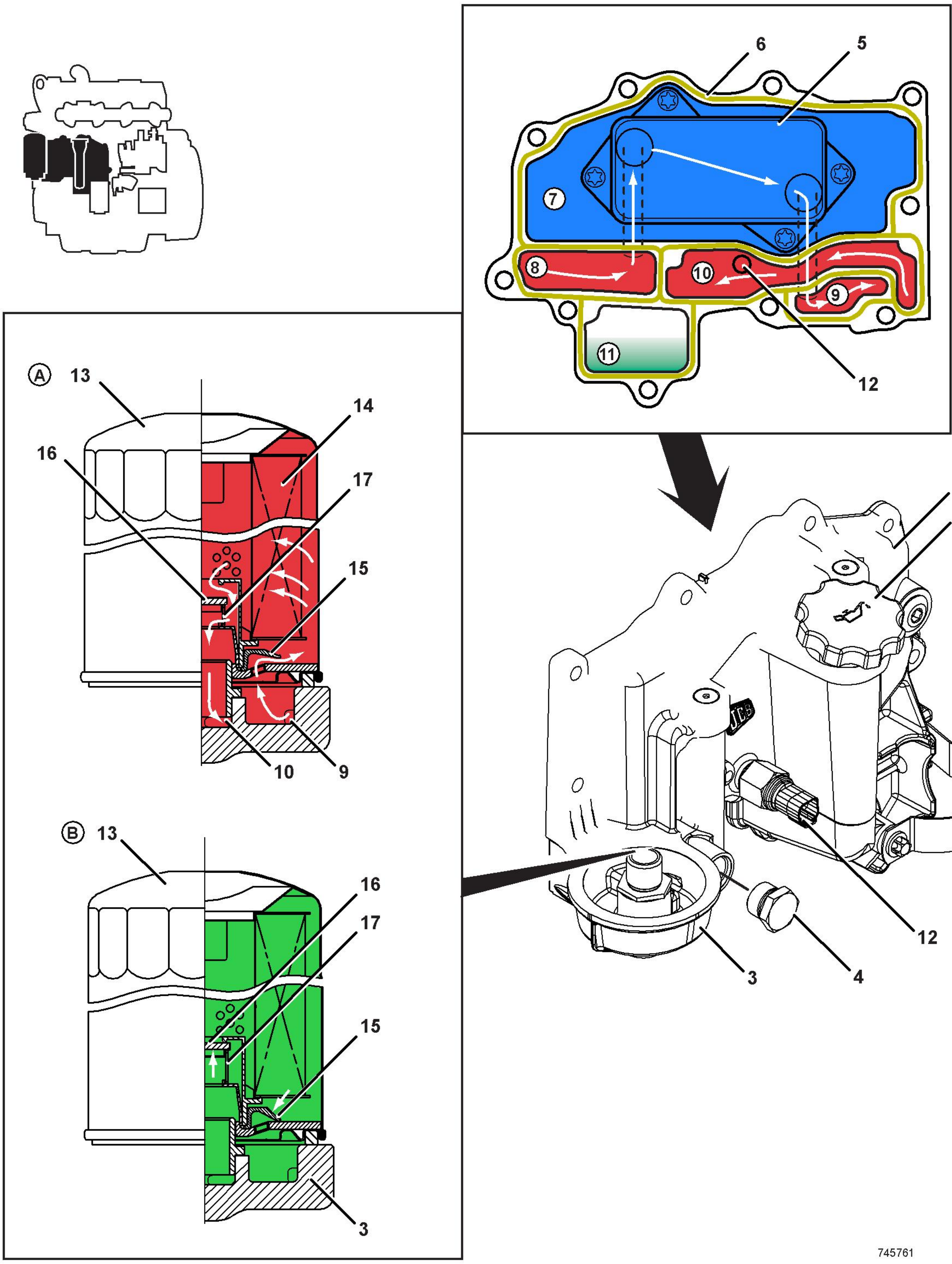


Fig 20.

Camshaft Lubrication

Oil is fed from the main gallery **21-1** via a drilling to the camshaft bearing **21-2**. A groove **21-3** around the diameter of the bearing and connecting cross drilling ensures that oil is always fed to the centre drilling **21-4**. Oil is then transferred to the remaining camshaft bearings by further cross drillings in the shaft. The cam lobes and tappets are `splash' lubricated.

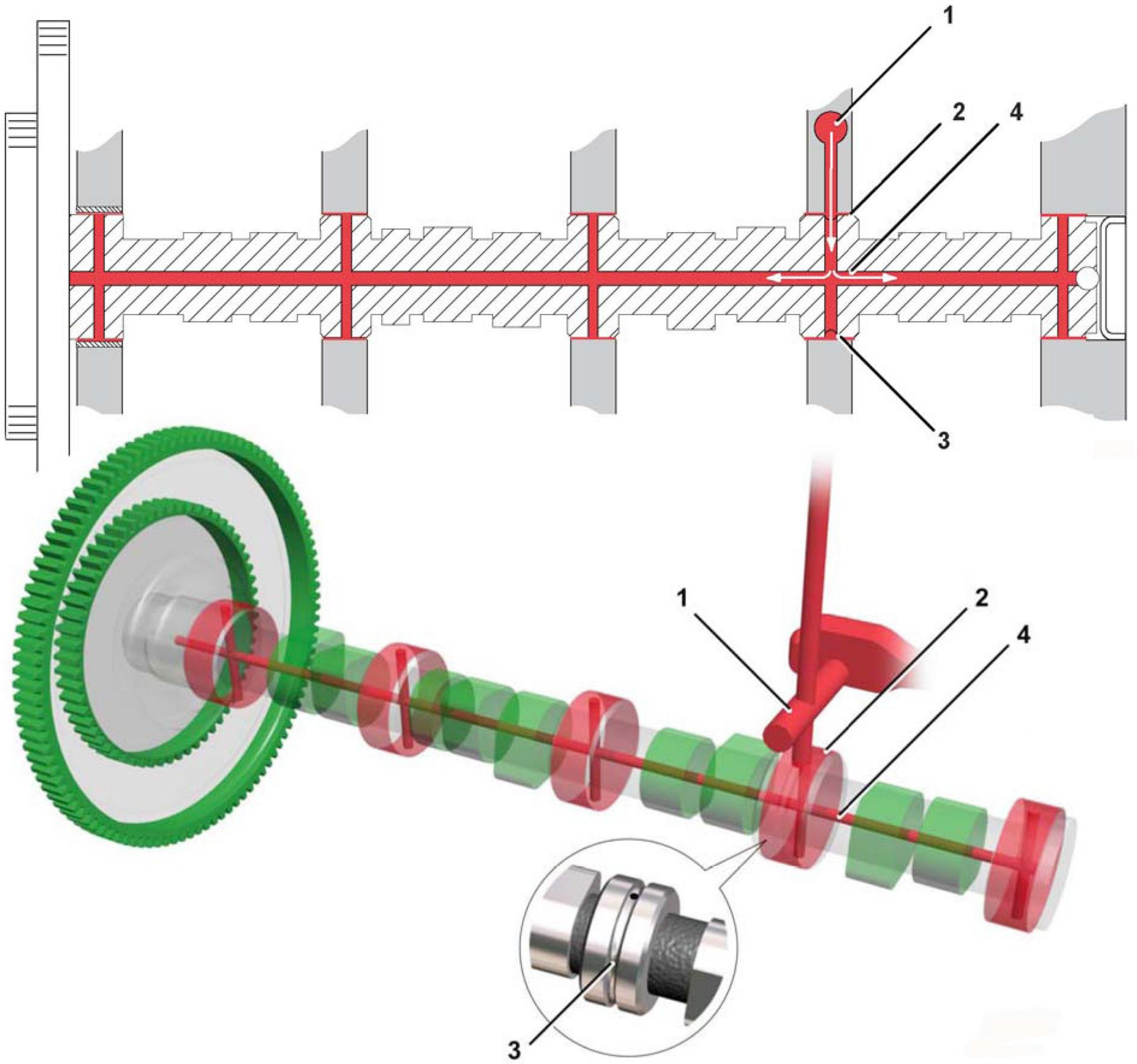


Fig 21.

Crankshaft Lubrication

Oil is fed from the main gallery **22-1** via 5 drillings **22-2**, one to each of the main bearings **22-3**. A groove around the diameter of the upper main bearing shell allows oil transfer to cross drillings **22-5** in the crankshaft to each of the big end bearings **22-4**.

Crankshaft gear **22-6** is `splash' lubricated. Front and rear crankshaft oil seals (**22-7** and **22-8**) prevent oil leakage from, and dirt ingress to, the engine.

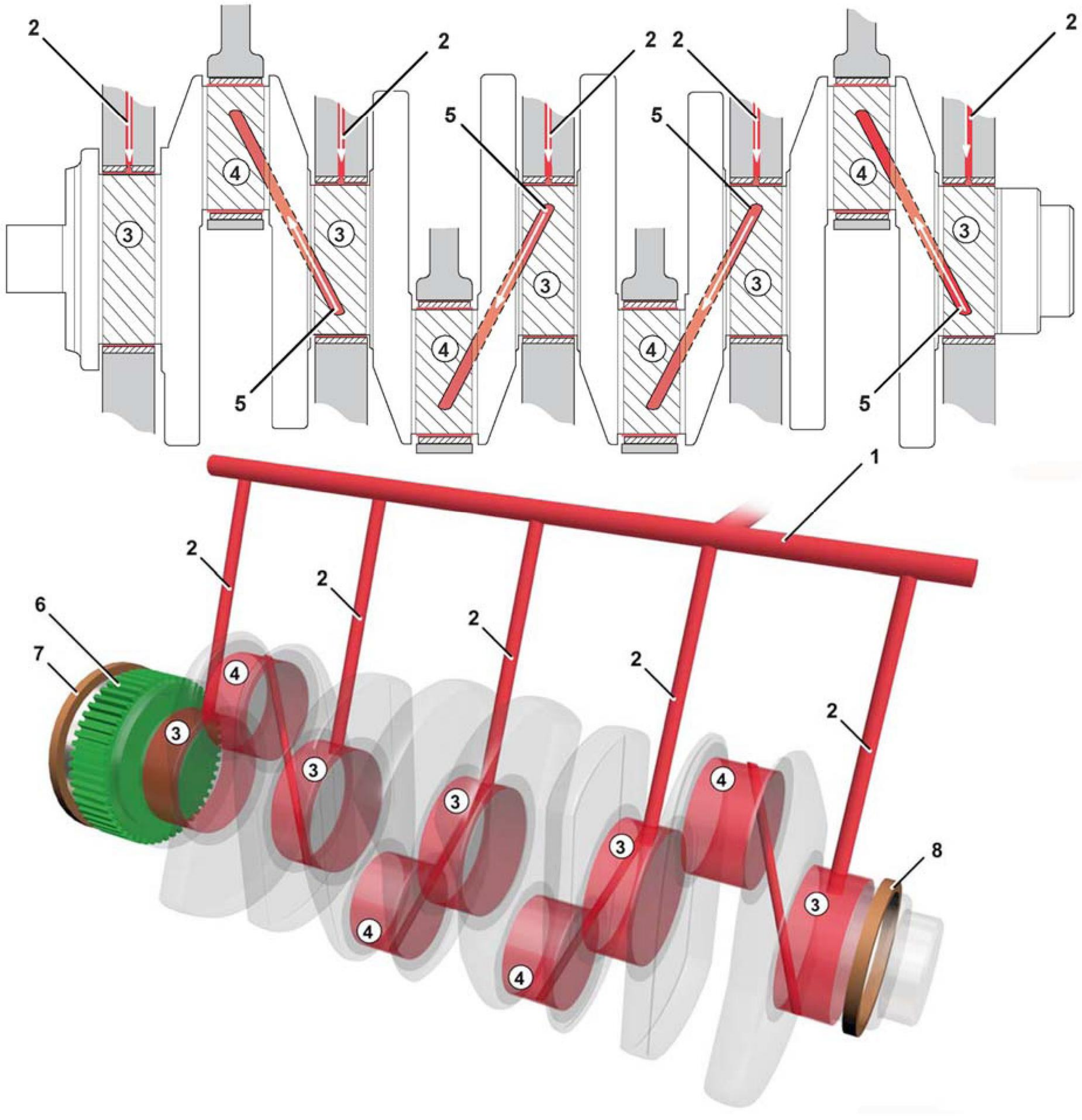


Fig 22.

Rocker Assembly Lubrication

Oil is fed from the main gallery **23-1** via a drilling which passes up through the block and cylinder head to a small transfer gallery **23-2** under rocker shaft pedestal **23-3**.

Oversize rocker shaft fixing bolt hole **23-4** allows oil to pass into a drilling **23-5** in the centre of the rocker shaft. Further cross drillings **23-6** transfer oil to each of the rocker pivot bushes **23-7**.

A cross drilling **23-8** in each rocker transfers oil to the top of the rocker where it flows by gravity along a groove **23-9** to the rocker tip.

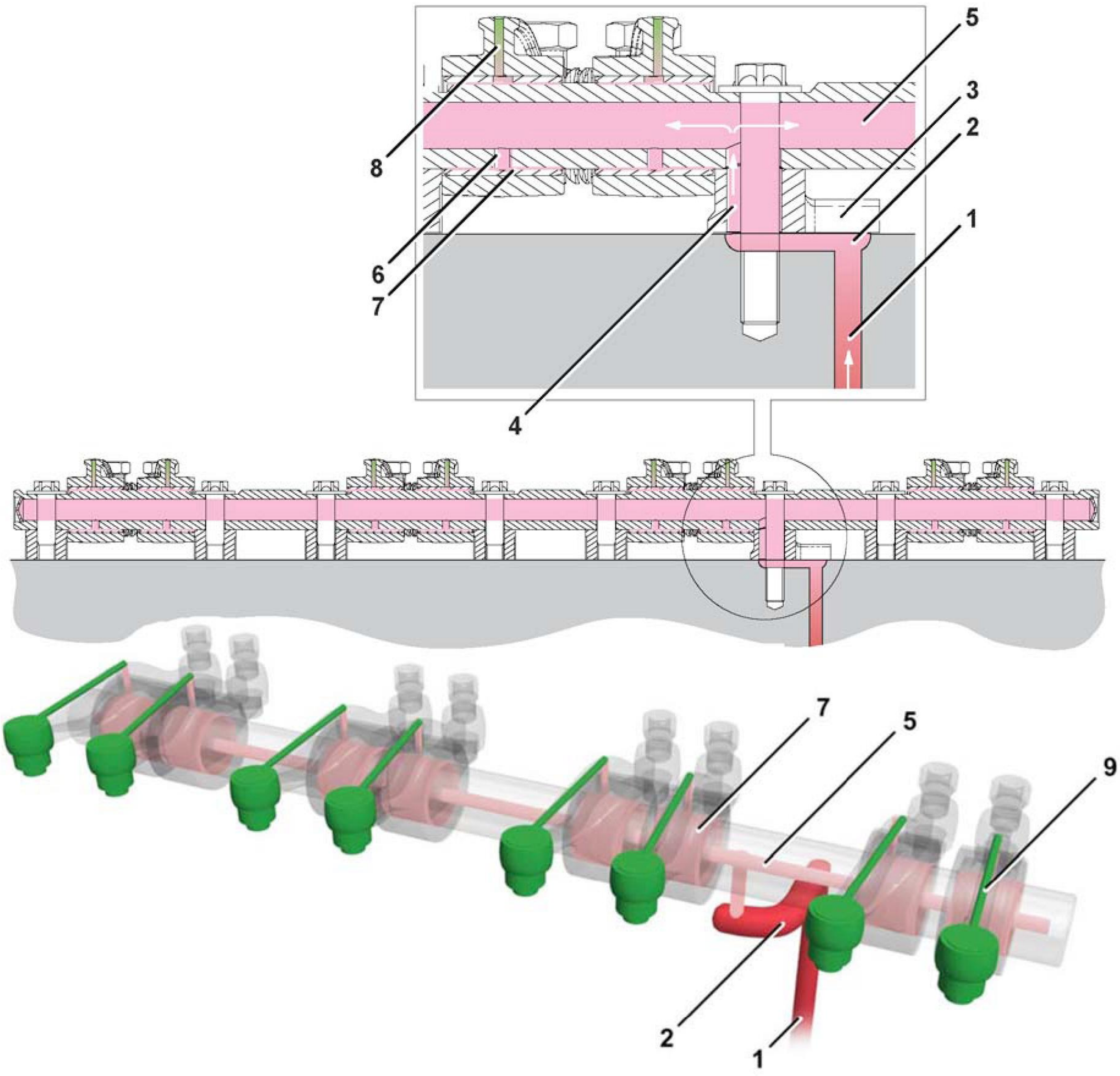
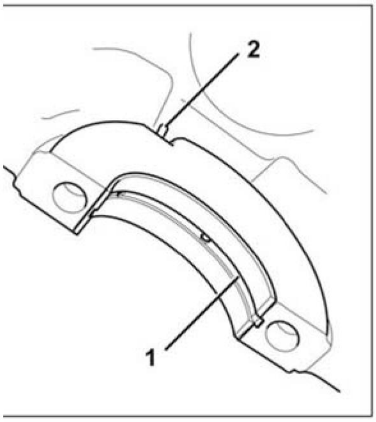


Fig 23.

Piston Cooling and Small End Bearing Lubrication

The groove **24-1** around the diameter of the upper main bearing shells allows oil transfer to an oil jet **24-2** located in the cylinder block bearing saddle. Jets are fitted at 4 of the main bearing positions. Since only 4 jets are required (1 for each piston) there is no jet at the main bearing next to the flywheel end of the crankshaft. The jets spray oil directly to the under side of the pistons **24-3** effectively transferring heat away form the top of the pistons.

Oil spray also enters the small end bearing bushes **24-4** via a feed hole on the top of each connecting rod.



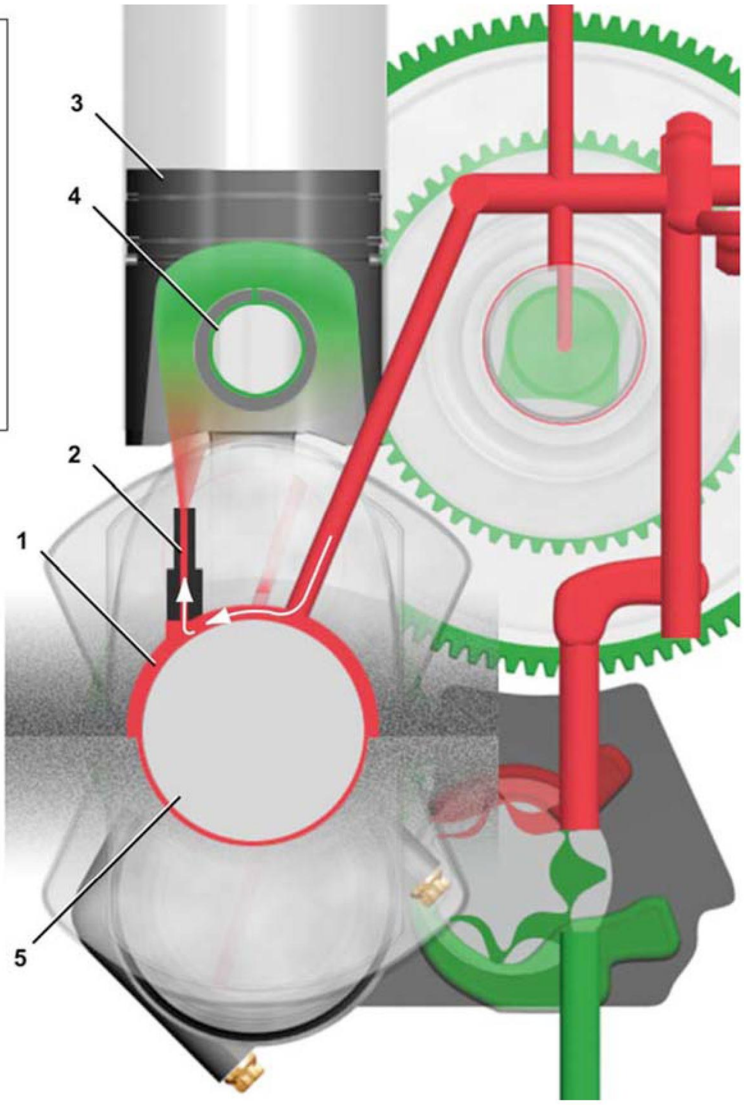


Fig 24.

Fuel System

Basic Description

➾ Fig 25. (4-38)

The fuel system is central to the performance and efficiency of the engine distributing an accurate amount of fuel to each cylinder at exactly the right time.

Fuel is drawn from the tank by engine driven lift pump **25-3** via the water trap **25-2**. The trap separates any water in the fuel before if passes through the lift pump.

Fuel is pressurised at low pressure by the lift pump **25-3** and passes through a fuel filter **25-4** on its way to the inlet on the fuel injection pump **25-5.** Effective filtration and decontamination of the fuel is essential. The injection pump can be damaged beyond repair by contaminated fuel.

The fuel injection pump **25-5** is of a rotary type and is driven by the engine. The pump delivers fuel at high pressure to the fuel injectors **25-6**. The high pressure fuel is delivered in `pulses' timed at the correct point in the combustion cycle for each cylinder.

When the fuel injectors **25-6** receive a pulse of fuel at high pressure they inject atomised fuel into the combustion chamber.

When the pressure of the fuel at the injectors falls, the injector snaps shut and any trapped fuel bleeds back to the fuel tanks via the bleed off fuel lines.

Some fuel flows through the pump at all times to provide internal lubrication and cooling. This fuel bleeds back to tank via the bleed-off fuel lines.

Table 17. Key

➾ Fig 25. (4-38)	
1	Fuel tank
2	Water trap (sedimenter)
3	Lift pump
4	Fuel filter
5	Fuel injection pump (FIP)
6	Fuel injectors (atomisers)

Table 18. Colour Key - Fuel Lines

➾ Fig 25. (4-38)	
Green	Suction
Yellow	Low pressure
Red	High pressure
Orange	Bleed-off (return to tank)

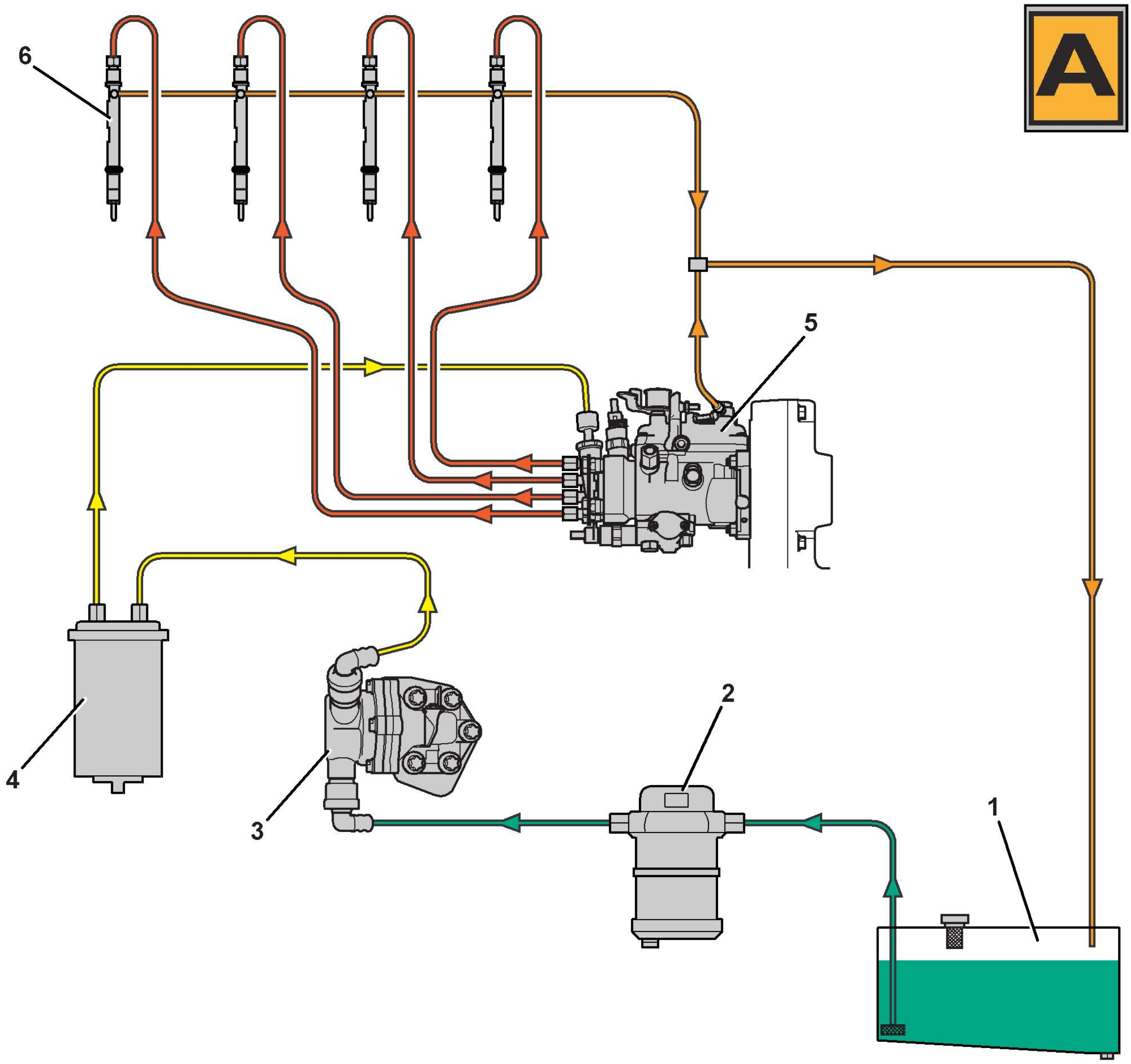


Fig 25.

Pre-Filter/Water Separator, Lift Pump and Fuel Filter

⇨ *Fig 26. (4-40)*

Pre Filter/Water Separator

The pre-filter/water separator **26-1** is designed to separate water and dirt from the fuel using a special chemically treated paper filter element. A bowl **26-1a** fitted to the bottom of the trap collects the water removed from the fuel. The bowl is fitted with an electric probe 26-1c which senses when the water is above a preset level. The probe enables a suitable alarm/indicator device. Water can be drained off by means of a drain screw **26-1b** fitted in the base of the bowl.

It is essential that the water trap is drained regularly. Water must be drained immediately if the probe signals an alarm.

Lift Pump

The lift pump **26-2** is a diaphragm type driven from the engine camshaft The pump draws fuel from the tank, through the water trap, pumping it through the filter and into the fuel injection pump.

The pump incorporates a manually operated priming lever **26-2a** to aid fuel priming after maintenance.

State A - Pumping

When the camshaft rotates the lobe **26-2a** pushes on the actuator pin **26-2b**. The pin operates the pump lever **26-2c** pushing the diaphragm **26-2d** and compressing spring **26-2e**. As the diaphragm moves, fuel in the pump chamber pressurises, forcing ball **26-2f** from its seat and compressing spring **26-2g**. Fuel flows from the pump chamber via oulet port **26-2h**. At the same time fuel pressure and spring **26-2j** force ball **26-2k** against its seat, preventing fuel flowing back through the inlet port **26-2m**.

State B - Lifting

When the camshaft rotates further the lobe **26-2a** moves away from actuator pin **26-2b**. Spring **26-2e** pushes on the diaphragm **26-2d** causing a pressure drop in the pump chamber. This draws ball **26-2k** of its seat compressing spring **26-2j** and fuel is drawn into the pump chamber through inlet port **26 -2m**. At the same time ball **26 -2f** is drawn onto its seat, assisted by spring **26-2g** preventing fuel flowing back through the outlet port **26 -2h**.

Fuel Filter

The fuel filter **26-3** consists of a paper element **26 -3a** folded in such a way as to give a very large surface area. Fuel is pumped into the filter and passes through the paper element where any dirt particles or water droplets are retained. An integral sediment bowl **26-3b** at the bottom of the filter enables water to be drained off by means of screw **26-3c**.

It is most important that the fuel filter is changed regularly in accordance with the machine service schedule. Use only genuine JCB replacement filters.

Table 19. Key

⇨ *Fig 26. (4-40)*			
1	Pre-filter/water separator	**2f**	Ball - outlet non return valve
1a	Bowl	**2g**	Spring - outlet non return valve
1b	Drain screw	**2h**	Oulet port
1c	Water level probe	**2j**	Spring - inlet non return valve
2	Lift pump	**2k**	Ball - inlet non return valve
2a	Cam lobe - fuel lift pump	**2m**	Inlet port
2b	Actuator pin	**3**	Fuel filter
2c	Pump lever	**3a**	Element
2d	Diaphragm	**3b**	Sediment bowl
2e	Spring	**3c**	Drain screw

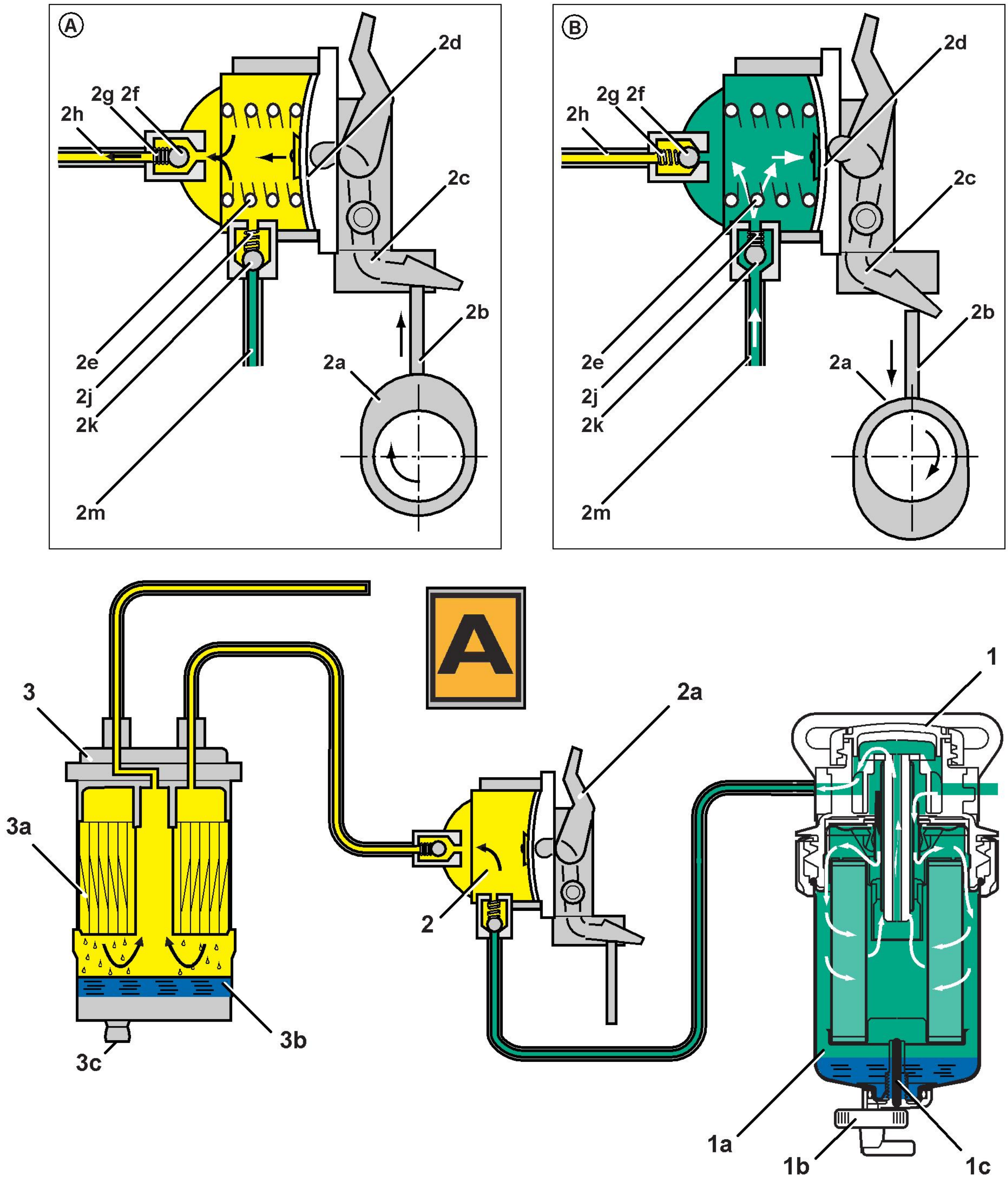


Fig 26.

⇨ *Table 19. Key (4-39)*

Fuel Injection Pump - Injection Cycle

The job of the fuel injection pump is to deliver a precise quantity of fuel to the cylinder at exactly the right time in accordance with the required power. The fuel is injected into the cylinder at very high pressure (up to 600 bar (8702 lb/in^2)). The pump is manufactured to fine tolerances and it is essential that no dirt or water is allowed to enter the pump. Equally vital to the performance of the pump is the use of the correct quality diesel fuel.

The fuel pump is driven by the engine at half engine speed.

The fuel injection pump is of a rotary type and its basic principle of operation is as follows:

Fuel from the lift pump enters the injection pump at port **27 -1**, at low pressure. Fuel then passes to the integral vane type transfer pump **27-2**. The transfer pump raises the fuel pressure to a pre-set value. The fuel pressure is controlled via integral relief valve **27-3**.

Fuel flows through internal ports to the metering valve **28-4** which controls the amount of fuel entering the high pressure system via the throttle linkage **28-5** and governor **28-6**. For a full description of the governor operation, ⇨ *Fuel Injector Pump - Governor (4-43)*.

State A - Charging

As the pump shaft **28-7** rotates internal ports align and metered fuel `charges' a chamber **28-8** between two plungers **28-9**.

State B - Injecting

As the pump shaft **28-7** continues to rotate, the plungers **28-9** are forced together by lobes on the cam ring **28-10**, pressurising the fuel in the chamber **28-8**. As the fuel is pressurised, internal ports align to allow high pressure fuel to leave the pump via one of the 4 high pressure fuel outlet ports **28-11** to an injector.

This cycle is repeated once for every cylinder per revolution of the pump.

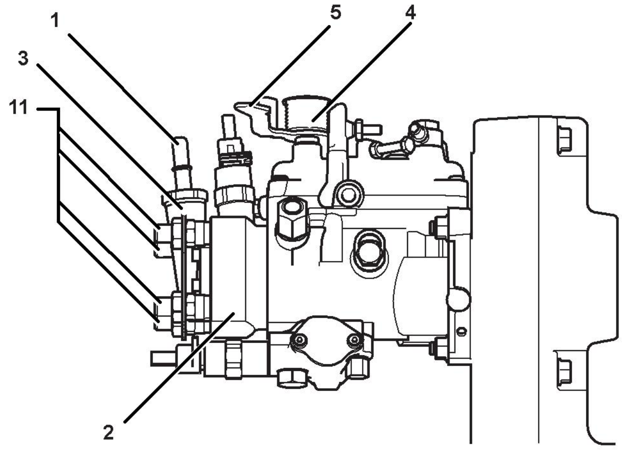


Fig 27.

Table 20. Key

⇨ *Fig 28. (4-42)*			
1	Injection pump low pressure fuel inlet port	8	Charging chamber
2	Integral fuel transfer pump	9	Plungers
3	Integral transfer pump relief valve	10	Cam ring
4	Metering valve	1	High pressure fuel outlet ports
5	Throttle linkage	A	Fuel pump state - charging
6	Integral governor	B	Fuel pump state - Injecting
7	Injection pump shaft (engine driven)		

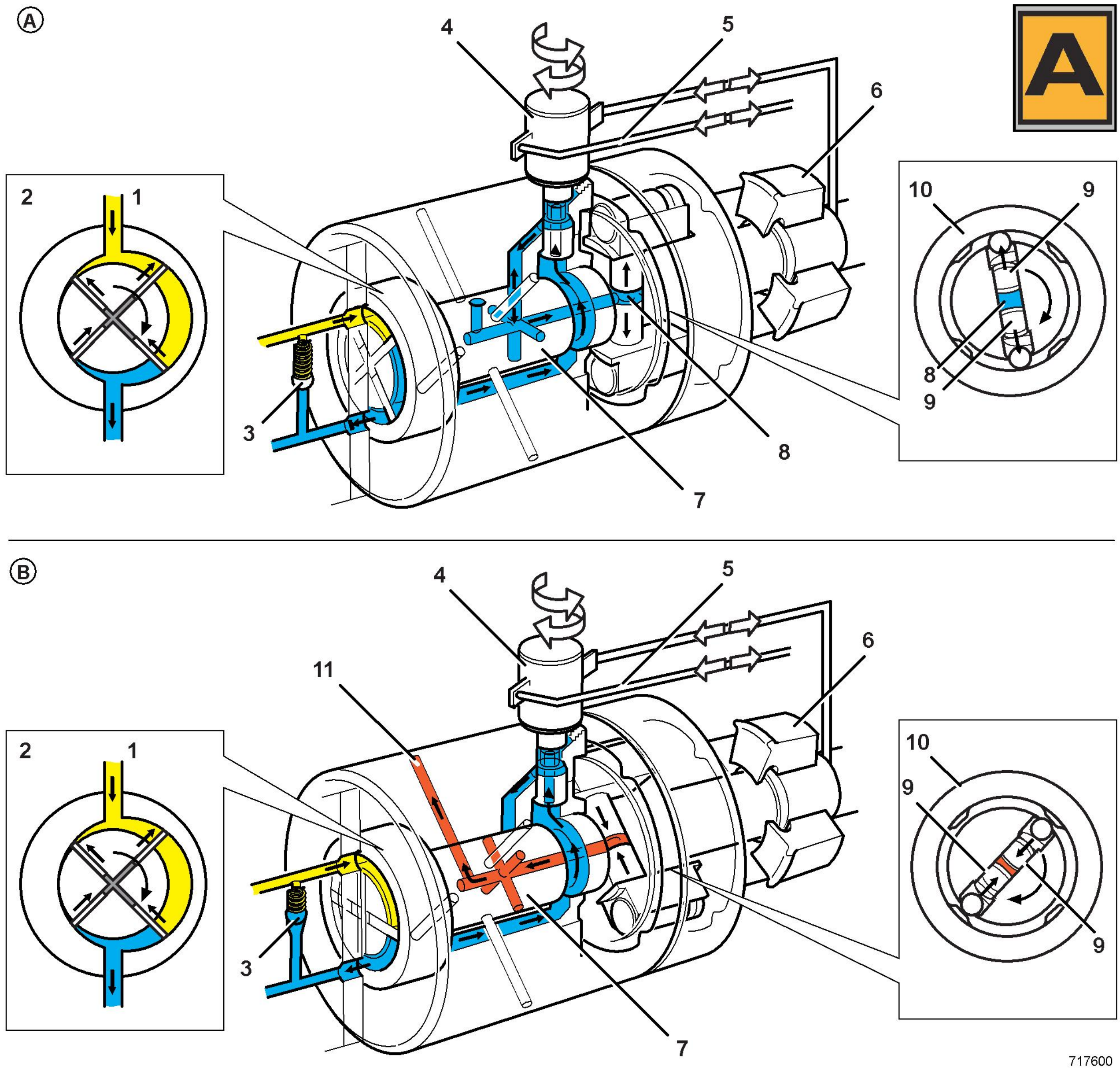


Fig 28.

Fuel Injector Pump - Governor

➩ *Fig 30. (4-44)*

The pump incorporates a mechanical governor. This works in conjunction with the throttle mechanism to control engine speed. The governor also acts to limit the maximum engine speed.

The governor consists of a series of weights **30-2** arranged around the rotating pump drive shaft **30-1**.

State A - Increasing Engine Speed

As the pump rotation speed increases, weights **30-2** are forced outwards by centrifugal force, moving a mechanical linkage **30-3** connected to the metering valve **30-4**. The linkage **30**-3 turns the metering valve, reducing the fuel supply and thus reducing the engine speed

State B - Decreasing Engine Speed

As the engine speed slows a reduction in centrifugal force causes the governor weights **30-2** to fall inwards. The linkage **30-3** turns the metering valve **30-4** to increase the fuel supply and thus increase the engine speed.

The governor control over the metering valve is precise, enabling fine control over the engine speed. Such is the degree of control that the engine is maintained at a virtually constant speed.

The point at which the governor acts on the metering valve is determined by throttle position. So when the operator sets the throttle for the required engine speed, the governor maintains the chosen speed.

The connection between the metering valve, throttle and governor linkages is via rods and springs housed in the case 30-**5**.

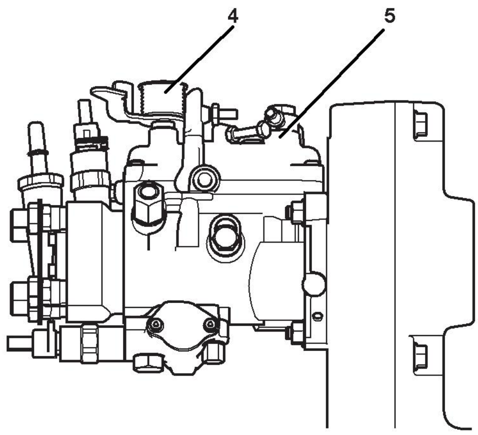


Fig 29.

Table 21. Key

➩ *Fig 30. (4-44)*	
1	Injection pump shaft (engine driven)
2	Governor weights
3	Governor linkage
4	Metering valve
5	Throttle linkage, governor linkage housing case
A	Governor state - increasing engine speed
B	Governor state - decreasing engine speed

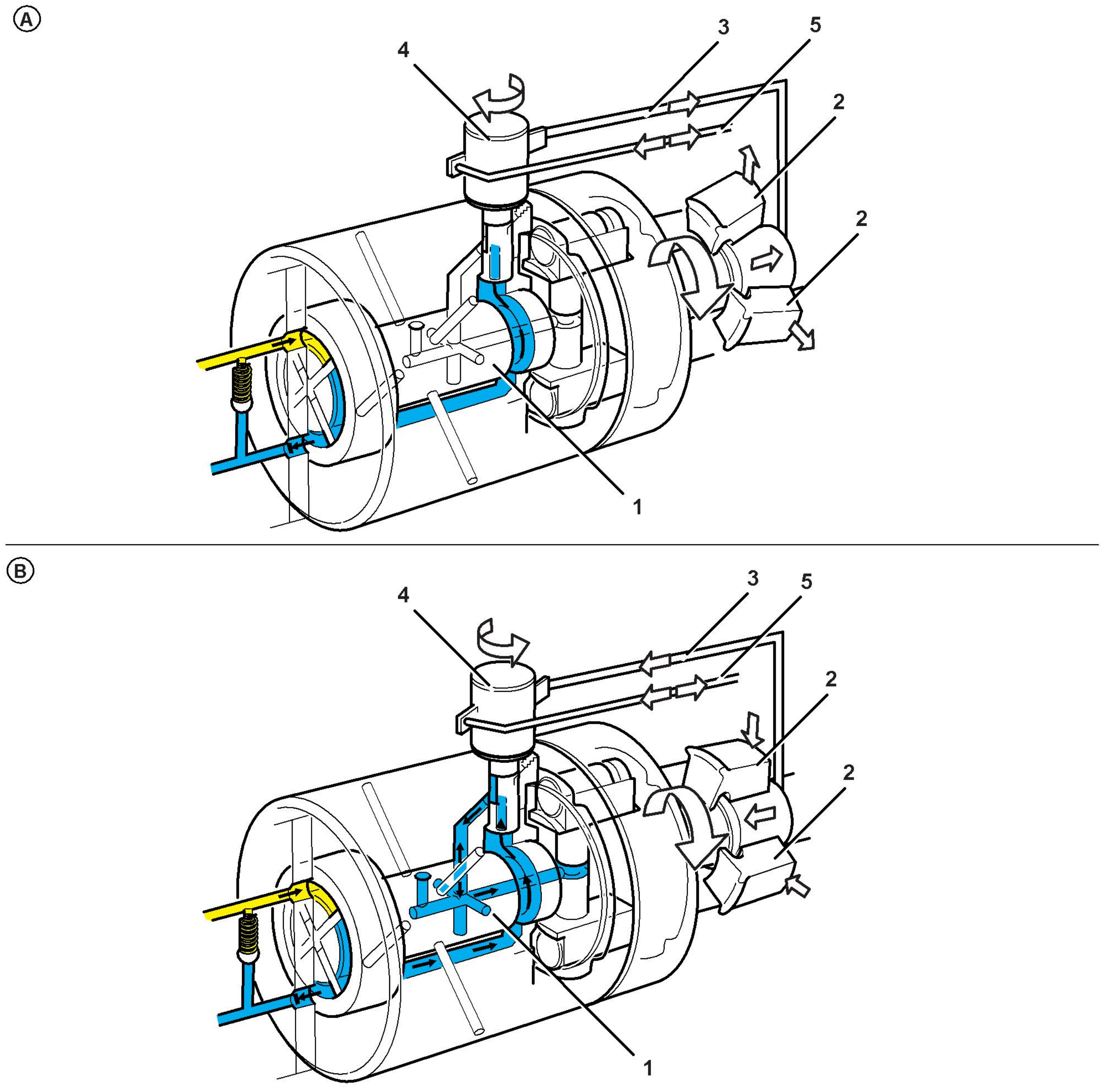


Fig 30.

Features of the Delphi DP210/DP310 Fuel Injection Pump

➩ Fig 31. (4-46)

The fuel pump incorporates several advanced design features to help improve engine performance and at the same time comply with current emissions regulations.

Cold Start Advance - Shown at A

By changing the angular position of the cam ring **31-1a**, the timing of the fuel injection can be altered. This is useful as an aid to cold starting and is achieved hydraulically using the fuel pressure.

When the engine coolant is cold, electrical switch **31-1e** closes, energising cold advance solenoid **31-1b**. The solenoid plunger lifts from its seat allowing fuel pressure to act on the advance piston **31-1d** moving the cam ring to the advance position. The cold advance solenoid is de-energised to return the cam ring to the hot running position.

Hydraulic Light Load Advance

It is advantageous to alter injection timing when the engine is running at light load. The light load advance valve **31-2a** uses fuel pressure to detect light load conditions which acts on the advance piston **31-1d** to alter the injection timing in a similar way to the cold start advance.

Variable Fuelling - Shown at B

To further enhance engine power and emissions control, the fuel injection `curve' is variable, depending on engine speed and load.

The injection `curve' is controlled by the shape of the lobes on the cam ring **31-1a**. The lobes determine the exact duration and pressure characteristics of each injection of fuel. Since one cam shape or profile will never be ideal for all engine operating conditions, the profile is changed by using scroll plates **31-3a**. These plates are moved radially to change the cam profile and thus the movement of the injection pump rollers and plungers. The scroll plates are activated by the position of the governor, the torque trimmer unit **31-3b** and the turbo boost control (if fitted).

The torque trimmer **31**-3b moves the scroll plates according to fuel pressure.

Latch Valve

The latch valve **31-4a** isolates the torque trimmer and timing advance systems until the engine has started, ensuring the pump remains in the optimum state for engine starting.

ESOS - Electric Shut Off Solenoid

The ESOS solenoid valve **31-5a** is de-energised to isolate the fuel supply to the injection pump and thus stop the engine. For the engine to start and run the solenoid must be permanently energised.

Turbo Boost Control (Turbocharged engines only)

Injection pumps on turbocharged engines are fitted with a boost diaphragm **31-6a**. The diaphragm has a vacuum connection **31-6b** from the engine inlet manifold. As the turbocharger boost pressure rises the boost diaphragm acts on the fuel metering valve to increase the fuel supply to the engine. There is also a link to the scroll plates **31-3a** to alter the fuel curve for maximum engine performance.

Table 22. Key

➩ Fig 31. (4-46)	
1a	Cam ring
1b	Cold advance solenoid
1c	Advance unit
1d	Advance piston
1e	Cold start switch
2a	Light load advance valve
3a	Scroll plates
3b	Torque trimmer
4a	Latch valve
5a	ESOS (Electric Shut Off Solenoid)
6a	Turbo boost diaphragm
6b	Turbo boost diaphragm vacuum connection

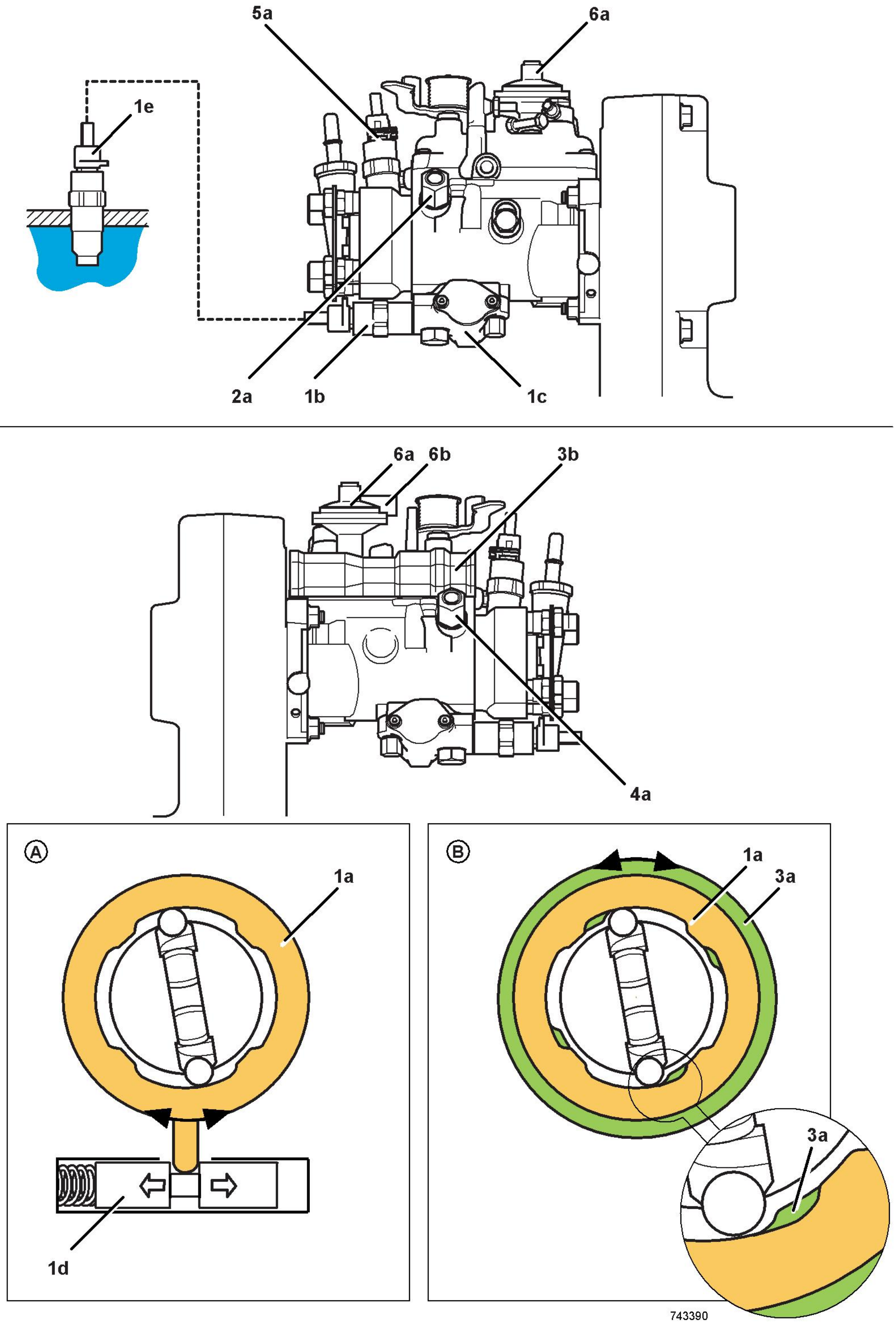


Fig 31.

Injectors and Combustion

Injectors

When fuel is injected it is sent through high pressure pipes to the multi-point injector **32-1** (atomiser).

Injector needle **32-2** is held on its seat by spring **32-3**. When the injection pressure generated by the injection pump is high enough, needle **32**-2 is forced off its seat compressing spring **32**-3. Fuel is then injected under high pressure into the cylinder. The high pressure is necessary to ensure the fuel atomises thoroughly.

When the fuel pressure from the injection pump begins to fall spring **32**-3 snaps needle **32**-2 back onto its seat. This ensures that only fuel at the highest pressure is injected into the cylinder producing maximum atomisation. Fuel trapped in the injector body is allowed to bleed back to the fuel tank via bleed-off port **32 -4**. The fuel at the bleed off port is at low pressure.

The high pressure fuel injector pipes **32-5** consist of thick walled, seamless steel tubing.The ends of the tubes are formed with conical nipples for sealing in the sealing cones on the injection pump and on the nozzle holder body 6. It is essential that the pipes are maintained and fitted correctly for safe and effective engine operation.

Table 23. Key

⇒ Fig 32. (4-47)	
1	Multi-point injector
2	Needle
3	Spring
4	Bleed-off port
5	High pressure injector pipe
6	Nozzel holder
7	Pressure channel
8	Injection nozzel
9	Pressure adjusting shims
10	Pressure spindle
11	Locating pins
12	Intermediate disc
13	Nozzel retaining nut
14	Filter
15	Union nut - injector pipe

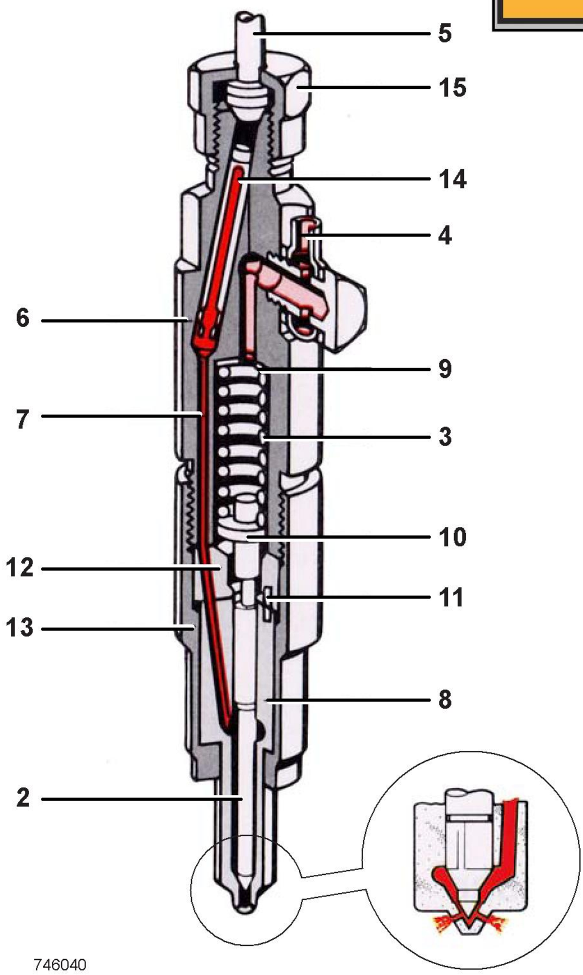


Fig 32.

Combustion

The engine employs a direct injection system. Fuel is injected directly into the cylinder, the mixing taking place in the combustion chamber **33-X** which is recessed into the crown of the piston. The process of mixing starts during the induction stroke and continues throughout the compression stroke. The inlet porting and combustion chamber are carefully designed to ensure that when the fuel is injected it is mixed thoroughly with the air. The multi-point injector and high injection pressure ensure a good distribution of fuel throughout the air which aids mixing. The mixing process continues until combustion is completed.

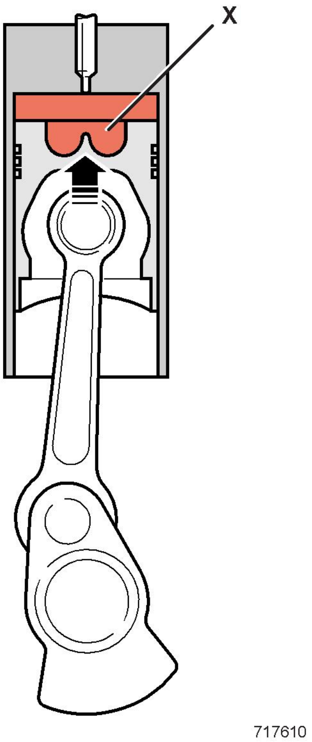


Fig 33.

Table 24. Key

⇨ Fig 33. (4-48)	
X	Combustion chamber

Induction, Exhaust and Breather Systems

Induction and Exhaust Systems

The induction system ensures the required volume of air enters the engine to provide efficient combustion of the fuel in the cylinders. There are 3 types of induction system to suite different engine applications:

– **Naturally aspirated**
– **Turbocharged**
– **Turbocharged and inter-cooled**

Each system is described separately on the following pages.

Naturally Aspirated

Air is drawn into the engine via the air filter **34-1**. The air at atmospheric pressure flows from the air filter to the inlet manifold **34-2**, from where it is pulled into the cylinder during the induction cycle. Exhaust gases leave the engine via exhaust manifold **34-3**.

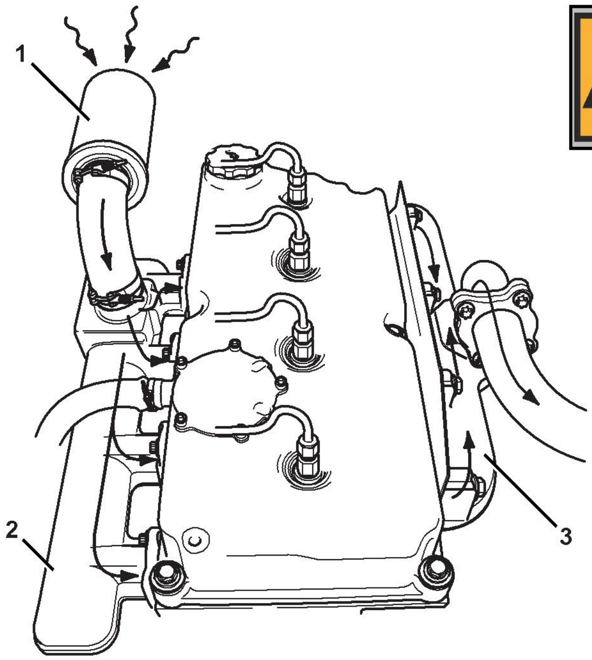


Fig 34.

Table 25. Component Identification

⇨ Fig 34. (4-49)	
1	Air filter
2	Inlet manifold
3	Exhaust manifold

Turbocharged

A turbocharger **36-1** is bolted to the outlet port of the exhaust manifold **35-2**.

The turbocharger uses energy from the exhaust gases to drive a turbine **35-3** which in turn drives the compressor **35-4** via a common shaft. Air is drawn through the air filter **35-5** into the compressor side of the turbocharger. The compressor forces pressurised air into the cylinders via the cross-over pipe **35-6** and inlet manifold **35-7**. The extra volume of air allows more fuel to be injected (*⇨ Fuel System (4-37)* description) increasing the engine power output.

The air is compressed to a minimum pressure of 1 bar (14.5 lb/in^2) depending upon engine speed and load. The turbocharger spins at up to 1000,000 rpm and reaches temperatures approaching 700 şC (1292 şF); it is essential, therefore, that a good supply of oil reaches it at all times. The oil not only lubricates the turbocharger but also carries away excess heat. External oil feed pipe **36-8** connected to a port on the cylinder block supplies oil to the turbocharger bearing. Oil returns to the engine oil pan via external drain pipe **36-9**. Integral oil seals prevent oil escaping to the compressor and turbine ends of the turbocharger.

The pressure generated by the compressor is known as `boost pressure' The boost pressure is controlled by the wastegate assembly **36-10**. Boost pressure acts on a pneumatic actuator **36-11**. The actuator is linked to the wastegate valve **36-13** via operating linkage **36-14**. When the boost pressure reaches a pre-set value the wastegate opens allowing exhaust gas to bypass the turbine, thus reducing the speed of the compressor. At higher engine speeds the wastegate is continually opening and closing a small amount, maintaining a constant boost pressure.

Table 26. Component Identification

⇨ Fig 35. (4-50), *⇨ Fig 36. (4-51)*	
1	Turbocharger
2	Exhaust manifold
3	Turbine
4	Compressor
5	Air filter
6	Cross-over pipe
7	Inlet manifold
8	Oil feed pipe - turbo bearing
9	Oil drain pipe - turbo bearing
10	Wastegate assembly
11	Pneumatic actuator
12	Exhaust outlet
13	Wastegate valve - turbine bypass
14	Operating linkage
15	Heat exchanger (inter-cooled) *⇨ Fig 38. (4-52)*

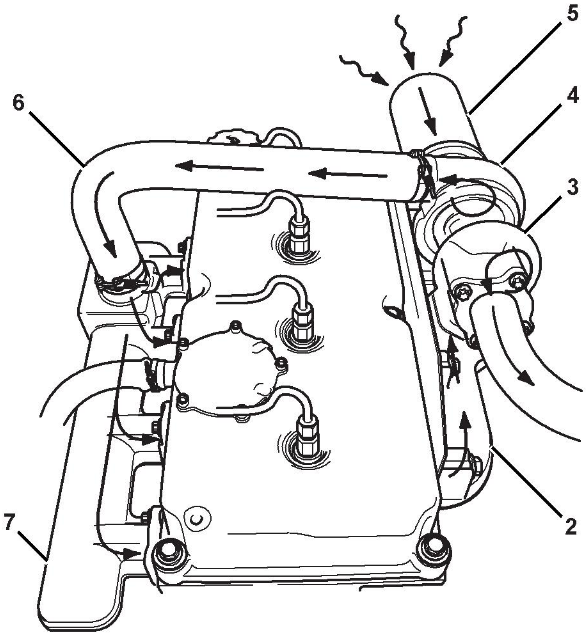


Fig 35.

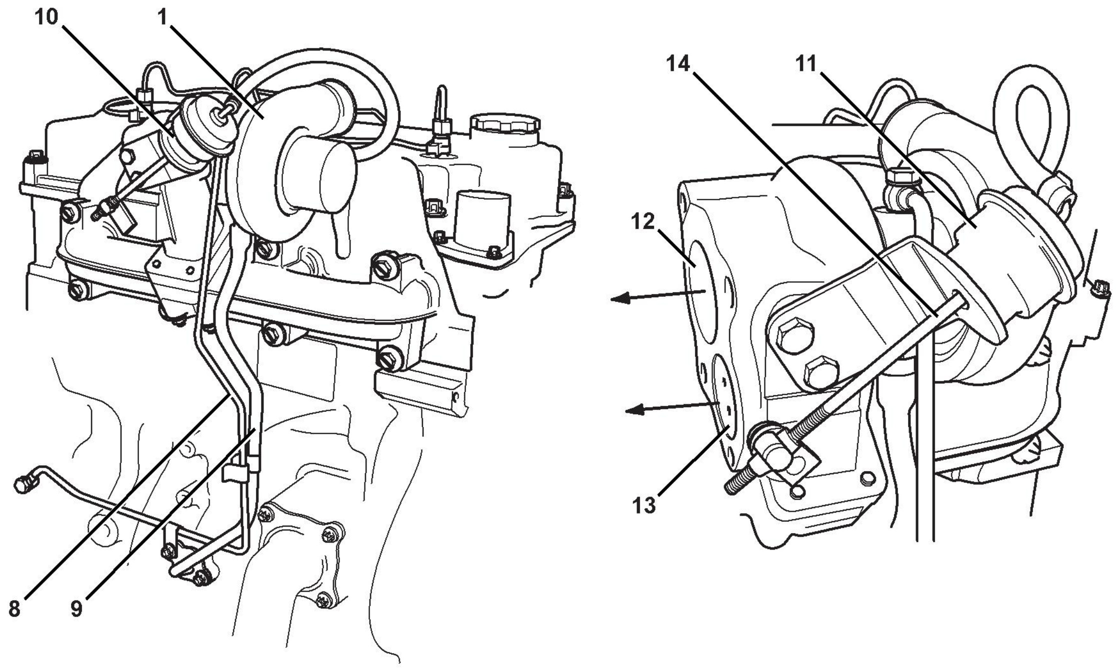


Fig 36.

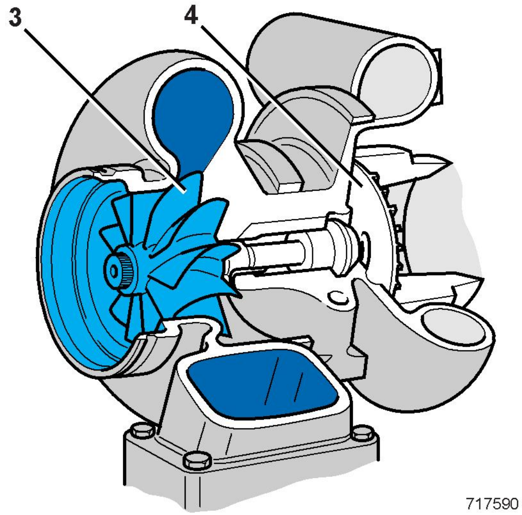


Fig 37.

Intercooled

Turbocharged engines can be configured for inter-cooling. As the air is compressed by the turbocharger it also heats up and becomes less dense, reducing the combustion efficiency. By passing the compressed air through a heat exchanger **38-15** or `inter-cooler' it is cooled before reaching the engine. The inter-cooler most commonly takes the form of an air blast matrix but can be a water cooled matrix.

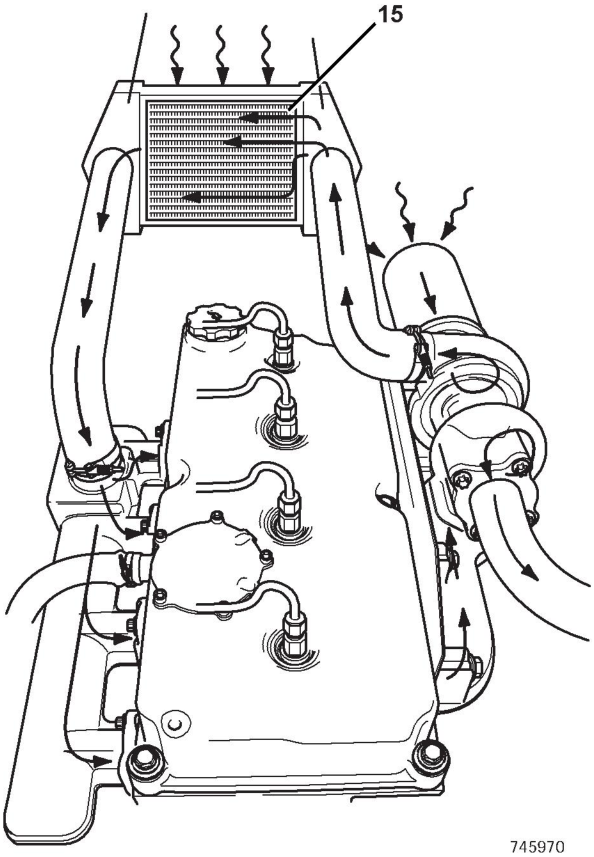


Fig 38.

Exhaust Gas Recirculation (EGR)

The engine features an exhaust gas recirculation system. This enables a small amount of exhaust gas to be introduced into the induction air for combustion.

The system reduces nitrogen oxide and nitrogen dioxide emissions.

A small anount of exhaust gas is introduced into the inlet manifold by using the camshaft to open the inlet valves during the exhaust stroke. The valves are opened only for a short period and at low lift.

Engine Breather

SA, SB, SC Engines

⇨ Fig 39. (4-55)

The engine is fitted with a `closed-loop' crankcase ventilation (CCV) system.

The engine breather assembly is housed in the rocker cover under a plate **39-1.** The breather prevents the build up of pressure in the crankcase, caused by the reciprocating motion of the pistons, and hot gases that may `blow by' the pistons during the combustion process.

A series of ports in the cylinder block **39-7**, cylinder head **39-8** and rocker cover **39-9** allow hot vapour to vent from the crankcase.

Gauze **39-5** located inside the rocker cover acts as a filter trapping the oil mist. The gauze prevents oil droplets suspended in the vapour escaping from the engine. The trapped oil droplets drain from the gauze back into the engine.

Diaphragm **39-2** acts as a non-return valve. When there is positive pressure in the crankcase, the filtered vapour opens the breather port **39-6** assisted by the force of the spring **39-3**, allowing the crankcase gas to vent along the breather hose **39-4**. Should a negative pressure develop however, the diaphragm will move against the force of the spring and close off the breather port to prevent unfiltered air being drawn into the engine.

A possible cause of negative crankcase pressure is a blocked air filter. This can result in oil being sucked from the sump into the cylinders. The engine can `run - away' by burning its own oil.

On naturally aspirated engines, the breather hose **39-4** connects directly to the inlet manifold. On turbocharged engines, the breather hose **39-4** connects to the air filter housing, and then enters the inlet manifold via the turbo charger. The crankcase gas is then drawn back into the engine.

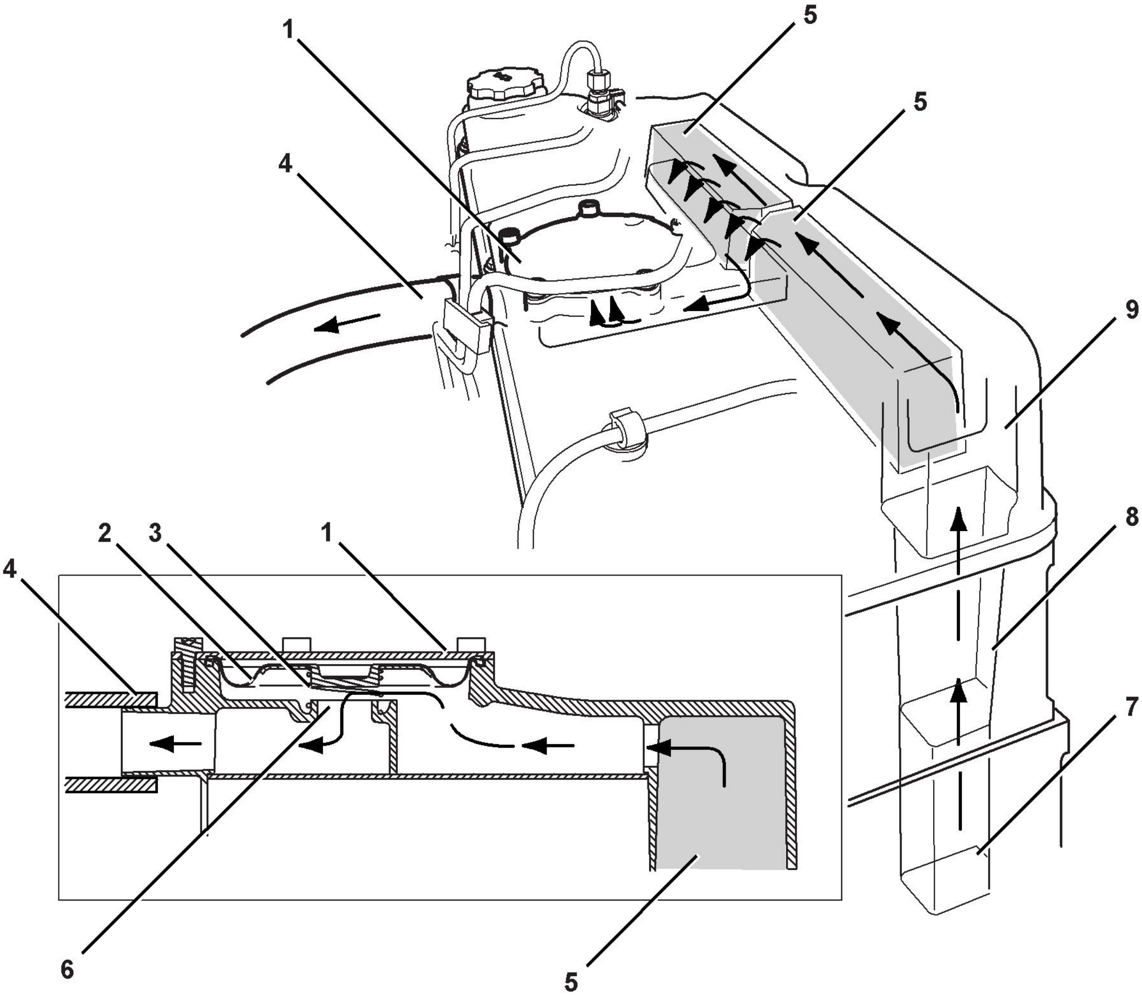


Fig 39. SA, SB, SC Engines

Table 27. Component Identification

1	Cover plate
2	Diaphram
3	Spring
4	Breather hose
5	Gauze filter (1)
6	Breather port
7	Cylinder block - breather port
8	Cylinder head - breather port
9	Rocker cover - breather duct

(1) SA, SB, SC engines only.

SD, SF Engines

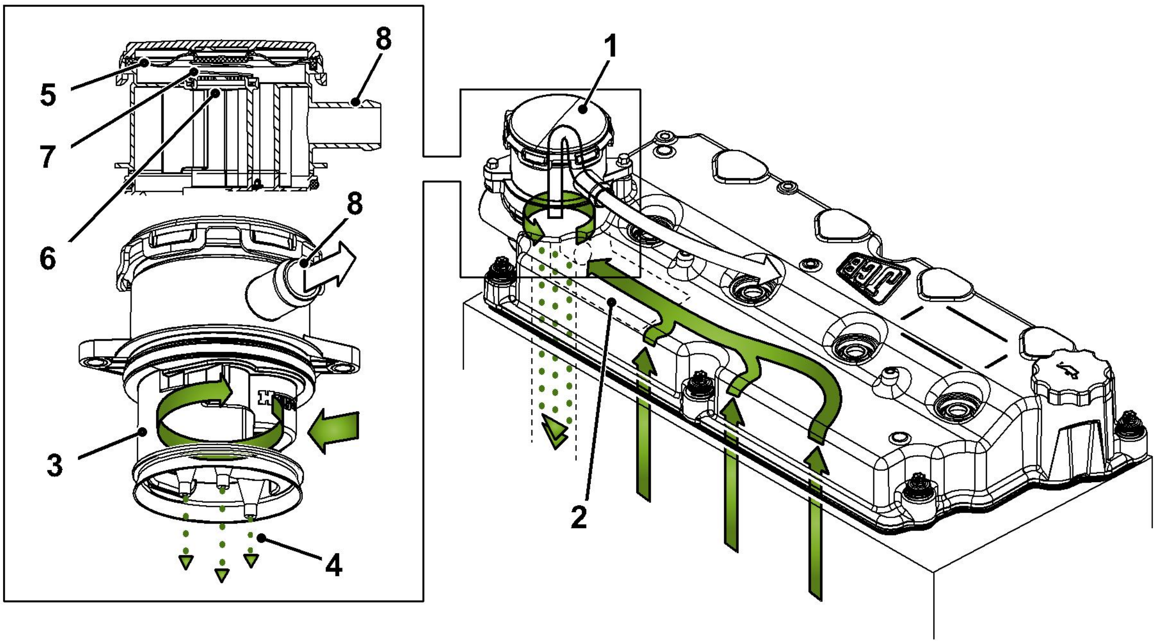


Fig 40.

The engine is fitted with an `open' crankcase ventilation (CCV) system.

The engine breather assembly **40-1** is mounted on the rocker cover. The breather prevents the build up of pressure in the crankcase, caused by the reciprocating motion of the pistons, and hot gases that may `blow by' the pistons during the combustion process. The breather also separates the oil trapped in the vapour from the crankcase.

A series of ports in the cylinder block and cylinder head allow hot vapour to vent from the crankcase and pass into the rocker cover. The vapour flows through a ventilation chamber **40-2** inside the rocker cover to the oil separator **40-3**.

Galleries inside the separator create a `cyclone' effect, this effect separates out the oil droplets suspended in the vapour. The trapped oil droplets **40-4** drain from the bottom of the separator back into the engine sump. The oil drains via a port in the cylinder head and block.

A possible cause of negative crankcase pressure is a blocked air filter. This can result in oil being sucked from the sump into the cylinders. The engine can `run - away' by burning its own oil.

Diaphragm **40-5** acts as a non-return valve. When there is positive pressure in the crankcase, the filtered vapour opens the breather port **40-6** assisted by the force of the spring **40-7** allowing the crankcase gas to vent to atmosphere via port **40-8**. Should a negative pressure develop however, the diaphragm will move against the force of the spring and close off the breather port to prevent unfiltered air being drawn into the engine.

Cooling System

Description

During the working cycle of the engine a great deal of heat is generated. It is important that the engine is kept at its normal operating temperature to achieve maximum efficiency. It is the function of the cooling system to allow the engine to reach this temperature quickly and then maintain it.

Coolant pump **41-1**, driven via a pulley and front end accessory drive belt **41-2**, draws coolant from the pump cavity **41-3**.

Coolant is pumped through the outlet gallery **41-4** to the oil cooler cavity **41-5** in the left-hand side of the cylinder block. As the coolant flows past the oil cooler matrix heat is exchanged from the oil to the coolant. This enables the oil to function as a coolant as well as a lubricant. See Lubrication System - ⇨ *Oil Cooler and Filter (4-31)*.

The coolant leaves the oil cooler cavity and passes into the main cylinder block gallery **41-6**. The gallery is connected to the cylinder water jackets **41-7**. Coolant flows around and up the jackets and then passes into the cylinder head via link galleries **41-8**. Coolant circulates around the cylinder head where it conducts heat away from the combustion chambers and also the fuel injector tips, see ⇨ *Injectors (4-60)*. The coolant then passes to the thermostat housing **41-9**.

When the engine is below normal operating temperature the thermostat **41-10** is closed, preventing coolant flowing to the machine radiator via the top hose connection port **41-11**. Instead coolant is directed through by-pass gallery **41-12** back to the pump cavity **3** and is again drawn into the pump **41-1**. See ⇨ *Thermostat (4-59)*.

When the engine is at operating temperature the thermostat opens, closing the by-pass gallery **41-12** to the pump and opening the top hose connection port **41-11** to the machine radiator. Coolant passes through the radiator matrix and is cooled. The coolant flows back to the engine via bottom hose connection port **41-13** and is again drawn into the pump **41-1**. See ⇨ *Thermostat (4-59)*.

A coolant temperature gauge and warning light sender unit is fitted at port **41-14**. See ⇨ *Electrical System (4-62)*.

A cab heater hose can be fitted at port **41-15**. This enables coolant to circulate through a heater matrix when the thermostat is open or closed, ensuring fast heater warm up.

A cold start switch is fitted at port **41-16**. When the coolant is cold the switch closes and energises a cold start solenoid on the fuel injection pump, enabling a cold start mode. See Fuel System - ⇨ *Features of the Delphi DP210/DP310 Fuel Injection Pump (4-45)* and ⇨ *Electrical System (4-62)*.

Table 28. Key

⇨ *Fig 41. (4-58)*			
1	Coolant pump	9	Thermostat housing - cylinder head
2	Drive belt - coolant pump	10	Thermostat - cylinder head
3	Pump cavity - cylinder block	11	Top hose connection port - cylinder head
4	Pump outlet gallery - cylinder block	12	By-pass gallery - cylinder head and block
5	Oil cooler cavity - cylinder block	13	Bottom hose connection port - cylinder block
6	Coolant gallery - cylinder block	14	Port - Coolant temperature sender and switch unit - cylinder head
7	Cylinder cooling jackets - cylinder block	15	Port - Cab heater hose connection - cylinder head
8	Link galleries - cylinder block to head	16	Port - Cold start switch - cylinder block

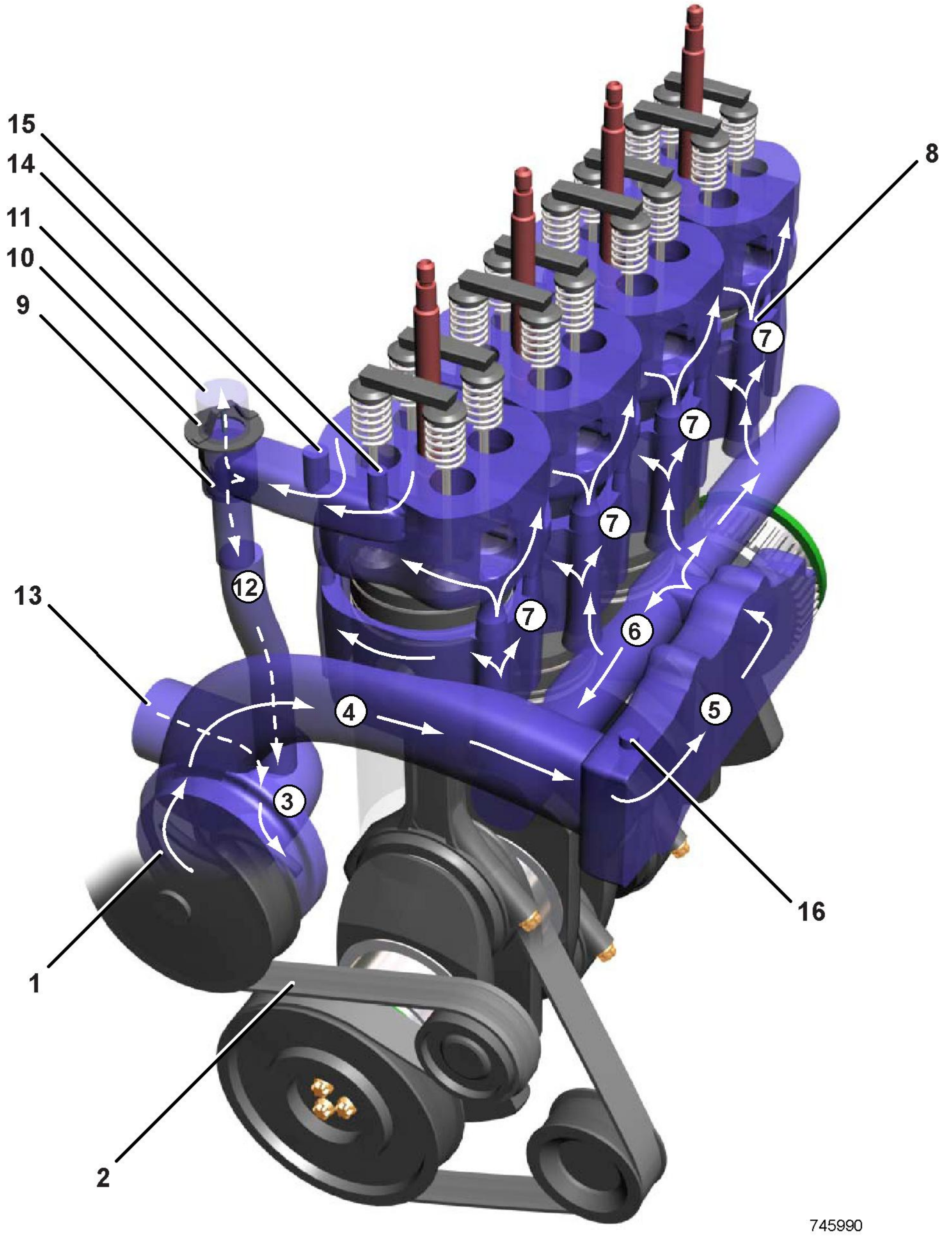


Fig 41.

Thermostat

The thermostat is of the wax element type and is configured for by-pass blanking. The thermostat functions as follows:

State A - `Closed' - Engine Cooled

Because the engine is cold the wax pellet **42-5** has contracted in its housing. This allows spring **42-2** to act against the thermostat body and move valve plate **42-3** up against its seat, closing the outlet port **42 -8** to the radiator. Since the bottom valve plate **42-4** is connected to the top valve plate it also moves up, opening the by-pass port **42-10**. Coolant flows from the thermostat housing inlet port **42-9** into the bypass gallery.

State B - `Open' - Engine Hot

When hot, the wax pellet melts. As it does so it expands and pushes against diaphragm **42-6**. The diaphragm reacts against the actuating rod **42-7** and both the top and bottom valve plates (**42-3** and **42-4**) move down in the thermostat body, compressing spring **42-2**. Now the outlet port **42-10** to the radiator is open and by-pass port **42 -10** is closed.

A 1.0 mm (0.039 in.) diameter orifice **42-11** allows trapped air to be expelled from the system.

Table 29. Key

⇨ *Fig 42. (4-59)*	
1	Thermostat
2	Spring
3	Thermostat top valve plate
4	Thermostat bottom valve plate
5	Wax pellet
6	Diaphragm
7	Actuating rod
8	Outlet port - to radiator top hose
9	Inlet port - thermostat housing
10	Outlet port - by-pass gallery
11	1.0 mm (0.039 in.) diameter orifice
A	Thermostat state - `Closed' - engine cold
B	Thermostat state - `Open' - engine hot

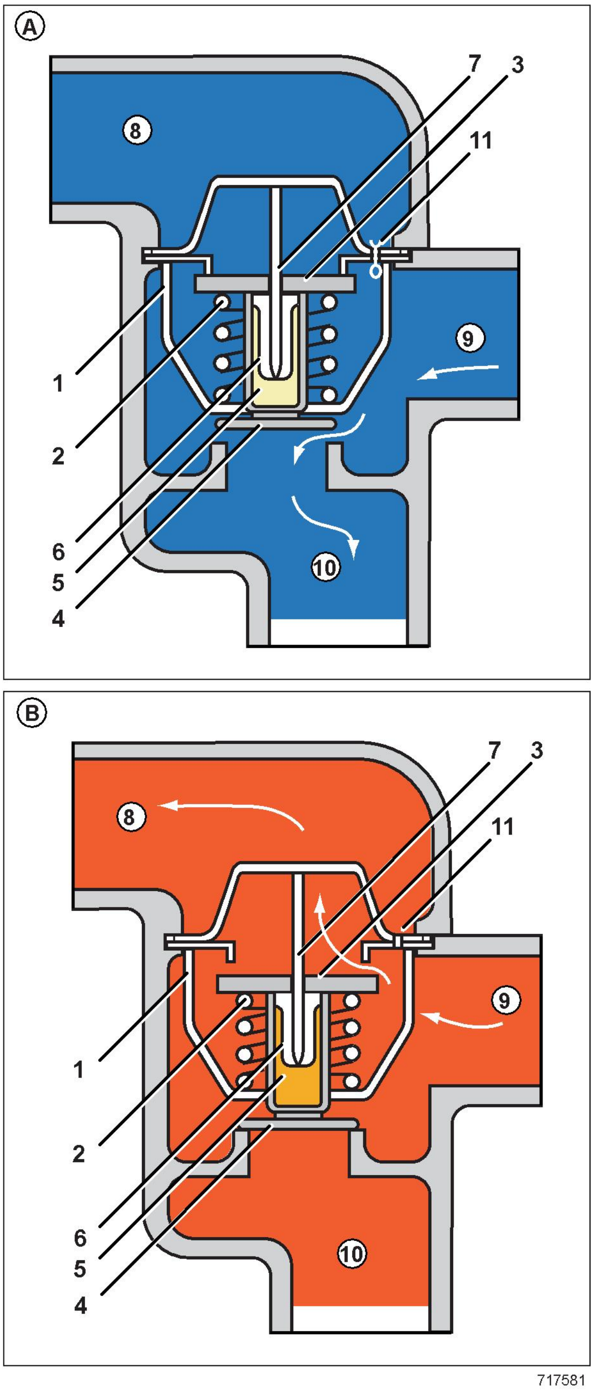


Fig 42.

A

Injectors

The injector tips are located inside the combustion chambers, so effective cooling is essential.

A special thin walled sleeve **43-2** is screwed into the cylinder head **43-3** which allows a coolant jacket **43-4** close to the injector **43-1.** The coolant jacket is sealed at the bottom by sealant on the sleeve thread **43-5** and at the top by `O' ring **43-6**.

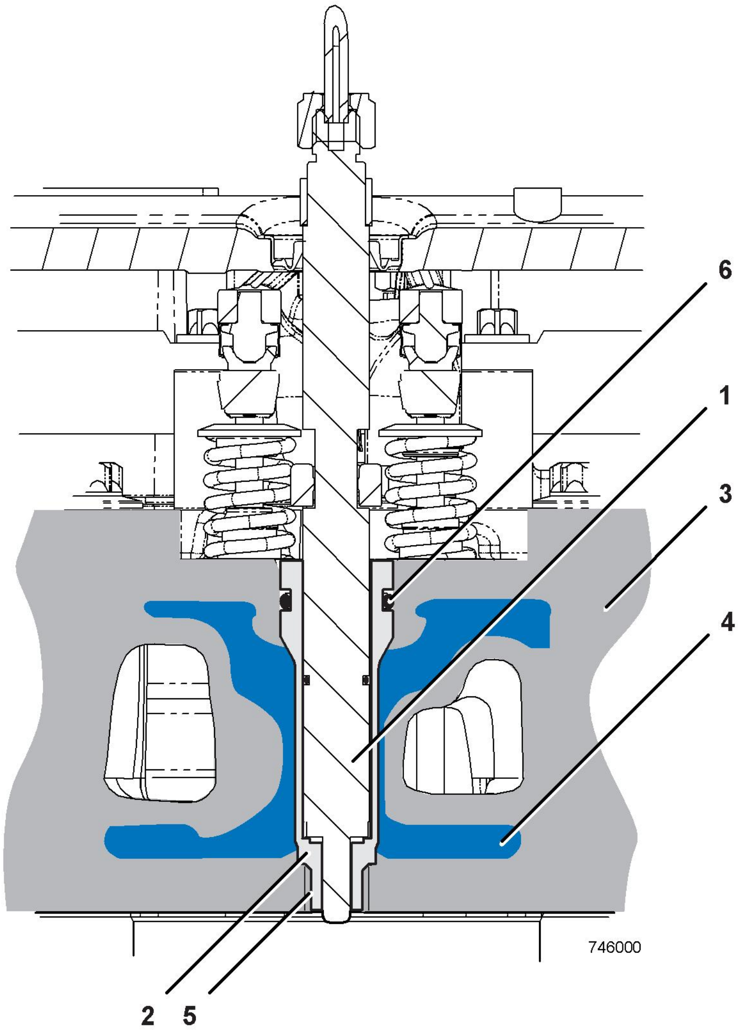


Fig 43.

Coolant Pump

The coolant pump **44-1** is a centrifugal type located in the front of the cylinder block, and is driven via a pulley **44 -2** by the front end accessory drive belt.

Table 30. Component Identification

⇨ *Fig 44. (4-61)*	
1	Coolant pump
2	Drive pulley
3	Impeller

The impeller **44-3** rotates clockwise to circulate the coolant through the cooling system. The pump shaft bearing and seal are not renewable.

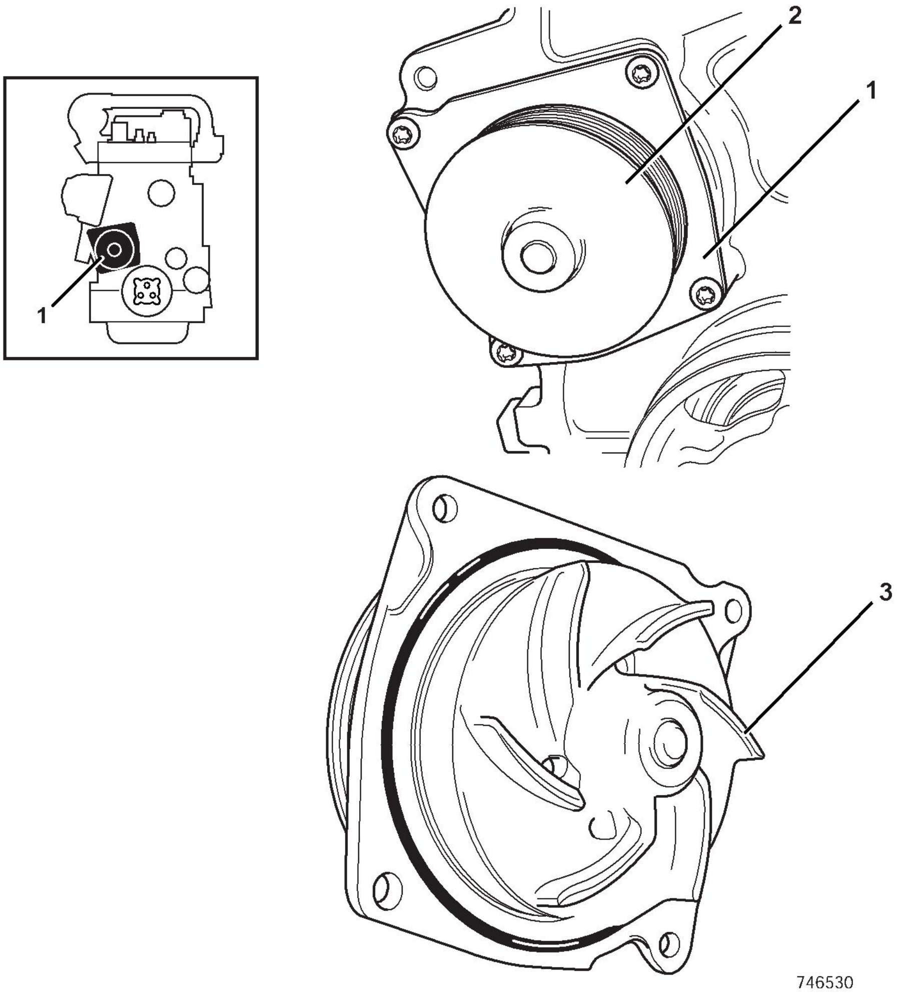


Fig 44.

Electrical System

Electrical Circuit Schematic

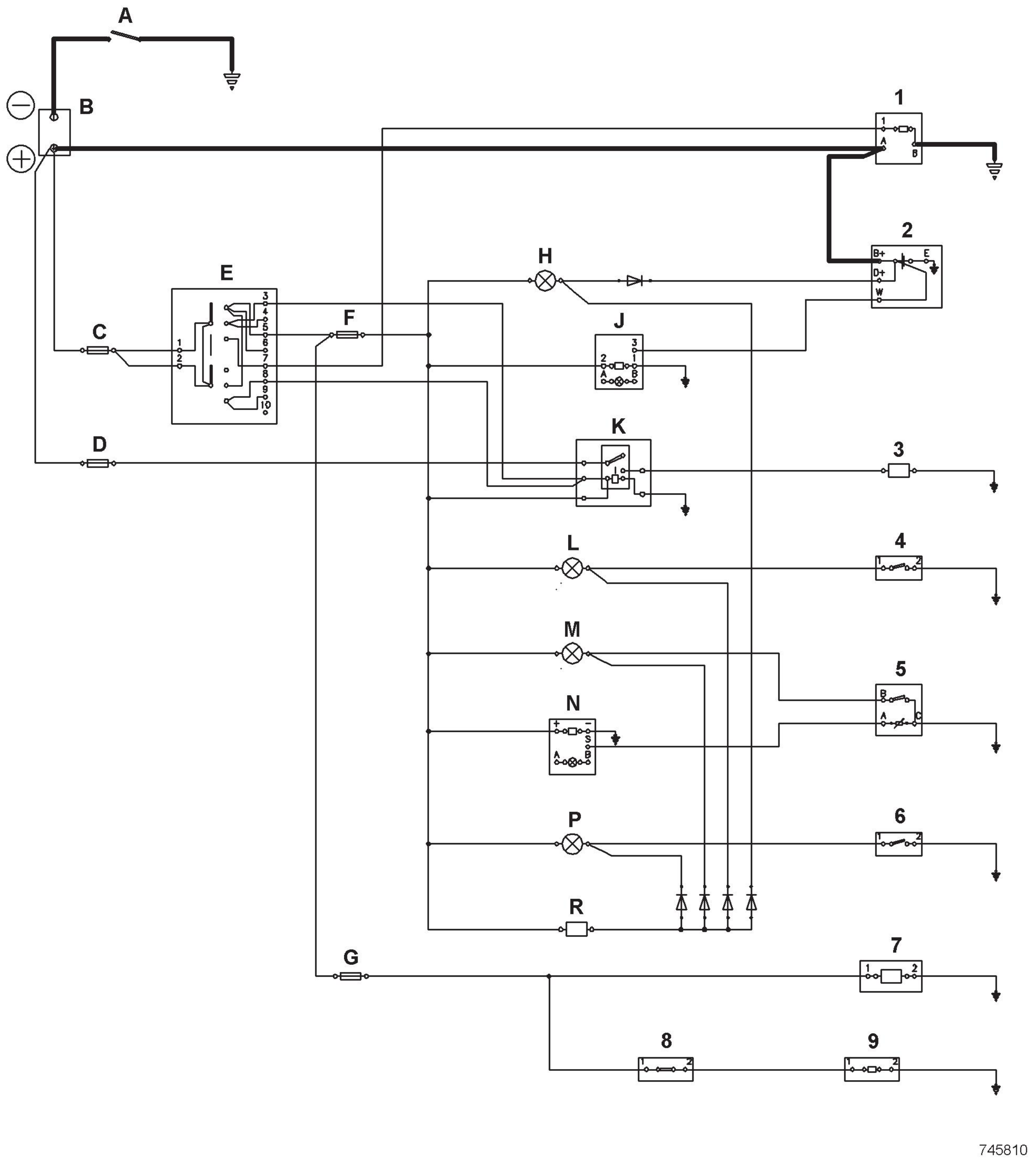


Fig 45.

Electrical Components

The engine electrical components operate on a 12 volt negative earth system. The schematic and component list are typical only and should not be used as a reference for a specific machine.

It is the responsibility of the original equipment manufactuter (OEM) to provide suitable fuses and relays within the parent machine electrical system to protect the components and wiring harness.

Note: *The engine components must have separate earth wires provided as part the parent machine wiring harness.*

Table 31. Component Identification

⇨ Fig 45. (4-62)	
Engine Components (supplied with the engine)	
1	Starter motor
2	Alternator
3	Grid heater - air intake (cold climate option)
	- Rating: 100 Amps
4	Water present switch - fuel sedimenter
5	Coolant temperature sender/switch
	- Setting: 105 - 111 °C
	- Connector: Deutsch DT 2-way
6	Lubricating oil pressure switch
	- Setting: 0.6 Bar (8.7 lb in^2)
	- Connector: Deutsch DT 2-way
7	Engine shut-off solenoid
	- Connector: AMP Junior Timer 2-way
8	Cold start advance switch
	- Setting: +40 °C
	- Connector: Deutsch DT 2-way
9	Cold start advance solenoid
	- Connector: AMP Junior Timer 2-way

Table 32. System Components (part of the parent machine)

⇨ Fig 45. (4-62)	
A	Battery Isolator (optional)
B	Battery
C	Primary fuse
D	Primary fuse (125 Amp typical)
E	Ignition switch
F	Fuse
G	Fuse (5 Amp typical)
H	Warning lamp - Alternator `No charge'
J	Tachometer
K	Timer relay - grid heater
L	Warning lamp - `Water in fuel'
M	Warning lamp - Coolant `Over temperature'
N	Coolant temperature gauge
P	Warning lamp - Lubricating oil `Pressure low'
R	Warning buzzer

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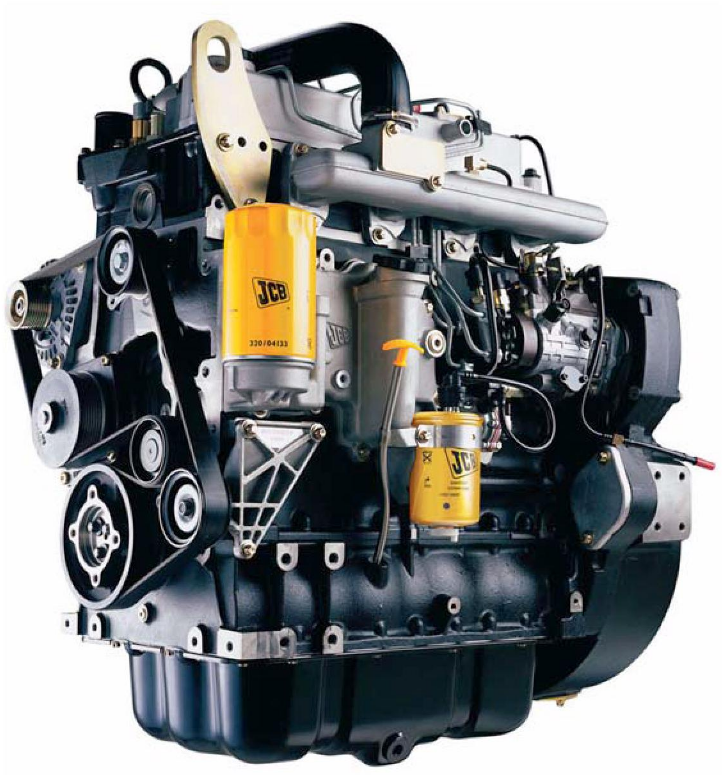
Section 5

Fault Finding

Service Manual - JCB 444 Engine



Publication No.

9806/3000-02

World Class
Customer Support

Issued by JCB Technical Publications, JCB Aftermarket Training, Woodseat, Rocester, Staffordshire, ST14 5BW, England. Tel +44 1889 591300 Fax +44 1889 591400

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Fault Finding

Introduction

The fault finding procedures are given in the form of flow charts. There are a number of charts, each one dedicated to a particular fault catagory.

The charts are designed to identify possible causes by performing checks and where applicable, specific tests on the engine. Having identified a cause the suggested remedy is given. The charts are designed to identify causes through a process of elimination, starting with the simplest, most easily rectified faults.

Due to the time and effort involved in removing, dismantling, assembling and replacing an engine, it is recommended that fault finding procedures are carried out until a fault can be identified with a good degree of certainty.

There are many reasons why an engine may malfunction, time and effort will be saved by following basic troubleshooting steps:

– Do not make assumptions.
– If possible, talk to the operator for a description of the fault. Also, check if any recent maintenance or repair has been completed on the engine.
– Start simple - for instance many starting and running faults can be attributed to low fuel level.
– Systematically work through each of the possible causes.
– Confirm your diagnosis before dismantling and assembling.
– Follow the recommended repair procedures in this manual.

Fault Finding Charts

A Charts - Engine

Table 1. Engine - Will Not Start or Difficult to Start (No Exhaust Smoke)

Cause	Remedy
No fuel in supply tank	Check the level in the fuel tank, use sight gauge or dipstick. Replenish as required.
Electrical fuel shut-off solenoid (ESOS) valve not functioning properly.	Check for correct operation of the electric shut-off solenoid (ESOS). Refer to ***Test Procedures, Section 6.***
Improper starting procedure.	Verify proper starting procedure. Refer to ***Starting the Engine, Section 1.***
Fuel Filter blocked with water or other contamination.	Drain fuel/water separator or replace fuel filter. Refer to ***Engine Fuel System, Section 3.***
Fuel lift pump not operating correctly (fuel supply inadequate).	Check that the lift pump is operating and delivering fuel to the injection pump. Refer to ***Test Procedures, Section 6.***
Fuel is aerated.	Check the fuel system for loose connections and possible air ingress points. Rectify and bleed the fuel system. Refer to ***Engine Fuel System, Section 3.***
Check fuel inlet restriction.	Maximum inlet restriction to fuel transfer pump must not exceed 100 mm Hg (4 in. Hg).
Air intake or exhaust system blocked.	Visually check the air intake and exhaust system for blockage or obstruction - remove as required. Check the air filter elements for signs of blocking - replace as required.
Fuel drain return line blocked, not connected properly.	Verify that the fuel return line is not obstructed and connected to the top of the fuel tank. Refer to ***System Descriptions, Section 4.***
Worn or malfunctioning fuel injection pump (injection pump not delivering fuel).	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6.*** The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
Injection pump timing incorrect.	If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed. The timing can only be checked by a local FIE specialist using the appropriate equipment. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
One or more engine injector worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.

Table 2. Engine - Will Not Start or Difficult to Start (Exhaust Smoke)

Cause	Remedy
Starting procedure incorrect.	Verify proper starting procedure. Refer to ***Starting the Engine, Section 1.***
Cold starting aid not working (if fitted).	Check for correct operation of the cold start advance. Refer to ***Test Procedures, Section 6.***
Air intake system blocked or restricted.	Visually check the air intake for blockage or obstruction - remove as required. Check the air filter elements for signs of blocking - replace as required.
Fuel is aerated.	Check the fuel system for loose connections and possible air ingress points. Rectify and bleed the fuel system. Refer to ***Engine Fuel System, Section 3***.
Fuel lift pump not operating correctly (fuel supply inadequate).	Check that the lift pump is operating and delivering fuel to the injection pump. Refer to ***Test Procedures, Section 6.***
Fuel is contaminated or incorrect grade diesel fuel used.	Refer to ***Fuel Systems Data, Section 1*** for recommended diesel fuels. If the fuel is suspect, verify by operating the engine with recommended clean fuel from a temporary tank.
Fuel filter(s) blocked, fuel supply restricted.	Check/replace the fuel filter(s). Refer to ***Engine Fuel System, Section 3***. Check fuel lines for restriction.
Fuel drain return line blocked, not connected properly.	Verify that the fuel return line is not obstructed and connected to the top of the fuel tank. Refer to ***System Descriptions, Section 4***.
Check fuel inlet restriction.	Maximum inlet restriction to fuel transfer pump must not exceed 100 mm Hg (4 in. Hg).
Injection pump timing incorrect.	If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed. The timing can only be checked by a local FIE specialist using the appropriate equipment. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
Inlet and exhaust valve clearances set incorrectly.	Set the valve clearances to the recommended clearances. Refer to ***Valve Clearances, Section 12***.
One or more engine injector worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Engine compression low in one or more cylinders.	Check the engine compression. Refer to ***Engine Compression Check, Section 6***.
Cranking speed too slow.	Refer to ⇨ ***Table 3. Engine - Will Not Crank or Cranks Slowly (5-5)*** for possible low cranking speed faults.
Worn or malfunctioning fuel injection pump (injection pump not delivering fuel).	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6.*** The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.

Table 3. Engine - Will Not Crank or Cranks Slowly

Cause	Remedy
Starting electrical circuit connections loose or corroded.	Clean and tighten connections. Refer to ***Electrical Circuit Checks, Section 6***.
Battery charge low.	Check battery voltage, charge the battery or replace as required. Make sure that the alternator is functioning correctly and charging the battery. Refer to ***Electrical Circuit Checks, Section 6***.
No electrical connection to starter solenoid.	Check voltage to solenoid. Refer to ***Electrical Circuit Checks, Section 6.***
Crankshaft rotation restricted.	Use special tool 892/01147 (crankshaft turning tool) to manual turn the engine and check for any severe rotational resistance.
Solenoid or starter motor fault.	Replace starter motor. Refer to ***Electrical Circuit Checks, Section 6***.
Starter motor operating but not cranking.	Remove the starter motor and check for broken teeth on the ring gear or broken starter motor spring. Refer to ***Starter Motor, Section 10***.

Table 4. Engine - Starts then Stops

Cause	Remedy
No fuel in supply tank.	Check the level in the fuel tank, use sight gauge or dipstick. Replenish as required.
Engine starting under load.	Check for added loading from malfunctioning accessories or driven units, brakes dragging and other changes in vehicle loading. Disengage the hydraulic controls.
Idle speed too low for accessories.	Adjust the idle speed. Refer to the machine's service manual for correct adjustment procedures and idling speed
Air intake or exhaust system blocked.	Visually check the air intake and exhaust system for blockage or obstruction - remove as required. Check the air filter elements for signs of blocking - replace as required.
Fuel is aerated.	Check the fuel system for loose connections and possible air ingress points. Rectify and bleed the fuel system. Refer to ***Engine Fuel System, Section 3***.
Fuel lift pump not operating correctly (fuel supply inadequate).	Check that the lift pump is operating and delivering fuel to the injection pump. Refer to ***Test Procedures, Section 6.***.
Fuel is waxing due to extremely cold weather.	Verify by inspecting the fuel filter. Clean the system and use climatised fuel. Refer to ***Fuel Systems Data, Section 1*** for recommended diesel fuels.
Fuel is contaminated or incorrect grade diesel fuel used.	Refer to ***Fuel Systems Data, Section 1*** for recommended diesel fuels. If the fuel is suspect, verify by operating the engine with recommended clean fuel from a temporary tank.
Fuel filter(s) blocked, fuel supply restricted.	Check/replace the fuel filter(s). Refer to ***Engine Fuel System, Section 3***. Check fuel lines for restriction.
Fuel drain return line blocked, not connected properly.	Verify that the fuel return line is not obstructed and connected to the top of the fuel tank. Refer to ***System Descriptions, Section 4***.

Table 5. Engine - Poor Running

Cause	Remedy
Condition only occurs at idle.	Refer to ⇨ *Table 6. Engine - Poor Running at Idle (5-8)* for possible poor running at idle faults.
Engine is cold, cold starting aid not working.	Check for correct operation of the cold start advance. Refer to ***Test Procedures, Section 6***. If engine will not reach operating temperature, ⇨ *Table 24. Coolant - Under Temperature (5-27)*.
Fuel injection lines leaking.	Inspect and correct as required leaks in the high pressure lines, fittings injector sealing washers, or delivery valves. **WARNING:** Fine jets of fluid at high pressure can penetrate the skin. Keep face and hands well clear of pressurised fluid and wear protective glasses. If fluid penetrates your skin, get medical help immediately.
Fuel is aerated.	Check the fuel system for loose connections and possible air ingress points. Rectify and bleed the fuel system. Refer to ***Engine Fuel System, Section 3***.
Fuel lift pump not operating correctly (fuel supply inadequate).	Check that the lift pump is operating and delivering fuel to the injection pump. Refer to ***Test Procedures, Section 6***.
Fuel filter(s) blocked, fuel supply restricted.	Check/replace the fuel filter(s). Refer to ***Engine Fuel System, Section 3***. Check fuel lines for restriction.
Fuel is contaminated or incorrect grade diesel fuel used.	Refer to ***Fuel Systems Data, Section 1*** for recommended diesel fuels. If the fuel is suspect, verify by operating the engine with recommended clean fuel from a temporary tank.
Inlet and exhaust valve clearances set incorrectly.	Set the valve clearances to the recommended clearances. Refer to***Valve Clearances, Section 12***.
Engine compression low in one or more cylidners.	Check the engine compression. Refer to ***Engine Compression Check, Section 6***.
Injection pump timing incorrect.	If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed. The timing can only be checked by a local FIE specialist using the appropriate equipment.Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
One or more engine injector worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Worn or malfunctioning fuel injection pump (injection pump not delivering fuel).	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6.*** The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
Camshaft or tappets damaged.	Inspect camshaft and tappets. Refer to ***Camshaft and Tappets, Section 12***.

Table 6. Engine - Poor Running at Idle

Cause	Remedy
Engine is cold, cold starting aid not working.	Check for correct operation of the cold start advance. Refer to ***Test Procedures, Section 6***. If engine will not reach operating temperature, ⇨ *Table 24. Coolant - Under Temperature (5-27)*.
Idle speed too low for the accessories.	Adjust the idle speed. Refer to the machine's service manual for correct adjustment procedures and idling speed
Engine mounts over-tightened, damaged or loose.	Verify condition of mounts. Refer to the machine's service manual for correct adjustment procedure.
Fuel injection lines leaking.	Inspect and correct as required leaks in the high pressure lines, fittings injector sealing washers, or delivery valves. **WARNING:** Fine jets of fluid at high pressure can penetrate the skin. Keep face and hands well clear of pressurised fluid and wear protective glasses. If fluid penetrates your skin, get medical help immediately.
Fuel is aerated.	Check the fuel system for loose connections and possible air ingress points. Rectify and bleed the fuel system. Refer to ***Engine Fuel System, Section 3***.
Fuel lift pump not operating correctly (fuel supply inadequate).	Check that the lift pump is operating and delivering fuel to the injection pump. Refer to ***Test Procedures, Section 6.***
Fuel filter(s) blocked, fuel supply restricted.	Check/replace the fuel filter(s). Refer to ***Engine Fuel System, Section 3***. Check fuel lines for restriction.
Fuel is contaminated or incorrect grade diesel fuel used.	Refer to ***Fuel Systems Data, Section 1*** for recommended diesel fuels. If the fuel is suspect, verify by operating the engine with recommended clean fuel from a temporary tank.
Inlet and exhaust valve clearances set incorrectly.	Set the valve clearances to the recommended clearances. Refer to ***Valve Clearances, Section 12.***
Engine compression low in one or more cylinders.	Check the engine compression. Refer to ***Engine Compression Check, Section 6***.
Injection pump timing incorrect.	If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed.
	The timing can only be checked by a local FIE specialist using the appropriate equipment.Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
One or more engine injectors worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Worn or malfunctioning fuel injection pump (injection pump not delivering fuel).	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6.*** The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.

Table 7. Engine - Noise Excessive

Cause	Remedy
Drive belt squeal, insufficient tension or abnormally high loading.	Check the tensioner and inspect the drive belt for loading. deterioration, Make sure water pump, tensioner pulley, fan alternator turn freely. Check for paint/oil or other material on pulleys. Check the tension of accessory drive belts.
Cold start advance not operating correctly.	Check for correct operation of the cold start advance. Refer to ***Test Procedures, Section 6***. If engine will not reach operating temperature, ***⇨ Table 24. Coolant - Under Temperature (5-27)***.
Intake air or exhaust leaks.	***⇨ Table 13. Engine - Exhaust Smoke Excessive (Black Smoke) (5-16)*** and ***⇨ Table 14. Engine - Exhaust Smoke Excessive (White/Blue Smoke) (5-17)***.
Fuel is contaminated or incorrect grade diesel fuel used.	Refer to ***Fuel Systems Data, Section 1*** for recommended diesel fuels. If the fuel is suspect, verify by operating the engine with recommended clean fuel from a temporary tank.
Inlet and exhaust valve clearances set incorrectly.	Set the valve clearances to the recommended clearances. Refer to***Valve Clearances, Section 12***. Make sure the push rods are not bent or the rocker levers are not severely worn.
Turbocharger noise.	Check turbocharger impeller and turbine wheel for housing contact.
Inlet and exhaust valve springs broken.	Check and fit new valve springs, Refer to ***Valves, Valve and Springs and Stem Seals, Section 12***.
Worn crank/connecting rod bearings (knocking under load).	Check/replace rod and main bearings. Refer to ***Crankshaft, Section 12***.
Excessive camshaft bearing wear.	Check bearings (engine overhaul required), refer to ***Section 12***.
Worn or damaged pistons and/or piston rings.	Check piston assemblies (engine overhaul required), refer to ***Section 12***.
One or more engine injectors worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Gear train noise.	Visually inspect and measure gear backlash. Replace gears as required.

Table 8. Engine - Compression Knocks

Cause	Remedy
Fuel is aerated.	Check the fuel system for loose connections and possible air ingress points. Rectify and bleed the fuel system. Refer to ***Engine Fuel System, Section 3***.
Fuel is contaminated or incorrect grade diesel fuel used.	Refer to ***Fuel Systems Data, Section 1*** for recommended diesel fuels. If the fuel is suspect, verify by operating the engine with recommended clean fuel from a temporary tank.
Injection pump timing incorrect.	If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed. The timing can only be checked by a local FIE specialist using the appropriate equipment. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
Inlet and exhaust valve springs broken.	Check and fit new valve springs, Refer to ***Valves, Valve Springs and stem Seals, Section 12.***
One or more engine injector worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Coolant operating temperature incorrect.	⇨ ***Table 23. Coolant - Over Temperature (5-26)*** and ⇨ ***Table 24. Coolant - Under Temperature (5-27)***.

Table 9. Engine - Reduced Power Output

Cause	Remedy
No fuel in supply tank.	Check the level in the fuel tank, use sight gauge or dipstick. Replenish as required.
Oil level incorrect.	Check oil level, refer to ***Engine Oil, Section 3.***.
Engine overload.	Check for added loading from malfunctioning accessories or driven units, brakes dragging and other changes in vehicle loading. Disengage the hydraulic controls.
Throttle adjustment incorrectly set of binding.	Check the engine maximum rpm setting is as specified in the machine's service manual. Check the throttle linkage and cable for binding etc.
Fuel is contaminated or incorrect grade diesel fuel used.	Refer to ***Fuel Systems Data, Section 1*** for recommended diesel fuels. If the fuel is suspect, verify by operating the engine with recommended clean fuel from a temporary tank.
Turbocharger boost control pipe leaking or damaged, or wastegate diaphragm ruptured (Turbocharged machines only)	Check boost control pressure, refer to ***Test Procedures, Section 6***. Inspect and tighten fittings, repair pipes, replace wastegate assembly.
Fuel injection lines leaking.	Inspect and correct as required leaks in the high pressure lines, fittings injector sealing washers, or delivery valves. **WARNING:** Fine jets of fluid at high pressure can penetrate the skin. Keep face and hands well clear of pressurised fluid and wear protective glasses. If fluid penetrates your skin, get medical help immediately.
Fuel filter(s) blocked, fuel supply restricted.	Check/replace the fuel filter(s). Refer to ***Engine Fuel System, Section 3***. Check fuel lines for restriction.
Fuel is aerated.	Check the fuel system for loose connections and possible air ingress points. Rectify and bleed the fuel system. Refer to ***Engine Fuel System, Section 3***.
Fuel lift pump not operating correctly (fuel supply inadequate).	Check that the lift pump is operating and delivering fuel to the injection pump. Refer to ***Test Procedures, Section 6.***
Air intake or exhaust system blocked.	Visually check the air intake and exhaust system for blockage or obstruction - remove as required. Check the air filter elements for signs of blocking - replace as required.
One or more engine injectors worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Worn or malfunctioning fuel injection pump (injection pump not delivering fuel).	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6***. The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
Exhaust leak at the manifold or turbocharger (if applicable).	Check/correct leaks in the manifold or turbocharger gaskets. Look for a cracked manifold.
Extra injector sealing washer installed under injector.	Remove extra injector sealing washer.

Cause	Remedy
Inlet and exhaust valve clearances set incorrectly.	Set the valve clearances to the recommended clearances. Refer to ***Valve Clearances, Section 12***.
Injection pump timing incorrect.	If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed.
	The timing can only be checked by a local FIE specialist using the appropriate equipment. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
Engine compression low in one or more cylinders.	Check the engine compression. Refer to ***Engine Compression Check, Section 6***.

Table 10. Engine - Will Not Reach Maximum RPM

Cause	Remedy
Tachometer faulty.	Verify engine speed with hand tachometer. Correct as required.
Engine overloaded.	Verify high idle speed without load. Investigate operation to be sure correct gear is being used.
Throttle adjustment incorrectly set or binding.	Check the engine maximum rpm setting is as specified in the machine's service manual. Check the throttle linkage and cable for binding etc.
Fuel is aerated.	Check the fuel system for loose connections and possible air ingress points. Rectify and bleed the fuel system. Refer to ***Engine Fuel System, Section 3***.
Fuel lift pump not operating correctly (fuel supply inadequated).	Check that the lift pump is operating and delivering fuel to the injection pump. Refer to ***Test Procedures, Section 6***.
Fuel is contaminated or incorrect grade diesel fuel used.	Refer to ***Fuel Systems Data, Section 1*** for recommended diesel fuels. If the fuel is suspect, verify by operating the engine with recommended clean fuel from a temporary tank.
Fuel filter(s) blocked, fuel supply restricted.	Check/replace the fuel filter(s). Refer to ***Engine Fuel System, Section 3***. Check fuel lines for restriction.
(Turbocharged machines only) Turbocharger wastegate actuator diaphragm ruptured.	Repair of replace turbocharger.
One or more engine injectors worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Worn or malfunctioning fuel injection pump (injection pump not delivering fuel).	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6.*** The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.

Table 11. Engine - RPM Surges

Cause	Remedy
Fuel level low.	Check/fill fuel tank.
If the condition occurs at idle, the idle speed set too low for accessories.	Check the engine idle rpm setting is as specified in the machine's service manual.
Throttle adjsutment incorrectly set or binding.	Check the engine maximum rpm setting is as specified in the machine's service manual. Check the throttle linkage and cable for binding etc.
Fuel injection lines leaking.	Inspect and correct as required leaks in the high pressure lines, fittings injector sealing washers, or delivery valves.
	WARNING: Fine jets of fluid at high pressure can penetrate the skin. Keep face and hands well clear of pressurised fluid and wear protective glasses. If fluid penetrates your skin, get medical help immediately.
Fuel tank cap vent/breather blocked.	Inspect and rectify as required - replace cap if necessary.
Fuel is aerated.	Check the fuel system for loose connections and possible air ingress points. Rectify and bleed the fuel system. Refer to ***Engine Fuel System, Section 3***.
One or more engine injector worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Worn or malfunctioning fuel injection pump (injection pump not delivering fuel).	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6.*** The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.

Table 12. Engine - Vibration Excessive

Cause	Remedy
Engine not running smoothly/misfiring.	⇨ ***Table 6. Engine - Poor Running at Idle (5-8)***.
Oil level over-full.	Check oil level, refer to ***Engine Oil, Section 3***.
If the condition occurs at idle, the idle speed set too low for accessories.	Check the engine idle rpm setting is as specified in the machine's service manual.
Fan damaged or accessories faulty.	Check/replace the vibrating component. Refer to the machine's service manual for correct installation and torque figures.
Fan hub faulty.	Inspect/replace the fan hub. Refer to the machine's service manual for correct installation and torque figures.
Engine mounts loose or broken.	Check/replace engine mounts. Refer to the machine's service manual for correct installation and torque figures.
Inlet and exhaust valve clearances set incorrectly.	Set the valve clearances to the recommended clearances. Refer to ***Valve Clearances, Section 12.***.
Engine compression low in one or more cylinders.	Check the engine compression. Refer to ***Engine Compression Check, Section 6***.
Alternator bearing worn or damaged.	Check/replace the alternator. Refer to ***Alternator, Section 10***.
Flywheel housing misaligned.	Check/correct flywheel alignment. Refer to ***Flywheel Housing, Section 12***.
Injection pump timing incorrect.	If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed. The timing can only be checked by a local FIE specialist using the appropriate equipment. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
Drive line components worn or unbalanced.	Check and inspect drive line components such as propshafts. Refer to the machine's service manual for correct installation and torque figures.

Table 13. Engine - Exhaust Smoke Excessive (Black Smoke)

Cause	Remedy
Engine being lugged down.	Use appropriate gear for task.
Air intake or exhaust system blocked.	Visually check the air intake and exhaust system for blockage or obstruction - remove as required. Check the air filter elements for signs of blocking - replace as required.
Air leak between the turbocharger and the intake manifold (Turbocharged machines only).	Check/correct leaks in the air crossover tube, hoses, or manifold cover. Refer to ***Section 11***.
Intercooler faulty.	Check for blocked cooler matrix.
Exhaust leak at the Manifold or Turbocharger (Turbocharged machines only).	Check/correct leaks in the manifold or turbocharger gaskets. Look for a cracked manifold.
Turbocharger wastegate faulty.	Repair or replace wastegate. Refer to ***Turbocharger, Section 11***.
Turbocharger malfunction.	Replace Turbocharger. Refer to ***Turbocharger, Section 11***.
One or more engine injector worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Worn or malfunctioning fuel injection pump (injection pump not delivering fuel).	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6.*** The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
Injection pump timing incorrect. Retarded if smokes under load and engine quieter than normal.	If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed.
Injection pump timing incorrect. Advanced if smokes under load and engine noisier than usual.	The timing can only be checked by a local FIE specialist using the appropriate equipment. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
Engine compression low in one or more cylinders. Smokes under load at all speeds, but mainly low to mid speed range.	Check the engine compression. Refer to ***Engine Compression Check, Section 6.***

Table 14. Engine - Exhaust Smoke Excessive (White/Blue Smoke)

Cause	Remedy
Improper starting procedure.	Verify proper starting procedure. Refer to ***Starting the Engine, Section 1.***
Fuel is contaminated or incorrect grade diesel fuel used.	Refer to ***Fuel Systems Data, Section 1*** for recommended diesel fuels. If the fuel is suspect, verify by operating the engine with recommended clean fuel from a temporary tank.
Oil level incorrect.	Check oil level, refer to ***Engine Oil, Section 3.***
Diesel or hydraulic oil in sump.	Check oil consistency. If oil contamination is suspected check equipment such as PTO pump for hydraulic oil leaks pass the seal into the engine. Drain, flush and fill with clean oil.
Coolant temperature too low (over-cooling) - light blue or white high speed/light load.	⇨ ***Table 24. Coolant - Under Temperature (5-27)***.
Injection pump timing incorrect. Retarded if smokes under light load at high speed. Note that this is a normal function of the cold start advance.	If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed.
	The timing can only be checked by a local FIE specialist using the appropriate equipment. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
One or more engine injector worn or malfunctioning. - white/ blue smoke at operating temperature.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Coolant leaking into combustion chamber.	⇨ ***Table 22. Coolant - Loss (5-25)***.
Leaking valve stem seals - evident after long idle period and then acceleration.	Replace valve seals, refer to ***Valves, Valve Springs and Stem Seals, Section 12.***
Worn or malfunctioning fuel injection pump (injection pump not delivering fuel).	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6.*** The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
Piston rings not sealing - evident with persistent blue smoke at all speeds/load.	Check the engine compression. Refer to ***Engine Compression Check, Section 6.***

Table 15. Engine - Will Not Shut Off

Cause	Remedy
Electrical fuel shut-off solenoid (ESOS) valve not functioning properly.	Check for correct operation of the electric shut-off solenoid (ESOS). Refer to ***Test Procedures, Section 6.***
Worn or malfunctioning fuel injection pump.	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6.*** The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.

B Charts - Fuel

Table 16. Fuel - Consumption Excessive

Cause	Remedy
Additonal load on engine.	Check/repair accessories and vehicle components. Refer to the equipment manufacturer's procedures.
Operator technique.	Review operation for correct gear shifts, deceleration and idling.
Fuel leaks.	Check for external leaks and engine lubricating oil dilution. For fuel dilution, check for internal leaks at the fuel transfer pump and injection pump. Inspect and correct as required leaks in the high pressure lines, fittings injector sealing washers, or delivery valves. **WARNING:** Fine jets of fluid at high pressure can penetrate the skin. Keep face and hands well clear of pressurised fluid and wear protective glasses. If fluid penetrates your skin, get medical help immediately.
Fuel is contaminated or incorrect grade diesel fuel used.	Refer to ***Fuel Systems Data, Section 1*** for recommended diesel fuels. If the fuel is suspect, verify by operating the engine with recommended clean fuel from a temporary tank.
Intake air or exhaust leaks.	⇨ ***Table 13. Engine - Exhaust Smoke Excessive (Black Smoke) (5-16)*** and ⇨ ***Table 14. Engine - Exhaust Smoke Excessive (White/Blue Smoke) (5-17)***.
Engine compression low in one or more cylinders.	Check the engine compression. Refer to ***Engine Compression Check, Section 6***.
Injection pump timing incorrect.	If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed. The timing can only be checked by a local FIE specialist using the appropriate equipment.Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
One or more engine injector worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Worn or malfunctioning fuel injection pump (injection pump not delivering fuel).	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6.***
	The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.
Inlet and exhaust valve clearances set incorrectly.	Set the valve clearances to the recommended clearances. Refer to ***Valve Clearances, Section 12.***

Table 17. Fuel/Oil - Leaking from Exhaust Manifold

Cause	Remedy
Operating for extended periods under light or no load conditions.	Review operation for correct gear shifts, deceleration and idling.
Intake air or exhaust leaks.	⇨ ***Table 13. Engine - Exhaust Smoke Excessive (Black Smoke) (5-16)*** and ⇨ ***Table 14. Engine - Exhaust Smoke Excessive (White/Blue Smoke) (5-17)***.
Turbocharger lubricating oil drain line obstructed.	Check/clean line.
Exhaust leak at the Manifold or Turbocharger (turbocharged machines only).	Check/correct leaks in the manifold or turbocharger gaskets. Look for a cracked manifold.
Valve guide seals are leaking.	Replace valve guide stem seals as required. Use the special tool in ***Service Tools, Section 1*** to ensure the seals are fitted correctly.
One or more engine injector worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Injection pump timing incorrect.	If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed. The timing can only be checked by a local FIE specialist using the appropriate equipment. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.

C Charts - Lubricating Oil

Table 18. Lubricating Oil - Consumption Excessive

Cause	Remedy
Oil leaks.	Inspect the engine for visible signs of leaks. Pay particular attentions to seals, gaskets oil cooler and external connections.
Oil level over-full.	Check oil level, refer to ***Engine Oil, Section 3.***
Incorrect lubricating oil (specification of viscosity).	Make sure the correct lubricating oil is being used. Refer to ***Lubricants and Capacities, Section 1.*** Look for reduced viscosity from dilution with fuel. Fuel dilution in lubricating oil can originate from fuel injection pump driveshaft seal or fuel transfer pump. Review/reduce the lubricating oil change intervals.
Excessive leaking out of the breather tube (system blocked). (turbocharged machines only).	Check the breather tube area for signs of lubricating oil loss. If necessary, replace the breather gauze, refer to ***Engine Breather, Section 3.***
Lubricating oil cooler leak.	Check for lubricating oil in the coolant. Refer to ***Lubricating Oil Cooler, Section 8.***
Turbocharger leaking lubricating oil to the air intake or exhaust (if fitted).	Inspect the air crossover tube for evidence of lubricating oil transfer.
Valve guide seals are leaking.	Replace valve guide stem seals as required. Use the special tool in ***Service Tools, Section 1*** to ensure the seals are fitted correctly.
Piston rings not sealing - lubricating oil being consumed by the engine (blue smoke from exhaust).	Check the engine compression. Refer to ***Engine Compression Check, Section 6.***
Worn cylinder bores - lubricating oil being consumed by the engine (blue smoke from exhaust).	Check the engine compression. Refer to ***Engine compression Check, Section 6.***
Glazed cylinder bores.	De-glaze bores as required.

Table 19. Lubricating Oil - Contaminated

Cause	Remedy
Coolant in the lubricating oil, internal engine component leaks.	⇨ *Table 22. Coolant - Loss (5-25)*.
Lubricating oil sludge excessive.	Change oil and filter. Refer to ***Engine Oil and Filter, Section 3.*** Review oil and filter change period. If operating in arduous applications, change more frequently. Refer to ***Maintenance Procedures, Section 3***, for a definition of `arduous applications'. Make sure the correct lubricating oil is being used, refer to ***Lubricants and Capacities, Section 1***.
Fuel in the lubricating oil, engine operating too cold.	Review the operation for excessive idling resulting in the engine running below normal temperature.
Fuel lift pump leaking.	Repair or replace fuel lift pump. Refer to ***Fuel Lift Pump, Section 7***.
One or more engine injector worn or malfunctioning.	Check and externally clean the injector. If the problem still persists, the injector must be checked by a local FIE specialist, or they can be replaced with new.
Worn or malfunctioning fuel injection pump (injection pump not delivering fuel).	Check for operation of the fuel injection pump, refer to ***Test Procedures, Section 6.***
Internal bearing or component damage.	The fuel injection pump must be take to a local FIE specialist to have the fuel delivery timing checked. Ensure that all obvious causes have been eliminated before removing the injection pump. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures. Have oil sample analysed. Repair engine as required.

Table 20. Lubricating Oil - Pressure Low

Cause	Remedy
Oil level incorrect.	Check oil level, refer to ***Engine Oil, Section 3***.
Incorrect lubricating oil (specification of viscosity).	Make sure the correct lubricating oil is being used. Refer to ***Lubricants and Capacities, Section 1***. Look for reduced viscosity from dilution with fuel. Fuel dilution in lubricating oil can originate from fuel injection pump driveshaft seal or fuel transfer pump. Review oil and filter change period. If operating in arduous applications, change more frequently. Refer to ***Maintenance Procedures, Section 3***, for a definition of \`arduous applications'.
Pressure switch or gauge fault.	Verify the pressure switch is functioning correctly. Refer to ***Test Procedures, Section 6***.
Lubricating oil filter blocked.	Change lubricating oil filter, refer to ***Engine Oil and Filter, Section 3***. Review oil and filter change period. If operating in arduous applications, change more frequently. Refer to ***Maintenance Procedures, Section 3***, for a definition of \`arduous applications'.
Lubricating oil filter drain down valve not fitted (refer to ***System Description, Section 4).***	Change lubricating oil filter, refer to ***Engine Oil and Filter, Section 3.***
Suction pump pressure relief valve stuck open.	Check/replace seal. Refer to ***Oil Pan (Sump), Section 9.***
Oil pump pressure relief valve stuck open.	Replace oil pump assembly. Refer to ***Oil Pump, Section 9.***
Lubricating oil pump worn.	Replace oil pump assembly. Refer to ***Oil Pump, Section 9.***

Table 21. Lubricating Oil - Pressure High

Cause	Remedy
Incorrect lubricating oil (specification of viscosity).	Make sure the correct lubricating oil is being used. Refer to ***Lubricants and Capacities, Section 1***. Review oil and filter change period. If operating in arduous applications, change more frequently. Refer to ***Maintenance Procedures, Section 3***, for a definition of `arduous applications'.
Pressure switch or gauge fault.	Verify the pressure switch is functioning correctly. Refer to ***Test Procedures, Section 6***.
Engine running too cold.	⇨ ***Table 24. Coolant - Under Temperature (5-27)***.
Oil pump pressure relief valve stuck closed.	Replace oil pump assembly. Refer to ***Oil Pump, Section 9.***

D Charts - Coolant

Table 22. Coolant - Loss

Cause	Remedy
Incorrect coolant level.	Check the level, refer to ***Engine Cooling System, Section 3***.
Coolant leaking from engine radiator or cab heater.	Visually inspect the radiator heater, hoses and connection to locate the leak. If oil is present in the coolant, check for a transmission or engine oil cooler leak
External engine coolant leak.	Visually inspect the engine and components for seal, gasket hose connection leaks. Make sure all hose clips are in good condition and torqued to the recommended figure.
Overheating or compression gases leaking, resulting in loss through the radiator overflow.	⇨ ***Table 23. Coolant - Over Temperature (5-26)***.
If equipped, transmission cooler leak.	Check for mixing of coolant and transmission fluid.
If the engine is coolant aftercooled, aftercooler leak.	Check/replace the aftercooler. Look for coolant in the intake manifold and in the oil.
Lubricating oil cooler leak.	Check/replace the oil cooler. Look for coolant in the oil.
Cylinder head gasket leak.	Check/replace the head gasket. Refer to ***Cylinder Head, Section 12***.
Cylinder head cracked or porous.	Check/replace the head. Refer to ***Cylinder Head, Section 12.***
Cylinder block coolant passages leaking.	Check/replace the cylinder block.

Table 23. Coolant - Over Temperature

Cause	Remedy
Incorrect coolant level (low).	Check the level, refer to ***Engine Cooling System, Section 3***. Ensure low level is not as a result of a coolant leak, ⇨ ***Table 22. Coolant - Loss (5-25)***.
External radiator matrix blocked with dirt or chaff.	Clean exterior or radiator matrix.
Air flow to the radiator inadequate or restricted.	Check/repair fan shroud, anti-recirculation sealing, shutters, fan sensors, fan speeds as required. Refer to the machine manufacturer's documentation for detailed information.
Coolant pump or fan drive belts loose.	Check/correct belt tension.
Radiator hose collapsed, restricted or leaking.	Check/replace hose.
Oil level over-full.	Check oil level, refer to ***Engine Oil, Section 3***.
Cooling system pressure cap incorrect or faulty.	Replace cap with the correct rating for the system.
Over concentration of anti-freeze.	Remove part of the coolant from cooling system and replace with water. Refer to ***Coolant Mixtures, Section 3***.
Temperature sensor gauge faulty.	Verify that the gauge and temperature sensor are accurate. Refer to ***Test Procedures, Section 6***.
Thermostat faulty, incorrect or missing.	Check/replace the thermostat. Refer to ***Thermostat, Section 8***.
Air or combustion gases in the cooling system.	Make sure the fill rate is not exceeded and the correct vented thermostat is installed. If aeration continued, check for a compression leak through the head gasket.
Coolant pump faulty.	Check/replace the coolant pump. Refer to ***Coolant Pump, Section 8.***
Vent line from engine and/or radiator blocked or incorrectly routed (sudden overheating).	Check routing and operation or vent line.
Leak between the top tank and the auxiliary tank (sudden overheating).	Check for coolant leakage between radiator auxiliary tank and radiator top tank.
Cooling passages in radiator, cylinder head, head gasket or block blocked.	Flush the system and fill with clean coolant.
Fuel injection pump timing incorrect.	Injection pump timing incorrect.If the pump has recently been removed and replaced, the timing could be incorrect if the correct removal procedures were not followed. The timing can only be checked by a local FIE specialist using the appropriate equipment. Refer to ***Fuel Injection Pump, Section 7*** for removal and replacement procedures.

Table 24. Coolant - Under Temperature

Cause	Remedy
Air flow across the radiator excessive.	Check/repair fan shroud, anti-recirculation sealing, shutters, fan sensors, fan speeds as required. Refer to the machine manufacturer's documentation for detailed information.
Temperature sensor gauge faulty.	Verify that the gauge and temperature sensor are accurate. Refer to ***Test Procedures, Section 6***.
Thermostat faulty, (open - not sealing).	Check/replace the thermostat. Refer to ***Thermostat, Section 8.***
Coolant not flowing by temperature sensor(1)	Check/clean coolant passages.

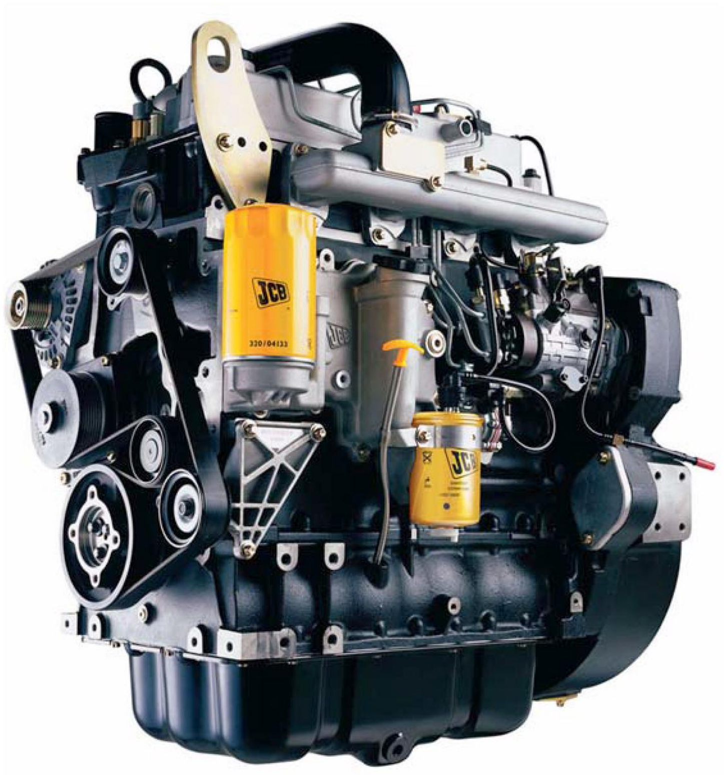
(1) *A total coolant loss may result in the gauge showing low temperature initially. In which case, check the level, refer to Engine Cooling System, Section 3.*

Table 25. Coolant - Contaminated

Cause	Remedy
Coolant rusty, operation without correct mixture of antifreeze and water.	Drain and flush the cooling system. Fill with correct mixture of antifreeze and water. Review the coolant change interval. Refer to the Operation and Maintenance Manual.
Engine oil cooler, or cooler housing allowing cross contamination of coolant with engine oil.	Remove the oil cooler assembly and check relevant sealing elements for damage. See ***Lubricating Oil Cooler and Filter Head, Section 9***.
Transmission lubricating oil cooler leaking (if applicable).	Check/replace lubricating oil cooler. Refer to equipment manufacturer's procedures.
Lubricating oil leaks from lubricating oil cooler, head gasket, head and cylinder block.	⇨ ***Table 22. Coolant - Loss (5-25)***.

Test Procedures

Service Manual - JCB 444 Engine



Publication No.
9806/3000-02

World Class
Customer Support

Issued by JCB Technical Publications, JCB Aftermarket Training, Woodseat, Rocester, Staffordshire, ST14 5BW, England. Tel +44 1889 591300 Fax +44 1889 591400

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Introduction

Test Procedures Introduction

When completing any tests on equipment, the appropriate safety precautions must be adhered to.

Refer to ***Care & Safety, Section 2***, for a reminder of safe practices and potential hazards.

Use appropriate testing equipment. Always use genuine parts and equipment.

A list of the recommended service tools is given in Section 1, use the tools when specified. For instance, there is a crankshaft turning tool specifically designed to enable the engineer to turn the engine by hand (say to set top dead centre (TDC)).

Safety must always come first, if you are unsure about any of the procedures, ask someone who knows.

If the engine must be running during the test, make sure there is adequate ventilation. If the machine is inside, then exhaust extraction equipment should be used.

Testing

Lift Pump Operation

➩ Fig 1. (6-3)

The lift pump is a diaphragm type driven from the engine camshaft The pump draws fuel from the tank, through the water trap, pumping it through the filter and into the fuel injection pump.

The pump incorporates a manually operated priming lever to aid fuel priming after maintenance.

Refer to ***Section 4, Fuel System Descriptions*** for a more detailed description of operation.

Pressure Test Procedures

If the fuel lift pump is suspect, then measure the output pressure between the fuel filter and the injection pump inlet.

1 Park and make the machine safe in accordance with the machine handbook instructions.

2 Fit a suitable pressure gauge in the low pressure fuel line **1-A** (the fuel filter to injection pump inlet).

3 Start the engine and increase the speed to the 2200rpm.

4 Note the gauge reading which should be as detailed in ***Section 1, Technical Data.***

5 If the volume of fuel is not being delivered, measure the lift pump inlet restriction.

Measuring the Inlet Restriction

1 Park and make the machine safe in accordance with the machine handbook instructions.

2 Fit a suitable vacuum gauge in the low pressure fuel line **1-B** (from pre-filter to lift pump inlet).

3 Start the engine and increase the speed to the 2200rpm.

4 Note the gauge reading which should be as detailed in ***Section 1, Technical Data***.

Note: *As the fuel filter becomes more blocked, the pressure drop from inlet to outlet will increase. If changing the fuel filter improves engine power performance, check if the lift pump is worn (a worn lift pump will not be able to force fuel through a partially blocked filter as easily as a clean filter).*

5 If the volume is low, repeat the same test but from a temporary clean fuel supply into the lift pump inlet.

6 If using the temporary clean fuel supply solves the problem, check for leaks, bad connection, kinks or severe bends etc between the tank and the lift pump inlet.

In cold weather check if waxing has occurred in the fuel lines. Clean the fuel lines as required.

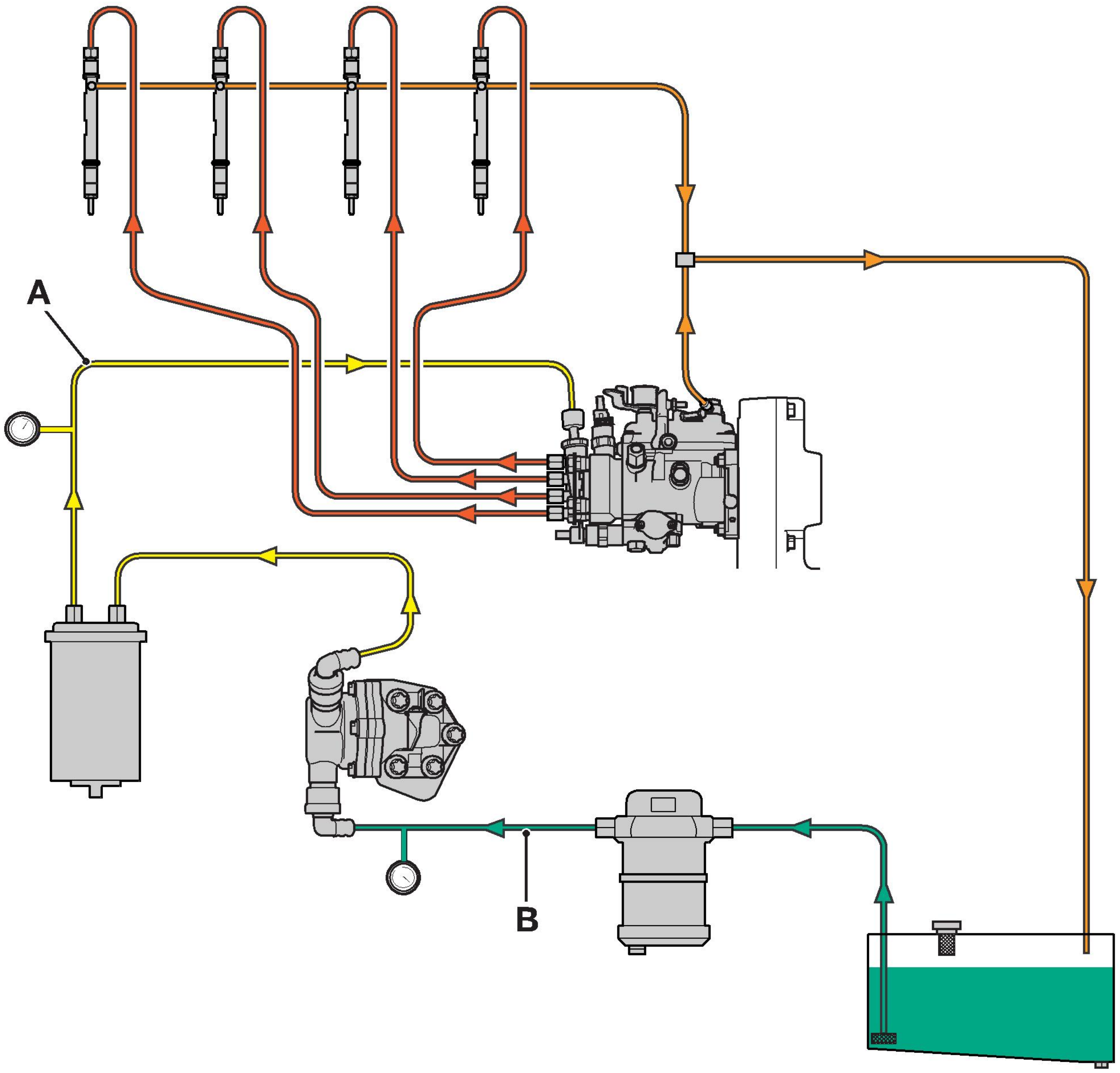

Fig 1.

Fuel Injection Pump Delivery

Use the procedure described to check that high pressure fuel is being delivered to the fuel injectors.

Do not complete the procedure on a hot engine, fuel spilled onto a hot exhaust could create a risk of fire.

WARNING

Diesel Fuel

Diesel fuel is flammable; keep naked flames away from the fuel system. Do not smoke while refuelling or working on the fuel system. Do not refuel with the engine running. There could be a fire and injury if you do not follow these precautions.

INT-3-2-2_1

WARNING

Fine jets of fluid at high pressure can penetrate the skin. Keep face and hands well clear of pressurised fluid and wear protective glasses. If fluid penetrates your skin, get medical help immediately.

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WARNING

Hot oil and engine components can burn you. Make sure the engine is cool before doing this job. Bleeding a hot engine could cause fuel to spill on to a hot exhaust manifold creating a danger of fire.

13-3-1-16

1 Park and make the machine safe in accordance with the machine handbook instructions.

2 With the engine switched off, loosen the 4 x injector union pipe fittings as shown at **2-A** (see Note).

Note: *It is not necessary to completely remove the fitting, simply release the holding torque and leave the fitting loose but not completely removed.*

3 Crank the engine and check for air free fuel from the loosened fittings.

4 Torque tighten the fittings to 25 - 26 Nm (16 - 19 lbf ft).

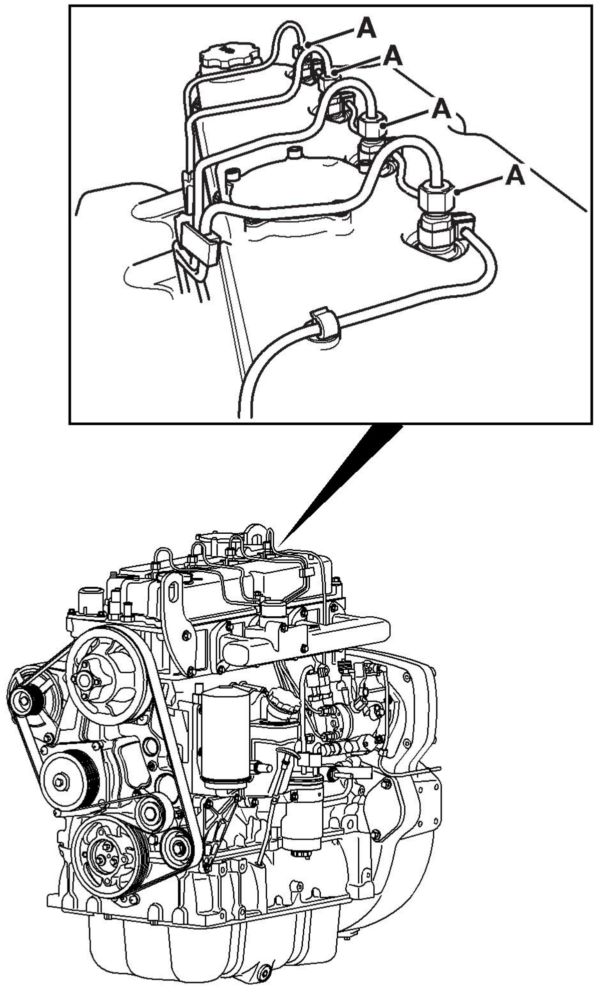


Fig 2.

Engine Compression

⇨ Fig 3. (6-6)

The following procedures describe how to check the engine compression using a `dummy injector', refer to ***Section 1, Special Tools*** for the dummy injector part number.

Several factors can influence the compression pressure, the following conditions are assumed:

– The valve clearances have been set correctly, refer to ***Section 12, Valve Clearances Adjustment*** for the correct procedure.
– The correct engine oil lubrication oil has been used, refer to ***Section 1, Lubricants and Capacities***.
– The engine oil level is correct, refer to ***Section 3, Checking the Oil Level***.
– The correct type of diesel fuel has been used and the system correctly primed, refer to ***Section 1, Fuel System Technical Data***.
– The battery and starting circuit is fully charged and in good condition, e.g. good earth paths, cable connections tight etc.

The compression tests should not be the only method used to check the condition of the engine, check other symptoms and complete additional tests were applicable.

When comparing the figures recorded in the following procedures, there should be a minimum variation of 3.5 bar (50 lb/in2) between each cylinder. If the variation is greater than this figure, then remove the cylinder head, refer to ***Section 12*** and closely inspect the cylinder bores, pistons and piston rings for signs of wear or damage. Repair as necessary.

1 Park and make the machine safe in accordance with the machine handbook instructions.

2 Remove all four fuel injectors, refer to ***Section 7, Fuel Injectors (Atomisers)***. Make sure the injectors are labelled for correct refitting at a later stage.

3 Install the `dummy injector' item **3-A** in one of the vacant cylinder injector bores.

4 Fit a suitable pressure test gauge into the dummy injector fitting (see Note).

Note: *The dummy injector is drilled and tapped 1/8-28 BSP x8.00mm deep to accept a standard pressure gauge fitting.*

5 Ensure the engine will not start by removing the electric shut off solenoid (ESOS) fuse - refer to the machine handbook for fuse location and identification.

⚠ WARNING

When the engine is turning, there are parts rotating in the engine compartment.

Before starting this job make sure that you have no loose clothing (cuffs, ties etc) which could get caught in rotating parts.

When the engine is turning, keep clear of rotating parts

2-3-3-10

6 Operate the starter motor to crank the engine, do not crank for longer than 20 seconds. Record the gauge reading.

7 Repeat steps 3 to 6 for the remaining three cylinders.

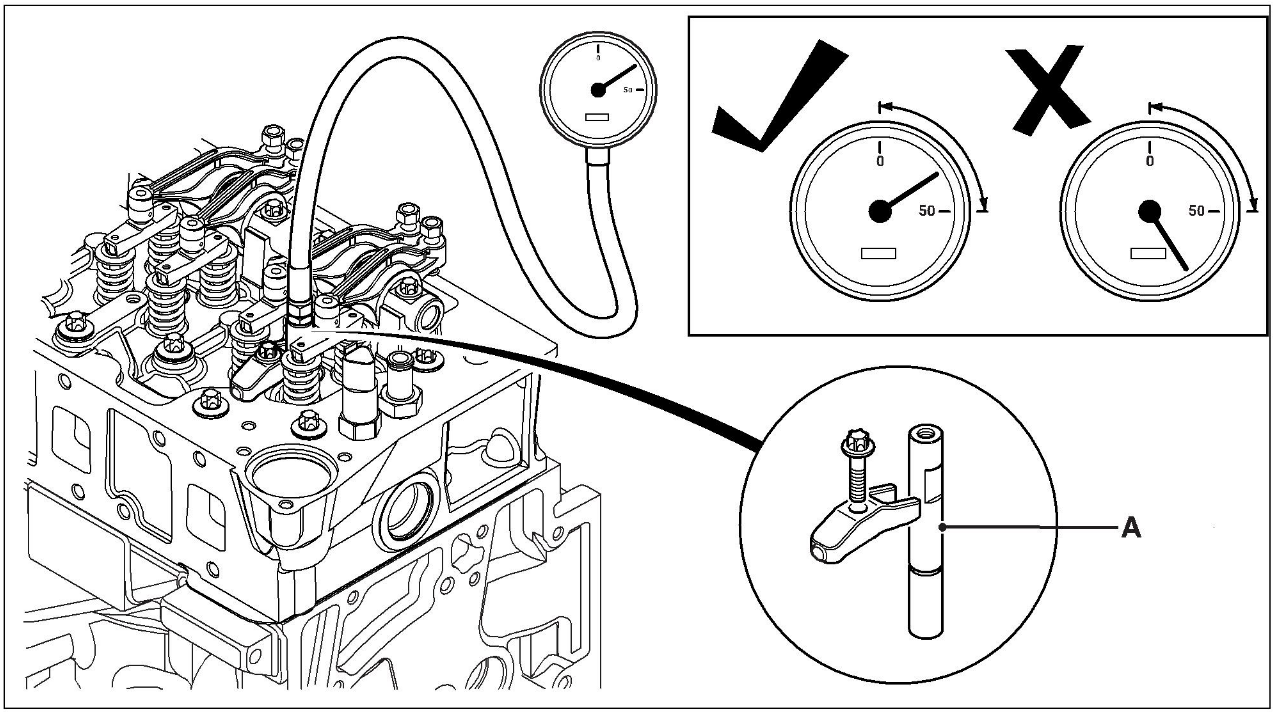


Fig 3.

Engine Oil Pressure

Use the following procedures to measure the oil pressure. Refer to ***Section 4, System Descriptions*** for a full explanation of the lubricating oil circuit.

Several factors can influence the engine oil pressure, the following conditions are assumed:

– The correct engine oil has been used, refer to ***Section 1, Lubricants and Capacities.***

– The engine oil level is correct, refer to ***Section 3, Checking the Oil Level.***

1 Park and make the machine safe in accordance with the machine handbook instructions.

2 Disconnect the electrical connector to oil pressure switch **4-A**, and remove the switch from the cooler housing.

3 Fit a suitable test gauge into the vacant pressure switch port (M10x1.5 thread). Make sure the gauge has a sealing washer as shown at **4-B**.

4 Start the engine, increase the engine revs to the rated speed. Record the pressure gauge reading - refer to ***Section 1, Technical Data***, for the recommended circuit pressure.

5 Remove the pressure gauge and refit the pressure switch.

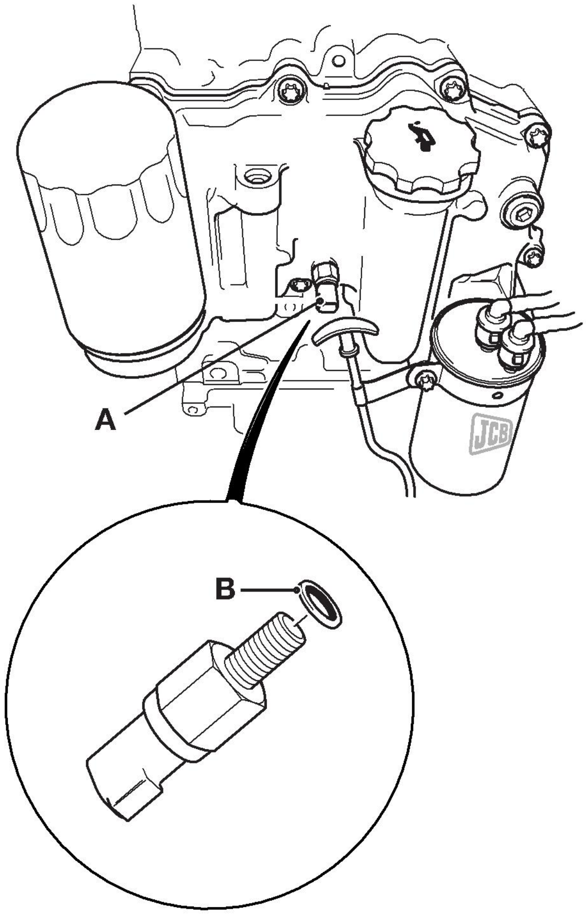


Fig 4.

High Lubrication Oil Pressure

High oil pressure will be evident when starting in cold conditions. Typically the pressure will be 1 to 2bar (15 to 30lb/in2) higher in cold operation, the pressure should drop when the engine reaches normal operating temperature.

If the pressure remains high when operating temperature is achieved, check the oil level, if this is correct, suspect the oil pump relief valve is at fault.

Low Lubrication Oil Pressure

Several factors can be the cause of low lubricating oil pressure:

– **low oil level** - typically evident as a loss of pressure when operating on uneven ground or on a gradient.
– **blocked oil filter** - a blocked filter will show as a gradual loss of pressure.
– **blocked suction strainer (pick-up pipe)** - typically evident as low pressure on start up, if the blockage frees itself in the sump, the pressure will pick up to normal.
– **coolant in the oil** - coolant in the lubricating oil will show as a `milky' discolouration of the oil. and an increase in oil level. Check for damaged core plugs, lubricating oil cooler, cylinder head and/or gasket.
– **fuel in the oil** - fuel in the oil will result in `thin' black lubricating oil, the oil will also have a diesel fuel smell. Check the FIP shaft seal, piston ring wear, lift pump diaphragm damage or injector leakage if fuel is evident in the oil.

Thermostat

⇒ *Fig 5. (6-10)*

A single thermostat **5-B** is used in the JCB 444 Engine. The thermostat is of the wax element type. Refer to S***ection 4, Cooling System Description*** for a detailed description of operation.

The thermostat is not repairable, if the unit is faulty, then a complete new item must be fitted.

WARNING

The cooling system is pressurised when the coolant is hot. When you remove the cap, hot coolant can spray out and burn you. Make sure that the engine is cool before you work on the cooling system.

9-3-3-1_2

1 Park and make the machine safe in accordance with the machine handbook instructions.

2 Remove the thermostat housing **5-A** and the thermostat **5-B** - refer to ***Section 8, Cooling System*** for the correct removal and replacement procedures.

3 Suspend the thermostat in a suitable container of coolant. Using an external heat source, gradually increase the temperature of the coolant.

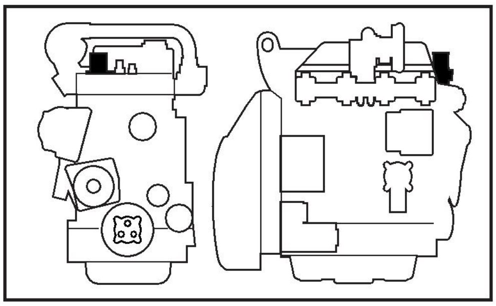
Note: *When working with boiling water, all the necessary safety precautions must be taken.*

4 Using a thermometer, measure the temperature of the coolant.

5 When the coolant reaches the operating range of the thermostat the valve should start to open - movement of valve plate **5-C** should be evident.

6 Record the starts to open temperature, the fully open temperature and the amount of valve lift when fully open. Compare this with the data in ***Section 1, Cooling System Technical Data.***

Note: *A period of 3 to 5 minutes before the thermostat valve starts to operate is normal because of the time required to `heat soak' the thermostat.*



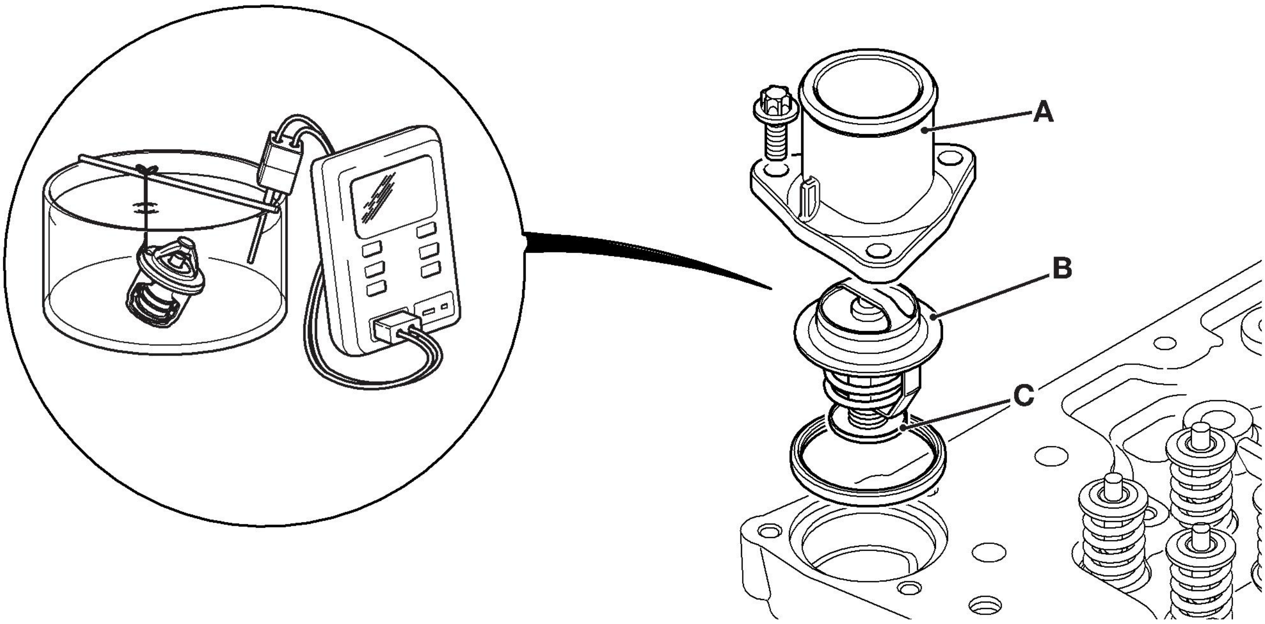


Fig 5.

Air System and Turbocharger

⇒ *Fig 6. (6-12)*

Excessive smoke from the exhaust stack combined with a complaint of low power could be as a result of:

- Dirt or dust (unfiltered air) ingested directly into the engine resulting in damage to the cylinder bores, there will also be a possible increase in oil consumption.
- Air leaks from the air hose connections.
- Exhaust manifold leaks (turbocharged engines).

Air Filters

The air filter inner element **6-A** and outer element **6-B** should be changed at the recommended interval, refer to ***Section 1, Service Schedules.***

In addition, most air filter housings will be fitted with a vacuum switch **6-C**. The switch will detect if there is a restriction on the air intake, and activate warning indicators such as an audible alarm and/or a visual indicator.

Air Intake Connections

Check all hose connections for loose fitting and damaged hose clamps. look specifically for splits or cracks in the hoses, as illustrated at **6-D**.

Naturally Aspirated Engines: Inspect the hoses regularly tightness, splits and cracks. Pay particular attention to the hose **6-E** after the air filter into the intake manifold.

Turbocharged Engines: Inspect the hoses regularly for tightness, splits and cracks. Pay particular attention to the connections on the air intake to turbo compressor **6-F** and on the cross-over tube **6-G**.

Exhaust Manifold Leaks (Turbocharged Engines)

Visually inspect for leaks at the exhaust manifold and turbocharger, shown at **6-H**. Make sure all gaskets are in good condition, replace as required.

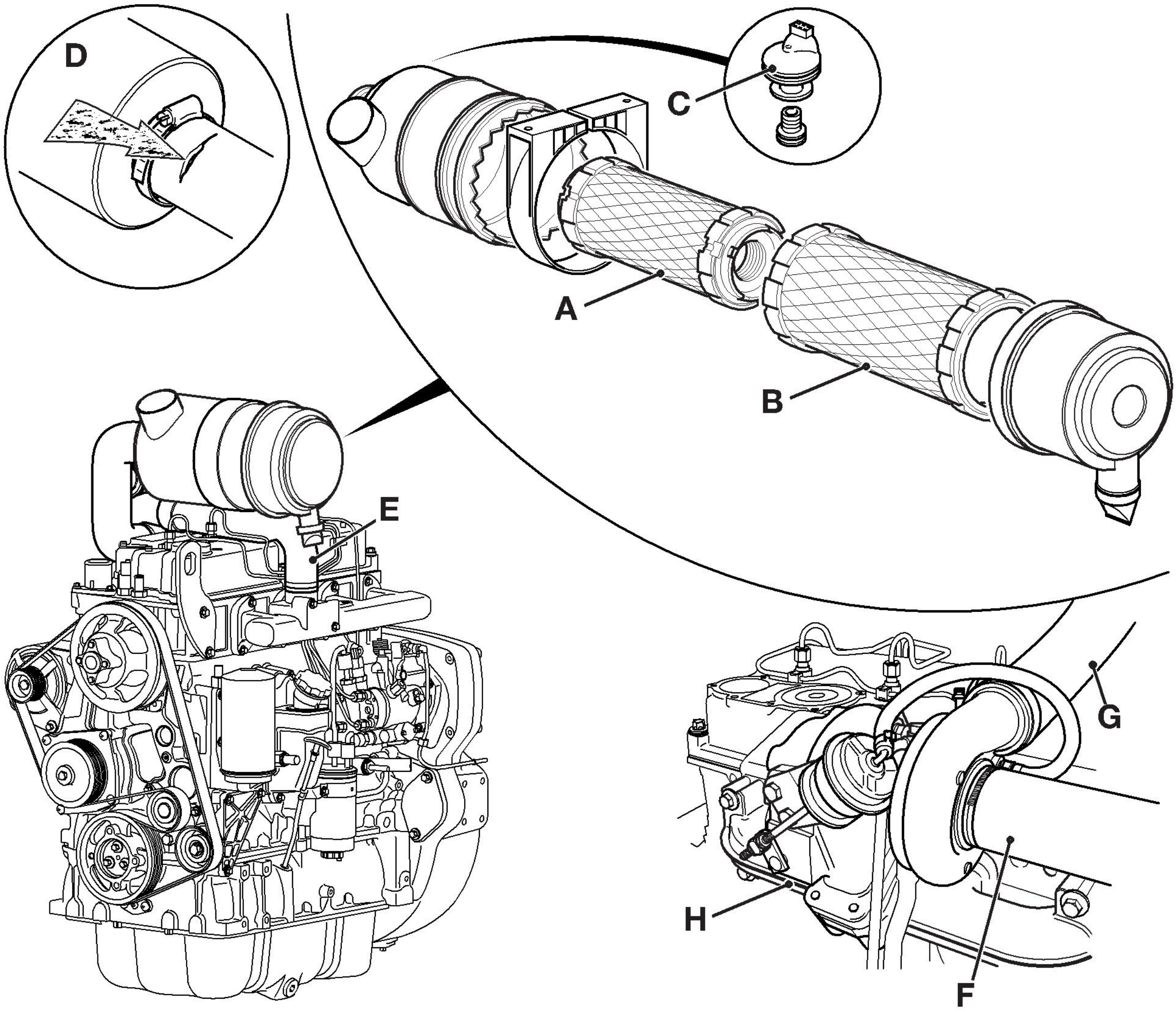


Fig 6.

Turbocharger Checks

If unfiltered air has entered the turbocharger, then this could damage the compressor blades causing the unit to become imbalanced, eventually leading to bearing damage.

This type of failure would be particularly noticeable due to a drop in engine performance, possibly associated with excessive smoke.

Checking of the turbocharger is limited to visual and mechanical inspection of the blades and bearings. Measuring boost pressures (see ***Section 4, Induction, Exhaust and Breather Systems***) is not an exact measurement of performance due to differing loads, engine ratings and application variants .

WARNING

Make sure the engine cannot be started. Disconnect the battery before doing this job.

2-3-3-5

1 Park and make the machine safe in accordance with the machine handbook instructions.

2 Remove the compressor intake hose (shown at **7-A**) and the exhaust pipe from the turbo unit (shown at **7-B**).

3 Manually turn the turbine assembly. The blades should rotate freely with no interference. If the blades contact the housing face, or if there is a `grating' feel as the unit is turned, then it is likely that the bearings have been damaged.

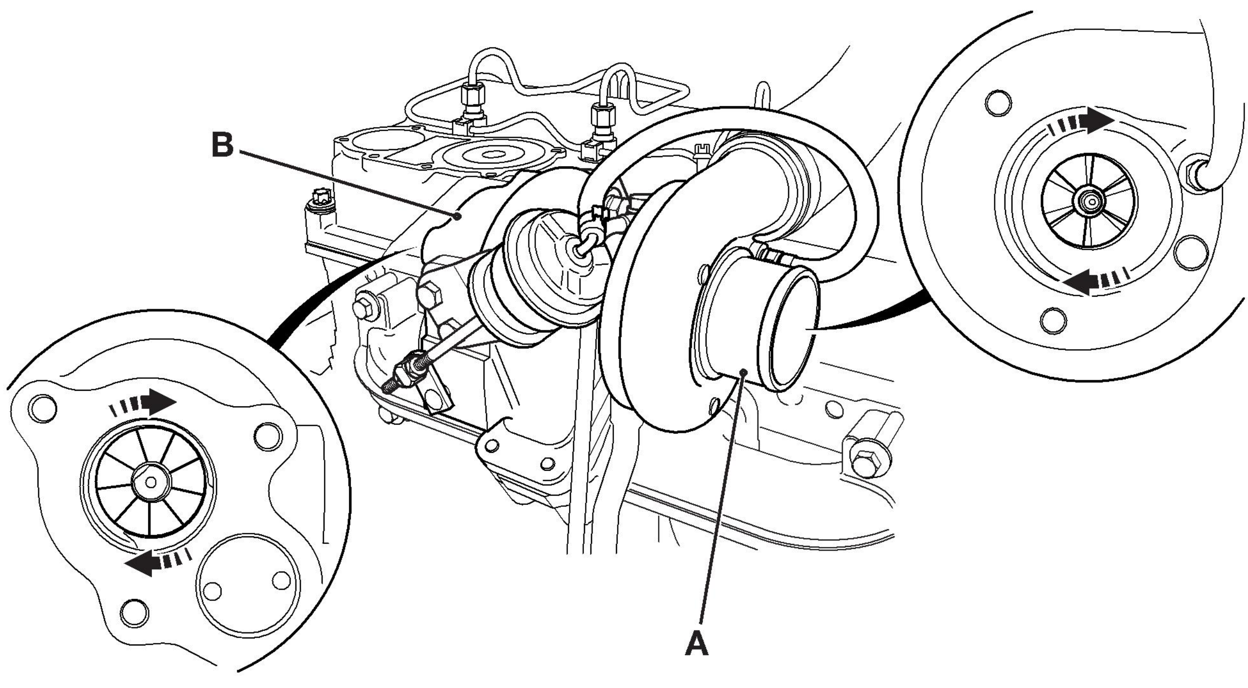


Fig 7.

Wastegate Operational Check

⇨ *Fig 8. (6-15)*

The pressure generated by the turbo compressor is known as `boost pressure'. The boost pressure is controlled by the wastegate assembly. Refer to ***Section 4, Induction, Exhaust and Breather Systems*** for a full description of operation.

The procedure below describes how to check for wastegate movement and operation.

⚠ WARNING

Make sure the engine cannot be started. Disconnect the battery before doing this job.

2-3-3-5

1 Park and make the machine safe in accordance with the machine handbook instructions.

2 Set a dial test indicator (DTI) **8-A** onto the end face of the pushrod assembly **8-B**, as shown.

3 Attach a clean and regulated remote air supply to the wastegate capsule, as shown at **8-C**.

4 Apply a 1 bar (14.5 lb/in2) air supply, the actuating rod should move approximately 5 mm (0.25 inches).

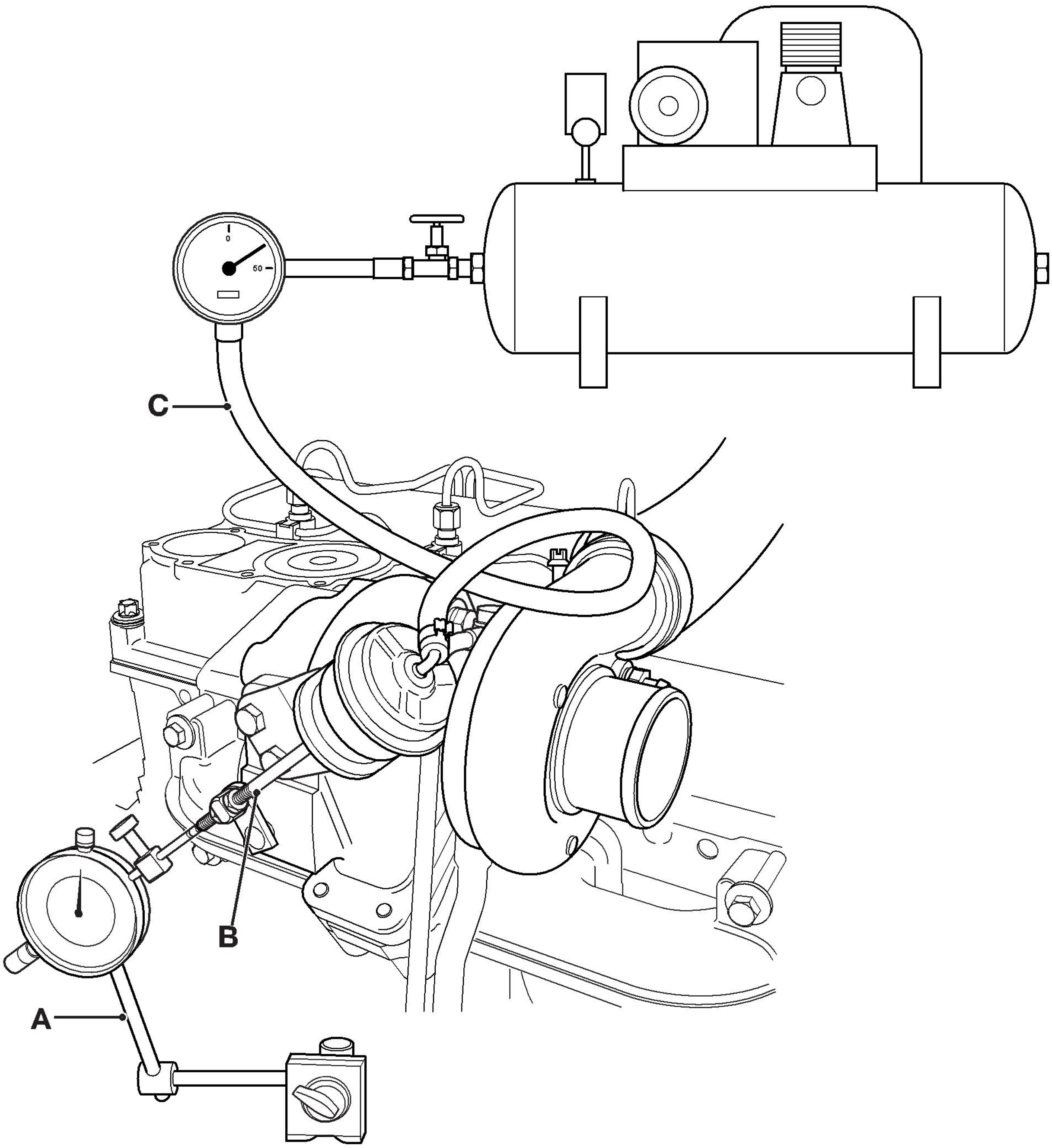


Fig 8.

Using a Multimeter

TC-002

In order to obtain maximum benefit from the fault finding information contained in Section C it is important that the technician fully understands the approach to fault finding and the use of the recommended test equipment, in this case a FLUKE 85 or AVO 2003 digital multimeter, or a moving pointer (analogue) multimeter. The approach is based on a fault finding check list. In tracing the fault from the symptoms displayed you will be directed to make measurements using a multimeter.

These instructions are intended to cover the use of the recommended multimeters.

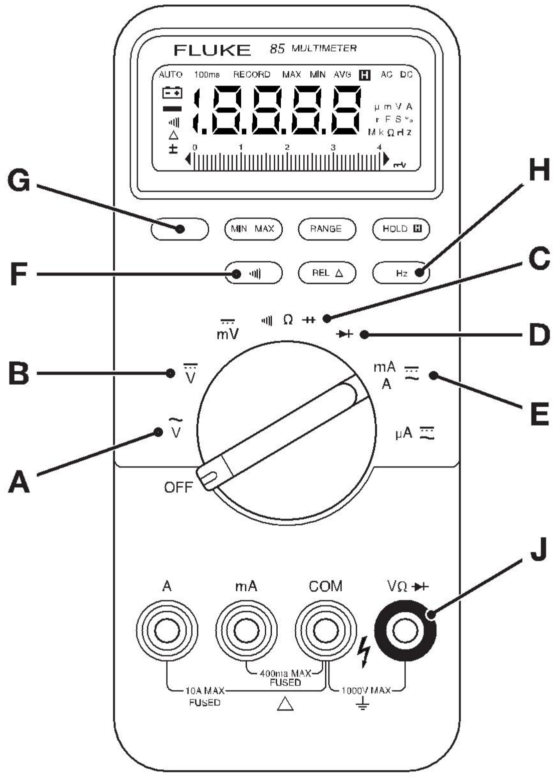


Fig 9. FLUKE 85

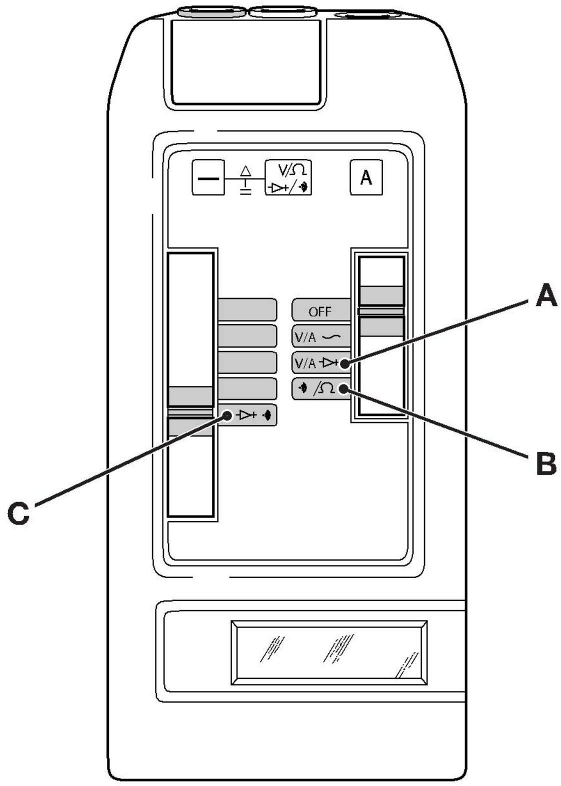


Fig 10. AVO 2003

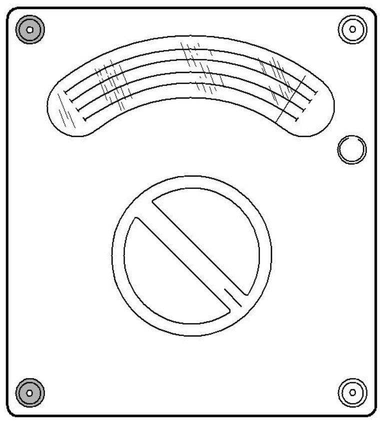


Fig 11. A Typical Analogue Meter

1 Make sure that the test leads are plugged into the correct sockets. The black test lead should be

plugged into the black socket (sometimes, this socket is also marked by a "-", or "**E**" or marked as "**COMMON**" or "**COM**"). The red test lead should be plugged into the red socket marked with "**+**", "**V**" or "Ω".

2 When making measurements ensure that the test probes have a good clean contact with bare metal, free from grease, dirt, and corrosion as these can cause a false reading.

3 When measuring voltage: Make sure that the correct range is selected, that is set the selector to a value equal to or greater than that you are about to measure. e.g. If asked to measure 12 Volts, set the selector to the 12V range. If there is no 12V range, set the selector to the next range higher, 20V for instance. If the meter is set to a range that is too low, it may be damaged. e.g. setting to the 2V range to measure 12V.

Measuring DC Voltage

1 Select the correct range on the multimeter.

a On the FLUKE 85.

Turn the switch to position **9-B**.

b On the AV0 2003.

Move the right slider switch to position **10-A**, and the left hand slider switch to the appropriate range.

c On an analogue meter.

Turn the dial to the appropriate DC Volts range.

2 Connect the black probe to the nearest available suitable earth point, usually this will be the starter motor earth, the battery negative, or the chassis. Connect the red probe to the wire or contact from which you are measuring the voltage.

Measuring Resistance

1 Make sure there is no power to the part of the circuit you are about to measure.

2 Connect one probe at one end of the component or wire to be checked and the other probe at the other end. It does not matter which way round the two probes are placed.

3 Select the correct range on the multimeter.

a On the FLUKE 85.

i Turn the switch to position **9-C** and check that the W sign at the right hand side of the display window is on. If the **F** sign is on instead, press the blue button **9-G** to change the reading to Ω. Touch the meter lead probes together and press the **REL**[3] key on the meter to eliminate the lead resistance from the meter reading.

b On the AV0 2003.

i Move the right hand slider switch to position **10-B**, and the left hand slider switch to the appropriate Ohms (Ω) range.

c On an analogue meter.

i Move the dial to the appropriate Ohms (Ω) range.

Measuring Continuity

1 Make sure there is no power to the part of the circuit you are checking for continuity.

2 Connect one probe to one end of the component or wire to be checked and the other probe to the other end. It does not matter which way round the two probes are placed.

3 Select the correct range on the multimeter.

a On the FLUKE 85.

Turn the switch to position **9-C** and check that the beeper symbol appears at the left hand side of the display window. If the F sign is on instead, press the button labelled **9-F** in the meter drawing.

If there is continuity in the circuit, the beeper will sound. If there is no continuity (open circuit), the beeper will not sound.

b On the AV0 2003.

Move the right hand slider switch to position **10-B**, and the left hand slider switch to position **10-C**.

If there is continuity (i.e. very low resistance) between two points the buzzer will sound.

c On an analogue meter.

Turn the dial to the lowest Ohms (Ω) range.

If there is continuity (i.e. very low resistance) between two points the needle will move across fully (or almost fully) to the right hand side of the scale.

Measuring Frequency

The AVO 2003 and the analogue meter are not capable of measuring frequency, therefore a Fluke 85 digital multimeter must be used.

1 Insert the black plug into the COM socket on the meter and attach the probe to the nearest suitable earth point on the chassis, for example, the battery negative terminal.

2 Insert the red probe into socket **9-J**.

3 Turn the selector switch to position **9-A** and depress **9-G** repeatedly until **9-F** is highlighted on the top row of the display.

4 Press button **9-H** once.

5 Touch or connect the red probe to the frequency source to be measured. Press and hold button if an average reading is required.

Testing a Diode or a Diode Wire

A diode wire is a diode with male connector fitted on one end and a female connector fitted on the other end. The diode is sealed in heatshrink sleeving.

1 To test a Diode or a Diode Wire

a On the FLUKE 85.

i Turn the switch to position **9-D**.

ii Press the **HOLD** button and check that the H sign appears at the top right hand side of the display window.

iii Connect the black probe to the end of the diode with a band or to the male connector of the diode wire. Connect the red probe to the other end of the diode or diode wire. If the beeper does not sound the diode or diode wire is faulty.

iv Connect the red probe to the end of the diode marked with a band, or to the male connector of the diode wire, the black probe should be connected to the other end of the diode or diode wire. If the beeper sounds or the meter does not read **O.L.**, the diode or diode wire is faulty.

v Press the HOLD button and check that the **H** sign disappears from the right hand side of the display window.

b On the AV0 2003.

i Move the right hand slider to position **10-A**, and the left hand slider switch to position **10-C**.

ii Connect the black probe to the end of the diode marked with a band, or to the male connector of the diode wire, the red probe should be connected to the other end of the diode or diode wire. If the Avometer does not buzz the diode is faulty.

iii Connect the red probe to the end of the diode marked with a band, or to the male connector of the diode wire, the black probe should be connected to the other end of the diode or diode wire. If the Avometer does not read "1" the diode is faulty.

c On an analogue meter.

i Select the Ohms 1000s (1k) range.

Connect the black probe to the end of the diode marked with a band, or to the male connector of the diode wire, the red probe should be connected to the other end of the diode or diode wire. The meter should read 20-400 kΩ, if it reads more than this the diode is faulty.

ii Select the Ohms 100s range.

Connect the red probe to the end of the diode marked with a band, or to the male connector of the diode wire, the black probe should be connected to the other end of the diode or diode wire. The meter should read 300-400Ω, if it reads less than this the diode is faulty.

Battery

TC-001_3

Maintenance

To ensure that the battery provides optimum performance the following steps should be observed:

1 Make sure that the electrical connections are clean and tight. Smear petroleum jelly on connectors to prevent corrosion.

2 When applicable - never allow the electrolyte level to fall below the recommended level - 6 mm (1/4 in) above the plates. Use only distilled water for topping up.

3 Keep the battery at least three quarters charged, otherwise the plates may become sulphated (hardened) - this condition makes recharging the battery very difficult.

Extra precautions must be taken when bench charging maintenance free batteries, they are more prone to damage by overcharging than the standard type of battery:

– Never boost-charge a maintenance free battery.
– Never charge a maintenance free battery at a voltage in excess of 15.8 Volts.
– Never continue to charge a maintenance free battery after it begins to gas.

⚠ WARNING

Batteries give off an explosive gas. Do not smoke when handling or working on the battery. Keep the battery away from sparks and flames.

Battery electrolyte contains sulphuric acid. It can burn you if it touches your skin or eyes. Wear goggles. Handle the battery carefully to prevent spillage. Keep metallic items (watches, rings, zips etc) away from the battery terminals. Such items could short the terminals and burn you.

Set all switches in the cab to OFF before disconnecting and connecting the battery. When disconnecting the battery, take off the earth (-) lead first.

Re-charge the battery away from the machine, in a well ventilated area. Switch the charging circuit off before connecting or disconnecting the battery. When you have installed the battery in the machine, wait five minutes before connecting it up.

When reconnecting, fit the positive (+) lead first.

First Aid - Electrolyte

Do the following if electrolyte:

GETS INTO YOUR EYES

Immediately flush with water for 15 minutes, always get medical help.

IS SWALLOWED

Do not induce vomiting. Drink large quantities of water or milk. Then drink milk of magnesia, beaten egg or vegetable oil. Get medical help.

GETS ONTO YOUR SKIN

Flush with water, remove affected clothing. Cover burns with a sterile dressing then get medical help.

5-3-4-3_1

Testing

This test is to determine the electrical condition of the battery and to give an indication of the remaining useful `life'.

Before testing ensure that the battery is at least 75% charged (SG of 1.23 to 1.25 for ambient temperature up to 27°C).

Ensure that the battery is completely disconnected from the vehicle.

Connect up the battery tester as follows:

1 Set the CHECK/LOAD switch **12-A** to OFF.

2 Set rocker switch **12-B** to the battery voltage (12V).

3 Connect the red flying lead to the battery positive (+) terminal and the black flying lead to the battery negative (-) terminal.

4 Set the CHECK/LOAD switch **12-A** to CHECK to read the battery no-load voltage which should be at least 12.4 volts.

5 Set the CHECK/LOAD switch **12-A** to LOAD and hold down for 5-10 seconds until the meter reading stabilises. The reading should be at least 9 volts.

Note: *Do not hold the switch in the LOAD position for more than 10 seconds.*

6 ⇨ *Table 1. Fault Diagnosis (6-21)*, if the foregoing tests are unsatisfactory.

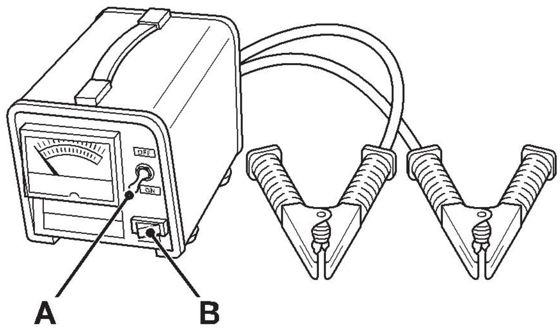


Fig 12. Battery Tester

Table 1. Fault Diagnosis

Battery Tester Readings	**Remedy**
1 CHECK: 0 - 12.6 Volts LOAD: less than 6 Volts	Renew battery
2 CHECK: 6 - 12.4 Volts LOAD: less than 9 Volts and falls steadily but remains in yellow zone.	Recharge and re-test. If tests still unsatisfactory renew battery.
3 CHECK: less than 10 Volts LOAD: less than 3 Volts	Indicates battery has been over-discharged and unlikely to recover. Renew battery.
4 CHECK: more than 11 Volts LOAD: 6 - 10 Volts steady	Charge battery which will probably recover.

Specific Gravity Testing

The specific gravity of the electrolyte gives an idea of the state of charge of the battery. Readings should be taken using a hydrometer, when the electrolyte temperature is 15°C (60°F). If the battery has recently been on charge, wait approximately one hour (or slightly discharge the battery) to dissipate the surface charge before testing.

Readings should be as tabulated and should not vary between cells by more than 0.04. A greater variation indicates an internal fault on that particular cell.

If the electrolyte temperature is other than 15°C (60°F) a 'correction factor' must be applied to the reading obtained. Add 0.07 per 10°C (18°F) if the temperature is higher than 15°C (60°F) and subtract the same if the temperature is lower.

Table 2. Specific Gravity at 15°C (60°F)

	Fully Charged	Half Discharged	Fully Discharged
Ambient temperature up to 27°C (80°F)	1.270 - 1.290	1.190 - 1.210	1.110 - 1.130
Ambient temperature above 27°C (80°F)	1.240 - 1.260	1.170 - 1.190	1.090 - 1.110

Alternator

TC-006

General Description

The alternator is a three phase generator having a rotating field winding and static power windings.

When the start switch is turned on, current from the battery flows by way of the 'No Charge' warning light to the field winding. This creates a magnetic field which supplements the residual magnetism in the rotor poles. As the engine is started, the fan belt drives the rotor and alternating current is generated in the power windings as they are cut by the rotating magnetic field. Output is controlled by a solid state regulator which varies the field current in accordance with electrical demand.

Servicing is restricted to periodic inspection of slip ring brushes. Bearings are 'sealed for life'.

Service Precautions

1 Ensure that the battery negative terminal is connected to the earthing cable.

2 Never make or break connections to the battery or alternator, or any part of the charging circuit whilst the engine is running. Disregarding this instruction will result in damage to the regulator or rectifying diodes.

3 Main output cables are 'live' even when the engine is not running. Take care not to earth connectors in the moulded plug if it is removed from the alternator.

4 During arc welding on the machine, protect the alternator by removing the moulded plug (or if separate output cables fitted, remove the cables).

5 If slave starting is necessary, connect the second battery in parallel without disconnecting the vehicle battery from the charging circuit. The slave battery may then be safely removed after a start has been obtained. Take care to connect batteries positive to positive, negative to negative.

Charging Circuit Test

1 Ensure that all battery and alternator connections are in place, secure and making good metal - to - metal contact, especially the 'earth' connections to chassis and engine.

2 Adjust the alternator drive belt tension if necessary and make sure that the battery is well charged.

3 Turn the start switch to the ON position.

'Oil pressure' and 'No charge' warning lights should glow. If any light fails, ⇨ Check 1 (6-23).

4 Start the engine; all warning lights should extinguish rapidly.

If the 'No charge' warning light remains ON, ⇨ Check 2 (6-24).

If the oil pressure warning remains on stop engine Immediately and investigate the engine lubrication system.

Check 1

With start switch 'ON' try the heater motor and screen wiper.

If they operate normally, check the warning light bulb for blown filament.

Simultaneous failure of all items indicates a fault at the start switch. Check for cable disconnection before condemning the switch itself.

If the 'No charge' warning bulb is in good order, withdraw the triple plug from the back of the alternator. Make a temporary connection between the SMALL terminal in the plug and earth as shown below. If the 'No charge' warning bulb still fails to light, check the cable for continuity. If the bulb now lights, check the alternator for a defective regulator. ⇨ Alternator Charging Test (6-24).

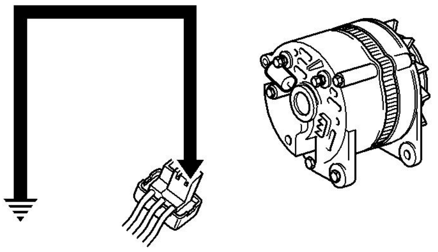


Fig 13.

Check 2

Note: *The following checks should be made using an analogue (moving pointer) type meter.*

1 Stop the engine and turn the starter switch to OFF.

2 Withdraw the alternator plug and connect the test meter between the large terminals and 'earth'. With the meter set to measure 12V DC, the meter should show battery voltage. If the reading is zero, check the cables for continuity, particularly at the starter terminals.

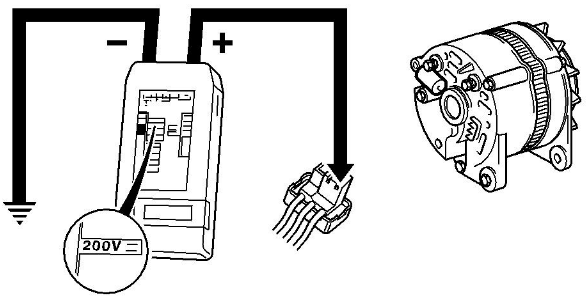


Fig 14.

If the voltage is correct, check the alternator. ⇨ ***Alternator Charging Test (6-24)***.

Alternator Charging Test

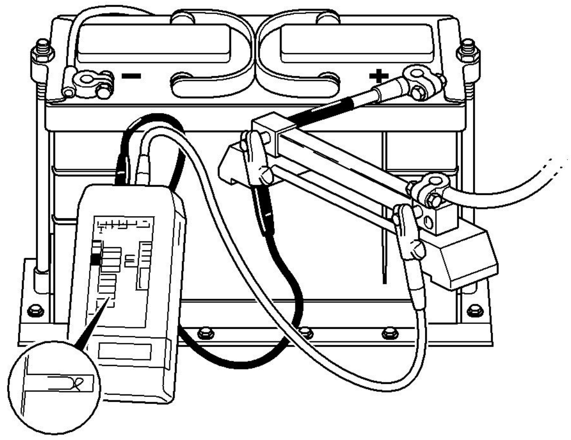


Fig 15.

1 Ensure that all battery and alternator connections are in place, secure and making good metal - to - metal contact, especially the 'earth' connections to chassis and engine.

2 Make sure that the alternator drive belt tension is correctly adjusted.

3 If the battery is in a fully charged condition, switch on the working lights for 3 minutes before commencing the test. Alternatively, operate the starter for a few moments with the engine shut off solenoid (ESOS) fuse removed (See ***Fuse Identification***).

4 Install a 100 amp open - type shunt between the battery positive lead and the battery positive terminal.

5 Connect a multimeter positive lead to machine side of the shunt and negative lead to battery side of the shunt.

6 Connect the leads to the meter and set the meter to the relevant range as follows.

AVO 2002	– Red lead to volts (middle) socket on meter.
	– Black lead to negative on meter.
	– RH slider to DC voltage.
	– LH slider. ⇒ *Fig 15. (6-24)*.
AVO 2003	– Red lead to amps socket (marked A) on the meter.
	– Black lead to negative on meter.
	– RH slider to DC voltage
	– LH slider to 200 Shunt
FLUKE 85	– Red lead to volts socket (marked V) on meter.
	– Black lead to COM socket on meter.
	– Set dial to mV.

7 Start the engine and run at maximum speed (see ***Technical Data***). Meter should show maximum alternator output in Amps (see ***Technical Data***).

Note: *The meter reading should be taken as soon as possible after starting the engine, as the charging current will fall rapidly.*

8 A zero reading indicates failure of the alternator and may be caused by one of the following conditions. These are listed in the order of probability.

a Defective suppression capacitor.

b Dirty slip rings or worn brushes.

c Defective regulator.

d Defective rectifier.

e Open or short - circuited field (rotor) windings.

f Open or short - circuited power (stator) windings.

9 To check for fault a, disconnect the capacitor and repeat the charging test. Renew the capacitor if necessary.

10 To check for faults b and c, remove the regulator and brush box assembly. Check the condition of the brushes and, if necessary, clean the slip rings using extra-fine glass paper. The regulator may only be checked by substitution.

11 Faults d, e, and f may be checked only by removing and dismantling the alternator for further testing.

Starter Motor

TC-005

Starting Circuit Test

Before carrying out the voltmeter tests, check the battery condition and ensure that all connections are clean and tight.

To prevent the engine starting during the tests ensure that the engine stop fuse is removed, (refer to ***Fuse Identification*** page).

Check the readings in the following sequence using a voltmeter. Unless otherwise stated, the readings must be taken with the starter switch held in the 'start' position ('HS') and the transmission forward/reverse selector in neutral.

Note: *Do not operate the starter motor for more than 20 seconds at one time. Let the starter motor cool for at least two minutes between starts.*

1 Connect the voltmeter across the battery terminals. ⇨ *Fig 16. (6-26)*. Reading in 'start' position: 10.0V approximately. Minimum permissible reading in 'start' position 9.5V.

A low reading probably indicates a fault in the starter motor.

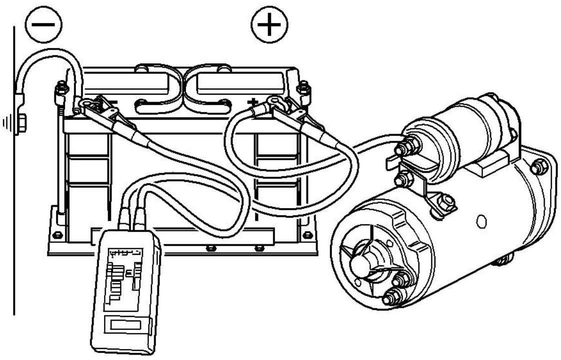


Fig 16.

2 Connect the voltmeter between the starter main terminal **17-A** and the commutator end bracket **17-B**. In the 'start' position, the reading should not be more than 0.5V below the reading obtained in Step 1. Minimum permissible reading in 'start' position 9.0V.

If the reading is within this limit, continue to Step 3. If the reading is outside the limit, proceed to Step 4 and Step 5.

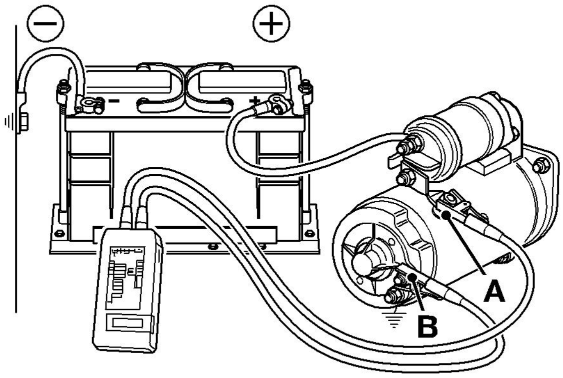


Fig 17.

3 Connect the voltmeter between the solenoid terminal **18-C** and a good earth. Minimum permissible reading in 'start' position: 8.0V.

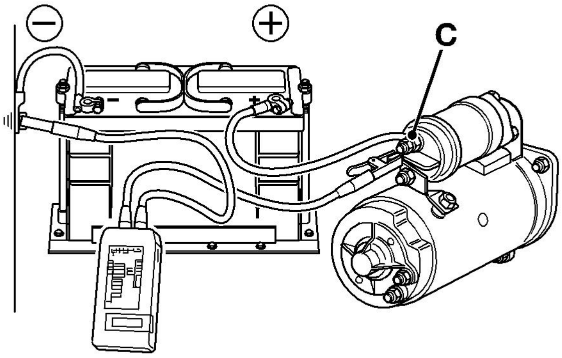


Fig 18.

a If the reading is less than specified, connect the voltmeter between the neutral start relay terminal **19-D** and earth. An increase in reading to 8.0V indicates a fault in the wiring from the start relay to the solenoid.

b If the reading between terminal **19-D** and earth is below 8.0V, connect the voltmeter between terminal **19-E** and earth. An increase in the reading to 8.0V indicates either a faulty start relay or a fault in the feed from the transmission selector switch to the relay solenoid. Check also the solenoid earth connection.

If the reading between **19-E** and earth is less than 8.0V, the fault must be in either the starter switch or in the wiring between the solenoid, starter switch, and the start relay.

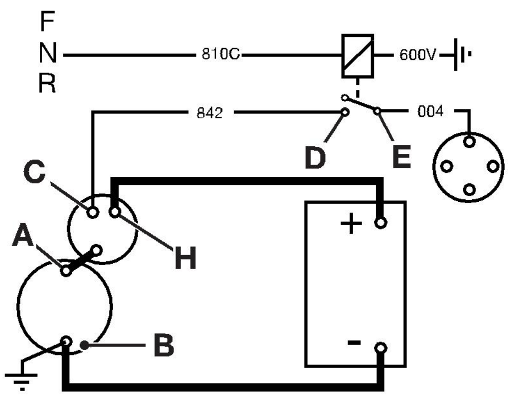


Fig 19.

4 Connect the voltmeter between battery negative and starter earth connection **20-B**. The reading in the 'start' position should be practically zero, maximum permissible reading 0.25V.

If the reading is above 0.25V, a high resistance in the earth lead or connections is indicated.

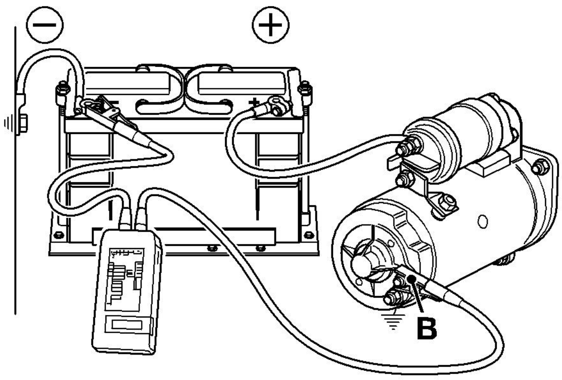


Fig 20.

5 Connect the voltmeter between battery positive and the starter main terminal **21-A**. With the starter switch 'off', the voltmeter should indicate battery voltage, but it should fall to practically zero when the switch is turned to the 'on' position, maximum permissible reading 0.25V.

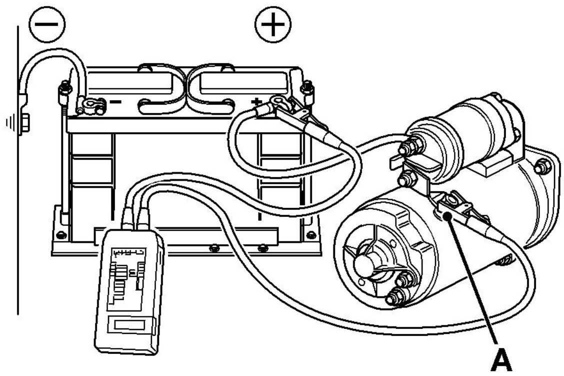


Fig 21.

If the reading is above 0.25V, a high resistance is present in the insulated lead or in the solenoid. Connect the voltmeter between the battery positive and solenoid connection **22-H**. If the voltmeter now reads zero with the switch closed, the fault is in the solenoid.

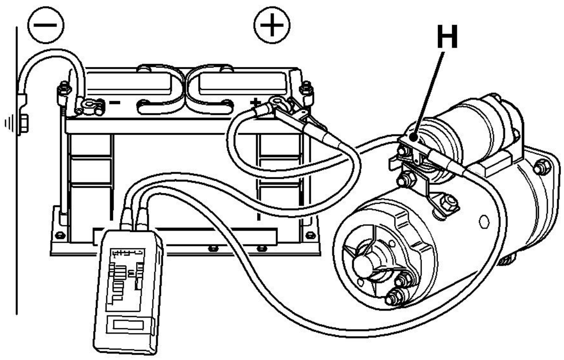


Fig 22.

6 Finally refit the engine stop fuse.

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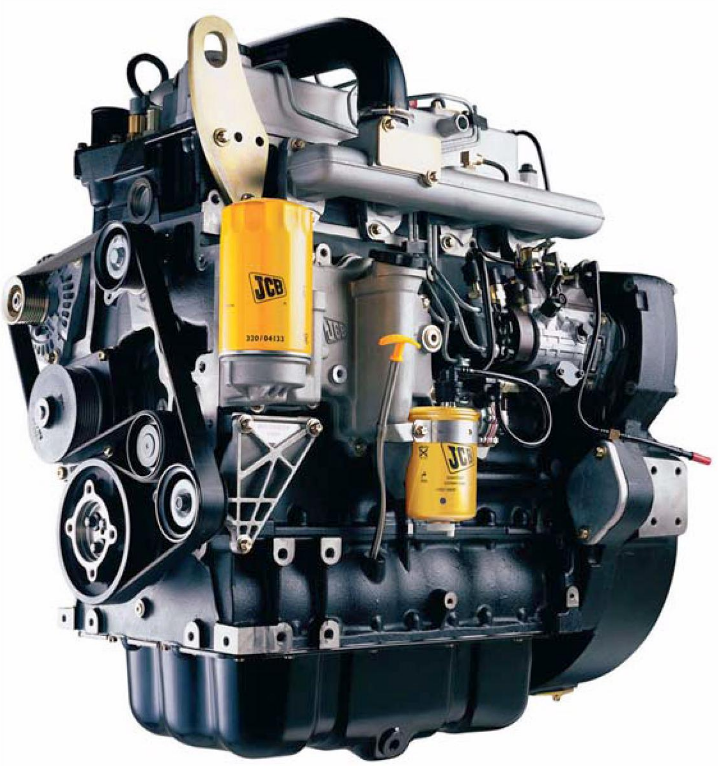
Fuel System

Service Manual - JCB 444 Engine



Publication No.
9806/3000-02

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Issued by JCB Technical Publications, JCB Aftermarket Training, Woodseat, Rocester, Staffordshire, ST14 5BW, England. Tel +44 1889 591300 Fax +44 1889 591400

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Contents **Page No.**

Fuel Filter

Removal and Replacement

The procedure for removing and replacing the fuel filter is described as part of the routine maintenance procedures, see ***Section 3 Routine Maintenance***.

Fuel Lines

Identification

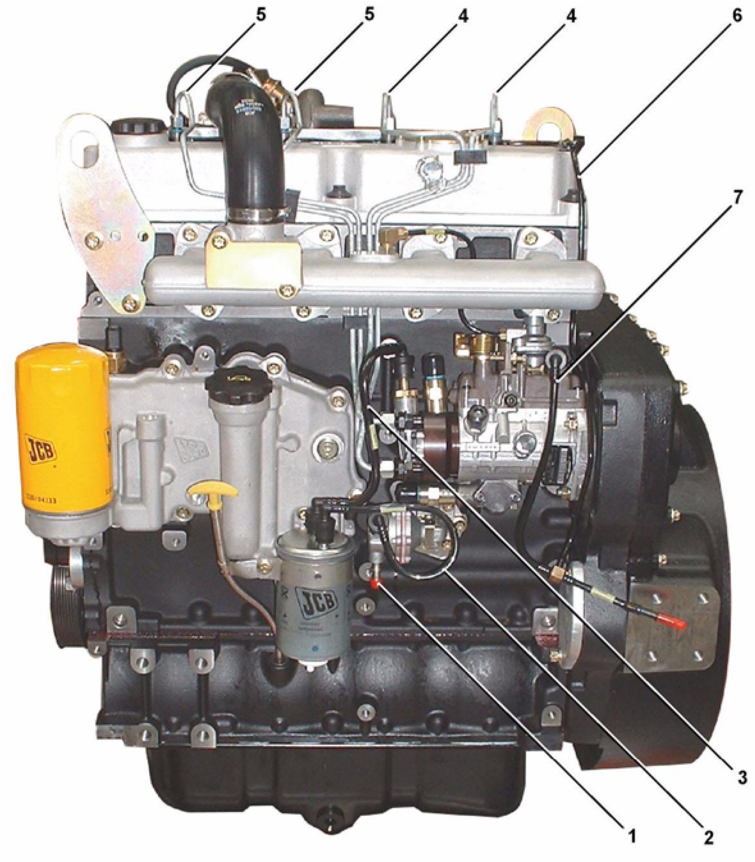


Fig 1.

Table 1. Low Pressure Fuel Lines

1	Fuel supply - fuel tank to lift pump
2	Lift pump to filter
3	Filter to fuel injection pump

Table 2. High Pressure Fuel Lines

4	Fuel line pipe assembly - 3 and 4 cylinders
5	Fuel line pipe assembly - 1 and 2 cylinders

Table 3. Bleed-off Fuel Lines (Low Pressure)

6	Fuel line assembly - fuel injectors to tank
7	Fuel injection pump to tank

Removal and Replacement

High Pressure Fuel Lines

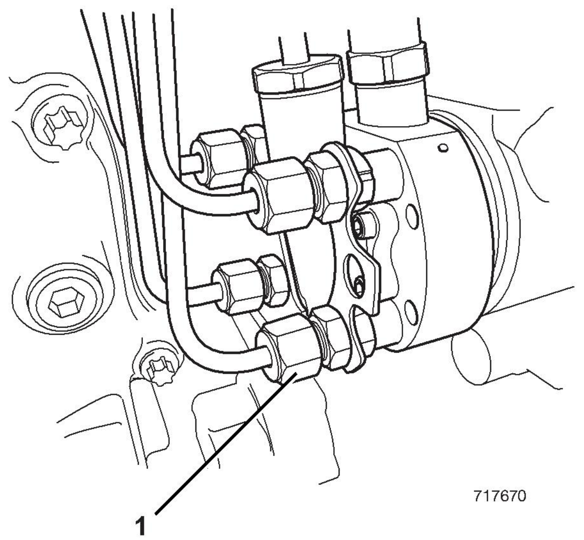


Fig 2.

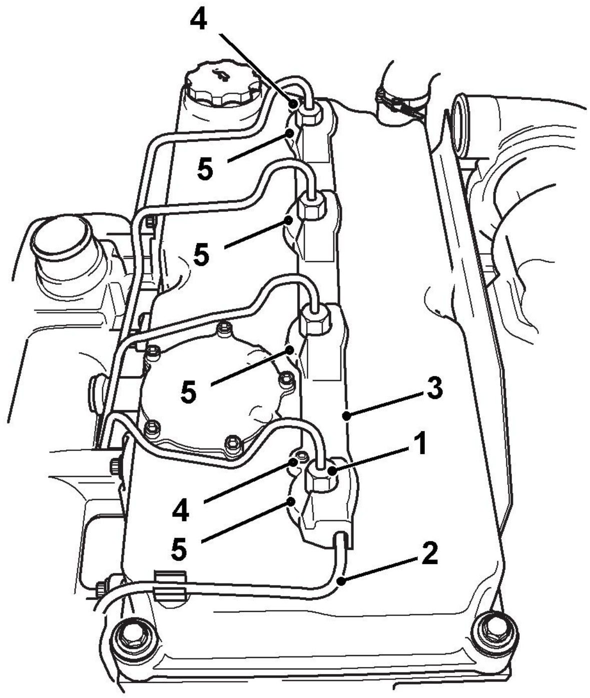


Fig 3.

Table 4. Component Identification

1	Union nuts - high pressure fuel lines
2	Bleed-off fuel line
3	Protective cover
4	Screws - protective cover
5	Removable inserts - protective cover

Table 5. Service Tools

Item	Part Number	Description
T1	General	Flare Nut Socket

Table 6. Torque Settings

Item	Nm	lbf ft
1	27	19.9

Before disconnecting or removing fuel lines

1 Ensure that the engine cannot be started.

2 Clean off all dirt and debris from around the fuel line connectors.

DO NOT attempt to repair fuel lines or connectors. If a fuel line or connector is damaged the fuel line assembly must be renewed.

Removal

1 Remove the protective cover **3** (if fitted). Unclip the four plastic segments **5**. Undo the screws **4** and lift off the cover.

2 Remove the fuel lines in pairs, starting with the lines for cylinders 3 and 4. (⇨ *Identification (7-2)*) Using the flare nut socket **T1**, undo the union nuts **1** at the fuel injection pump and injectors and lift the lines away.

3 Repeat for the lines at cylinder 1 and 2.

4 Cap all open ports to prevent ingress of dirt and debris.

Replacement

Replacement is the reverse of removal but note the following:

1 Make sure that the bleed-off fuel lines **2** are connected at the injectors BEFORE fitting the high pressure lines.

2 Ensure that the pipes are properly seated. Torque tighten the nuts **1**, see ***Torque Settings***. DO NOT OVER TIGHTEN THE NUTS. If the nuts are over tightened the pipe sealing seats may be damaged causing fuel leaks.

After replacing fuel lines:

1 Ensure that all lines are correctly fitted and located in retaining clips as applicable. If retaining clips are missing or damaged they must be replaced or renewed.

⚠ WARNING

Fluid Under Pressure

Fine jets of fluid at high pressure can penetrate the skin. Keep face and hands well clear of fluid under pressure and wear protective glasses. Hold a piece of cardboard close to suspected leaks and then inspect the cardboard for signs of fluid. If fluid penetrates your skin, get medical help immediately.

INT-3-1-10_2

⚠ WARNING

Fuel oil is highly inflammable. Stop the engine immediately if a fuel leak is suspected. Completely wipe off any spilt fuel which could cause a fire.

8-3-4-3_1

2 Start the engine and check for fuel leaks.

Low Pressure Fuel Lines

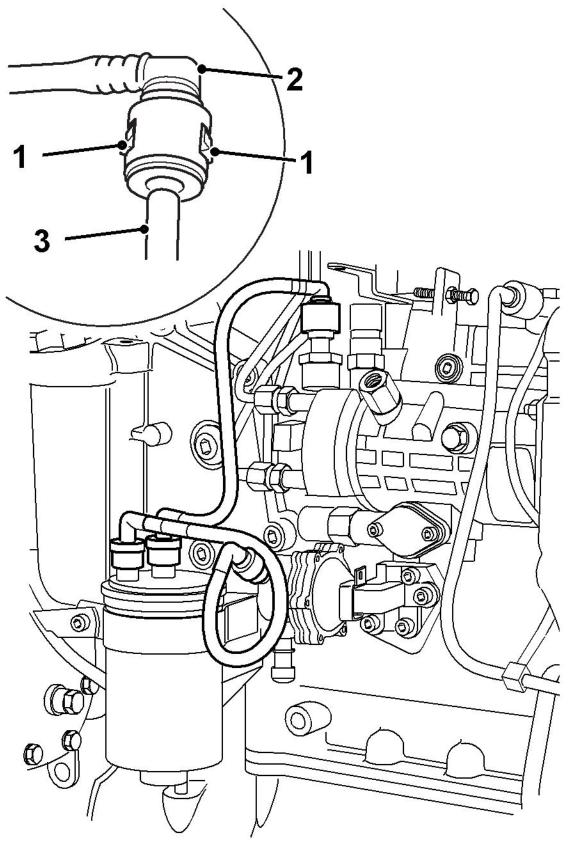


Fig 4.

Before disconnecting or removing fuel lines:

1 Ensure that the engine cannot be started.

2 Clean off all dirt and debris from around the fuel line connectors.

DO NOT attempt to repair fuel lines or connectors. If a fuel line or connector is damaged the fuel line assembly must be renewed.

Removal

The low pressure fuel lines have a nylon fitting attached to the pipe that replaces the nut and olive. The fittings are part of the pipe and not a separate item. A damaged fitting will result in the pipe having to be replaced as a completed assembly.

1 To release the fuel line, first press and hold buttons **1** (1 each side of the coupler). Push the coupler **2** towards the connector spigot **3** then withdraw.

2 Cap all open ports to prevent ingress of dirt and debris.

Replacement

1 To refit the fuel line, press and hold buttons **1**. Push the coupler **2** over the connector spigot **3** and release the button **1**. The connector will be heard to click when it is fully home and locked in place.

2 To check that the connection has been fully remade, attempt to pull the connector from the connector spigot without releasing the lock mechanism. (A gentle pull is all that is required, if the connection is not good the connector will release very easily.)

After replacing fuel lines:

1 Ensure that all lines are correctly fitted and located in retaining clips as applicable. If retaining clips are missing or damaged they must be replaced or renewed.

⚠ WARNING

Fluid Under Pressure

Fine jets of fluid at high pressure can penetrate the skin. Keep face and hands well clear of fluid under pressure and wear protective glasses. Hold a piece of cardboard close to suspected leaks and then inspect the cardboard for signs of fluid. If fluid penetrates your skin, get medical help immediately.

INT-3-1-10_2

⚠ WARNING

Fuel oil is highly inflammable. Stop the engine immediately if a fuel leak is suspected. Completely wipe off any spilt fuel which could cause a fire.

8-3-4-3_1

2 Start the engine and check for fuel leaks.

Fuel Bleed-off Lines (Low Pressure)

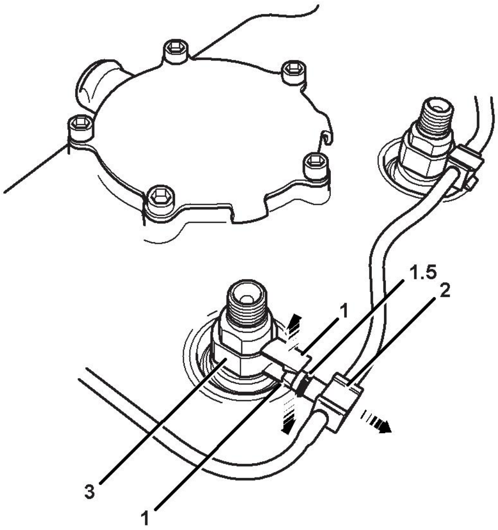


Fig 5.

Table 7. Component Identification

1	Location tabs - bleed line clip
2	Connector - bleed line
3	Bleed line clip

Table 8. Service Parts

1	\`O' ring - bleed line connector (4 off)

Before disconnecting or removing fuel lines:

1 Ensure that the engine cannot be started.

2 Clean off all dirt and debris from around the fuel line connectors.

3 Remove the high pressure fuel lines. ⇨ ***High Pressure Fuel Lines (7-3)***.

DO NOT attempt to repair fuel lines or connectors. If a fuel line or connector is damaged the fuel line assembly must be renewed.

Removal

Note: *The following details the removal and replacement of 1 bleed-off connector. The procedure for the remaining 3 connectors is identical.*

1 Gently spring the location tabs **1** apart and pull out the bleed line connector **2**. DO NOT use excessive force on the tabs **1**.

2 Remove and discard \`O' ring **1.5**.

3 Pull off discard the bleed line clip **3**.

4 Cap all open ports to prevent ingress of dirt and debris.

Replacement

1 Push a new bleed line clip **3** over the injector the correct way round, aligned with the bleed port in the injector.

2 Fit new a \`O' ring **1.5**.

3 Push in the bleed line connector **2** until the tabs **1** snap over the connector.

After replacing the fuel lines:

1 Ensure that all lines are correctly fitted and located in retaining clips as applicable.

2 Replace the high pressure fuel lines. ⇨ ***High Pressure Fuel Lines (7-3)***.

⚠ WARNING

Fluid Under Pressure

Fine jets of fluid at high pressure can penetrate the skin. Keep face and hands well clear of fluid under pressure and wear protective glasses. Hold a piece of cardboard close to suspected leaks and then inspect the cardboard for signs of fluid. If fluid penetrates your skin, get medical help immediately.

INT-3-1-10_2

⚠ WARNING

Fuel oil is highly inflammable. Stop the engine immediately if a fuel leak is suspected. Completely wipe off any spilt fuel which could cause a fire.

8-3-4-3_1

3 Start the engine and check for fuel leaks.

Fuel Lift Pump

Removal and Replacement

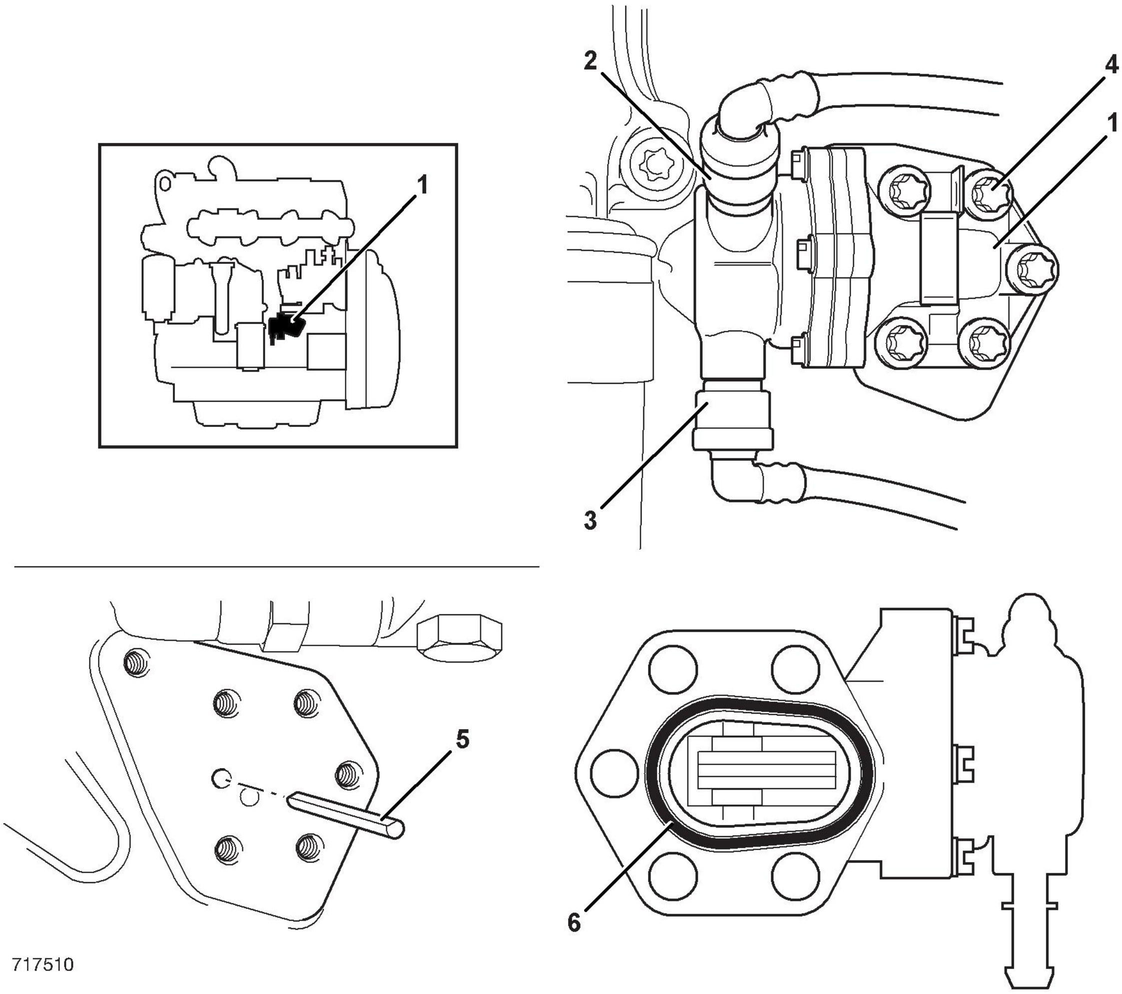


Fig 6.

Table 9. Component Identification

1	Fuel lift pump assembly
2	Fuel line connector (outlet)
3	Fuel line connector (inlet)
4	Fixing bolts (5 off)
5	Actuator pin
6	Sealing `O' ring

Table 10. Service Tools

Item	Part Number	Description
T1	General	Star Drive Socket

Removal

Before Removal:

1. Ensure that the engine cannot be started.

2. Clean the area around the fuel lift pump **6-1**.

Removal

1. Release the fuel line couplings **6-2** and **6-3** from the lift pump, see ***Low Pressure Fuel Lines - Removal and Replacement***. Label the fuel lines to ensure they are refitted in the correct positions on assembly.

2. Undo bolts **6-4** and lift the pump assembly away from the cylinder block. Be sure to retrieve `O' ring seal **6-6**.

3. Withdraw the actuator pin **6-5** from the cylinder block.

If the pump performance is in question, perform tests to confirm its serviceability, see ***Section 6 Test Procedures***. Note that the lift pump is a non serviceable item. If the pump is faulty or damaged it must be renewed.

Replacement

Replacement is the reversal of removal but note the following:

1. Make sure actuator pin **6-5** is correctly located in the cylinder block. Note that the pin has a flat side to allow oil feed to the pump mechanism. Make sure that the oil way along the pin is not restricted by sludge or debris.

2. Make sure that `O' ring **6-6** is located correctly in its groove.

3. Torque tighten bolts **6-4**, see ***⇨ Table 11. Torque Settings (7-8)***.

4. Be sure to reconnect the fuel lines to the lift pump in the correct positions.

Table 11. Torque Settings

Item	Nm	lbf ft
T1	24	17.7

After replacing:

1. Bleed the fuel system, see ***Section 3 Routine Maintenance***.

2. Run the engine and check for fuel leaks.

Fuel Injection Pump

Removal and Replacement

Component Identification

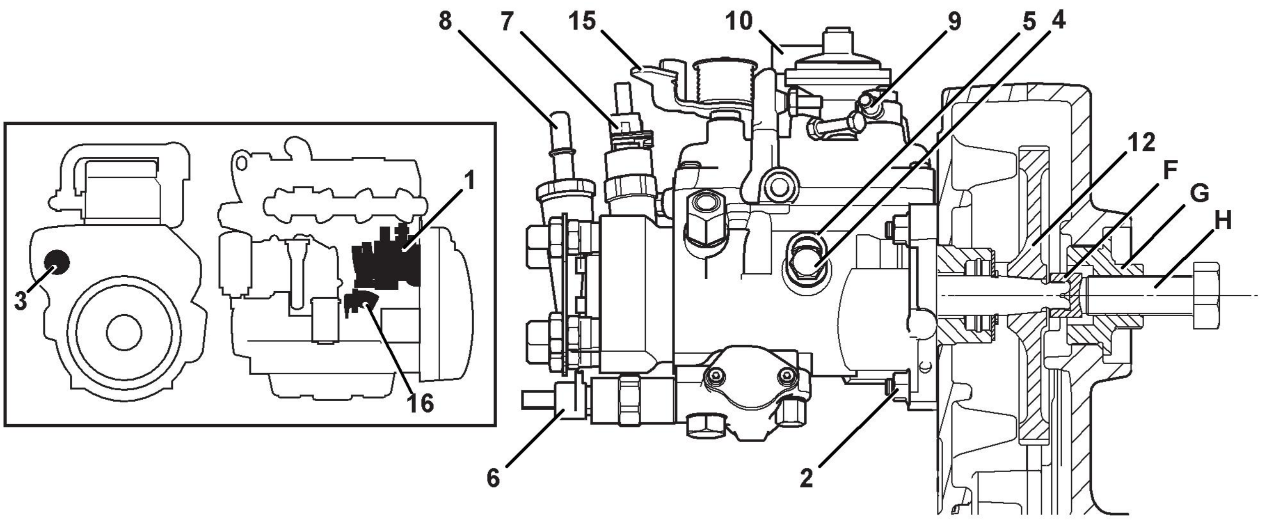


Fig 7.

Table 12. Component Identification

1	Fuel injection pump
2	Pump fixing nuts (3 off)
3	Injection pump gear cover
4	Injection pump lock bolt
5	Keyhole washer
6	Cold start advance solenoid
7	Electric shut-off solenoid (ESOS)
8	Fuel line connector (inlet)
9	Fuel bleed-off connector
10	Turbo boost vacuum pipe (if fitted)
11	Drive shaft nut
12	Drive gear
14	Injection pump oil seal
15	Throttle lever
16	Fuel lift pump

Table 13. Service Tools

Item	Part Number	Description
A	892/01148	Timing pin - crankshaft
B	892/01154	Socket - Injection pump gear cover
C	892/01147	Crankshaft turning tool
D	892/01169	Top dead centre setting tool
E	892/01155	Gear removal tool comprises:
F		Reaction cap
G		Tool body
H		Special bolt
J	General	`C' shaped ring spanner - Injection pump inner nut

Before Removing:

1 Ensure that the engine cannot be started.

2 Release the fuel line couplings at the inlet connection **7-8** and bleed-off connection **7-9** on the pump. Remove the high pressure fuel lines, see ***Fuel Lines - Removal and Replacement***.

Important: *DO NOT attempt to remove the fuel injection pump until both the engine and pump are mechanically locked in the correct position - refer to the procedures below. The pump will need the timing reset by a fuel injection equipment specialist if it is not locked in the correct position prior to removal.*

Removal

1 Uncouple the electrical connectors at the shut-off solenoid **10-7** and cold advance solenoid **10-6**.

2 **Turbocharged Engines Only:** Disconnect the boost control vacuum pipe **10-10** at the diaphragm on the injection pump.

3 Disconnect the throttle cable.

4 Fit the crankshaft turning tool:

- **a** Remove the taper blanking plug **9-13**.
- **b** Bolt the tool **9-C** to the crankshaft pulley.
- **c** Locate a suitable socket and ratchet drive on the tool.

5 Set number 1 piston to top dead centre (on its compression stroke):

- **a** Remove the fuel lift pump see ***Fuel Lift Pump - Removal and Replacement***.
- **b** Install the TDC setting tool **8-D**, use one of the lift pump retaining bolts **8-17** to hold the tool in position. Make sure that the top hole locates centrally over the lift pump actuating pin **8-19**.
- **c** Using the crankshaft turning tool turn the crankshaft until timing pin **9-A** engages in the crankshaft timing hole. Check that the lift pump actuating pin **9-19** is protruding from the face of the setting tool, if not complete steps **d** and **e**.
- **d** Remove the timing pin **9-A**.
- **e** Rotate the crank pulley 360° and refit the timing pin **9-A.**

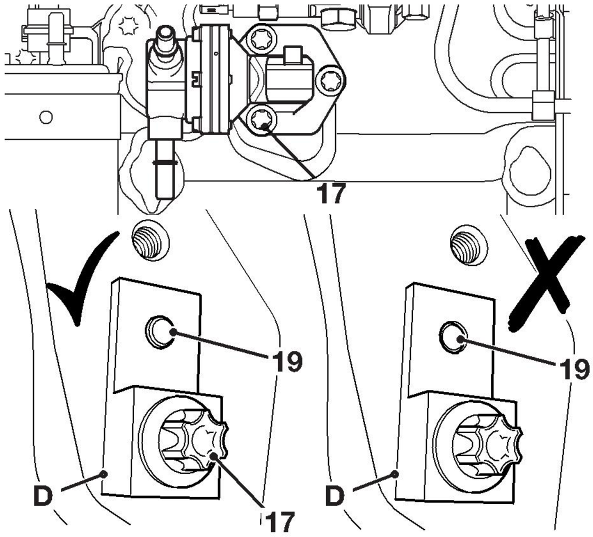


Fig 8.

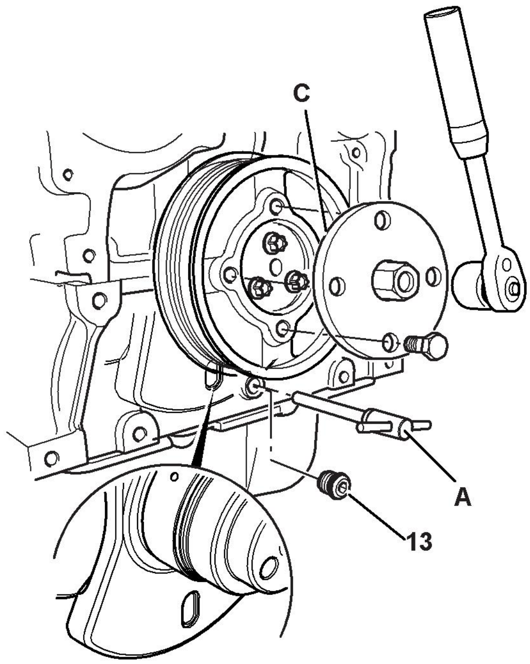


Fig 9.

***Note:** The timing pin MUST be engaged in the crankshaft timing hole. It is possible that the pin may appear to `engage' but it is in fact between the crankshaft webbing. Always check the pin has engaged correctly by trying to move the crankshaft clockwise and anti-clockwise. If you can not turn the crankshaft in both directions, the pins will be engaged.*

6 Remove fuel injection pump gear cover **11-3** using service tool **11-B** and a suitable ratchet drive.

7 Undo and remove the drive shaft nut **11-11**.

8 Loosen lock bolt **10-4** on the fuel injection pump so that the special keyhole washer **10-5** can be slid across to its locking position (as shown at **10-Y**). Screw the lock bolt in and torque tighten to 12 Nm (8.8 lbf ft). The washer **10-5** should be loose.

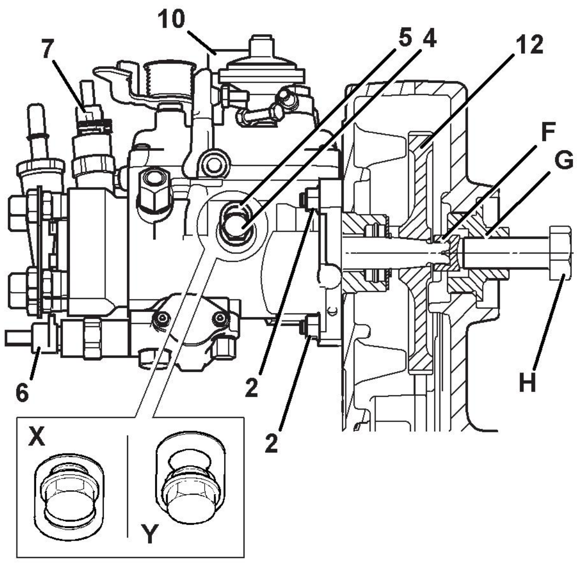


Fig 10.

9 Undo and remove the nuts **10-2**. Use special spanner **J** to undo the nut close to the cylinder block. Be sure to remove all 3 nuts.

10 Fit reaction cap **11-F** (service tool) over the pump shaft. Screw service tool **11-G** to the housing. Using a suitable ratchet drive and socket screw in bolt **11-H** (service tool) until resistance is felt.

11 The injection pump drive gear **10-12** is located on a taper on the pump drive shaft. To remove the pump the taper lock must be `broken'. Support the fuel injection pump. Tap the end of bolt **11-H** with a soft faced hammer. When the taper `breaks' there will be an audible sound.

***Note:** The pump drive gear connects to the injection pump drive shaft by means of taper lock alone. There is no mechanical locking key.*

12 Remove service tools **11-H**, **11-G** and **11-F**. Withdraw the pump from the flywheel housing.

***Important:** DO NOT remove the engine locking pin **9-A**. Make sure that no one attempts to turn the engine.*

***Important:** DO NOT loosen the fuel injection pump lock bolt **10-4**.*

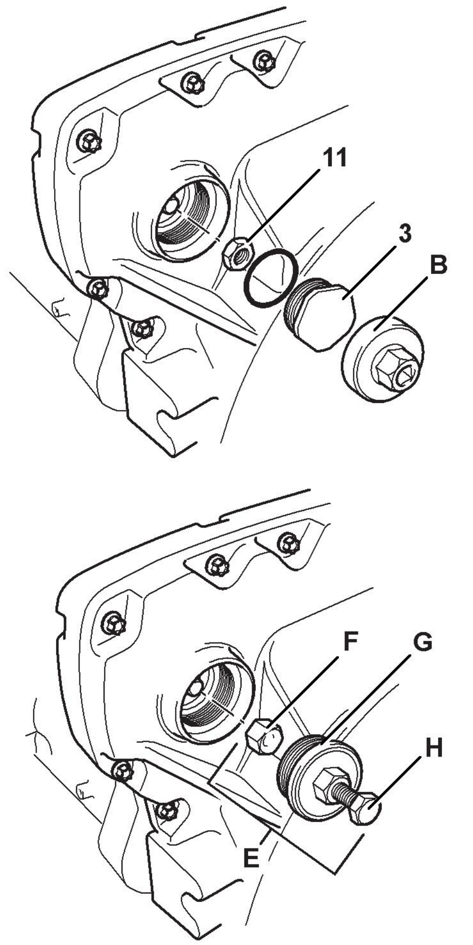


Fig 11.

Replacement

Service procedures on the fuel injection pump can only be carried out by specialist personnel with the relevant training and equipment. Before replacing an injection pump with a new one, or one that has been serviced, make sure that the drive shaft is locked, with bolt **12 -4** tightened with keyhole washer **12-5** in the correct position. Make sure that the engine is still locked in the correct position.

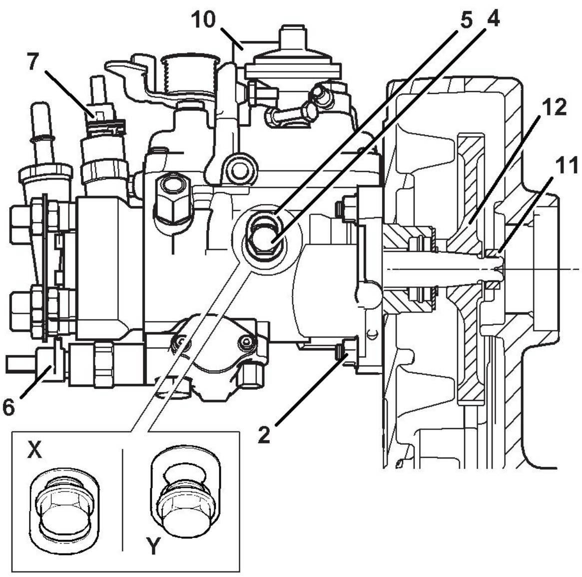


Fig 12.

1 Make sure that taper surfaces on the injection pump drive shaft and gear **12-12** are clean and free from oil.

2 Make sure that the oil seal **13-16** is correctly located on the injection pump mounting face.

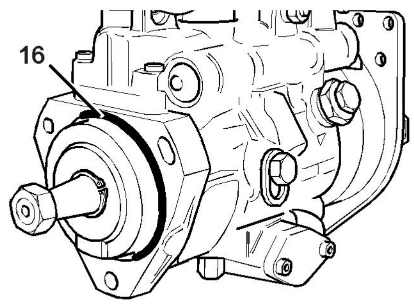


Fig 13.

3 Locate the pump onto the mounting studs. Locate the drive gear **12-12** over the pump drive shaft.

4 Fit and torque tighten the nuts **12-2** to 24 Nm (17.7 lbf ft). Use special spanner **H** to tighten the nut close to the cylinder block.

5 Fit and torque tighten the pump gear nut **12-11** to the 1st stage pre torque. ⇨ ***Table 14. Torque Settings (7-13)***.

Note: *If the washer is supplied with a replacement pump, DO NOT FIT THE WASHER. Secure the gear with the nut **11** only.*

6 Loosen lock bolt **12-4** until the keyhole washer **12-5** can be slid under the bolt (as shown at **12-X**). Then torque tighten bolt **12-4**. ⇨ ***Table 14. Torque Settings (7-13)***. The washer **12-5** should be locked.

7 Torque tighten pump gear nut **12-11** to final stage. ⇨ ***Table 14. Torque Settings (7-13)***.

8 Fit the gear cover **14-3** using service tool **14-E**. Make sure its sealing `O' ring is correctly fitted. Torque tighten the gear cover. ⇨ ***Table 14. Torque Settings (7-13)***.

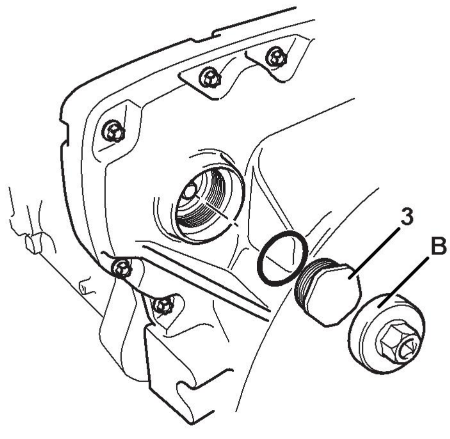


Fig 14.

9 Remove the engine lock pin **15-A** and refit the blanking plug **15-B**.

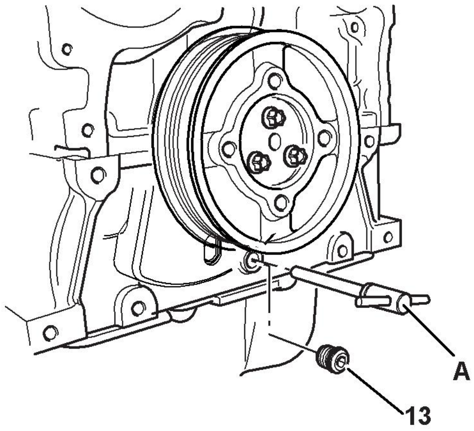


Fig 15.

10 Couple the electrical connectors at the shut-off solenoid (ESOS) **12-7** and cold advance solenoid **12-6**.

11 Turbocharged Engines Only: Reconnect the boost control vacuum pipe **12-10** at the diaphragm on the injection pump.

Table 14. Torque Settings

Item	Nm	lbf ft
3	70	51.6
4	12	8.8
11	25	18.4 1st Stage
11	90	66.3 Final Stage

After Replacing

1 Replace the rocker cover, see ***Section 12 Base Engine, Cylinder Head***.

2 Reconnect the fuel line couplings at the inlet connection **16-8** and bleed-off connection **16-9** on the pump. Fit the high pressure fuel lines, see ***Fuel Lines - Removal and Replacement***.

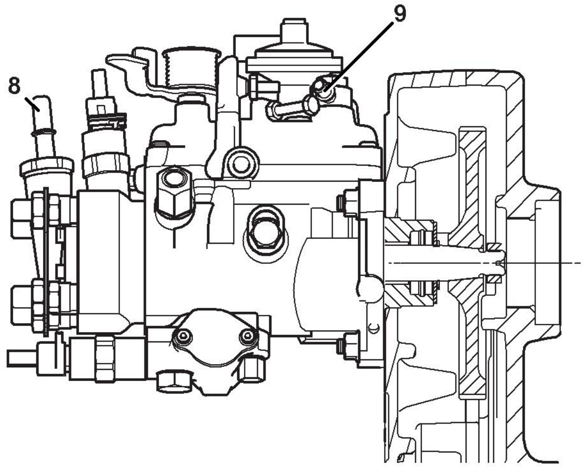


Fig 16.

3 Remove the TDC setting tool and replace the fuel lift pump, see ***Fuel Lift Pump - Removal and Replacement***.

4 Reconnect the throttle cable.

5 Bleed the fuel system, see ***Section 3 Routine Maintenance***.

6 Start the engine and check for fuel leaks.

Fuel Injectors (Atomisers)

Removal and Replacement

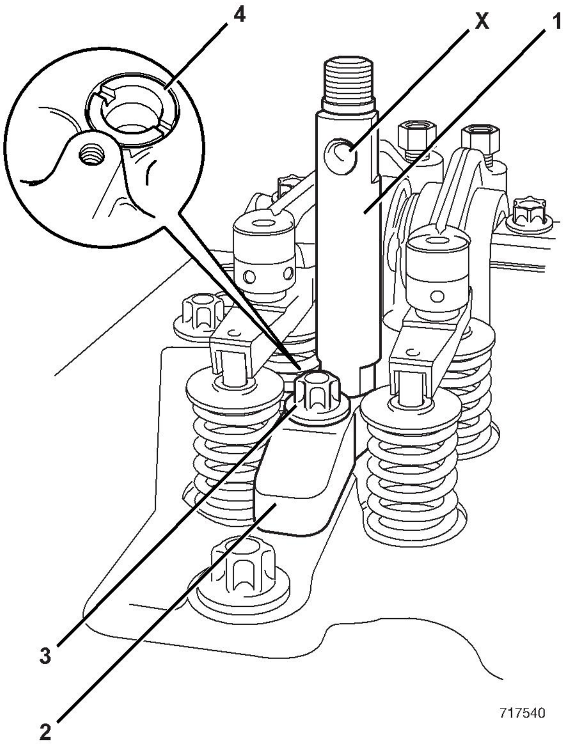


Fig 17.

Table 15. Component Identification

1	Injector
2	Injector clamp
3	Injector clamp bolt
4	Injector sleeve
X	Injector bleed-off port

Table 16. Service Parts

1.3	Fuel Injector Caps
6.9	Sealing Washer
6.10	Injector Sealing `O' Ring

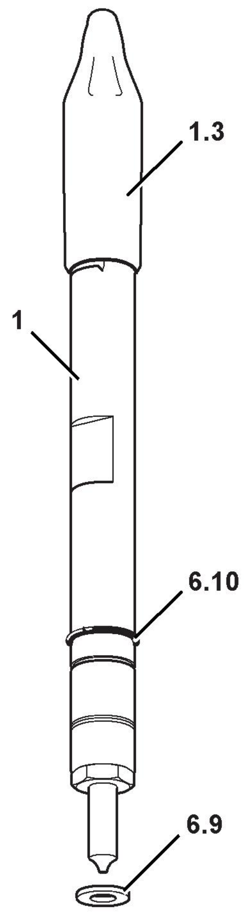


Fig 18.

Table 17. Service Tools

Item	Part Number	Description
T1	General	Star Drive Socket

Removal

Before removing

1 Remove the high pressure and fuel bleed-off lines, see ***Fuel Lines - Removal and Replacement***. Be sure to cap all open ports on the fuel lines, injection pump and injectors.

2 Remove the rocker cover, see ***Section 12 Base Engine - Cylinder Head.***

Note that the fuel injectors are non serviceable items. If an injector is faulty or damaged it must be renewed.

Removal

The following procedure is for **17-1** injector, the procedures are identical for all injectors.

1 Undo the injector clamp retaining bolt **17-3** and lift away the clamp **17-2**.

2 Pull the injector **17-1** from its sleeve **17-4**. DO NOT remove the caps from the injector ports.

3 Remove and discard the sealing washer **18-6.9**. Label the injector to ensure its replacement in its original cylinder. Place a clean protective cap over the nozzle of the injector.

4 Remove and discard the `O' ring **18-6.10**.

Replacement

Replacement is the reverse of removal but note the following:

1 Clean off any sludge or oil from the inner bore of the injector sleeve **17-4**. Be sure not to damage the surface of the bore. Any damage or surface contamination will cause the injector sealing `O' ring **18-6.10** to fail.

2 Fit a new `O' ring **18-6.10**.

3 Fit a new sealing washer **18-6.9**.

4 Be sure to orientate the injector correctly, with the bleed-off port **17-X** facing the right hand side (exhaust manifold) of the engine. Make sure the injector is pushed fully into the cylinder head.

5 Torque tighten the injector clamp bolt **17-3**, see ⇨ ***Table 18. Torque Settings (7-15)***

Table 18. Torque Settings

Item	Nm	lbf ft
3	24	17.7

After Replacing

1 Replace the rocker cover, see ***Section 12 Base Engine, Cylinder Head.***

2 Reconnect the high pressure and fuel bleed-off lines, see ***Fuel Lines - Removal and Replacement.***

3 Start the engine and check for fuel leaks.

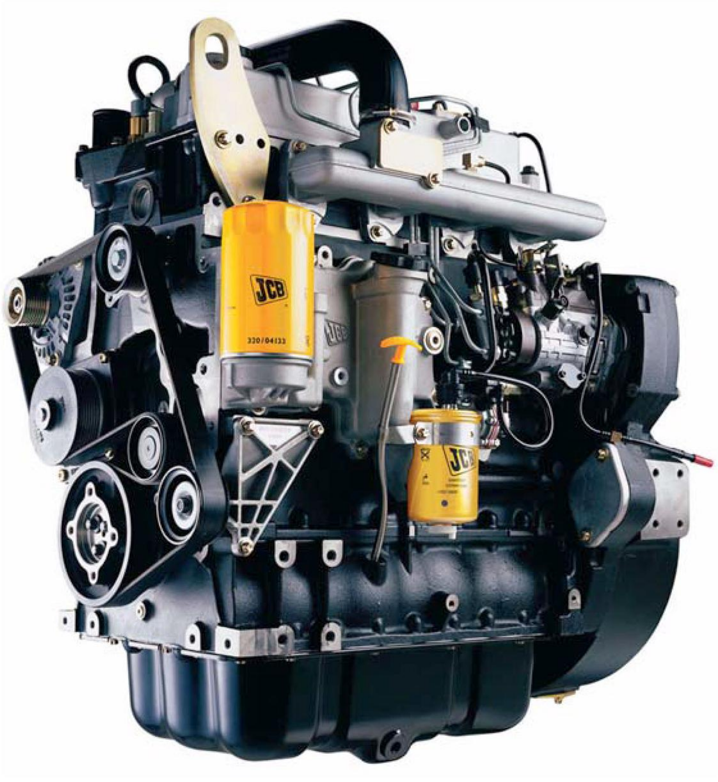
Bleeding Air From The System

Bleeding Air From The System

The procedure for bleeding air from the fuel system is described as part of the routine maintenance procedures, see ***Section 3 Routine Maintenance***.

Cooling System

Service Manual - JCB 444 Engine



Publication No.
9806/3000-02

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Issued by JCB Technical Publications, JCB Aftermarket Training, Woodseat, Rocester, Staffordshire, ST14 5BW, England. Tel +44 1889 591300 Fax +44 1889 591400

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Drive Belt - Coolant Pump

Front End Accessory Drive Belt (FEAD)

Removal and Replacement

The coolant pump and cooling fan (if fitted) is driven by the front end accessory drive belt. The procedure for removing and replacing the belt is described as part of the routine maintenance procedures, see ***Section 3 Routine Maintenance.***

Thermostat

Removal and Replacement

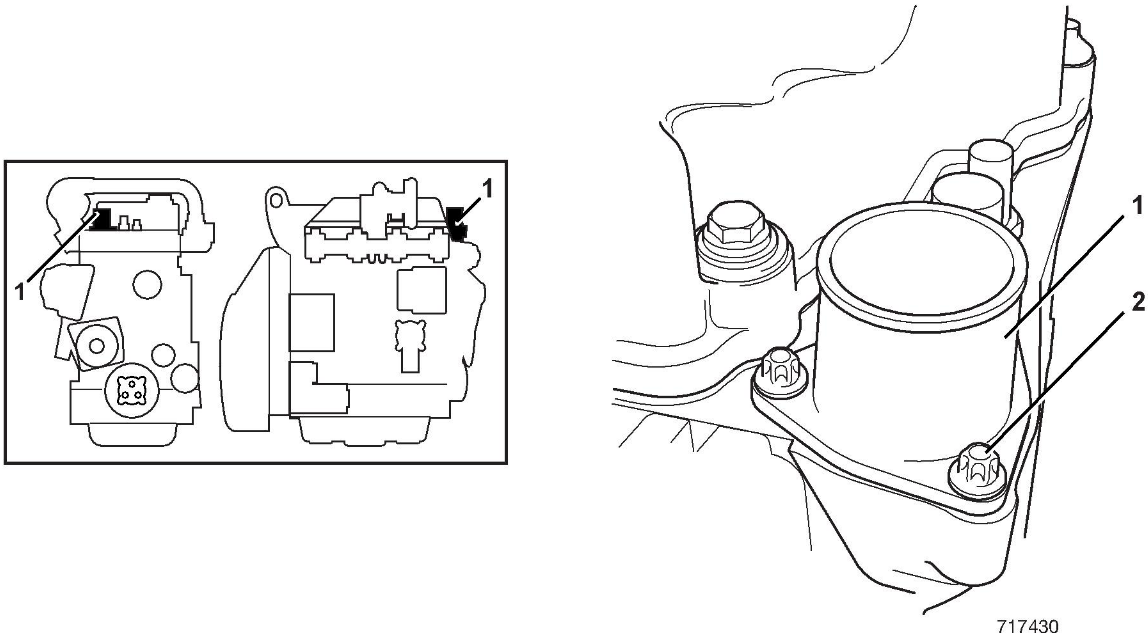


Fig 1.

Table 1. Component Identification

1	Thermostat housing
2	Fixing bolts (3 off)
3	Thermostat

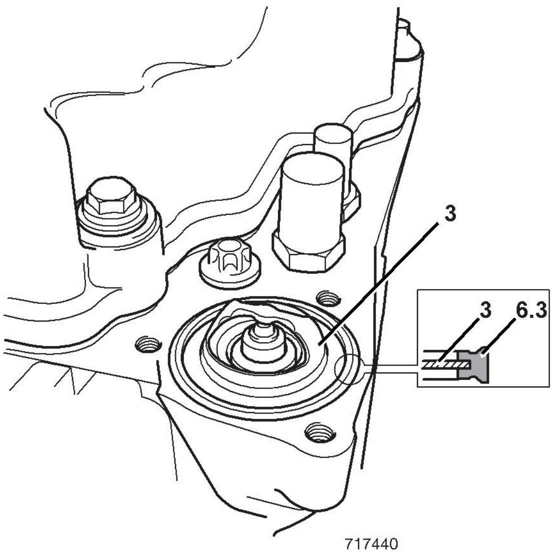


Fig 2.

Table 2. Service Parts

6.3	Seal - thermostat

Table 3. Service Tools

Item	Part Number	Description
T1	General	Star Drive Socket

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

2 Drain the coolant, see ***Section 3 Routine Maintenance***.

Removal

1 Disconnect the radiator hose at the thermostat housing **1-1**.

2 Undo the bolts **1-2** and lift off the housing **1-1**.

3 Lift out the thermostat **2-3**.

If the thermostat is suspected of being faulty, perform tests to confirm its serviceability, see ***Section 6 Test Procedures***. Note that the thermostat is a non serviceable item. If the thermostat is faulty or damaged it must be renewed.

Replacement

Replacement is the reverse of removal but note the following:

1 Inspect the seal **2-6.3** for damage or splits. If necessary renew the seal. Locate the seal correctly as shown.

2 Be sure to fit the thermostat **2-3** the right way up.

3 Torque tighten bolts **1-2**, see ⇨ ***Table 4. Torque Settings (1-2)***

4 Reconnect the radiator hose at the housing **1-1**.

Table 4. Torque Settings

Item	Nm	lbf ft
2	24	17.7

After Replacing

1 Refill the cooling system with the recommended coolant mixture, see ***Section 3 Routing Maintenance***.

2 Start the engine and check for coolant leaks.

Coolant Inlet Assembly

Removal and Replacement

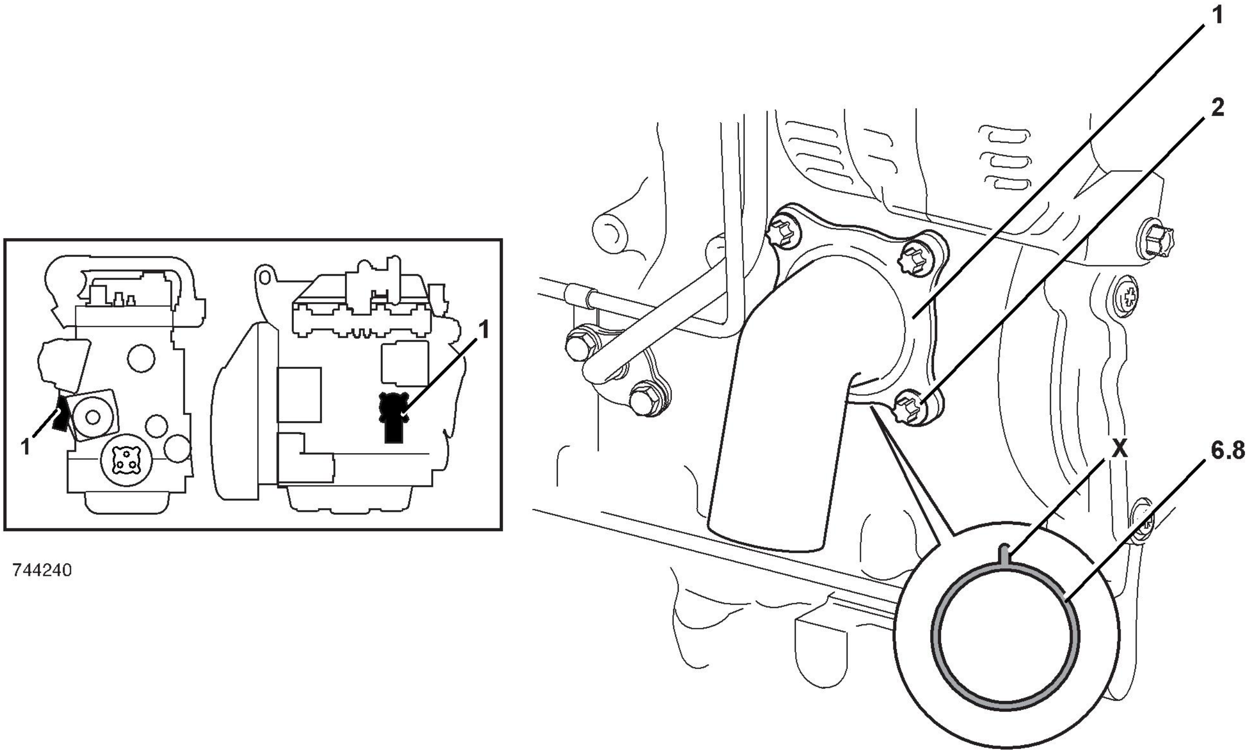


Fig 1.

Table 1. Component Identification

1	Inlet housing
2	Fixing bolts (4 off)
X	Locating tab - sealing ring

Table 2. Service Parts

6.8	Sealing Ring

Table 3. Service Tools

Item	Part Number	Description
T1	General	Star Drive Socket

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

2 Drain the coolant, see ***Section 3 Routine Maintenance.***

Note: *The housing may be orientated differently to that shown in the illustration, depending on the engine installation.*

Removal

1 Disconnect the radiator hose at the inlet housing **1-1**.

2 Undo the bolts **1-2** and lift off the housing **1-1**.

Replacement

Replacement is the reverse of removal but note the following:

1 Make sure that the sealing ring **1-6.8** is undamaged. If necessary fit a new seal. Make sure that the seal is correctly located in its groove on the housing **1-1**. Note the locating tab **1-X**.

2 Torque tighten bolts **1-2**, see ⇨ ***Table 4. Torque Settings (1-2)***.

3 Reconnect the radiator hose at the housing **1-1**.

Table 4. Torque Settings

Item	Nm	lbf ft
2	24	17.7

After Replacing

1 Refill the cooling system with the recommended coolant mixture, see ***Section 3 Routine Maintenance.***

2 Start the engine and check for coolant leaks.

Coolant Pump

Removal and Replacement

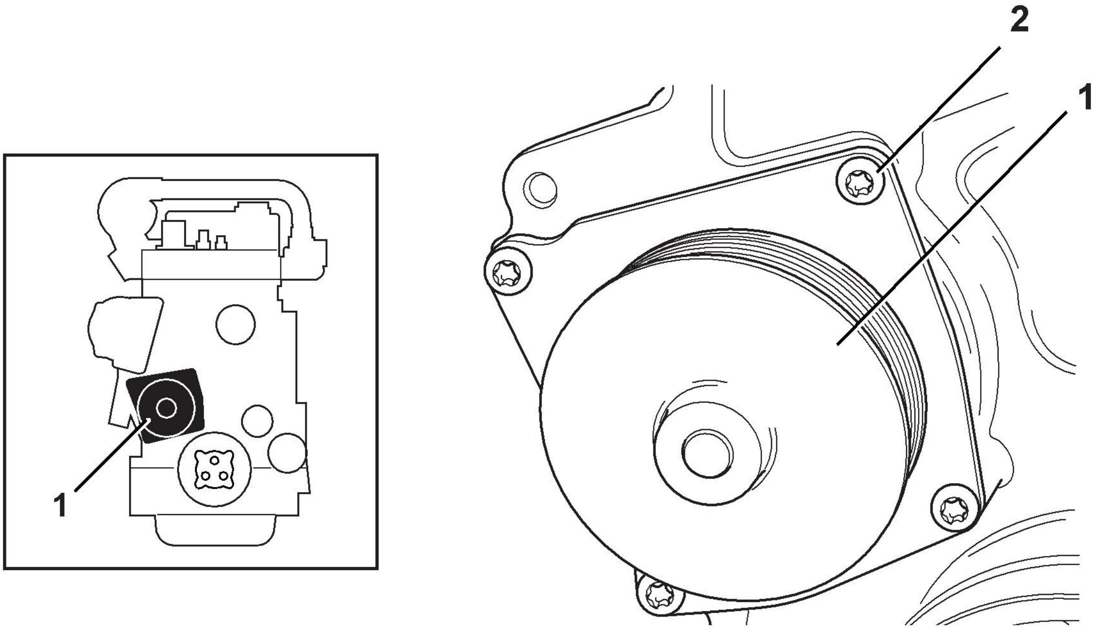


Fig 1.

Table 1. Component Identification

1	Coolant pump assembly
2	Fixing screws (4 off)

Table 2. Service Parts

P1	Sealing `O' ring

Table 3. Service Tools

Item	Part Number	Description
T1	General	Star drive key

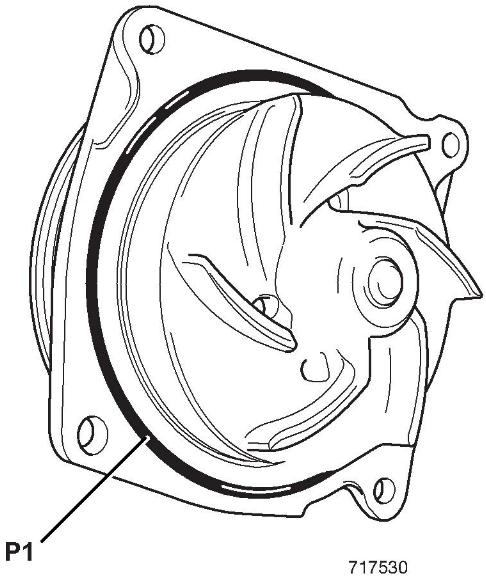


Fig 2.

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

2 Drain the coolant, see ***Section 3 Routine Maintenance.***

3 Remove the coolant pump drive belt (accessory drive belt), see ***Section 3 Routine Maintenance.***

Removal

1 Undo the screws **1-2** and pull off the pump assembly **1-1**.

2 Remove and discard the sealing `O' ring **2-P1**.

Note that the pump is a non serviceable item. If the pump is faulty or damaged it must be renewed.

Replacement

Replacement is the reverse of removal but note the following:

1 Make sure that the mating face on the cylinder block is clean and free from damage.

2 Fit a new sealing `O' ring **2-P1**.

3 Torque tighten screws **2-2**, see ⇨ ***Table 4. Torque Settings (1-2)***

Table 4. Torque Settings

Item	Nm	lbf ft
2	24	17.7

After Replacing

1 Refit the coolant pump drive belt, see ***Section 3 Routine Maintenance.***

2 Refill the engine with the recommended coolant mixture, see ***Section 3 Routine Maintenance***.

3 Start the engine and check for coolant leaks.

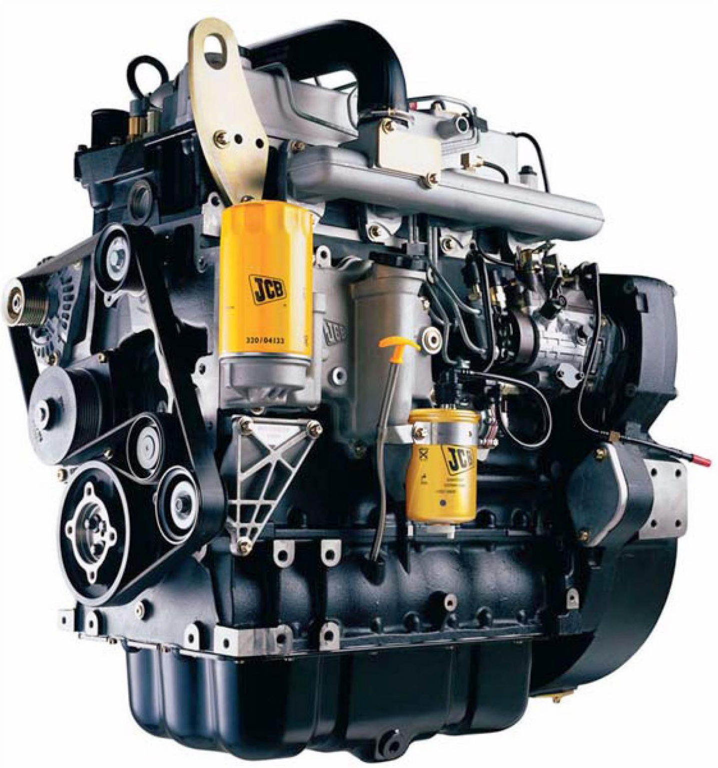
Lubricating Oil Cooler

Removal and Replacement

The lubricating oil cooler is an integral part of the lubrication system, see ***Section 9 Lubrication System - Lubricating Oil Cooler and Filter Head.***

Lubrication System

Service Manual - JCB 444 Engine



Publication No.
9806/3000-02

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Oil Filter Head

Removal and Replacement

The oil filter head is an integral part of the oil cooler assembly, see ***Lubricating Oil Cooler - Removal and Replacement.***

Oil Pan (Sump)

Removal and Replacement

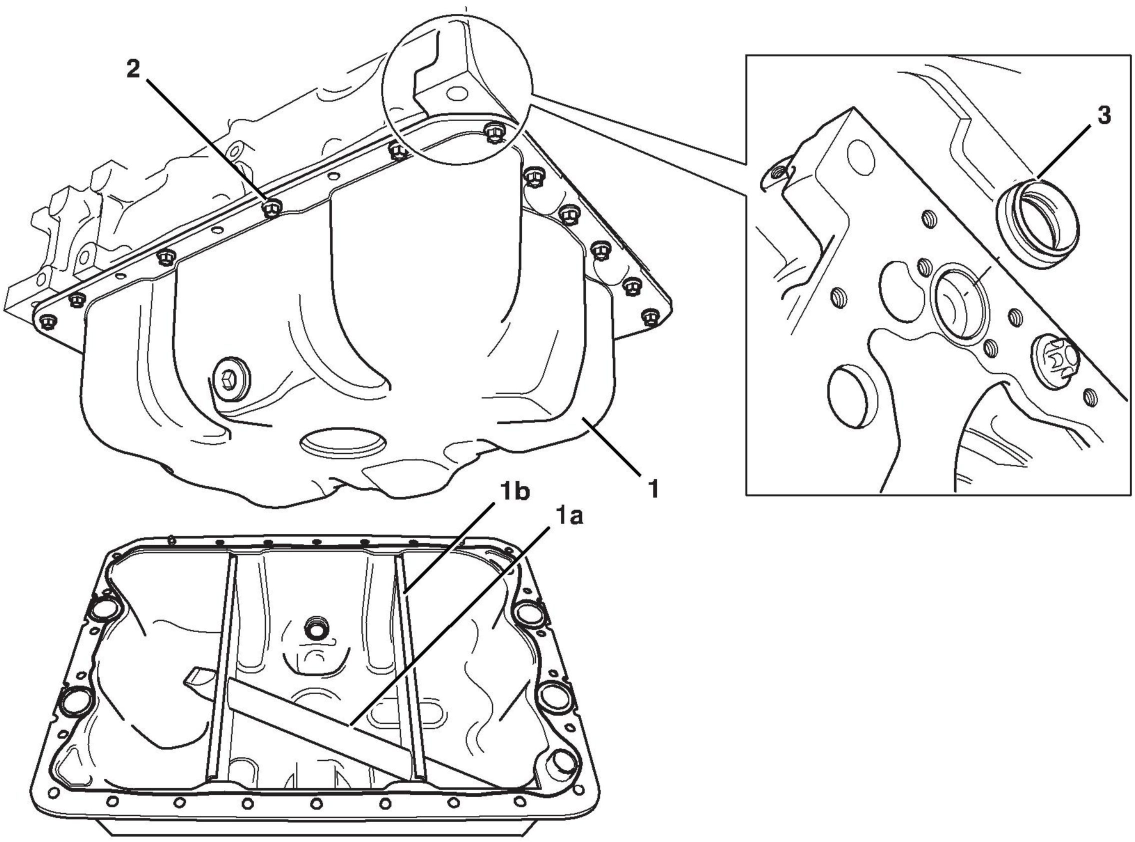


Fig 1.

Table 1. Component Identification

1	Oil pan
1a	Integral suction tube
1b	Integral baffle plates
2	Oil pan fixing bolts (20 off)
3	Oil pick up seal

Table 2. Service Parts

Item	Description
8.4	Silicone Sealant
8.5	Sealant template - oil pan

Table 3. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	892/01150	Oil sump location dowels (2 off)

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

2 Drain the lubricating oil, see ***Section 3 Routine Maintenance.***

Removal

1 Undo the fixing bolts **2-2** and remove the oil pan **2-1** from the engine. The oil pan may be difficult to remove due to adhesion of sealing compound. If necessary, carefully lever the mating flanges apart. DO NOT USE EXCESSIVE FORCE, the oil pan could be damaged. Be sure to retrieve the oil pick up seal **2-3**.

2 Using a gasket removing compound, carefully remove all traces of sealing compound from the oil pan and engine mating faces. DO NOT allow sealing compound to enter the engine.

3 Use a suitable degreasing agent to thoroughly clean the oil pan.

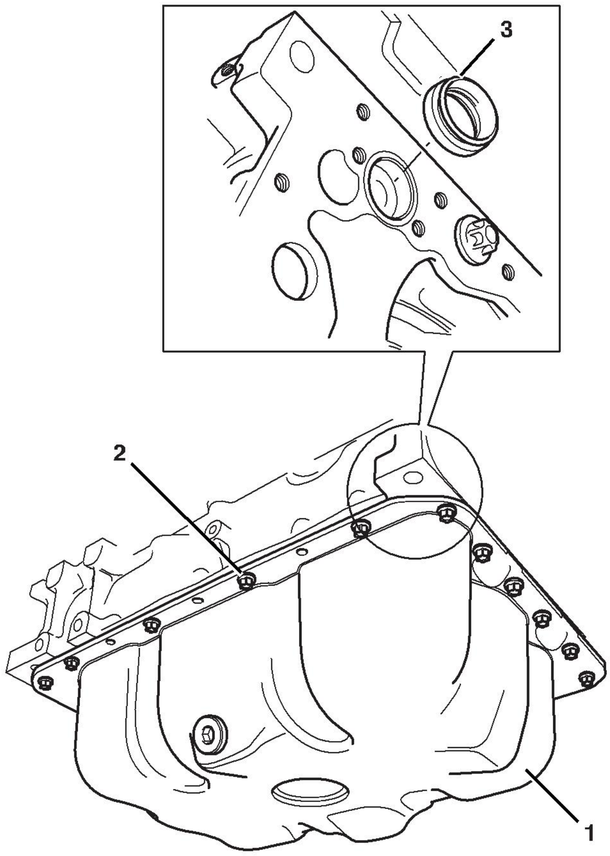


Fig 2.

Replacement

1 Lightly smear new oil pick up seal **3-3** with oil and fit into the bedplate as shown.

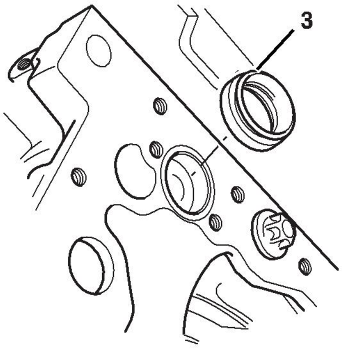


Fig 3.

2 Fit two guide pins **4-T2** at the oil pan screw holes in the engine, see ⇨ *Table 2. Service Parts (9-2)*.

3 Locate the template **4-8.5** to the oil pan mating face using 4 fixing bolts **5-2**. Make sure that the template is the correct way round (note that holes **4-S** and **4-T** are on different centres).

4 Apply a 4 mm bead of sealing compound **P1** around the oil pan flange using the inside edge of the template as a guide as shown. Note the beads around holes **4-S** and **4-T**. Carefully remove the template without smudging the sealant beads.

5 Apply a 4mm beads of sealant **4-X** so as to join the sealant beads around holes **4-S** and **4-T** with the bead around the oil pan flange.

Note: *The oil pan must be fitted and the bolts torque tightened within 5 minutes of applying sealing compound.*

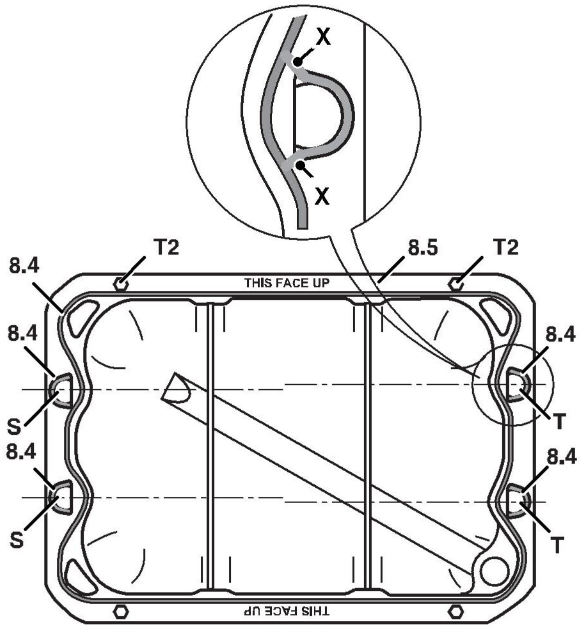


Fig 4.

6 Position the oil pan with the suction tube outlet aligned with the oil pump inlet port on the engine. Take care not to damage the oil pick up seal **3-3** when fitting.

7 Locate the oil pan on the guide pins on the engine. Avoid smudging the sealant beads, DO NOT remove the guide pins until some of the bolts **5-2** have been loosely fitted.

8 Fit the bolts **5-2**. Note that the bolts are not fitted at 6 positions **5-Y**. Torque tighten the bolts **5-2**. ⇨ *Table 4. Torque Settings (9-5)*.

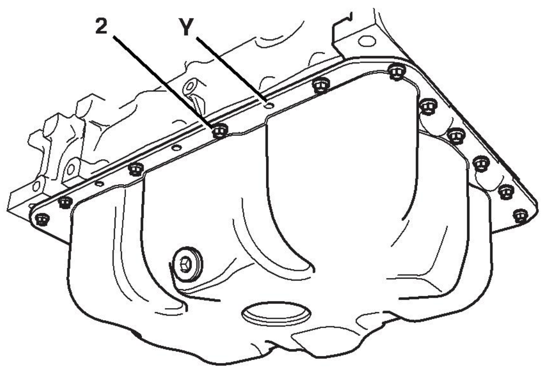


Fig 5.

Table 4. Torque Settings

Item	Nm	lbf ft
2	24	1

After Replacing

1 Allow approximately 20 minutes for the sealant to cure then refill the engine with the recommended lubricating oil, see ***Section 3 Routine Maintenance.***

2 Start the engine and check for oil leaks.

Oil Pump

Removal and Replacement

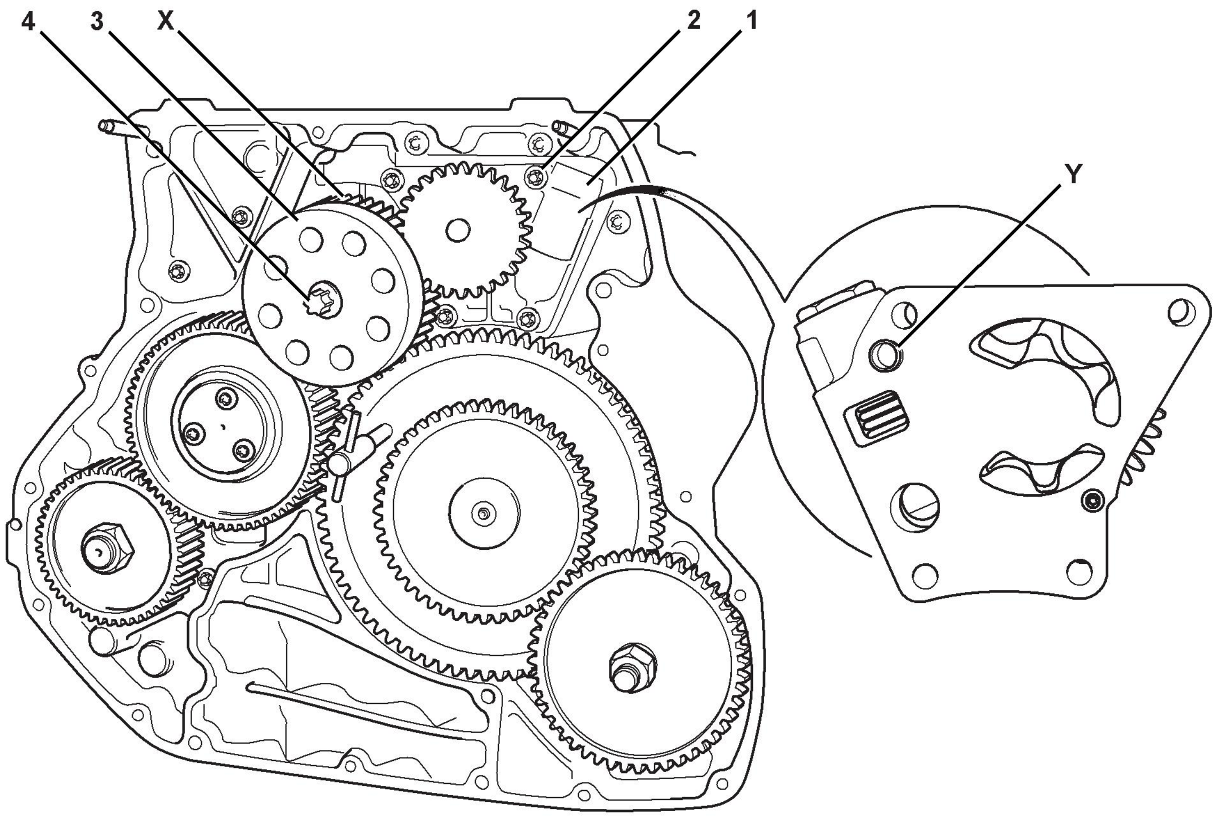


Fig 6.

Table 5. Component Identification

1	Oil pump
2	Oil pump fixing bolts (4 off)
3	Flywheel hub
4	Flywheel hub fixing bolt
X	Crankshaft gear
Y	Oil pump location dowel

Table 6. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Torque wrench

Before Removing

Note: *The illustrations show the engine inverted. If the oil pump is being removed prior to crankshaft or camshaft removal the engine must be inverted. If the oil pump only is being removed (for inspection or renewal) then the engine need not be inverted.*

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Drain the oil from the engine, see ***Section 3 Routine Maintenance***.

3 Remove the starter motor, see ***Section 10 Electrical System - Starter Motor***.

4 Remove the flywheel, see ***Flywheel - Removal and Replacement***.

5 Remove the flywheel housing, see ***Flywheel Housing - Removal and Replacement.***

Removal

1 Undo bolt **6-4** and remove the flywheel hub **6-3**. DO NOT remove the crankshaft gear **6-X**.

2 Undo bolts **6-2** and lift the oil pump **6-1** away from the timing case.

Note that the oil pump is a non serviceable item. If the oil pump is damaged or worn it must be renewed as a complete assembly.

Inspection

1 Check the oil pump internal parts for signs of damage and excessive wear.

2 Using feeler gauges, measure the inner and outer rotor clearance, and the rotor end float to confirm they are within service limits, see ***Section 1 Technical Data.***

Replacement

Replacement is the reverse of removal but note the following:

1 Ensure that all items are clean and free from damage and corrosion.

2 Lubricate the pump rotor with clean engine oil.

3 Make sure the dowel **6-Y** locates into the hole in the timing case.

4 Fit the flywheel hub **6-3** to the crankshaft gear **6-X**, locating on the dowel. Torque tighten the bolts **6-2** and **6-4**, see ⇨ ***Table 7. Torque Settings (9-7)***.

Table 7. Torque Settings

Item	Nm	lbf ft
2	24	17.7
4	47	34.7

After Replacing

1 Refit the flywheel housing, see ***Flywheel Housing - Removal and Replacement.***

2 Refit the flywheel to the crankshaft hub, see ***Flywheel - Removal and Replacement.***

3 Refit the starter motor, see ***Section 10 Electrical System - Starter Motor.***

Lubricating Oil Cooler and Filter Head

Removal and Replacement

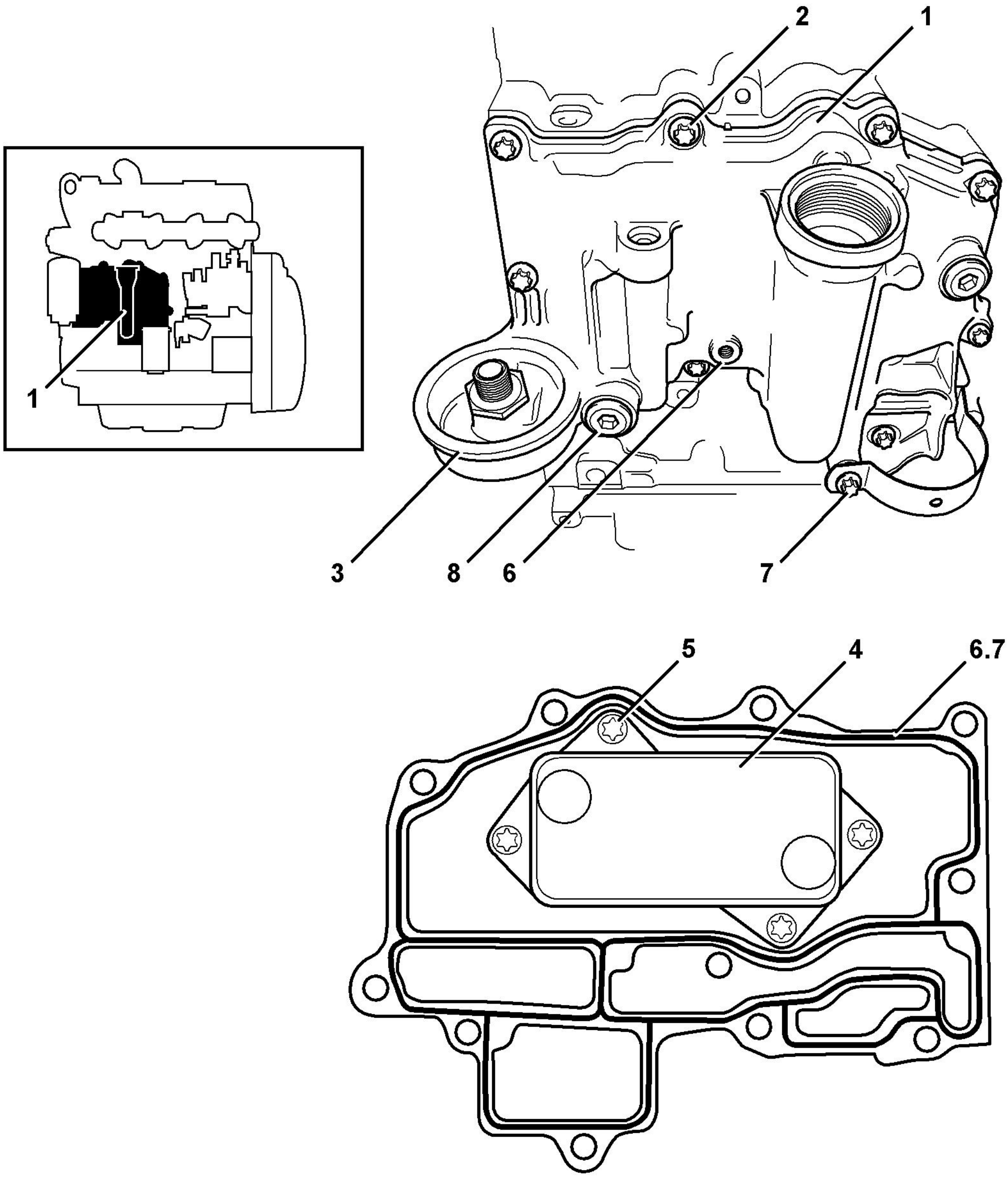


Fig 7.

Table 8. Component Identification

⇨ *Fig 7. (9-8)*	
1	Oil cooler housing
2	Oil cooler housing fixing bolts (11 off)
3	Oil filter head
4	Oil cooler matrix
5	Oil cooler matrix fixing bolts (4 off)
6	Oil pressure switch port
7	Fuel filter/dipstick tube retaining bolt
8	Oil filter drain plug

Table 9. Service Parts

6.7	Sealing Gasket

Table 10. Service Tools

Item	Part Number	Description
A	General	Star Drive Socket

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

2 Drain the coolant, see ***Section 3 Routine Maintenance***.

3 Remove the oil filter, see ***Section 3 Routine Maintenance***.

4 Remove the fuel filter, see ***Section 3 Routine Maintenance***.

Removal

1 Undo bolt **7-7** and release the filter and dipstick tube clips from the cooler housing **7-1**.

2 Uncouple the electrical connector at the oil pressure switch fitted at port **7-6**.

3 Undo the bolts **7-2** and lift the cooler housing **7-1** away from the cylinder block. DO NOT attempt the remove the matrix **7-4** from the housing **7-1**.

Note: *If there is cross contamination of coolant and lubricating oil, the oil cooler matrix may be faulty. If a faulty matrix is suspected renew the matrix and its seals.* ⇨ ***Dismantling, Inspection and Assembly (9-10)***

Replacement

Replacement is the reverse of removal but note the following:

1 Make sure that sealing gasket **7-6.7** is undamaged and correctly located in its groove. A faulty gasket will cause cross contamination of the lubricating oil and coolant. If in doubt fit a new gasket.

2 Torque tighten bolts **7-2**. ⇨ ***Table 11. Torque Settings (9-9)***.

Table 11. Torque Settings

Item	Nm	lbf ft
2	24	17.7

After Replacing

1 Refit the oil filter and fuel filter, see ***Section 3 Routine Maintenance.***

2 Refill the cooling system with the recommended coolant mixture, see ***Section 3 Routing Maintenance***.

3 Start the engine and check for oil and coolant leaks.

Dismantling, Inspection and Assembly

Dismantling of the oil cooler and filter head assembly is not necessary unless the cooler matrix or its seals are faulty.

Dismantling

1 Undo the four fixing bolts **8A** and lift off the cooler matrix **8B**.

2 Remove and discard the two sealing O-rings **8C**.

3 Remove the sealing gasket **8D**.

Inspection

1 Inspect the sealing faces on the matrix **8B**, housing **8E** and engine block. Make sure that the faces are clean and free from scale or damage. Inspect the sealing gasket **8D** for signs of damage. If in doubt, renew the gasket.

Assembly

1 Locate new O-rings **8C**. Fit the cooler matrix **8B**. Torque tighten the bolts **8A**. ⇨ *Table 12. Torque Settings (9-10)*.

2 Fit the sealing gasket to the housing **8E**.

Table 12. Torque Settings

Item	Nm	lbf ft
8A	21 - 25	15 - 18

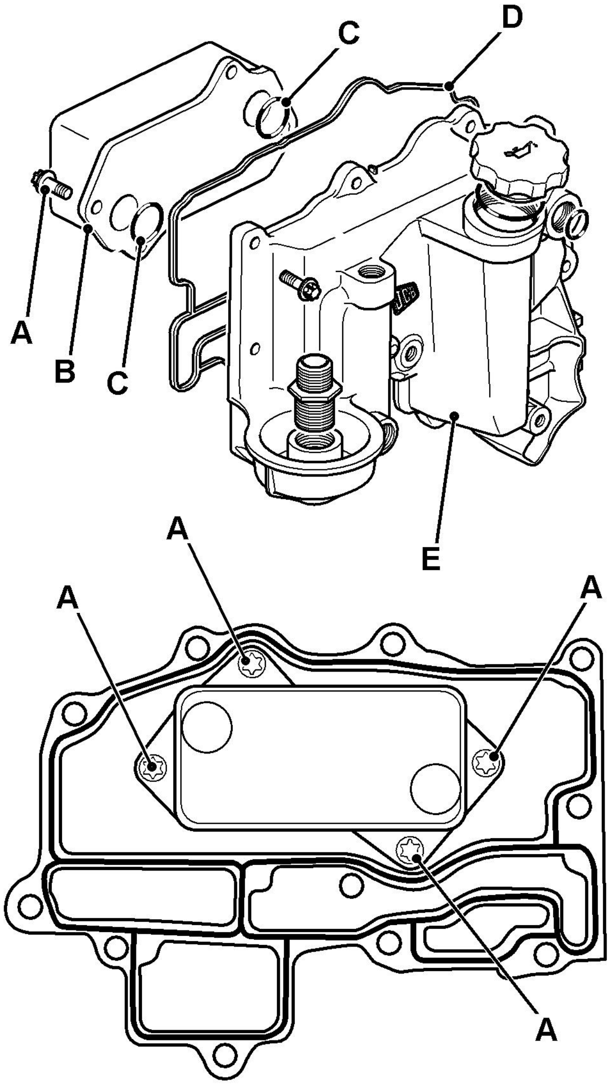
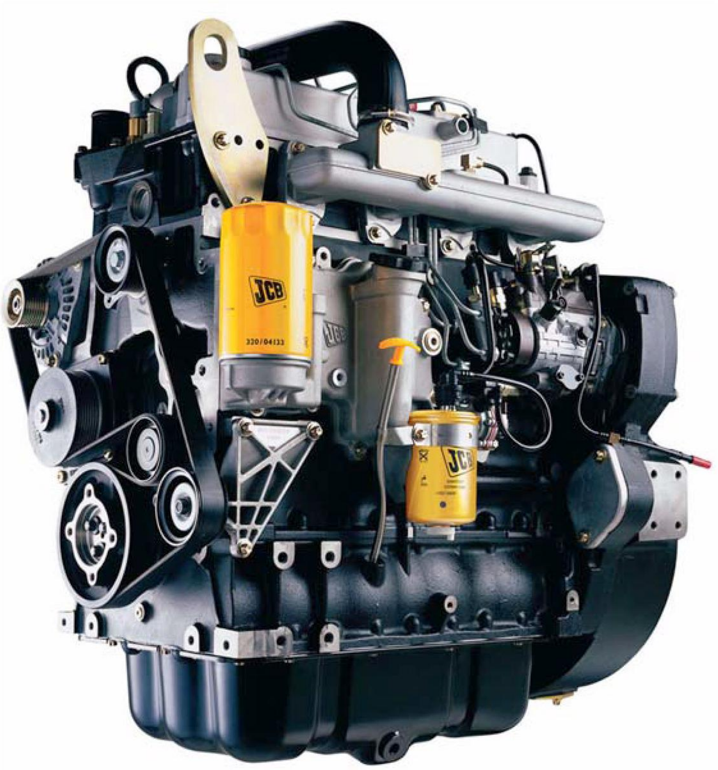


Fig 8.

Section 10

Electrical System

Service Manual - JCB 444 Engine



Publication No.

9806/3000-02

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Starter Motor

Removal and Replacement

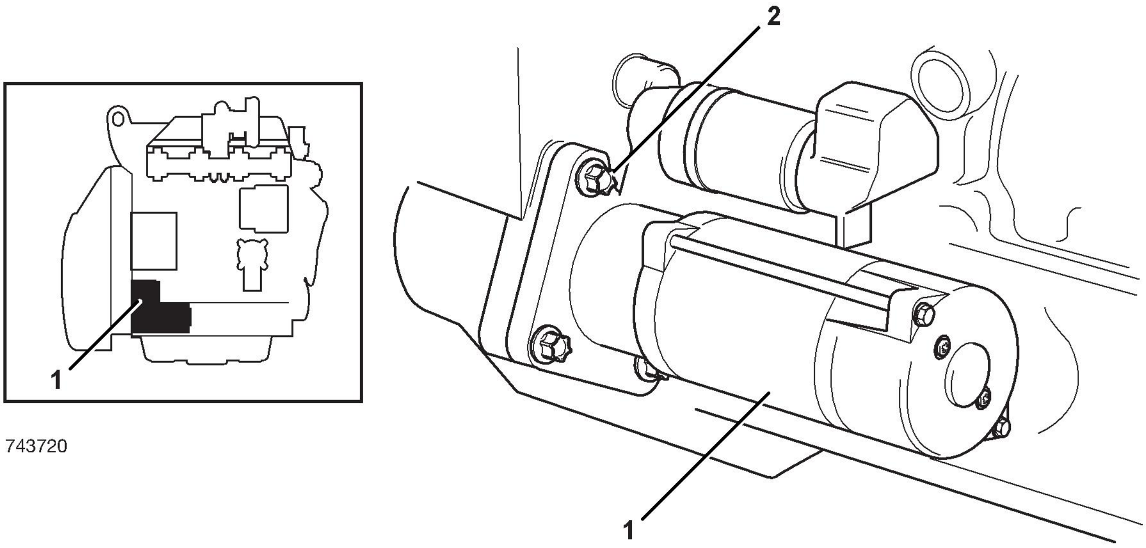


Fig 1.

Table 1. Component Identification

1	Starter motor
2	Fixing bolts (3 off)

Weight - 6.5 Kg (14.3 lb)

Table 2. Service Tools

Item	Part Number	Description
T1	General	Star drive socket

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

2 Disconnect the negative (-) lead followed by the positive (+) lead from the battery terminals.

Removal

1 Disconnect the electrical leads from the starter motor terminals. Label the leads to ensure they are refitted in the correct positions on assembly.

2 Undo the bolts **1-2** and withdraw the starter motor **1-1** from the flywheel housing.

Note: *Service parts are available to repair this item, see* ***Dismantling and Assembly*** *for fitting procedures.*

Inspection

1 Check the drive pinion splines for damage and excessive wear.

2 Check the brushes for wear. Renew the brushes if the length is less than 8 mm (0.3 in), see ***Dismantling and Assembly***.

3 Check the field windings for open or short circuits, see ***Section 6 Test Procedures***.

Replacement

Replacement is the reverse of removal but note the following:

1 Ensure that the flywheel housing and starter motor mating faces are clean.

2 Smear the drive pinion splines with JCB MPL Grease before assembly.

3 Torque tighten bolts **1-2**, ⇨ ***Table 3. Torque Settings (10-2)***.

4 Be sure to reconnect the electrical leads to the starter motor in the correct positions.

5 Reconnect the battery, fit the positive (+) lead first followed by the negative (-) lead.

Table 3. Torque Settings

Item	Nm	lbf ft
2	47	34.7

Dismantling and Assembly

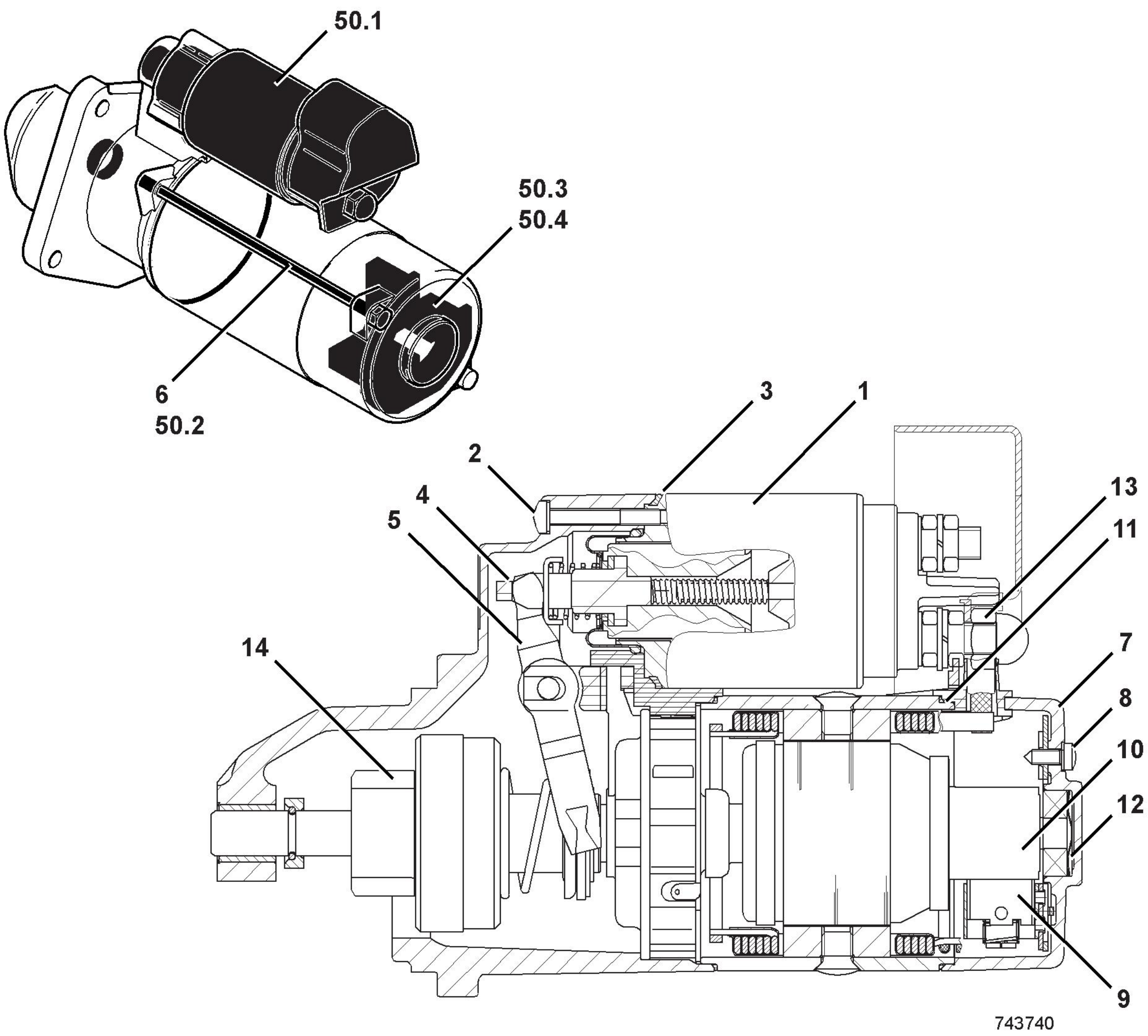


Fig 2.

Table 4. Component Identification

⇨ Fig 2. (10-3)	
1	Starter solenoid
2	Screws - starter solenoid (3 off)
3	Sealing ring - solenoid
4	Solenoid actuator rod
5	Pinion lever arm
6	Tie bolts (2 off)
7	Commutator end cover
8	Screws - commutator end cover (2 off)
9	Brush set
10	Commutator
11	Sealing ring - commutator end cover
12	Wave washer
13	Cable connector post
14	Pinion gear

Table 5. Service Parts

⇨ Fig 2. (10-3)

Item	Description
50.1	Starter Solenoid
50.2	Tie bolts and `O' rings
50.3	Brush holder
50.4	Brushes

Table 6. Service Tools

⇨ Fig 2. (10-3)

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Screwdriver

The following procedures describe the limited dismantling necessary in order to renew the starter solenoid or brush gear. These items are available as service parts, ⇨ *Table 5. Service Parts (10-4)*. If other parts of the starter motor are damaged or faulty then the starter motor must be renewed.

1 Renew the starter solenoid as follows:

a Disconnect the starter motor cable from the solenoid connector post **2-13**.

b Undo screws **2-2** and carefully withdraw the solenoid assembly **2-1**. Discard the solenoid.

c Before fitting the new solenoid, make sure that the sealing ring **2-3** is undamaged and correctly fitted.

d When fitting the new solenoid, be sure to engage the pinion lever arm **2-5** through the hole in the solenoid actuator rod **2-4**, then tighten the screws **2-2**.

e Reconnect the starter motor cable to the solenoid connector post **2-13**.

2 Renew the brush gear as follows:

a Undo tie bolts **2-6** and carefully separate the commutator end cover **2-7**.

b Undo screws **2-8**. Remove and discard the existing brush holder and brushes **2-9** as required and fit new brushes.

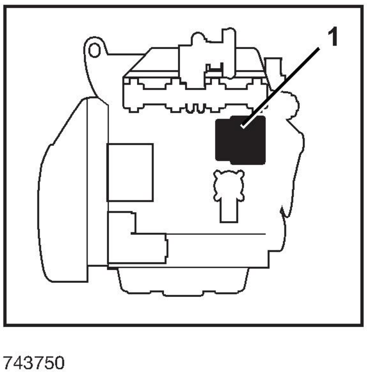
c Clean the commutator **2-10**.

d Before refitting the commutator end cover, make sure that the sealing ring **2-11** is undamaged and correctly fitted. Ensure wave washer **2-12** is fitted inside the cover.

e Carefully fit the commutator end cover, then tighten the tie bolts **2-6**.

Alternator

Removal and Replacement



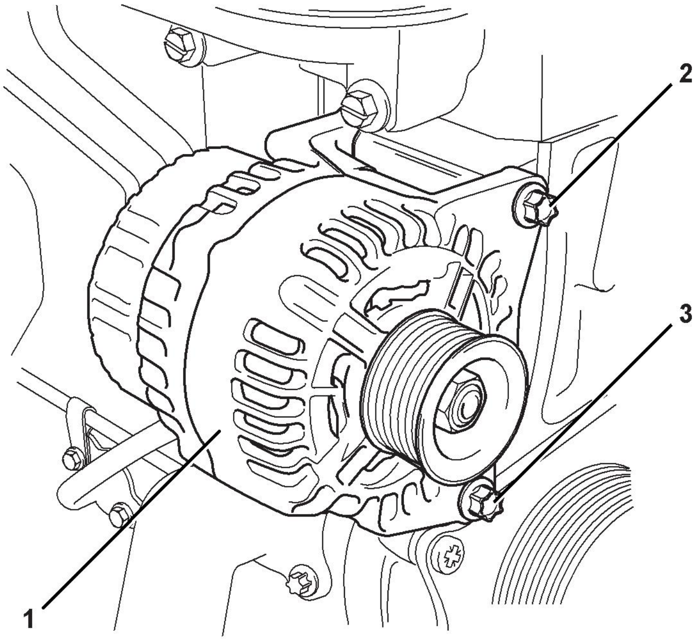


Fig 3.

Table 7. Component Identification

1	Alternator
2	Fixing bolt (long)
3	Fixing bolt (short)

Weight - 7.3 Kg (16.1 lb)

Table 8. Service Tools

Item	Part Number	Description
T1	General	Star drive socket

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

2 Disconnect the negative (-) lead followed by the positive (+) lead from the battery terminals.

3 Remove the alternator drive belt, see ***Section 3 Routine Maintenance.***

Removal

1 Disconnect the electrical leads from the alternator terminals. Label the leads to ensure they are refitted in the correct positions on assembly.

2 Undo the bolts **3-2** and **3-3** and lift the alternator **3-1** away from the cylinder block mounting.

Note: *Service parts available to repair this item, see* ***Dismantling and Assembly*** *for fitting procedures.*

Inspection

1 Check the brushes for wear. Renew the brushes if the length is less than 8 mm (0.3 in), see ***Dismantling and Assembly.***

2 Check the field windings for open or short circuits, see ***Section 6 Test Procedures***.

Replacement

Replacement is the reverse of removal but note the following:

1 It is not necessary to adjust the position of the alternator in order to tension the drive belt, as the auxiliary drive belt arrangement is self-tensioning.

2 Torque tighten bolts **3-2** and **3-3**, ⇨ ***Table 9. Torque Settings (10-6)***.

3 Be sure to reconnect the electrical leads to the alternator in the correct positions.

4 Reconnect the battery, fit the positive (+) lead first followed by the negative (-) lead.

Table 9. Torque Settings

Item	Nm	lbf ft
2	47	34.7
3	47	34.7

After Replacing

1 Refit the alternator drive belt, see ***Section 3 Routine Maintenance***.

2 Check the charge rate, refer to ***Section 6, Test Procedures.***

Dismantling and Assembly

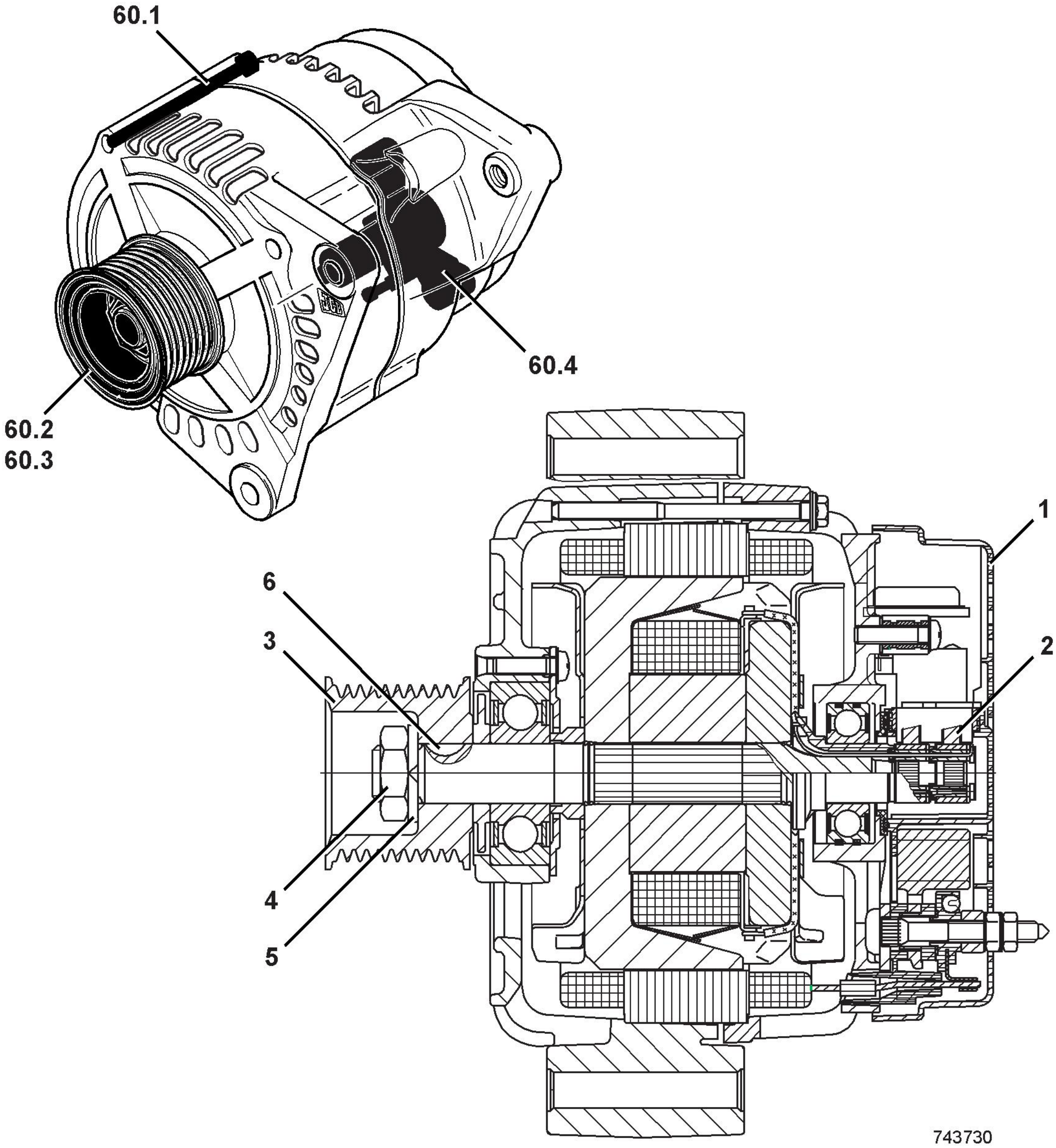


Fig 4.

Table 10. Component Identification

⇒ Fig 4. (10-7)	
1	Cover - brushes
2	Regulator and brush assembly
3	Drive pulley
4	Nut - drive pulley
5	Washer - drive pulley
6	Woodruff key - drive pulley

Table 11. Service Parts

⇒ Fig 4. (10-7)	
Item	**Description**
60.1	Tie bolts
60.2	Pulley
60.3	Nut and spacer
60.4	Regulator and brush box

Table 12. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Screwdriver

The following procedures describe the limited dismantling necessary in order to renew the voltage regulator and brushes assembly or the drive pulley. These items are available as service parts, ⇒ *Table 11. Service Parts (10-8)*. If other parts of the alternator are damaged or faulty then the alternator must be renewed.

1 Renew the voltage regulator and brushes assembly as follows:

- **a** Carefully remove the protective cover **4-1**.
- **b** Withdraw and discard the existing voltage regulator and brushes assembly **4-2** and fit new assembly.
- **c** Refit the protective cover.

2 Renew the drive pulley as follows:

- **a** Undo nut **4-4** and remove washer **4-5**. Using suitable pullers, withdraw the pulley **4-3** from the shaft. Take care to retain the woodruff key **4-6**.
- **b** Fit new drive pulley onto shaft, locating the key.
- **c** Refit the washer and tighten the nut.

Electric Shut-Off Solenoid (ESOS)

Removal and Replacement

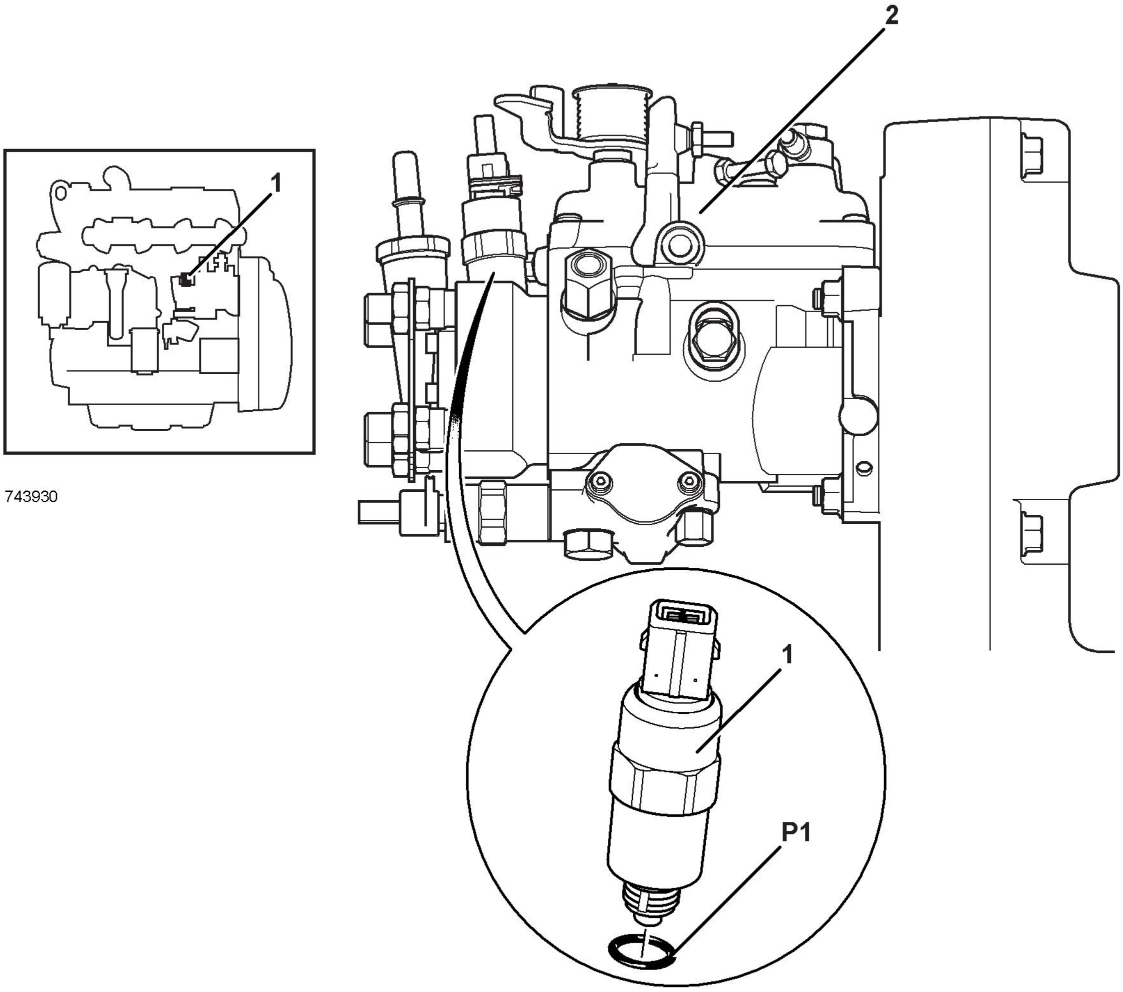


Fig 5.

Table 13. Component Identification

1	Electric shut-off solenoid (ESOS)
2	Fuel injection pump

Table 14. Service Parts

P1	`O' ring - ESOS

Table 15. Service Tools

Item	Part Number	Description
T1	General	Ring spanner

Before Removing

1 Ensure that the engine cannot be started.

Removal

1 Uncouple the electrical connector at the shut-off solenoid (ESOS) **5-1**.

2 Unscrew the shut-off solenoid (ESOS) cartridge from the fuel injection pump body **5-2**. Discard the `O' ring seal **5-P1**. Cap open ports to prevent ingress of dirt.

Note: *The shut-off solenoid (ESOS) is a non serviceable item. If the shut-off solenoid (ESOS) is faulty or damaged it must be renewed. It is essential that the correct solenoid is fitted, as there are types available which operate in the reverse sense or require additional wiring and resistors.*

Table 16. Torque Settings

Item	Nm	lbf ft
1	15	11

Inspection

1 If a faulty solenoid is suspected, perform tests to confirm its serviceability, see ***Section 6 Test Procedures.***

Replacement

Replacement is the reverse of removal but note the following:

1 Renew the `O' ring seal **5-P1**.

2 Torque tighten the shut-off solenoid (ESOS) cartridge, ***⇨ Table 16. Torque Settings (10-10)***.

3 Start the engine and check for fuel leaks.

Cold Start Advance Solenoid

Removal and Replacement

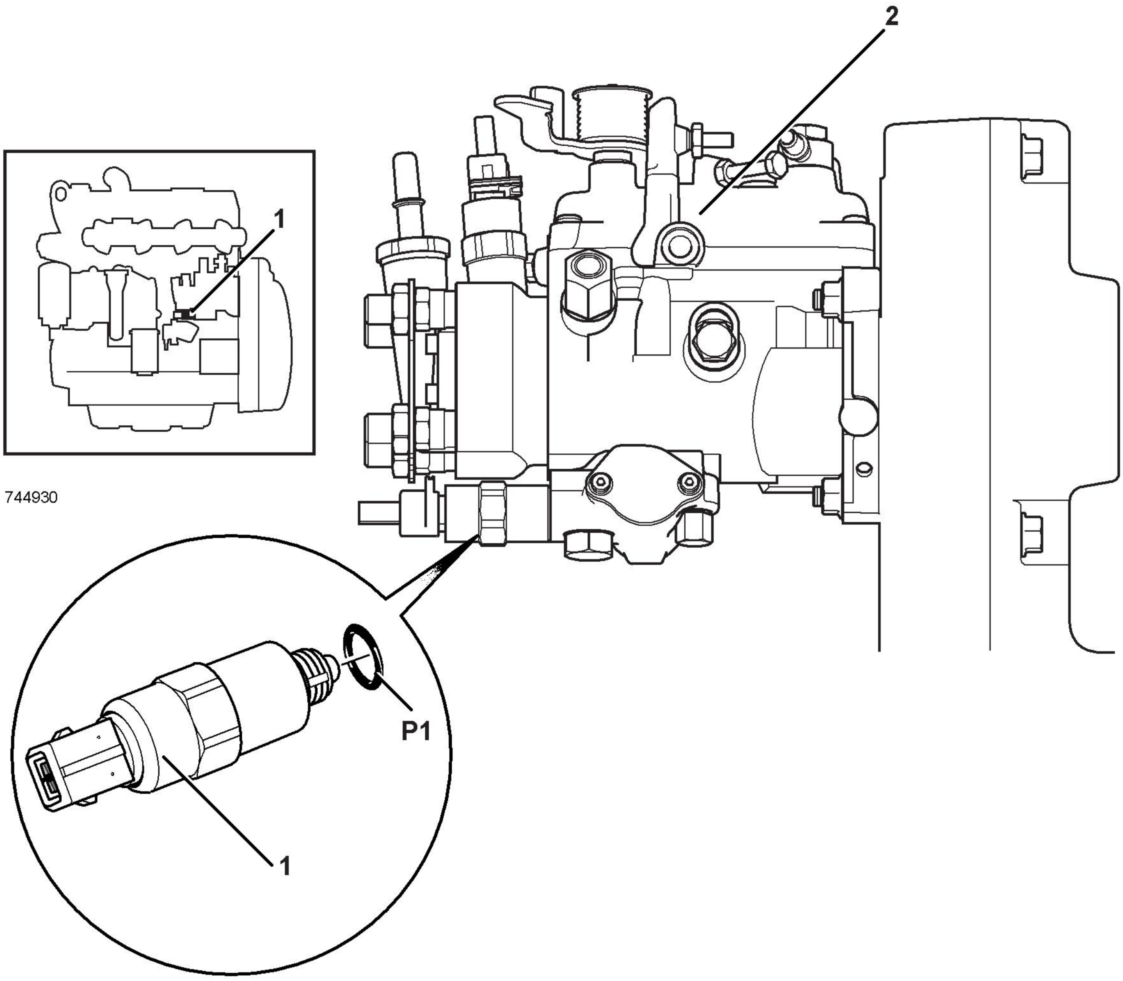


Fig 6.

Table 17. Component Identification

1	Cold start advance solenoid
2	Fuel injection pump

Table 18. Service Parts

P1	\`O' ring - cold start advance solenoid

Table 19. Service Tools

Item	Part Number	Description
T1	General	Ring Spanner

Before Removing

1 Ensure that the engine cannot be started.

Removal

1 Uncouple the electrical connector at the cold start advance solenoid **6-1**.

2 Unscrew the solenoid cartridge from the fuel injection pump body **6-2**. Discard the `O' ring seal **6-P1**. Cap open ports to prevent ingress of dirt.

Note: *The cold start advance solenoid is a non serviceable item. If the solenoid is faulty or damaged it must be renewed. It is essential that the correct solenoid is fitted.*

Inspection

1 If a faulty solenoid is suspected, perform tests to confirm its serviceability, see ***Section 6 Test Procedures.***

Replacement

Replacement is the reverse of removal but note the following:

1 Renew the `O' ring seal **6-P1**.

2 Torque tighten the cold start advance solenoid cartridge, ⇨ *Table 20. Torque Settings (10-12)*.

3 Start the engine and check for fuel leaks.

Table 20. Torque Settings

Item	Nm	lbf ft
1	15	11

Engine Cold Start Switch

Removal and Replacement

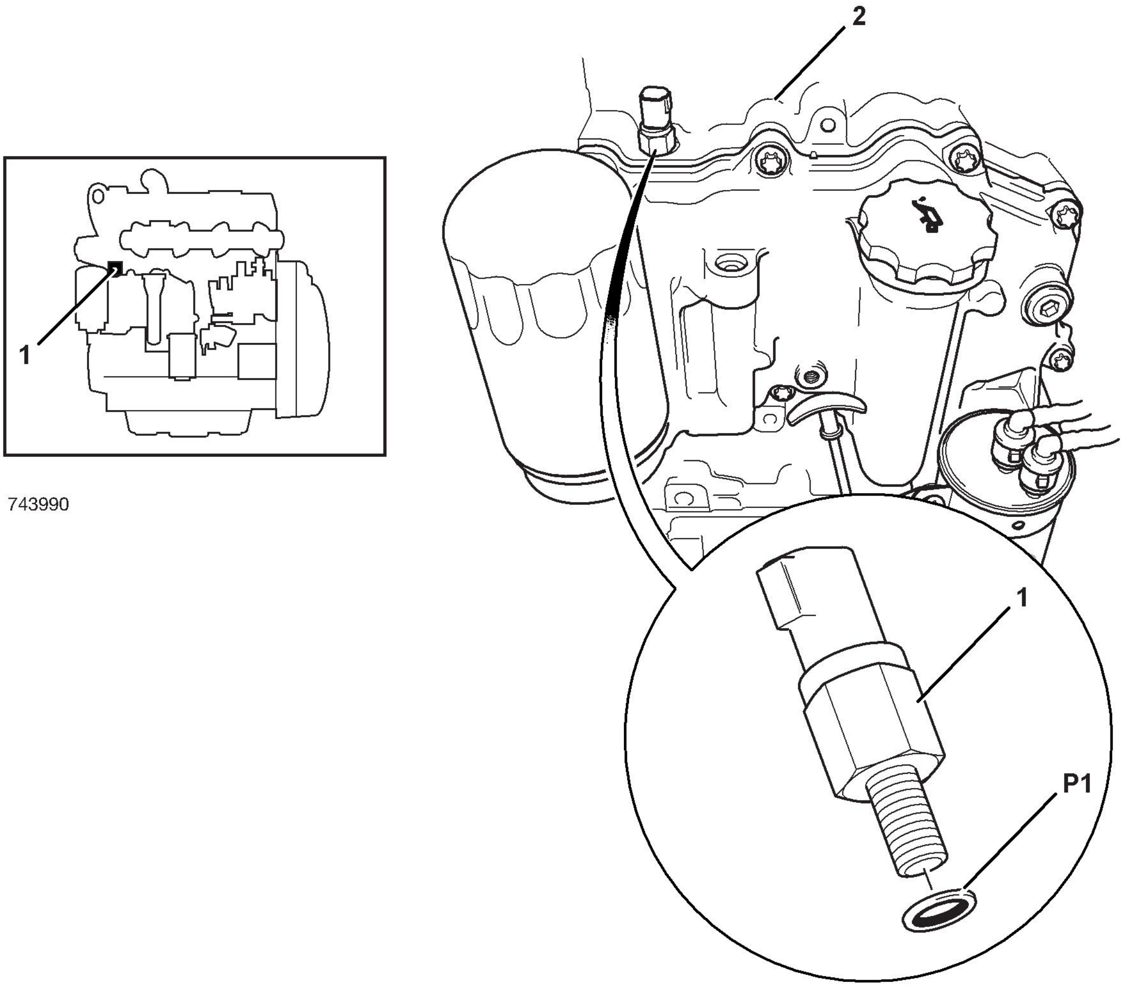


Fig 7.

Table 21. Component Identification

1	Engine cold start switch
2	Cylinder block

Table 22. Service Parts

P1	Sealing washer - switch

Table 23. Service Tools

Item	Part Number	Description
T1	General	Ring spanner

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

2 Drain the coolant, see ***Section 3 Routine Maintenance.***

Removal

1 Uncouple the electrical connector at the engine cold start switch **7-1**.

2 Unscrew the engine cold start switch from the cylinder block **7-2**. Discard the sealing washer **7-P1**. Cap open ports to prevent ingress of dirt.

Note: *The engine cold start switch is a non serviceable item. If the engine cold start switch is faulty or damaged it must be renewed.*

Inspection

1 If a faulty switch is suspected, use a suitable multimeter to check that the correct supply voltage is present at the switch electrical connector. Carry out tests on the parent machine electrical circuits to check for possible wiring faults. The fault may be caused by failure of other components within the electrical system.

Replacement

Replacement is the reverse of removal but note the following:

1 Renew the sealing washer **7-P1**.

2 Torque tighten the engine cold start switch, ⇨ ***Table 24. Torque Settings (10-14)***.

Table 24. Torque Settings

Item	Nm	lbf ft
1	16	12

After Replacing

1 Refill the cooling system with the recommended coolant mixture, see ***Section 3 Routine Maintenance***.

2 Start the engine and check for coolant leaks.

Engine Oil Pressure Switch

Removal and Replacement

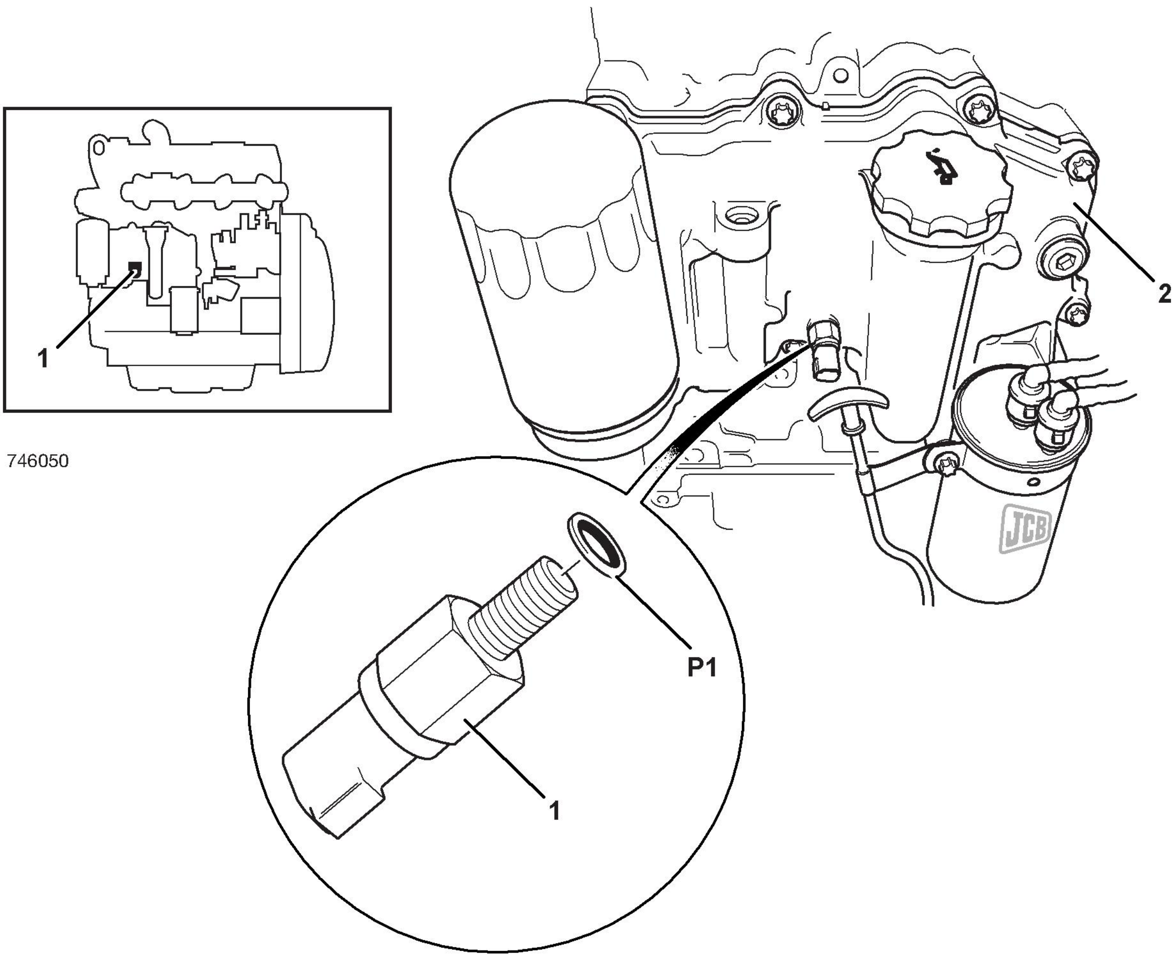


Fig 8.

Table 25. Component Identification

1	Engine oil pressure switch
2	Oil cooler housing

Table 26. Service Parts

P1	Sealing washer - switch

Table 27. Service Tools

Item	Part Number	Description
T1	General	Ring Spanner

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

Removal

1 Uncouple the electrical connector at the engine oil pressure switch **8-1**.

2 Unscrew the switch from the oil cooler housing **8-2**. Discard the sealing washer **8-P1**. Note that some oil will be lost from the open port. Cap open ports to prevent ingress of dirt.

Note: *The engine oil pressure switch is a non serviceable item. If the switch is faulty or damaged it must be renewed.*

Inspection

1 If a faulty switch is suspected, use a suitable multimeter to check that the correct supply voltage is present at the switch electrical connector. Carry out tests on the parent machine electrical circuits to check for possible wiring faults. The fault may be caused by failure of other components within the electrical system.

Replacement

Replacement is the reverse of removal but note the following:

1 Renew the sealing washer **8-P1**.

2 Torque tighten the engine oil pressure switch. ⇨ ***Torque Settings (10-16)***.

Table 28. Torque Settings

Item	Nm	lbf ft
1	16	12

Coolant Temperature Sender Unit

Removal and Replacement

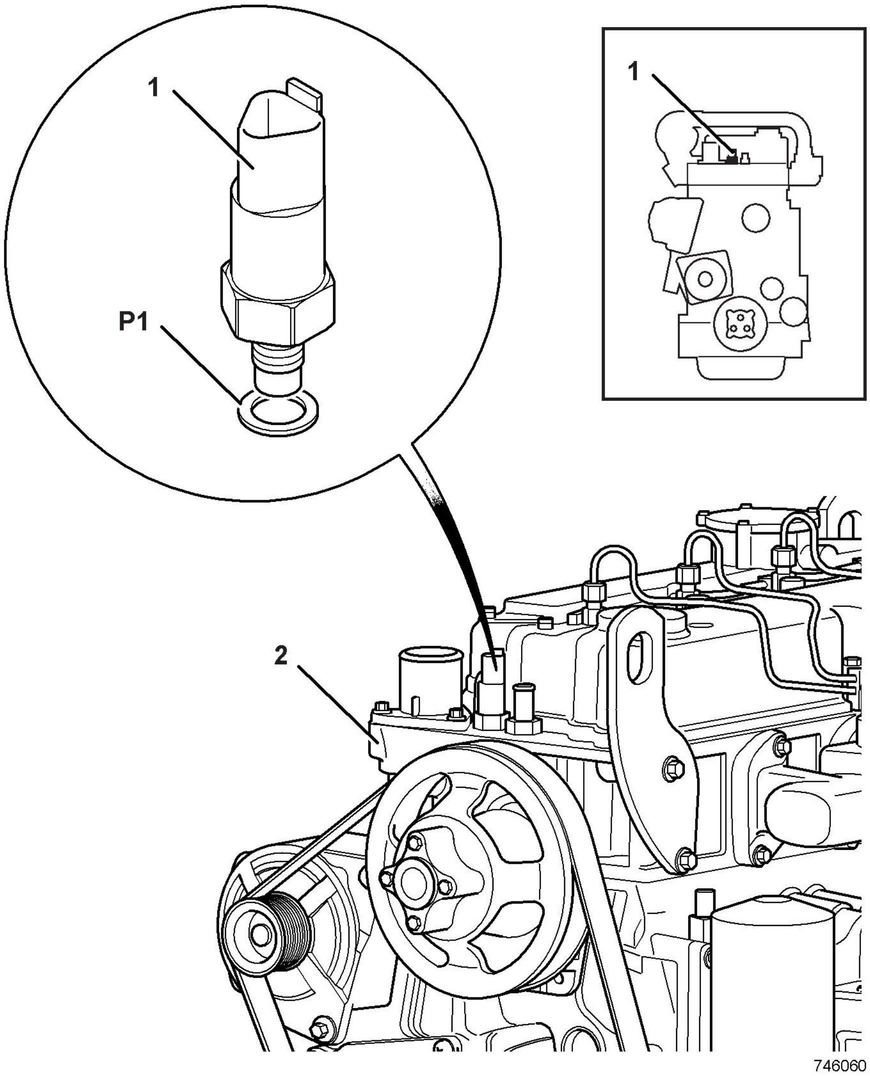


Fig 9.

Table 29. Component Identification

⇨ *Fig 9. (10-17)*	
1	Coolant temperature sender unit
2	Cylinder head

Table 30. Service Parts

⇨ *Fig 9. (10-17)*	
P1	Sealing washer - sender unit

Table 31. Service Tools

Item	Part Number	Description
T1	General	Ring spanner

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

2 Drain the coolant, see ***Section 3 Routine Maintenance.***

Removal

1 Uncouple the electrical connector at the sender unit **9-1.**

2 Unscrew the sender unit from the cylinder head **9-2**. Discard the sealing washer **9-P1**. Cap open ports to prevent ingress of dirt.

Note: *The coolant temperature sender unit is a non serviceable item. If the switch is faulty or damaged it must be renewed.*

Inspection

1 If a faulty sender unit is suspected, use a suitable multimeter to check that the correct supply voltage is present at the sender unit electrical connector. Carry out tests on the parent machine electrical circuits to check for possible wiring faults. The fault may be caused by failure of other components within the electrical system.

Replacement

Replacement is the reverse of removal but note the following:

1 Renew the sealing washer **9-P1**.

2 Torque tighten the sender unit, ⇨ ***Table 32. Torque Settings (10-18)***.

Table 32. Torque Settings

Item	Nm	lbf ft
1	16	12

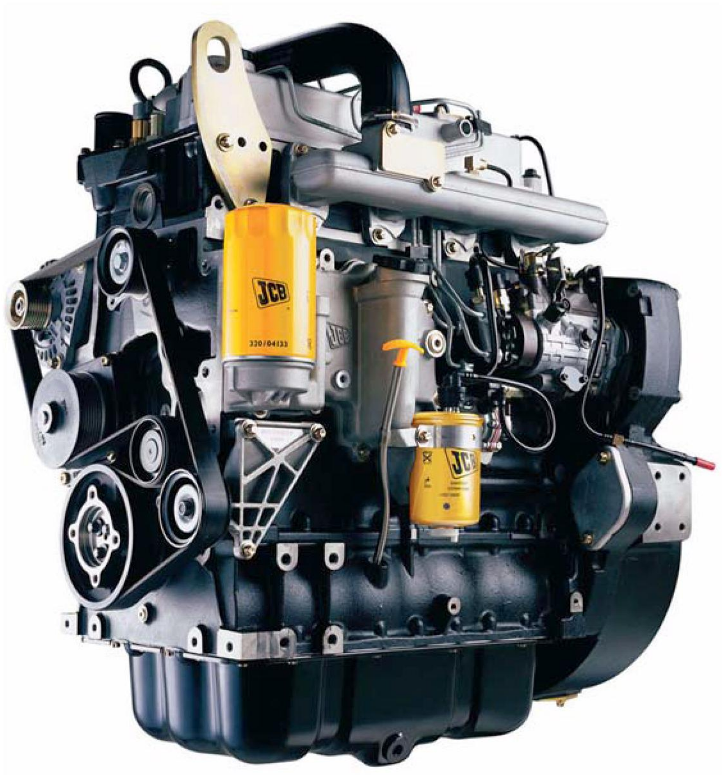
After Replacing

1 Refill the cooling system with the recommended coolant mixture, see ***Section 3 Routine Maintenance.***

2 Start the engine and check for coolant leaks.

Induction and Exhaust System

Service Manual - JCB 444 Engine



Publication No.

9806/3000-02

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Turbocharger

Removal and Replacement

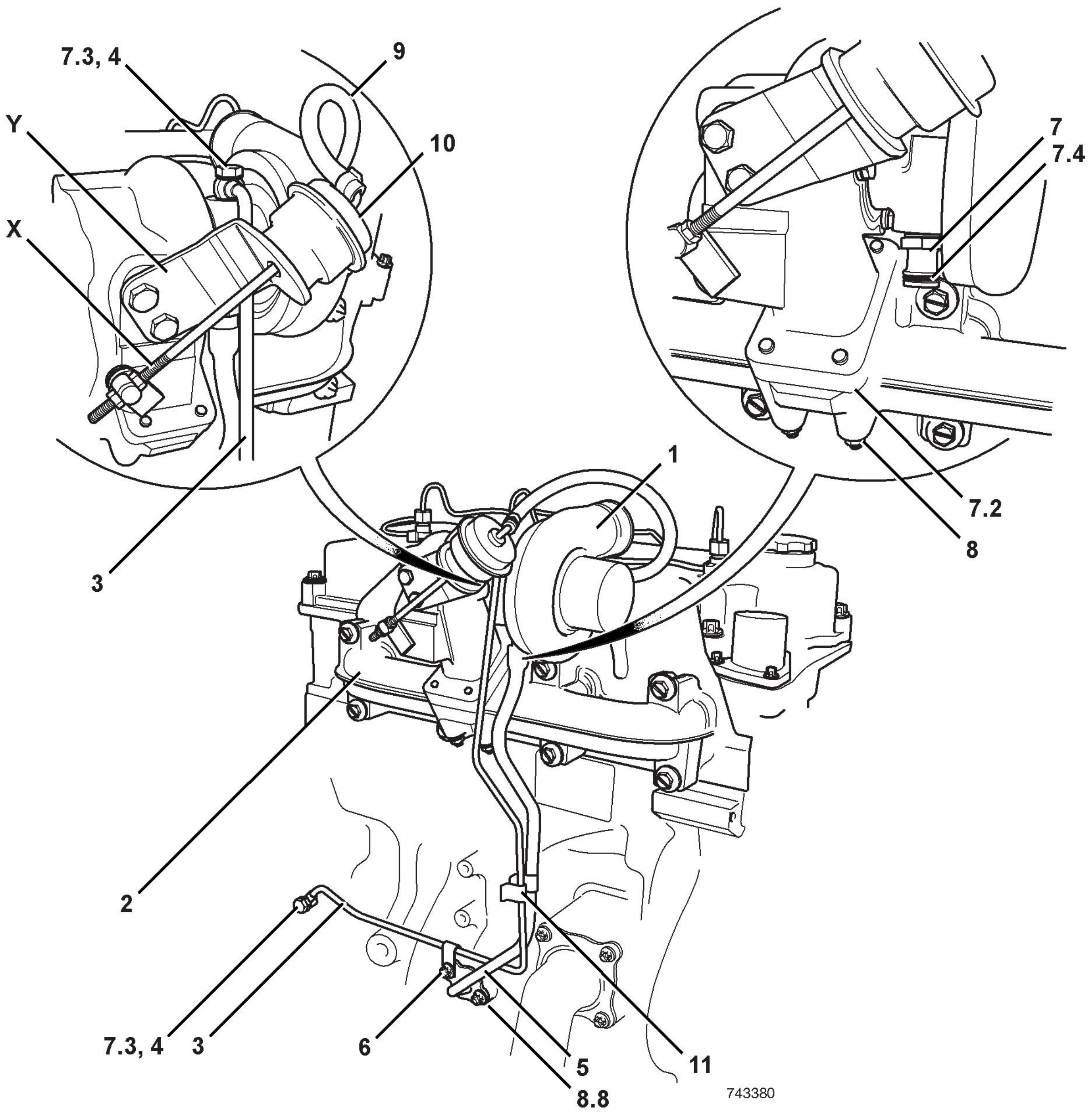


Fig 1.

Table 1. Component Identification

⇨ Fig 1. (11-1)	
1	Turbocharger
2	Exhaust manifold
3	Oil feed pipe (turbo bearing)
4	Banjo bolts (2 off)
5	Oil drain pipe (turbo bearing)
6	Fixing bolts (2 off)
7	Pipe adaptor (drain connection)
8	Retaining nuts (4 off)
9	Boost air hose - wastegate
10	Actuator - wastegate
11	Pipe clip
X	Operating rod - wastegate
Y	Mounting bracket - wastegate

Table 2. Service Parts

Item	Description
7.1	Gasket - exhaust manifold
8.8	Gasket - oil drain pipe
7.4	`O' ring - oil drain pipe connector
7.3	Sealing washers (4 off) - oil feed pipe banjo
7.2	Gasket - turbocharger

Table 3. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Socket wrench

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

Removal

1 Disconnect the air cross-over hose at the inlet manifold and turbocharger. Remove the hose.

2 Remove the pipe clip **1-11**. Undo bolts **1-6** and remove the oil drain pipe **1-5**. Note that the pipe pulls off the pipe adaptor **1-7**, leaving the adaptor in place. Cap open ports to prevent ingress of dirt. Discard the `O' ring **1-7.4** and the gasket **1-8.8**.

3 Undo the banjo bolts **1-4** at each end of the oil feed pipe **1-3**, remove pipe. Cap open ports to prevent ingress of dirt. Discard the sealing washers **1-7.3**.

4 Remove the exhaust manifold **1-2** from the cylinder head complete with the turbocharger **1-1** still fitted, see ***Exhaust Manifold - Removal and Replacement***. Discard the exhaust manifold gasket **1-7.1**.

5 With the exhaust manifold removed from the engine, undo the nuts **1-8** and separate the turbocharger from the manifold. Discard the gasket **1-7.2**.

Note: *If the rotor and bearing housing only are to be renewed there is no need to remove the turbocharger from the exhaust manifold, see* ***Dismantling and Assembly.***

Service parts are available to repair this item, see ***Dismantling and Assembly*** for fitting procedures.

Important: *It is important that the wastegate actuator setting is not altered. The wastegate operating rod* ***1-X*** *is factory set and sealed. DO NOT remove the actuator* ***1-10****, mounting bracket* ***1-Y*** *or make any adjustment to the wastegate actuator operating mechanism.*

Inspection

1 Make sure that the boost air hose **1-9** is free from damage and connected correctly at the turbocharger and wastegate actuator **1-10**.

2 Check that the turbine and compressor blades inside the turbocharger rotate freely and smoothly by hand. If the blades are stiff to turn, or damaged the turbocharger rotor and bearing assembly must be renewed, see ***Turbocharger - Dismantling and Assembly***.

3 Make sure that the oil feed pipe **3** and oil drain pipe **5** are clear and free from debris and sludge.

Replacement

Replacement is the reverse of removal but note the following:

1 Renew all `O' rings, sealing washers and gaskets.

2 Note that the exhaust manifold gasket **1-7.1** also functions as a heat shield. Be sure to position the gasket the correct way round.

3 Torque tighten nuts **1-8**, bolts **1-6** and banjo bolts **1-4**, ⇨ *Table 4. Torque Settings (11-3)*.

Table 4. Torque Settings

Item	Nm	lbf ft
4	12	8.8
6	24	17.7
8	24	17.7

After Replacing

1 Start the engine and check for exhaust leaks.

2 Test the turbocharger boost pressure, see ***Section 6 Test Procedures.***

Dismantling and Assembly

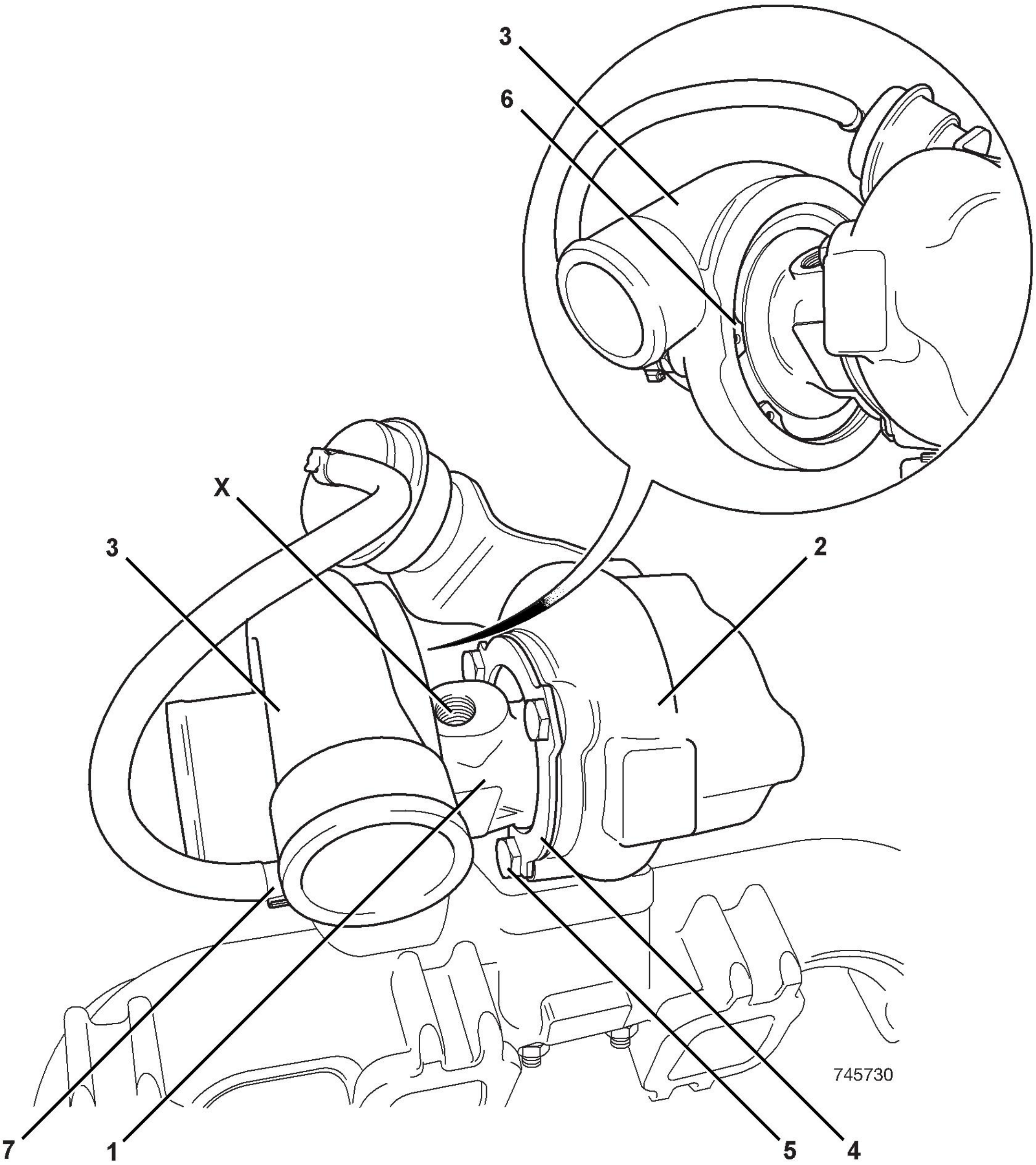


Fig 2.

Table 5. Component Identification

1	Rotor and bearing housing
2	Turbine (exhaust) casing
3	Compressor (air) casing
4	Clamp plate
5	Clamp plate fixing bolts (3 off)
6	Circlip
7	Pipe clip - boost hose
X	Bearing oil feed port

Table 6. Service Parts

Item	Description
P1	Rotor and bearing housing

Table 7. Service Tools

Item	Part Number	Description
T1	General	Socket wrench
T2	General	Circlip pliers - internal

Dismantling

The following procedure describes the limited dismantling necessary in order to renew the turbocharger rotor and bearing housing **2-1**, which may be available as a replacement part. Generally, the turbocharger does not need to be separated from the exhaust manifold to renew the rotor and bearing housing.

1 Release the clip **2-7** and pull off the boost air hose.

2 Make reference marks on the turbine (exhaust) casing **2-2** and on the compressor (air) casing **2-3**, to indicate the relative position of the bearing oil feed port **2-X**, so that the new rotor and bearing housing can be aligned in the correct position on assembly.

3 Undo bolts **2-5**, remove the clamp plate **2-4** and carefully lift out the rotor and bearing housing **2-1** complete with the compressor (air) casing **2-3** still attached.

4 Carefully remove the circlip **2-6** and separate the compressor (air) casing **2-3**.

Assembly

Note: *Use extreme care when handling the turbocharger assembly. The turbine and compressor blades are easily bent. Any damage to the blades will cause the unit to be out of balance and unusable.*

1 Assemble the new rotor and bearing housing into the compressor (air) casing. Orientate the bearing oil feed port into the correct position relative to the reference marks made previously, then refit the circlip.

2 Fit the assembly into the turbine (exhaust) casing and refit the clamp plate and bolts. Orientate the assembly into the correct position, before tightening the bolts. Torque tighten bolts **2-5**. ⇨ ***Table 8. Torque Settings (11-5)***

Table 8. Torque Settings

Item	Nm	lbf ft
2-5	22	16

Exhaust Manifold

Removal and Replacement

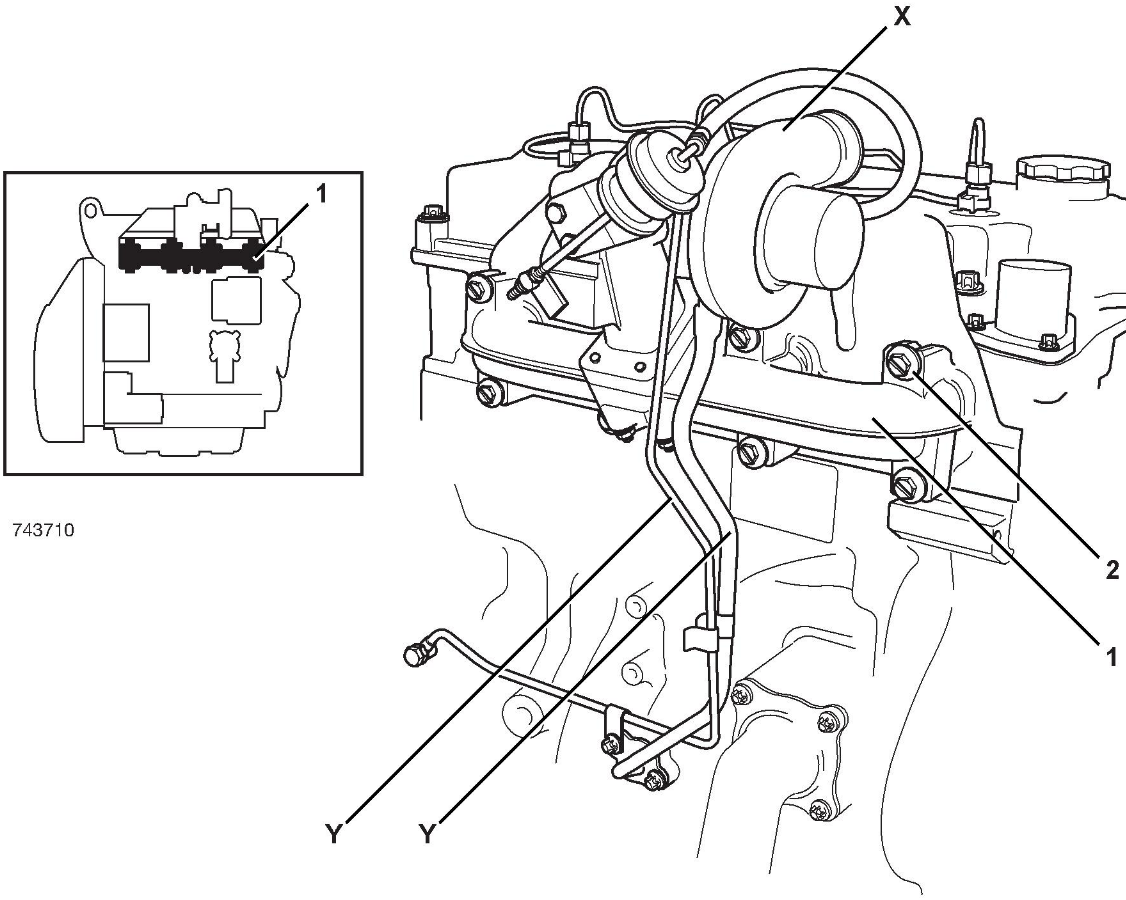


Fig 3.

Table 9. Component Identification

1	Exhaust manifold
2	Fixing bolts (8 off)
X	Turbocharger (turbocharged engines only)
Y	Oil pipes (turbocharged engines only)

Table 10. Service Parts

6.5	Manifold gasket

Table 11. Service Tools

Item	Part Number	Description
T1	General	13 mm socket
T2	General	Torque wrench

Before Removing

Note that the illustration shows an engine with a turbocharger **3-X** fitted.

1. This procedure requires service parts. Make sure you have obtained the correct service parts before you start, ⇨ ***Table 10. Service Parts (11-6)***.

2. Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

3. **Turbocharged Engines Only**: Disconnect the oil pipes **3-Y** to the turbocharger, see ***Turbocharger - Removal and Replacement.***

Removal

1. Undo the upper four bolts **3-2**.

2. Loosen the lower four bolts and lift the exhaust manifold **3-1** from the cylinder head. Remove the bolts and discard the gasket.

3. Cap the exhaust ports to prevent ingress of dirt.

Inspection

1. Check the manifold mating faces for signs of damage and distortion.

2. Check the manifold casting for signs of cracks.

Replacement

Replacement is the reverse of removal but note the following:

1. Renew the manifold gasket **3-6.5**.

2. Fit the lower 4 bolts, together with the new exhaust gasket to the cylinder head (screw in the bolts approximately 8 mm).

3. Rest the manifold in position on the row of lower bolts by locating the slots, then fit the remaining 4 upper bolts.

4. Torque tighten bolts **3-2**, ⇨ ***Table 12. Torque Settings (11-7)***.

Table 12. Torque Settings

Item	Nm	lbf ft
2	25	18.5

After Replacing

1 Reconnect the oil pipes to the turbocharger (turbocharged engines only).

2 Refit the exhaust pipe and silencer box.

3 Start the engine and check for exhaust leaks.

Inlet Manifold

Removal and Replacement

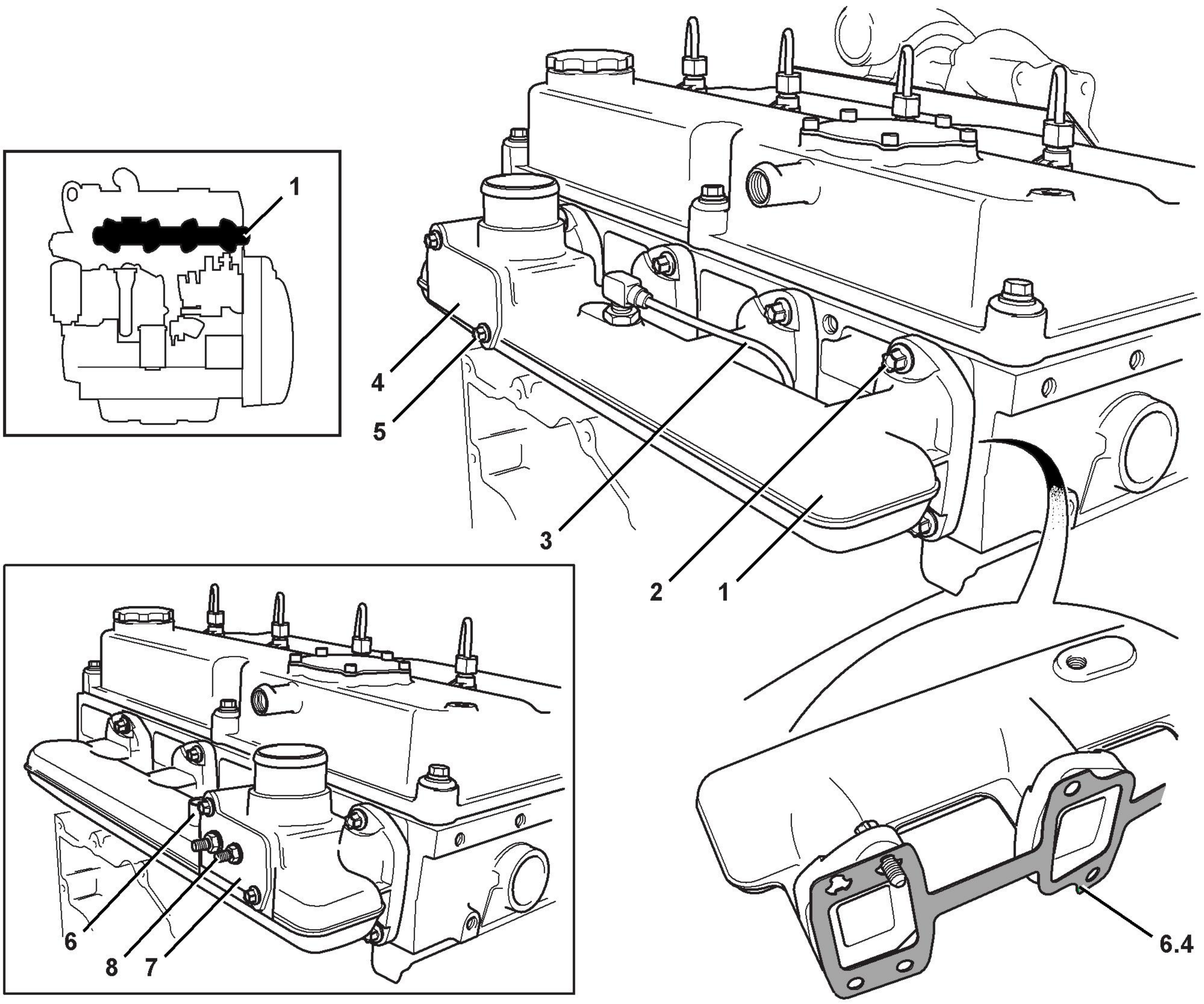


Fig 4.

Table 13. Component Identification

1	Inlet manifold
2	Fixing bolts (8 off)
3	Boost control pipe (Turbocharged engines only)
4	Grid heater blanking plate (if fitted)
5	Fixing bolts (2 off)
6	Breather pipe connector (Naturally aspirated engines only)
7	Grid heater (if fitted)
8	Electrical connection, grid heater (if fitted)

Table 14. Service Parts

6.4	Manifold gasket
6.6	Intake heater gasket (Grid heater or blanking plate as applicable)

Table 15. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Torque wrench

Before Removing

1. This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.
2. Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

Removal

1. **Turbocharged Engines Only**: Disconnect the boost control pipe **4-3** from the adaptor.
2. **Naturally Aspirated Engines Only**: Disconnect the breather hose at the manifold connection **4-6**.
3. Disconnect the grid heater electrical cable at the heater connector **4-8** (if fitted).
4. Disconnect the air inlet hose.
5. Undo bolts **4-2** and lift the inlet manifold **4-1** from the cylinder head. Discard the gasket **4-6.4**.
6. Cap the inlet ports to prevent ingress of dirt.
7. If required, undo bolts **4-5** and remove the blanking plate **4-4** or grid heater **4-7** (if fitted). Discard the gasket **4-6.6**.

Inspection

1. Check the manifold mating faces for signs of damage and distortion.
2. Check the manifold casting for signs of cracks.

Replacement

Replacement is the reverse of removal but note the following:

1. Renew the manifold gasket **4-6.4**.
2. Loosely assemble the manifold, together with the new inlet gasket to the cylinder head using two bolts (one at each end).
3. With the manifold and gasket in position, fit the remaining six bolts.
4. Torque tighten bolts **4-2**. ⇒ ***Table 16. Torque Settings (🗋 11-10)***.
5. If the grid heater **4-7** or blanking plate **4-4** have been removed renew the gasket **4-6.6**.
6. Be sure to fit the grid heater the correct way up. Orientate with the arrow pointing down (aligned with the air flow direction through the manifold).
7. Torque tighten bolts **4-5** (if applicable). ⇒ ***Table 16. Torque Settings (🗋 11-10)***.

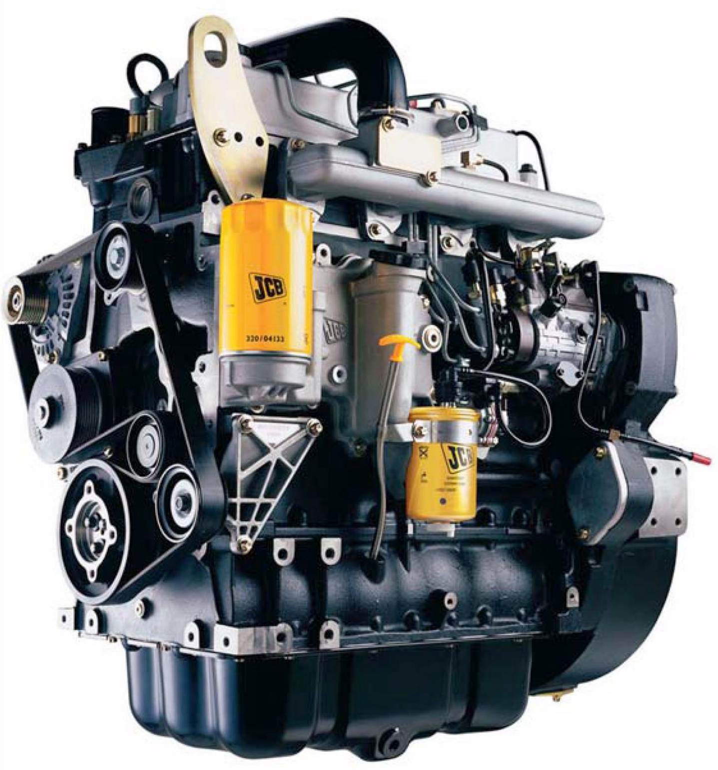
Table 16. Torque Settings

Item	Nm	lbf ft
2	24	17.7
5	24	17.7

Section 12

Base Engine

Service Manual - JCB 444 Mechanical Engine



Publication No.

9806/3000-04

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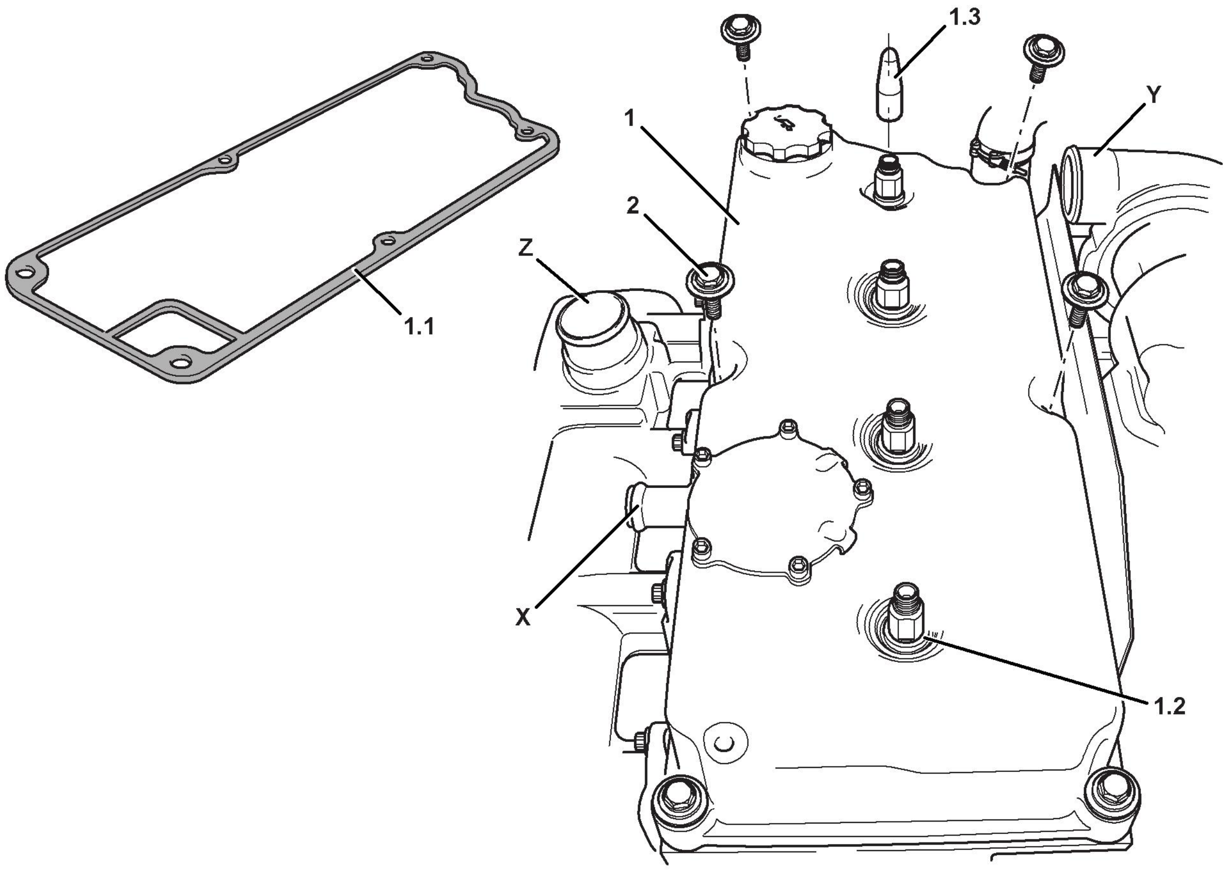


Fig 1.

Table 1. Service Parts

1	Rocker cover gasket kit
	Includes:
1.1	Rocker cover gasket
1.2	Rocker cover injector seals
1.3	Injector sleeves/covers
1.4	Injector pipe caps

Table 2. Component Identification

1	Rocker cover
2	Retaining bolts (6 off)
X	Pipe stub (Breather hose)
Y	Turbocharger outlet (Turbocharged engines only)
Z	Inlet manifold

Before Removing

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

2 Clean the top of the rocker cover and around the fuel injectors.

3 Disconnect and remove the fuel lines from the injectors, see ***Section 7 Fuel System - Fuel Lines***. Note that caps **1.4** for blanking the open ends of the fuel pipes are supplied with the rocker cover gasket kit.

Removal

1 Disconnect the breather hose from the pipe stub **X**.

2 **Turbocharged Engines Only:** Disconnect the air hose from the turbocharger outlet **Y** and inlet manifold **Z**. Remove the hose.

3 Undo the bolts **2** and lift the rocker cover **1** from the cylinder head. Discard the gasket **1.1**.

4 Place sleeves/covers **1.3** over the injectors.

5 The rocker cover injector seals **1.2** cannot be re-used. Support the rocker cover and tap out the seals **1.2** from inside the cover using seal dolly **T2** as shown at **V**. Discard the seals.

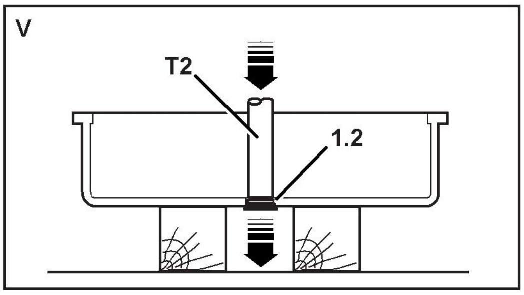


Fig 2.

Replacement

Replacement is the reverse of removal but note the following:

1 Renew the rocker cover injector seals **1.2** Support the rocker cover and tap in the new seals using the fitting tool **T2** as shown at **W**.

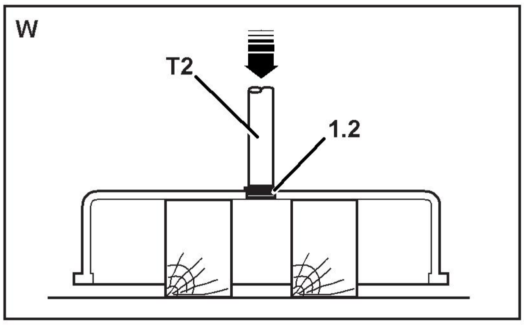


Fig 3.

2 Renew the rocker cover gasket **1.1**.

3 Make sure the sleeves/covers **1.3** are located over the four injectors. The seals **1.2** will be damaged if the sleeves are not fitted. Apply a suitable rubber lubricant to the seals **1.2** before fitting the rocker cover.

4 Torque tighten bolts **2**, ⇨ ***Table 3. Torque Settings (12-2)***. Remove the sleeves/covers **1.3**.

Table 3. Torque Settings

Item	Nm	lbf ft
2	24	17.7

After Replacing

1 Reconnect the fuel lines to the injectors, see ***Section 7 Fuel System - Fuel Lines.***

2 Start the engine and check for oil and fuel leaks.

Dismantling and Assembly

The rocker cover assembly incorporates the crank case ventilation (CCV) gauze filters and diaphragm valve assembly. If necessary the diaphragm valve can be removed with the rocker cover fitted to the engine. The rocker cover must be removed from the engine before the gauze filters can be removed.

CCV Diaphragm Valve

Dismantling

1 Undo the five screws **A**. Lift off the diapragm valve cover **B**.

2 Carefully lift out the diaphragm **C**, followed by plate **D** and spring **E**.

Assembly

Assembly is the reverse of dismantling but note the following:

1 Wipe away any oil residue from inside the valve chamber.

Important: *If the valve chamber is heavily contaminated with oil or sludge the rocker cover MUST be removed from the engine for decontamination. Remove and discard the gauze filters. Use a suitable degreaser to remove all sludge and oil deposits from the valve chamber and gauze cavity. Also ensure that the transfer duct is clean and clear of sludge.* ⇨ ***CCV Gauze Filters (12-3)***.

2 Before fitting the valve diaphragm C carefully inspect it for splits and punctures. If any holes are evident the diaphragm must be renewed.

3 Torque tighten screws **A**. ⇨ ***Table 4. Torque Settings (12-3)***.

Table 4. Torque Settings

Item	Nm	lbf ft
A	8 - 10	6 - 7.4

CCV Gauze Filters

Dismantling

1 Undo the five screws **A** and lift off the cover **B**.

2 Lift out the gauze filters **C**.

Note: *It is not advisable to remove the transfer duct cover plate D. Some plates are riveted in position and cannot be removed. Others are retained using screws and these should not be removed.*

Assembly

Assembly is the reverse of dismantling but note the following:

1 Wipe away any oil residue from inside the gauze chamber.

2 Using a suitable safe cleaning solvent clean the filters (or fit new filters). Make sure any residual oil has been fully removed.

Important: *If the gauze filters are heavily contaminated with oil or sludge, discard the filters. Use a suitable degreaser to remove all sludge and oil deposits from the gauze cavity. Dismantle the diaphragm valve and clean the valve cavity.* ⇨ ***CCV Diaphragm Valve (12-3)***. *Also ensure that the transfer duct E is clean and clear of sludge.*

3 Apply JCB Threadlocker to screws **A**. Make sure that the tapped holes in the rocker cover are clean and free from excessive oil. Torque tighten the screws **A**. ⇨ ***Table 5. Torque Settings (12-3)***.

Table 5. Torque Settings

Item	Nm	lbf ft
A	8 - 10	6 - 7.4

Rocker Assembly

Removal and Replacement

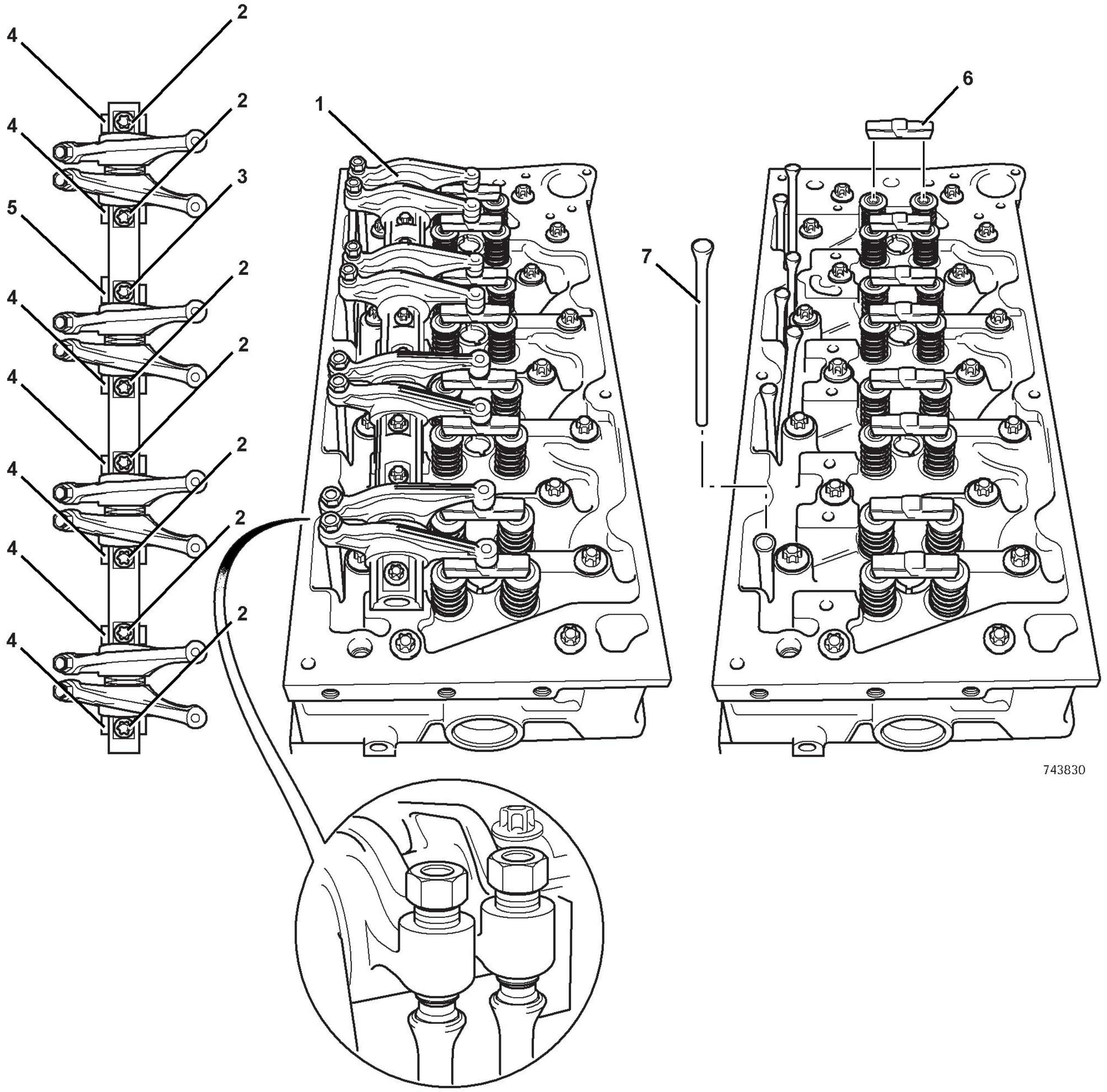


Fig 4.

Table 6. Component Identification

⇨ Fig 4. (12-4)	
1	Rocker assembly
2	Rocker shaft fixing bolts (7 off)
3	Rocker shaft fixing bolt - oil feed pedestal (1 off)
4	Pedestals (7 off)
5	Oil feed pedestal (1 off)
6	Bridge pieces (8 off)
7	Push rods (8 off)

Table 7. Torque Settings

Item	Nm	lbf ft
2	24	17.7
3	24	17.7

Table 8. Service Tools

Item	Part Number	Description
T1	General	Star drive socket

Before Removing

1 Disconnect and remove the fuel lines from the injectors, see **Section 7 Fuel System - Fuel Lines**.

2 Remove the rocker cover, see ***Rocker Cover - Removal and Replacement.***

Removal

1 Undo the bolts **2** and bolt **3**. DO NOT withdraw bolts **2** and **3**. Lift the rocker shaft assembly **1** from the cylinder head complete with pedestals **4** and **5** still attached.

Important: *Keep all pedestals and fixing bolts in their original positions.*

2 Lift off the bridge pieces **6** from the pairs of inlet and exhaust valves.

3 Withdraw the push rods **7** from the cylinder block.

Before Replacing

1 Ensure that all items are clean and free from damage and corrosion. If components within the rocker assembly are damaged or worn, see ***Rocker Assembly - Dismantling, Inspection and Assembly.***

2 Make sure that all oil ways and cross drillings in the cylinder head, rocker shaft and pedestals are clear and free from debris. Use an air line to blow through cross drillings.

Replacement

Replacement is the reverse of removal but note the following:

1 Clean the top of the cylinder head using a suitable degreasing agent.

2 Fit the bridge pieces **6** onto the pairs of inlet and exhaust valves in the cylinder head.

3 Insert the push rods **7** into the cylinder block. Ensure that they engage with the camshaft tappets.

4 Fit the rocker shaft assembly **1** into the cylinder head. Make sure that the pedestals are located in their original positions. Note the position of the oil feed pedestal **5** and its longer bolt **3**. Ensure that the push rods engage with the tappet adjusters and that the rockers are located over the bridge pieces. Torque tighten bolts **2** and **3**, ***⇨ Table 7. Torque Settings (12-5)***.

After Replacing

1 Measure and adjust the valve clearances, see ***Valve Clearances - Adjustment.***

Dismantling, Inspection and Assembly

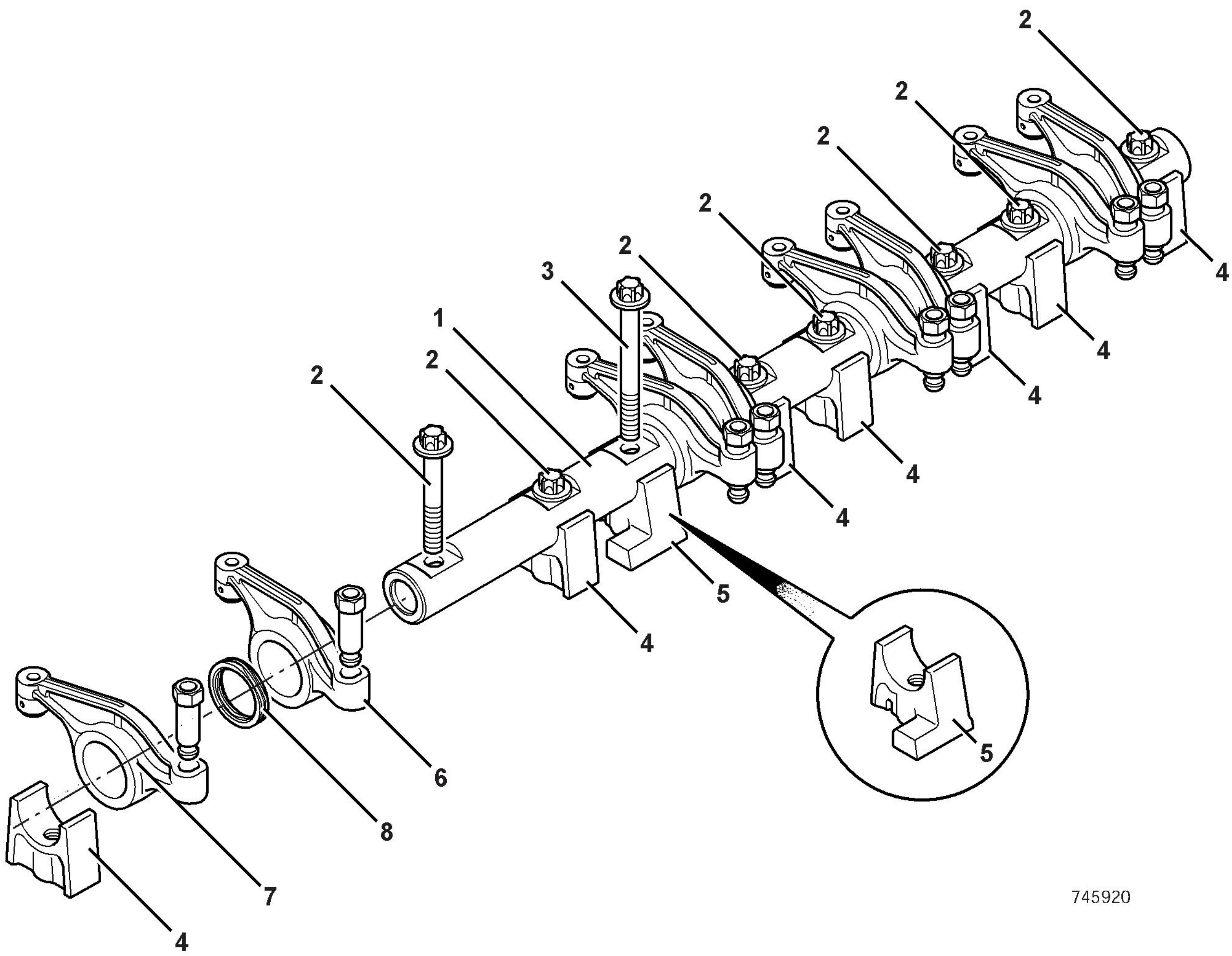


Fig 5.

Table 9. Component Identification

1	Rocker shaft
2	Rocker shaft fixing bolts (7 off)
3	Rocker shaft fixing bolt - oil feed pedestal (1 off)
4	Pedestals (7 off)
5	Oil feed pedestal (1 off)
6	Rockers - inlet (4 off)
7	Rockers - exhaust (4 off)
8	Wave washers (8 off)

Before Dismantling

1 Remove the rocker cover, see ***Rocker Cover - Removal and Replacement.***

2 Remove the rocker assembly, see ***Rocker Assembly - Removal and Replacement.***

Dismantling

1 Lift out the rocker shaft fixing bolts **2** and **3**, then slide the pedestals **4** and **5**, rockers **6** and **7**, and wave washers **8** off the rocker shaft **1** as shown. Label the pedestals and rockers to ensure they are refitted in the correct positions on assembly.

Inspection

1 Check the rocker shaft and rocker bushings for signs of damage and excessive wear. Measure the rocker shaft diameter and rocker bearing bushes to confirm they are within service limits, see ***Section 1 Technical Data.***

Note: *The rocker bearing bushes are not renewable. If a rocker bearing bush is damaged or worn the rocker must be renewed as a complete assembly.*

2 Make sure that all oil ways and cross drillings in the rocker shaft and pedestals are clear and free from debris. Use an air line to blow through cross drillings.

Assembly

Assembly is the reverse of dismantling but note the following:

1 Lubricate the rocker shaft and rocker bearing bushes with clean engine oil.

2 Make sure that the rockers and pedestals are refitted in their original positions along the rocker shaft. Note the position of the oil feed pedestal **5**.

3 Insert the rocker shaft fixing bolts to hold the rockers and pedestals loosely in position before fitting the assembly into the cylinder head. Note the position of the longer bolt **3**.

After Assembly

1 Refit the rocker assembly, see ***Rocker Assembly - Removal and Replacement***.

2 Measure and adjust the valve clearances, see ***Valve Clearances - Adjustment.***

Valve Clearances

Adjustment

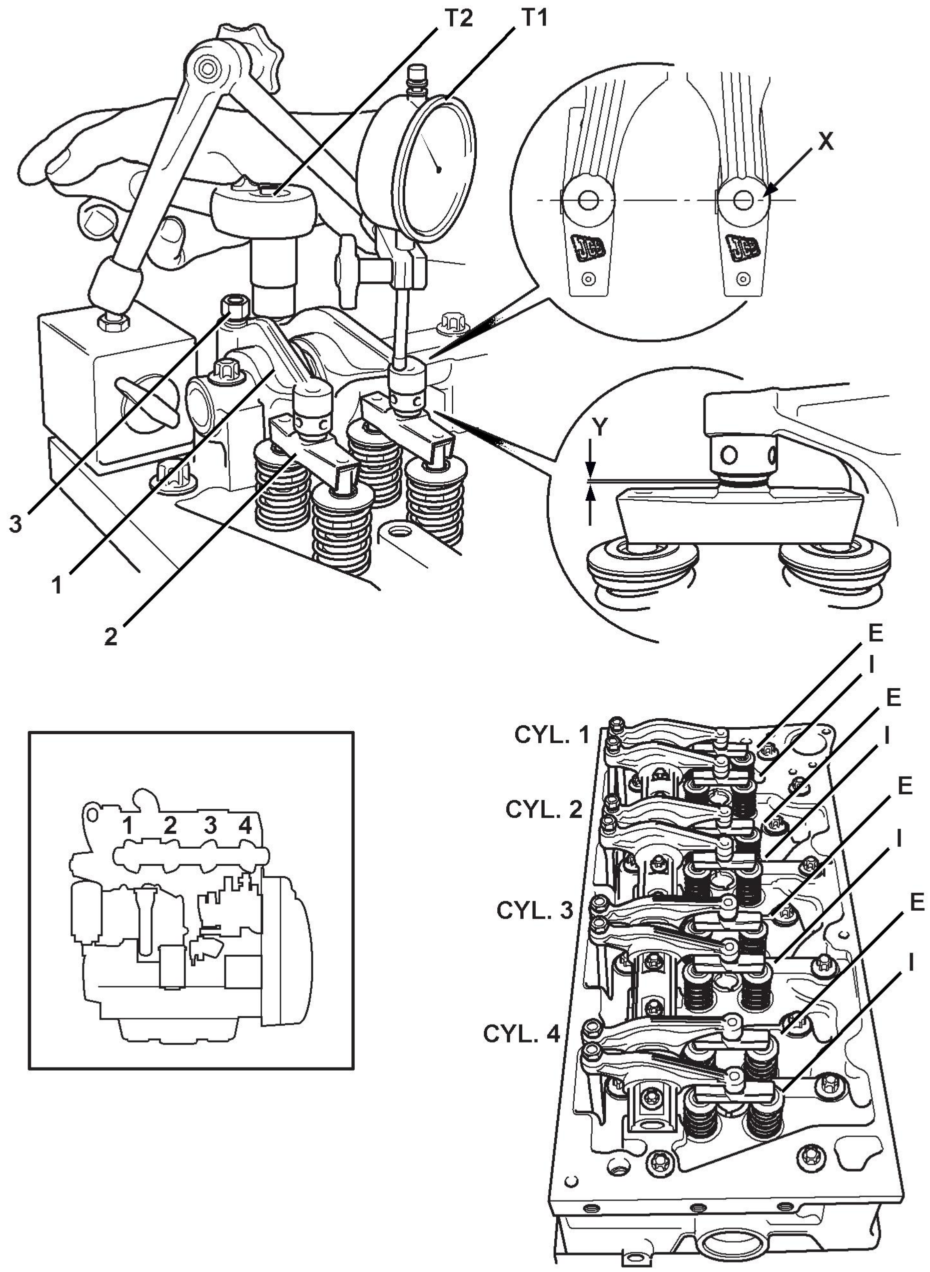


Fig 6.

Table 10. Component Identification

⇨ Fig 6. (12-8)	
1	Rockers (8 off)
2	Bridge pieces (8 off)
3	Tappet adjusters (8 off)
I	Inlet valves
E	Exhaust valves

Table 11. Service Tools

Item	Part Number	Description
T1	General	Dial test indicator (DTI)
T2	General	Socket wrench
T3	892/01147	Crankshaft rotation tool

Table 12. Tappet Clearances (Engine Cold)

Item	mm	inch
Inlet Valves	0.19 - 0.27	0.007 - 0.010
Exhaust Valves	0.56 - 0.64	0.022 - 0.026

Table 13. Torque Settings

Item	Nm	lbf ft
1	12 (minimum)	8.8 (minimum)

Before Adjustment

1 Ensure that the engine is safe to work on. If the engine has been running, make sure the engine has cooled sufficiently before you start.

2 Disconnect and remove the fuel lines from the injectors, see ***Section 7 Fuel System - Fuel Lines***.

3 Remove the rocker cover, see ***Rocker Cover - Removal and Replacement***.

4 Ensure that all items are clean and free from damage and corrosion.

Important: *The tappet adjusters **3** rely on thread interference with the rockers **1** to retain their position. If any of the rockers or tappet adjusters have been renewed ensure that the turning torque for the tappet adjusters is above the minimum required.* ***⇨ Table 13. Torque Settings (12-9)****. If any of the adjusters register a lower torque value then the adjuster and its associated rocker must be renewed.*

Adjustment

The valve clearances should be checked/adjusted in a set sequence as given in the adjacent table.

The preferred method to measure the clearance is to use a dial test indicator (DTI) **T1** mounted on a magnetic base as shown. Note that the DTI must be positioned to contact the machined surface of the rocker on the centre line **X**. If a DTI is not available, feeler gauges can be used to measure the clearance **Y** between the bridge piece and the rocker insert as shown.

1 Using a socket and wrench **T2** (or a short extension) as shown, move the rocker **1** to open the valves against the force of the springs.

2 Slowly relax the force on the rocker until you feel the exact position at which the valves shut. Measure the valve clearance from this point.

Note: *Take care to keep the rocker at right angles to the rocker shaft when making measurements, otherwise incorrect values will be obtained. Always use a socket or ring spanner to turn the tappet adjusters **3**, DO NOT use an open ended spanner.*

Table 14. Adjustment Sequence Table

Step	\`Set-up' Cylinder No.	Check/Adjust Cylinder No.
a	4	1
b	2	3
c	1	4
d	3	2

Example:

Step a - Rotate the crankshaft in the normal direction of rotation (clockwise when viewed from the front of the engine) to \`set-up' the valves of No.4 cylinder so that the point is reached where the exhaust valve is closing while the inlet valve is just starting to open. This is the point where the two rockers are moving past one another in opposite directions.

With No.4 cylinder in this position, measure the clearance of No.1 cylinder inlet and exhaust valves, and adjust them if necessary. ***⇨ Table 12. Tappet Clearances (Engine Cold) (12-9)***.

Step b - Further rotate the crankshaft to `set-up' the valves of No.2 cylinder as above, then measure the clearance of No.3 cylinder valves.

Complete steps **c** and **d** in sequence for the remaining cylinders.

After Adjustment

1 Replace the rocker cover, see ***Rocker Cover - Removal and Replacement.***

2 Reconnect the fuel lines to the injectors, see ***Section 7 Fuel System - Fuel Lines.***

Cylinder Head Assembly

Removal and Replacement

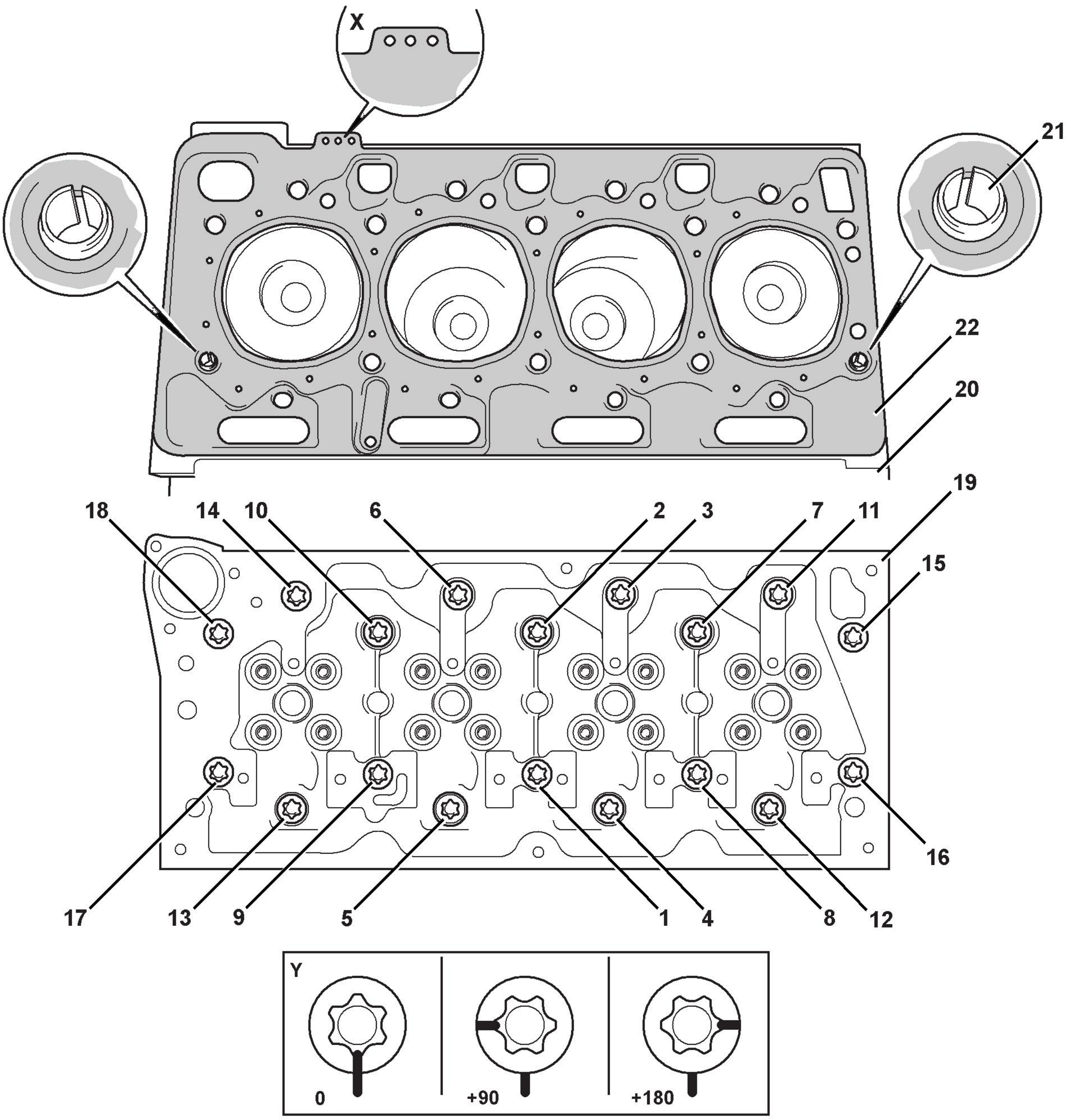


Fig 7.

Table 15. Component Identification

⇨ *Fig 7. (12-11)*	
1-18	Cylinder head fixing bolts (18 off)
19	Cylinder head
20	Cylinder block
21	Location dowels (2 off)
22	Head gasket

Table 16. Service Parts

P1	Cylinder head fixing bolts
P2	Head gasket

Table 17. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Dowel punch
T3	General	Dial gauge torque wrench
T4	General	Angle gauge

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct parts before you start, see ***Service Parts***.

2 Remove the thermostat, see ***Section 8 Cooling System - Thermostat***.

3 Remove the fuel lines, see ***Section 7 Fuel System - Fuel Lines***.

4 Remove the rocker cover, see ***Rocker Cover - Removal and Replacement***.

5 Remove the injectors, see ***Section 7 Fuel System - Fuel Injectors (Atomisers)***.

6 Remove the rocker assembly, see ***Rocker Assembly - Removal and Replacement.***

7 Remove the exhaust manifold, see ***Section 11 Induction and Exhaust System - Exhaust Manifold***.

8 Remove the inlet manifold, see ***Section 11 Induction and Exhaust System - Inlet Manifold.***

Removal

1 Progressively undo the cylinder head bolts **1-18** in reverse order, starting at bolt **18**. Note that the bolts MUST NOT be re-used. Discard the bolts **1-18**.

2 Carefully lift the cylinder head **19** from the cylinder block **20**. If necessary use a soft face hammer. DO NOT use a lever to separate the cylinder head from the cylinder block. Discard the head gasket **22**.

3 Using a suitable cleaning agent, carefully remove all traces of the head gasket material from the cylinder head and cylinder block mating faces.

Inspection

1 Check the cylinder head and cylinder block mating faces for signs of damage and distortion, see ***Section 1 Technical Data.***

Before Replacing

1 Obtain the correct new cylinder head bolts **1-18**. Note that the original bolts MUST NOT be re-used.

2 Obtain the correct replacement head gasket **22**. Note the number of identification holes as shown at **X**.

3 Ensure that all items are clean and free from damage and corrosion.

Replacement

The cylinder head bolts are tightened using a `torque+angle' method, refer to ***section 1, Torque Settings*** for more information. Replacement is the reverse of removal but note the following:

1 Make sure that the location dowels **21** are correctly fitted into the cylinder block **20**. Use dowel punch **T2** to fit the dowels as required, see ***Service Tools***.

2 Position a new head gasket **22** onto the cylinder block mating face. Ensure the gasket is fitted the correct way round and correctly located over the dowels **21**.

3 Lower the cylinder head **19** onto the cylinder block. Make sure that the cylinder head is correctly located on the dowels **21**. Fit new cylinder head bolts **1-18**. Torque tighten the bolts in five stages, see Torque Settings.

a Torque tighten the bolts, starting with the middle pair and working outwards (in sequence 1-18) to the 1st stage pre-torque.

b Then, further tighten the bolts, starting with the middle pair and working outwards (in sequence 1-18) to the 2nd stage pre-torque.

c Then, re-tighten the bolts, starting with the middle pair and working outwards (in sequence 1-18) to the 3rd stage pre-torque.

d Using angle gauge **T4**, angle tighten the bolts, starting with the middle pair and working outwards (in sequence 1-18) to the 4th stage pre-torque.

Note: *As a visual check, match mark the bolts to the cylinder head before you start. When the bolts have been angle tightened, the match marks will appear as shown at **Y**.*

e Finally, angle tighten the bolts, starting with the middle pair and working outwards (in sequence 1-18) for the final stage torque.

Valves, Valve Springs and Stem Seals

Removal and Replacement

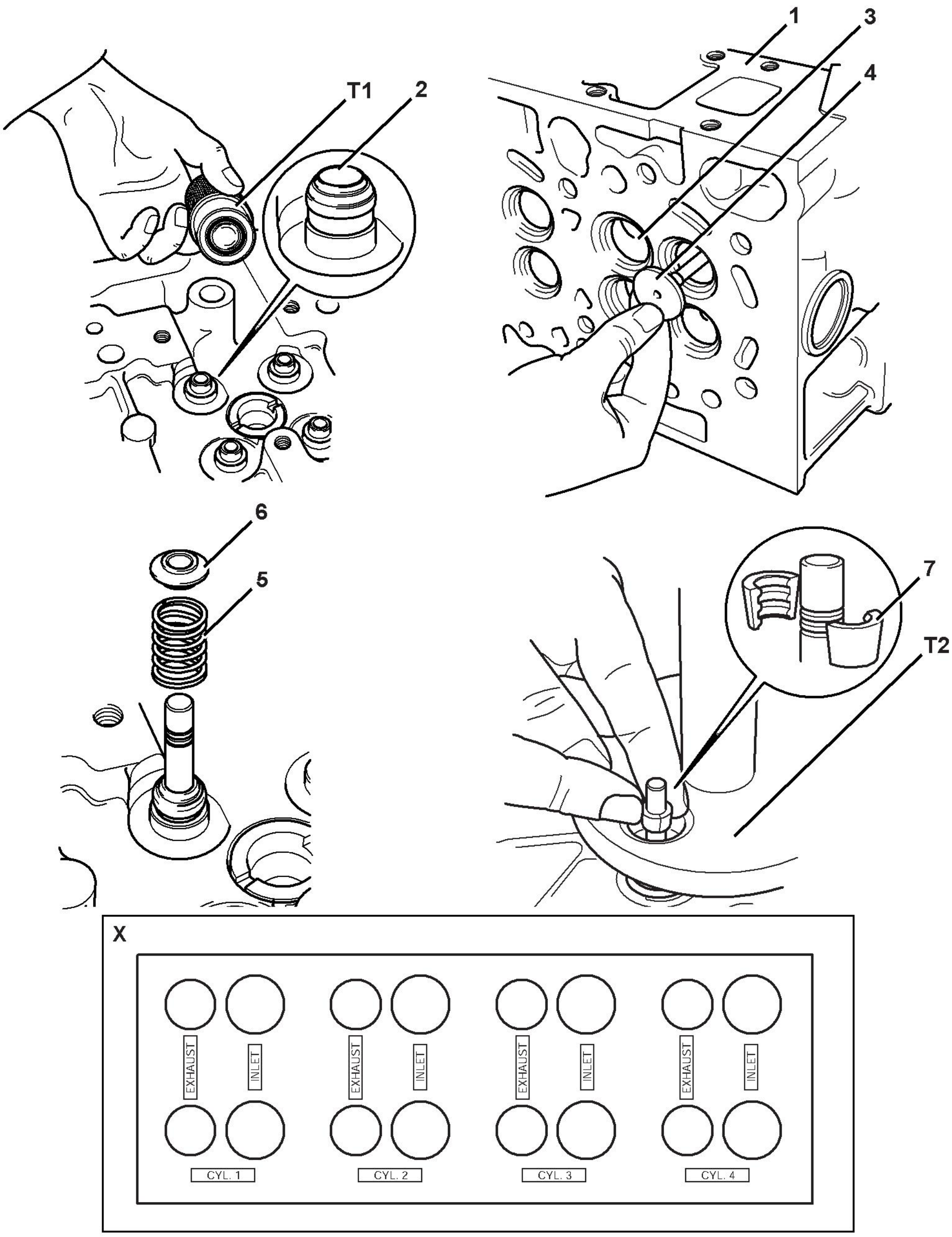


Fig 8.

Table 18. Component Identification

⇒ Fig 8. (12-14)	
1	Cylinder head
2	Valve stem seals (16 off)
3	Inlet valves (8 off)
4	Exhaust valves (8 off)
5	Valve springs (16 off)
6	Retainers (16 off)
7	Collets (32 off)

Table 19. Service Parts

P1	Valve stem seals

Table 20. Service Tools

Item	Part Number	Description
T1	892/01152	Seal fitting tool - stem seals
T2	General	Valve spring compressor
T3	General	Rubber mallet

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Remove the thermostat, see ***Section 8 Cooling System - Thermostat.***

3 Remove the fuel lines, see ***Section 7 Fuel System - Fuel Lines***.

4 Remove the rocker cover, see ***Rocker Cover - Removal and Replacement***.

5 Remove the injectors, see ***Section 7 Fuel System - Fuel Injectors (Atomisers)***.

6 Remove the rocker assembly, see ***Rocker Assembly - Removal and Replacement***.

7 Remove the exhaust manifold, see ***Section 11 Induction and Exhaust System - Exhaust Manifold.***

8 Remove the inlet manifold, see ***Section 11 Induction and Exhaust System - Inlet Manifold***.

9 Remove the cylinder head assembly from the cylinder block, see ***Cylinder Head Assembly - Removal and Replacement***.

Measure the valve recession with a dial test indicator (DTI). Clean the carbon deposits from a small area of the valve heads for location of the DTI probe. If the valve recession is outside serviceable limits, it is advisable to obtain a new or reconditioned cylinder head assembly, see ***Section 1 Technical Data.***

10 To aid removal and replacement, make up a wooden stand to retain the valves after removal as shown at **X**. Add labels to ensure correct replacement of the valves.

Removal

1 Use spring compressor tool **T2** to compress each valve spring and remove the collets **7**. Be sure to compress the springs squarely. Remove the spring compressor tool and lift off the retainer **6** and valve spring **5**.

2 Turn the cylinder head on its side and withdraw the inlet valves **3** and exhaust valves **4** as shown. When removing, note the respective position of each valve. Use a suitable stand as shown at **X** to keep the valves together and identify them with their respective cylinder.

Note: *The exhaust valves have smaller diameter heads.*

3 Remove the valve stem seals **2**. Discard the seals

Inspection

1 Carefully clean the carbon deposits from the valves taking care not to damage the seats.

2 Check that the valves and valve seats are not cracked, burnt or damaged.

3 Check the valve stems and valve guides for wear, see ***Section 1 Technical Data***.

Note: *If there is evidence of wear or damage to the valves, guides or seats, it is advisable to obtain a new or reconditioned cylinder head assembly.*

Before Replacing

1 Position the cylinder head **1** upside down in a suitable jig or fixture.

2 Ensure that all items are clean and free from damage and corrosion.

3 Trial fit the injectors into the cylinder head to check the nozzle protrusion. Note the relative positions for the injectors, and then remove the injectors for fitment at a later stage.

Replacement

Replacement is the reverse of removal but note the following:

1 Fit new valve stem seals **2** as shown. Use punch tool **T1** to avoid damaging the seals. Pre-assemble the seal into the tool. Locate the tool over the valve guide and gently press the seal into place. Lubricate the seal with P80 fluid.

2 With the cylinder head on its side, insert the inlet valves **3** and exhaust valves **4** as shown. Ensure that the valves are refitted in the correct positions. Lubricate the valve stems with clean engine oil before assembling. Carefully push the end of the valve stem through the stem seals.

3 Fit the valve springs **5** onto the valve stems, together with a retainer **6**. Use spring compressor tool **T2** to compress each valve spring and insert the collets **7**. Ensure that the collets are correctly seated in the valve stem grooves, before removing the spring compressor tool.

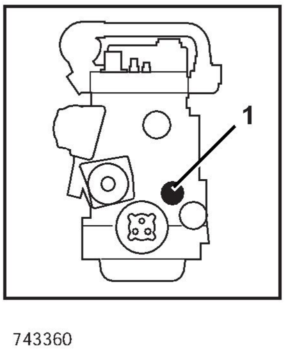
After Replacing

1 `Pop' the valves by tapping the valve stems in turn using a rubber mallet.

Front End Accessory Drive Belt System (FEAD)

Tensioner

Removal and Replacement



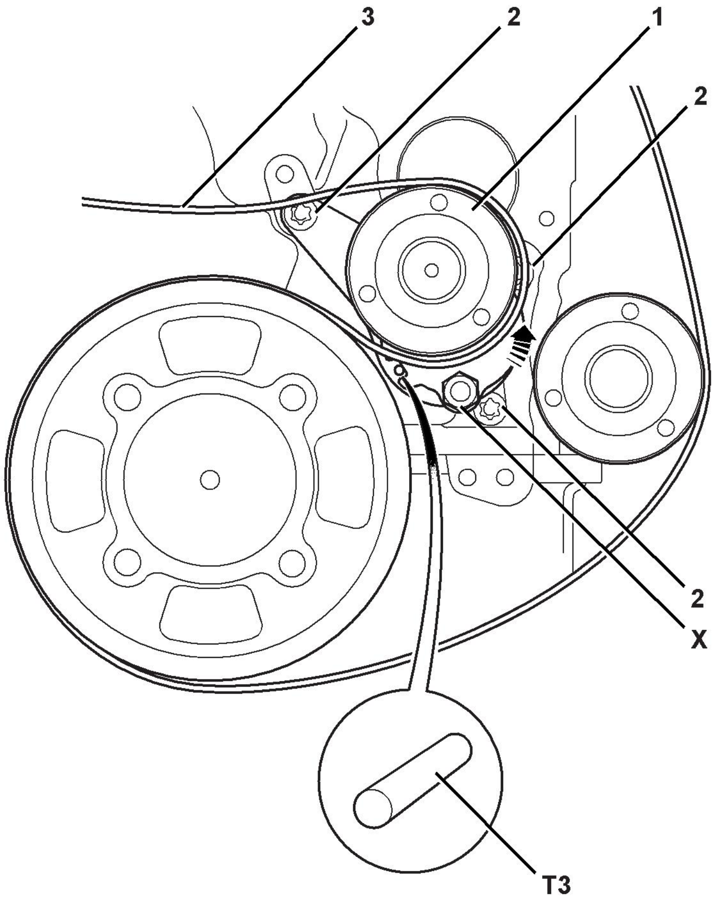


Fig 9.

Table 21. Component Identification

⇨ *Fig 9. (12-17)*	
1	Drive belt tensioner pulley
2	Fixing bolts (3 off)
3	Accessory drive belt
X	Hexagon spigot

Table 22. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Socket wrench
T3	General	Locking pin

Before Removing

1 Ensure that the engine cannot be started.

2 Remove the accessory drive belt, see ***Section 3 Routine Maintenance.***

Removal

1 To remove the tensioner assembly, undo the bolts **2** and lift the tensioner pulley **1** from the cylinder block.

Note: *The drive belt tensioner is a non serviceable item. If the drive belt tensioner or its idler wheel is faulty or damaged it must be renewed as a complete assembly.*

Replacement

Replacement is the reverse of removal but note the following:

1 Torque tighten bolts **2**, ⇨ ***Table 23. Torque Settings (12-18)***.

2 Refit the accessory drive belt, see ***Section 3 Routine Maintenance***.

3 Ensure that the accessory drive belt is under tension and the locking pin **T3** is removed before starting the engine.

Table 23. Torque Settings

Item	Nm	lbf ft
2	24	17.7

Flywheel and Housing

Flywheel

Removal and Replacement

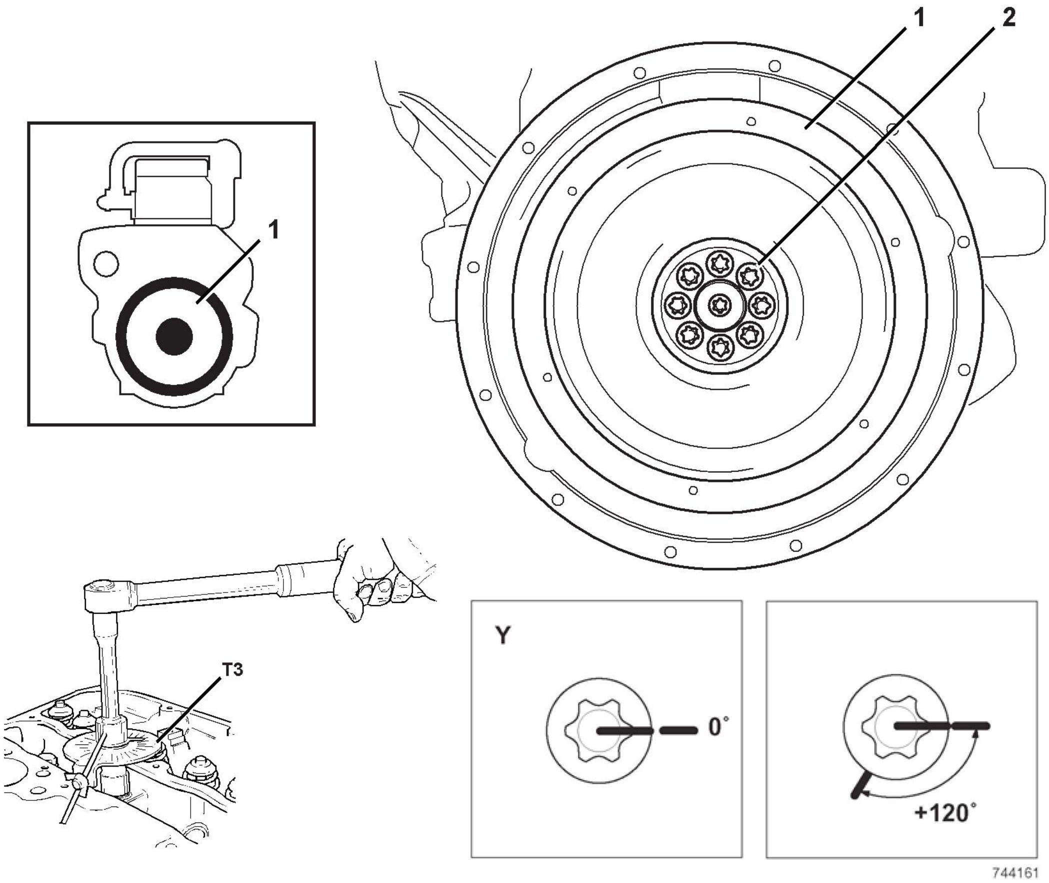


Fig 10.

Table 24. Component Identification

1	Flywheel
2	Flywheel fixing bolts (8 off)

Table 25. Service Parts

2	Flywheel fixing bolts

Table 26. Service Tools

Item	Part Number	Description
T1	General	Star drive wrench
T2	General	Dial gauge torque wrench
T3	General	Angle gauge

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start. ⇨ *Table 25. Service Parts (12-19)*.

Removal

1 Undo the bolts **2** and withdraw the flywheel **1** from the crankshaft hub. Note that the bolts MUST NOT be re-used. Discard the bolts **2**.

Replacement

Replacement is the reverse of removal but note the following:

1 Ensure that all items are clean and free from damage and corrosion.

2 Renew the fixing bolts. Torque tighten new bolts **2** in three stages. ⇨ *Table 27. Torque Settings (12-20)*.

Note: *Tighten the bolts in sequence in diagonally opposing pairs. As a visual check match mark the bolts to the flywheel before you start as shown at **Y**. When the bolts have been angle tightened the marks will appear as at +120°.*

Table 27. Torque Settings

Item	Nm	lbf ft	Angle	
2	40	29.5	-	1st stage
	120	88.5	-	2nd stage
	-	-	+120°	Final stage

Flywheel Gear Ring

Removal and Replacement

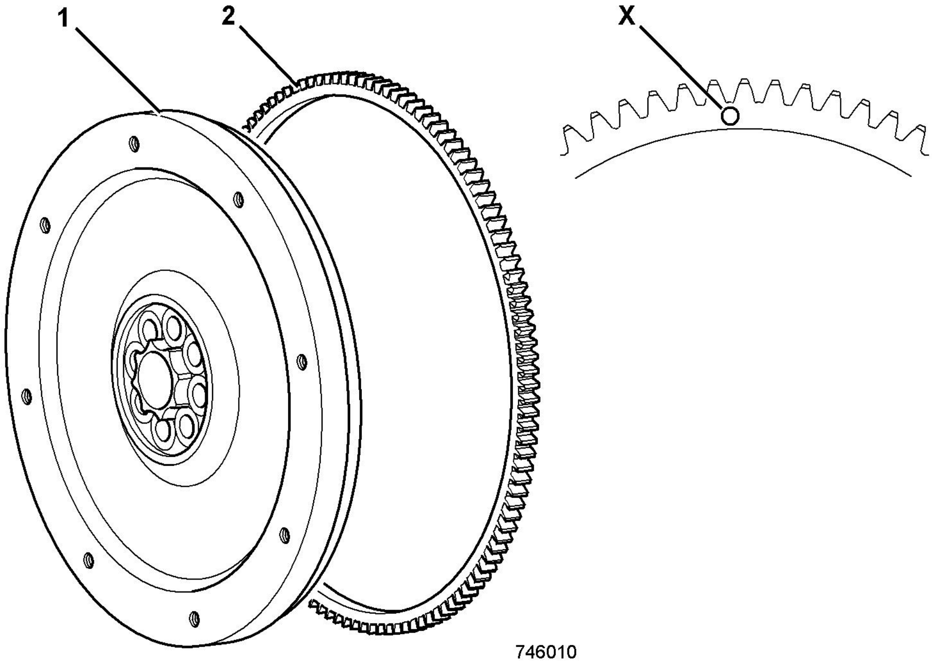


Fig 11.

If the flywheel gear teeth are damaged or excessively worn, the gear ring **2** can be replaced with a new one.

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Remove the flywheel from the crankshaft hub, see ***Flywheel - Removal and Replacement.***

Removal

1 Note that the gear teeth have a lead-in chamfer on one side to assist the starter motor pinion to engage. Note which way round the gear ring is fitted to ensure the new ring is fitted the same way on assembly.

2 Place the flywheel flat on a firm surface. Using a hammer and chisel hit the gear ring **2** around the circumference to separate it from the flywheel **1**. Take care not to damage the flywheel.

WARNING

Wear eye protection when you drive the gear ring off the flywheel.

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Note: *It may be easier to drill a hole **X** through the gear ring below the root of one of the gear teeth as shown, and then drive a chisel into the adjacent tooth to spread the gear ring apart.*

Replacement

1 Ensure that all items are clean and free from damage and corrosion.

2 Heat up the new gear ring, preferably in an oven to ensure that the heat is applied evenly around the

circumference. DO NOT heat the gear ring above 200°C (390° F).

WARNING

Wear eye protection when you drive the gear ring off the flywheel.

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3 When sufficiently heated, fit the gear ring **2** into position over the flywheel **1**. Ensure the gear ring is fitted the correct way round.

After Replacing

1 Refit the flywheel to the crankshaft hub, see ***Flywheel - Removal and Replacement.***

Flywheel Housing

Removal and Replacement

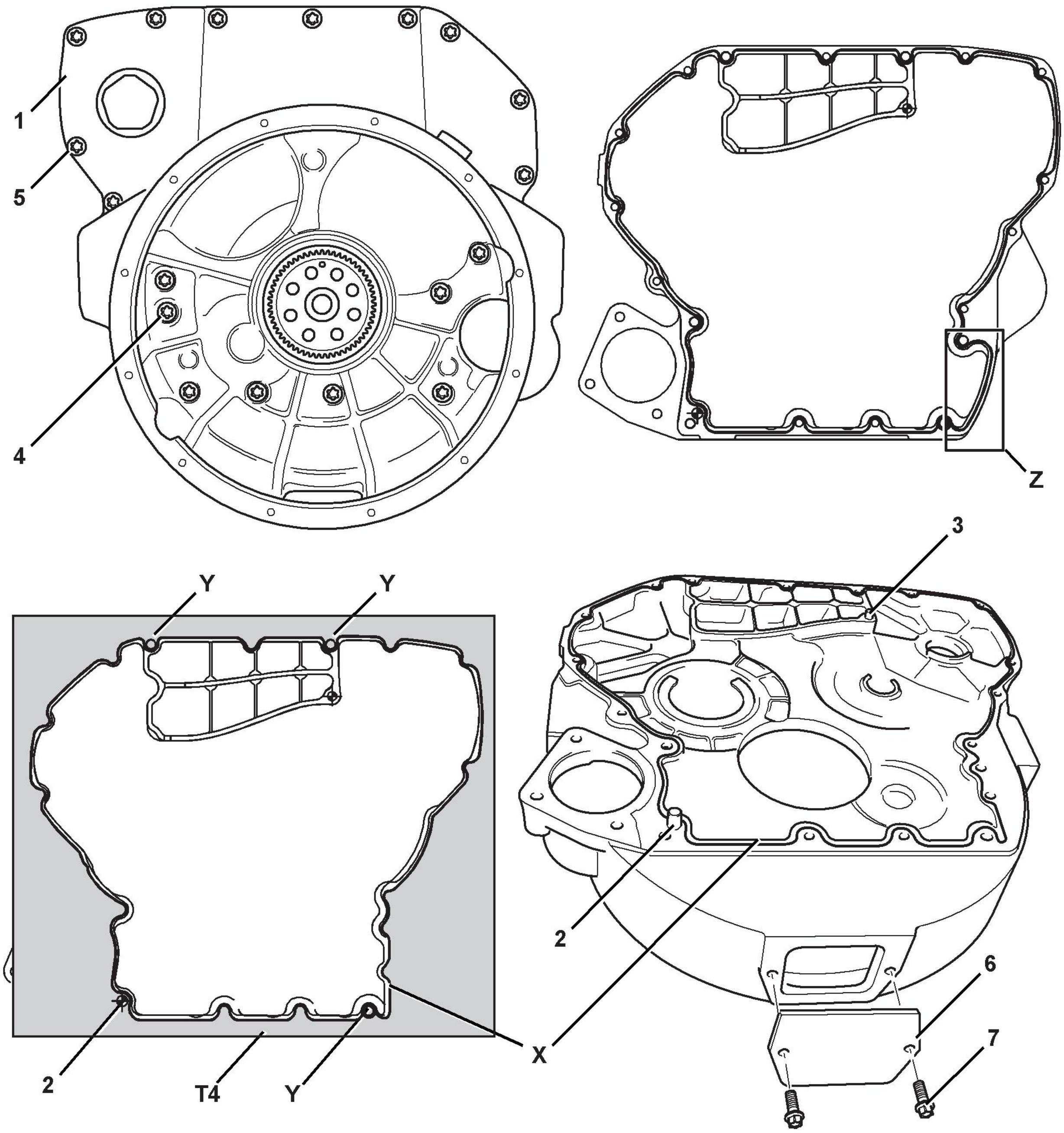


Fig 12.

Table 28. Component Identification

⇨ *Fig 12. (12-23)*	
1	Flywheel housing
2	Dowel 12 mm
3	Dowel 10 mm
4	Flywheel housing fixing bolts (6 off) M10
5	Flywheel housing fixing bolts (12 off) M8
6	Access cover
7	Access cover fixing bolts (2 off)

Table 29. Service Parts

P1	Crankshaft oil seal - Rear
P2	320/00831 Anaerobic Sealant

Table 30. Service Tools

Item	Part Number	Description
T1	General	Star drive wrench
T2	General	Dowel punch
T3	General	Alignment pins (Locally manufactured)
T4	892/01176	Sealant template

Before Removing

The flywheel housing is integral with the drive gears front case. When the housing is removed the drive gears will be exposed.

Important: *DO NOT attempt to remove the camshaft and its drive gears. Removing the camshaft with the engine in the upright position will cause the tappets to dislodge, requiring the engine block to be dismantled, see* ***Camshaft and Tappets.***

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start. ⇨ ***Table 29. Service Parts (12-24)***.

2 Remove the flywheel, see ***Flywheel - Removal and Replacement***.

3 Remove the starter motor, see ***Section 10 Electrical System - Starter Motor.***

Removal

1 Undo bolts **4** and **5** then separate the flywheel housing **1** from the gearcase.

2 If required, undo bolts **7** and remove the access cover **6**.

3 Remove and discard the crankshaft rear oil seal. Take care not to damage the seal bore in the housing.

Before Replacing

1 Carefully remove all traces of the old sealant compound from the flywheel housing mating faces.

2 Clean the inside of the flywheel housing using a suitable degreasing agent.

3 Carefully inspect all gears, bearings and shafts for signs of excessive wear or damage. If wear or damage is evident, the components must be renewed, see ***Gearcase and Drive Gears***.

Replacement

Important: *Anaerobic sealant will not start to cure whilst it is open to the atmosphere, however when air is excluded (for instance when the two parts are put together) it will immediately start to harden. Make sure that all the necessary tools, bolts etc are readily available prior to assembling the components. The parts must be fitted and torque tightened within 5 minutes (with a maximum permissible time of 15 minutes).*

Replacement is the reverse of removal but note the following:

1 Ensure that all items are clean and free from damage and corrosion.

2 Make sure that the dowels **2** and **3** are fitted to the mating face of the flywheel housing.

3 Fit the sealant template **T4** on the housing. Locate the holes in the template using dowel **2** and three fixing bolts at positions **Y**.

4 Using the template **T4** as a guide, apply a continuous 1.5 mm (0.060 in.) bead of sealant **P2** around the flywheel housing mating face as shown at **X**.

Note: *Some engines feature a flywheel housing with a different fixing hole pattern. Use the template to apply the sealant but apply sealant manually in the position shown at **Z**.*

5 Remove the three fixing bolts at positions **Y**. Remove the template **T4** making sure not to smudge the sealant. Discard the template.

6 Locate the flywheel housing on the alignment pins **T3** on the cylinder block and fit the fixing bolts. Progressively torque tighten bolts **4** and **5**. ⇨ ***Table 31. Torque Settings (12-25)***.

Note: *Remove the alignment pins to fit the last two M10 fixing bolts.*

Important: *If the parts have not been torque tightened within the maximum 15 minute time period, then the parts must be separated, thoroughly cleaned and fresh sealant applied.*

7 Fit the access cover **6** and secure using bolts **7**. Torque tighten bolts **7**. ⇨ ***Table 31. Torque Settings (12-25)***.

Table 31. Torque Settings

Item	Nm	lbf ft
4	47	35
5	24	18
7	24	18

After Replacing

1 Fit a new crankshaft rear oil seal, see ***Crankshaft Assembly - Rear Oil Seal***.

2 Refit the flywheel, see ***Flywheel - Removal and Replacement.***

3 Refit the starter motor, see ***Section 10 Electrical System - Starter Motor.***

Timing Case and Drive Gears Assembly

Drive Gear - Fuel Injection Pump

Removal and Replacement

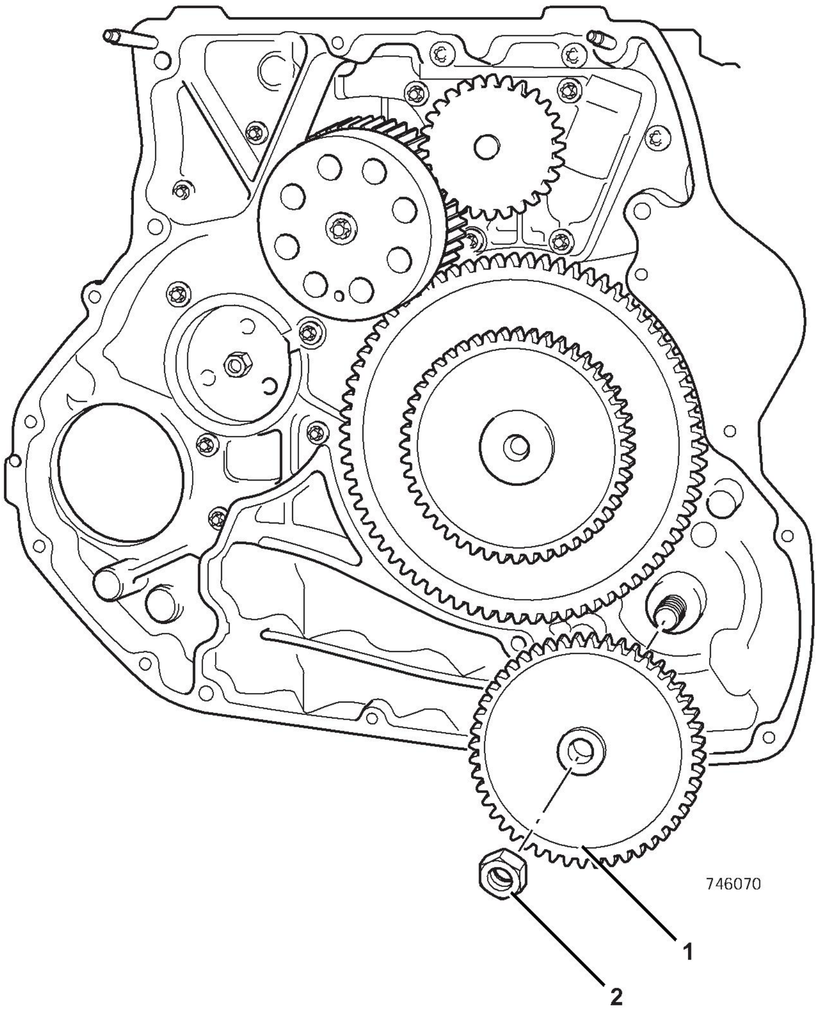


Fig 13.

Table 32. Component Identification

1	Drive gear - fuel injection pump
2	Fixing nut - drive gear - fuel injection pump

Before Removing

Note: *The illustrations show the engine inverted. If the drive gear components are being removed prior to crankshaft or camshaft removal the engine must be inverted. If the gear components only are being removed (for inspection/renewal) then the engine need not be inverted.*

1 Remove the fuel injection pump, see ***Section 7 Fuel System - Fuel Injection Pump.***

2 After releasing the drive gear from the injection pump drive shaft, loosely refit the fixing nut **2**, retaining the gear **1**. DO NOT lock the gear **1** to the taper on the injection pump drive shaft.

3 Remove the starter motor, see ***Section 10 Electrical System - Starter Motor***.

4 Remove the flywheel, see ***Flywheel - Removal and Replacement.***

5 Remove the flywheel housing, see ***Flywheel Housing - Removal and Replacement.***

Removal

1 Undo the the fixing nut **2** and lift out the gear **1**.

2 If the the rear timing case is to be removed, remove the fuel injection pump.

Replacement

1 Loosely fit the fuel injection pump and the drive gear 1 using fixing nut **2**. DO NOT lock the gear **1** to the taper on the injection pump drive shaft.

2 Carry out the procedures listed under Before removing in reverse order. Note that gear fixing nut 2 is torque tightened as part of the fuel injection pump replacing procedure.

Drive Gear - Crankshaft

Removal and Replacement

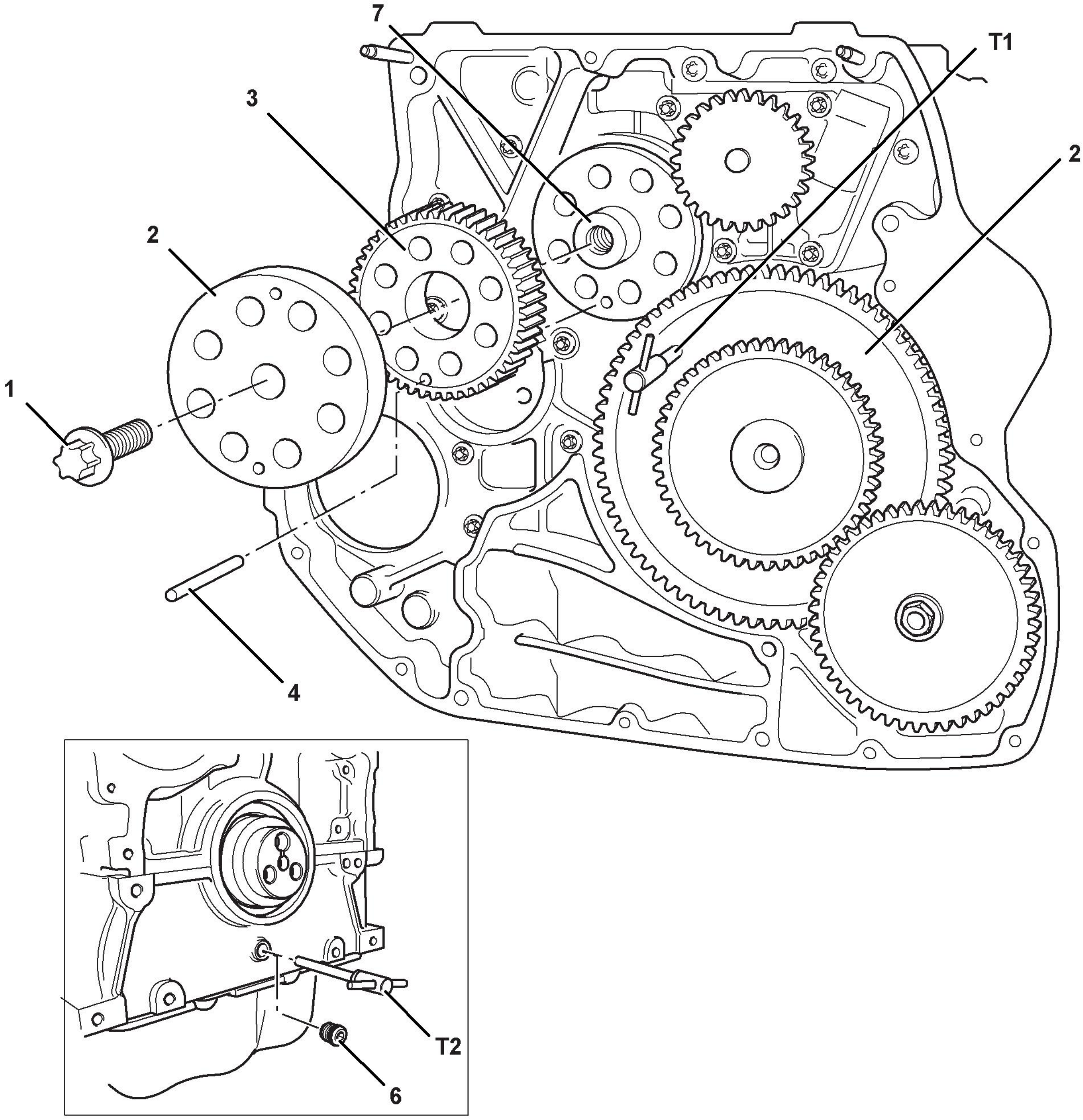


Fig 14.

Table 33. Component Identification

⇨ *Fig 14. (12-28)*	
1	Drive gear and flywheel hub fixing bolt
2	Flywheel hub
3	Crankshaft gear
4	Location dowel
5	Camshaft drive gear
6	Blanking plug - crankcase
7	Crankshaft - gear location spigot

Table 34. Service Tools

Item	Part Number	Description
T1	892/01148	Timing pin - camshaft
T2	892/01148	Timing pin - crankshaft

Table 35. Torque Settings

Item	Nm	lbf ft
1	47	34.7

Before Removing

Note: *The illustrations show the engine inverted. If the drive gear components are being removed prior to crankshaft or camshaft removal the engine must be inverted. If the gear components only are being removed (for inspection/renewal) then the engine need not be inverted.*

1 Remove the starter motor, see ***Section 10 Electrical System - Starter Motor.***

2 Remove the flywheel, see ***Flywheel - Removal and Replacement***.

3 Remove the flywheel housing, see ***Flywheel Housing - Removal and Replacement.***

Note: *The camshaft and crankshaft lock pins must be in position to lock the crankshaft and camshaft before removing the crankshaft gear.*

4 Rotate the crankshaft until the camshaft gear lock pin **T1** can be inserted through the gear **5** and into the aligning hole in the rear gear case.

5 Remove the taper blanking plug **6** and insert crankshaft locking pin **T2**.

Removal

1 Undo the bolt **1** and remove the flywheel hub **2**.

2 Remove the crankshaft gear **3** from the crankshaft. Be sure to retrieve location dowel **4**.

Inspection

1 Carefully inspect the outer diameter of flywheel hub **2** for signs of wear or damage. Wear or damage will cause the crankshaft rear oil seal to fail. If in doubt renew the hub.

Replacement

1 Apply some clean engine oil to the spigot **7** on the end of the crankshaft.

2 Make sure that dowel **4** is located in the gear **3** and locate the gear and dowel onto the crankshaft spigot **7**.

3 Fit the flywheel hub to the gear **3**, locating on dowel **4**. Fix the hub with bolt **1**. Torque tighten the bolt, ⇨ ***Table 35. Torque Settings (12-29)***.

Drive Gear - High Duty P.T.O. Idler

Removal and Replacement

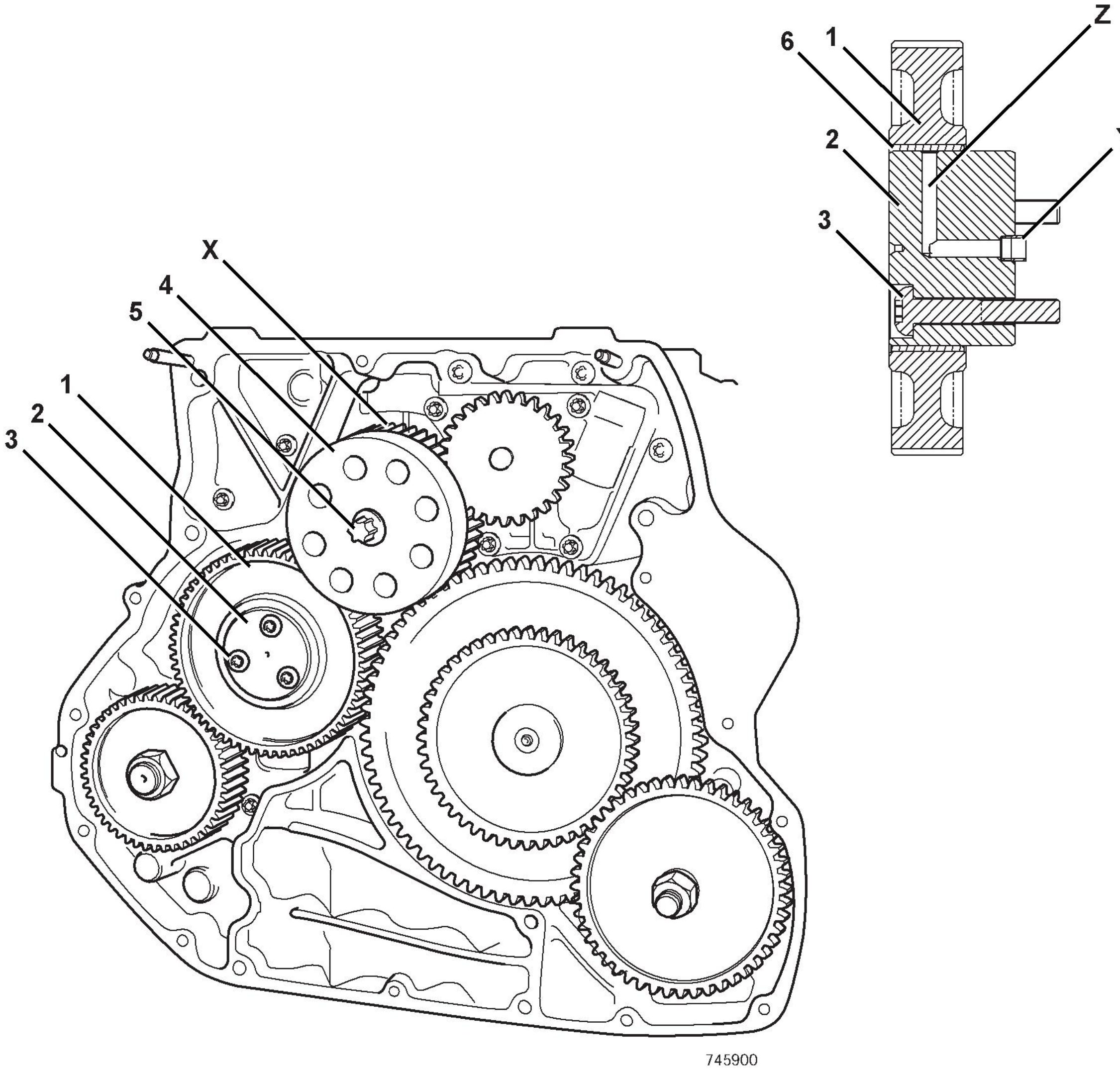


Fig 15.

Table 36. Component Identifcation

⇒ Fig 15. (12-30)	
1	High duty PTO idler gear
2	Idler gear hub
3	Idler gear hub retaining screws (3 off)
4	Flywheel hub
5	Flywheel hub fixing bolt
6	Idler gear bearing bush
X	Crankshaft gear
Y	Idler gear hub location dowel
Z	Oil feed drilling

Table 37. Service Parts

P1	Sealing compound

Table 38. Service Tools

Item	Part Number	Description
T1	General	Star drive key
T2	General	Star drive socket
T3	General	Torque wrench

Table 39. Torque Settings

Item	Nm	lbf ft
3	65	48
5	47	34.7

Before Removing

Note: *The illustrations show the engine inverted. If the idler gear is being removed prior to crankshaft or camshaft removal the engine must be inverted. If the idler gear only is being removed (for inspection or renewal) then the engine need not be inverted.*

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Remove the starter motor, see ***Section 10 Electrical System - Starter Motor***.

3 Remove the flywheel, see ***Flywheel - Removal and Replacement.***

4 Remove the flywheel housing, see ***Flywheel Housing - Removal and Replacement.***

Removal

1 Undo bolt **5** and remove the flywheel hub **4**. DO NOT remove the crankshaft gear **X**.

2 Lift the idler gear **1** from the hub **2**.

3 If required, remove screws **3** and lift out the hub **2**.

Inspection

1 Check the idler gear teeth and bearing bush **6** for signs of damage or excessive wear.

2 Measure the bearing bush inside diameter to confirm it is within service limits, see ***Section 1 Technical Data.***

Replacement

Replacement is the reverse of removal but note the following:

1 Ensure that all items are clean and free from damage and corrosion.

2 Make sure the oil way in the idler gear hub is clear and free from debris. Use an air line to blow through the oil drilling **Z**.

3 When refitting the idler gear hub, make sure the dowel **Y** locates into the hole in the cylinder block.

4 Lubricate the idler gear bearing bush with clean engine oil.

5 Fit the flywheel hub **4** to the crankshaft gear **X**, locating on the dowel. Torque tighten the screws **3** and bolts **5**, ⇒ ***Table 39. Torque Settings (12-31)***.

After Replacing

1 Refit the flywheel housing, see ***Flywheel Housing - Removal and Replacement***.

2 Refit the flywheel to the crankshaft hub, see ***Flywheel - Removal and Replacement.***

3 Refit the starter motor, see ***Section 10 Electrical System - Starter Motor.***

Drive Gear - Camshaft

Removal and Replcement

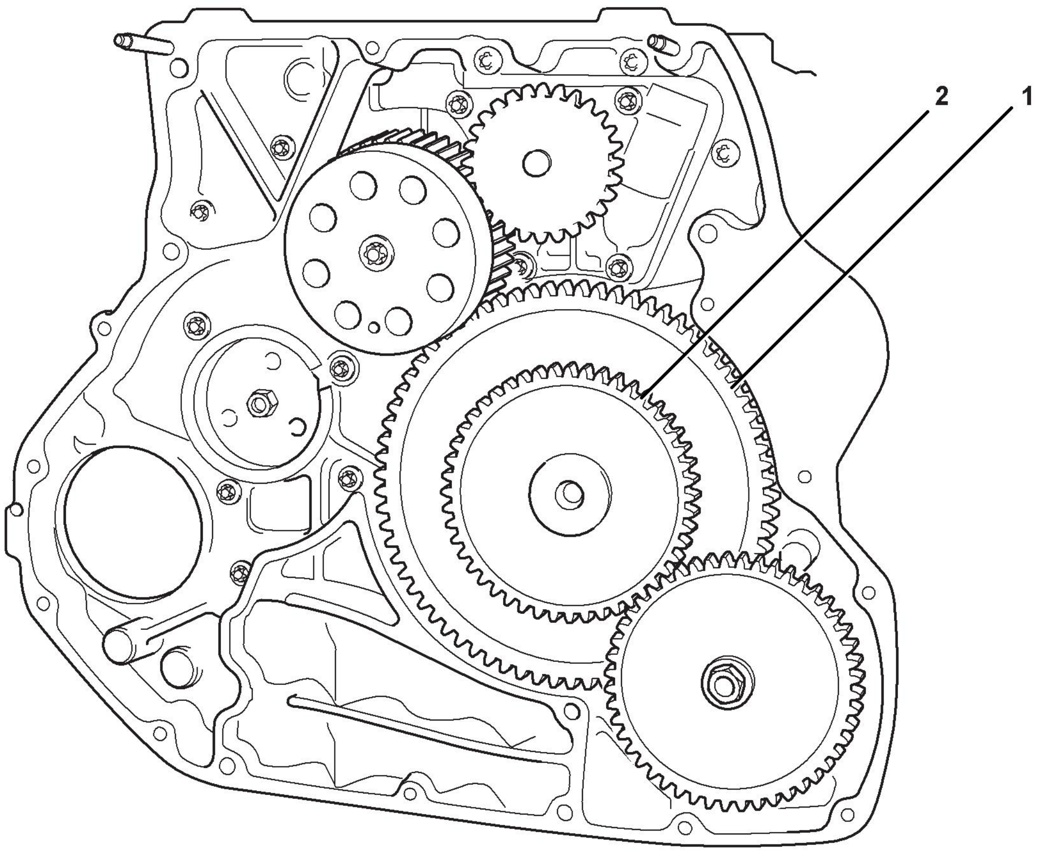


Fig 16.

Table 40. Component Identification

1	Camshaft gear 1 (104 teeth)
2	Camshaft compound gear 2 (65 teeth)

The camshaft drive gears **1** and **2** are an interference fit on the end of the camshaft and cannot be removed individually. If the gears are damaged or worn the complete camshaft and gear assembly must be renewed. See ***Camshaft - Removal and Replacement***.

Camshaft and Tappets

Removal and Replacement

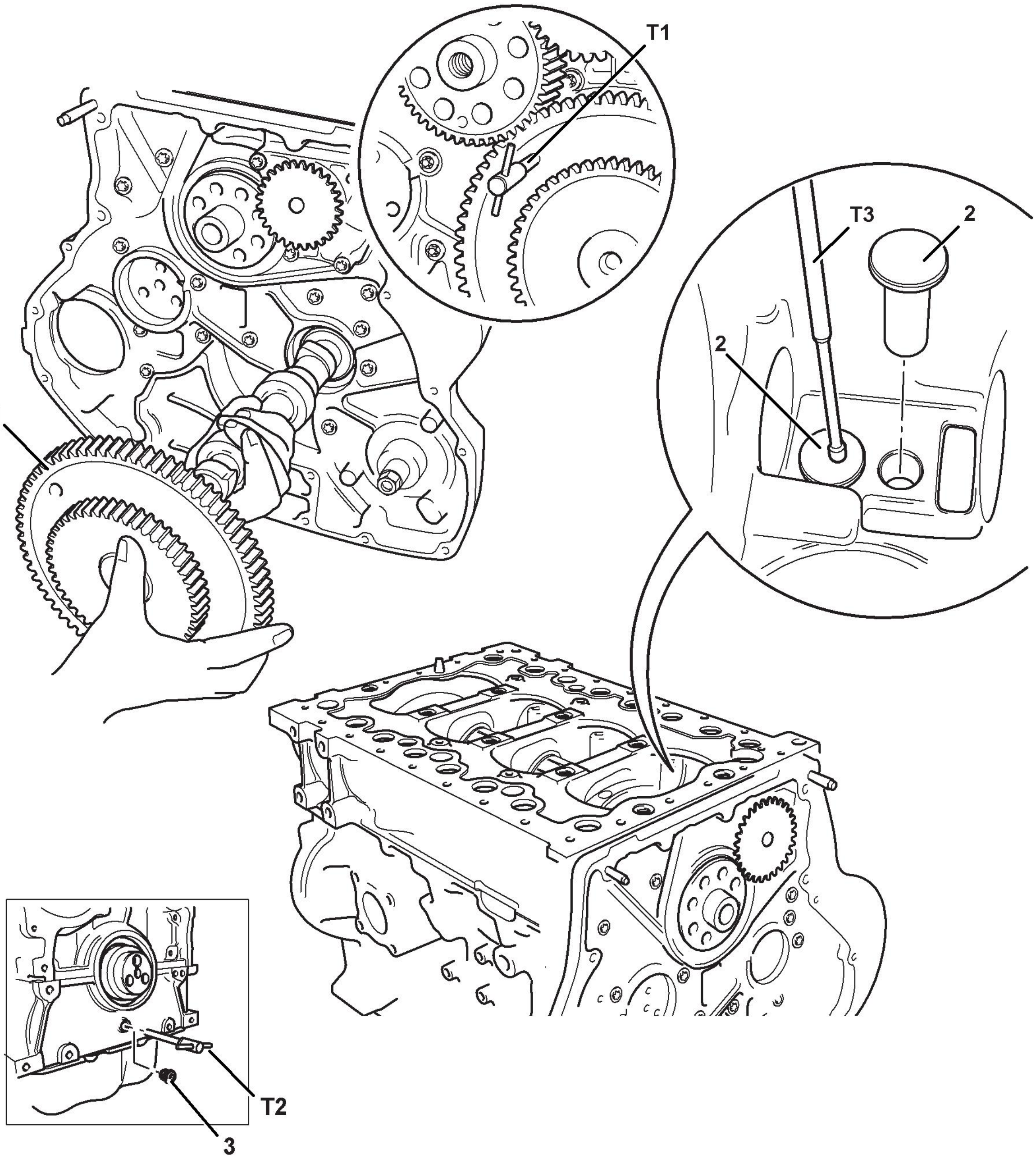


Fig 17.

Table 41. Component Identifcation

⇨ Fig 17. (12-33)	
1	Camshaft and drive gear
2	Tappet (8 off)
3	Blanking plug

Table 42. Service Tools

Item	Part Number	Description
T1	892/01148	Timing pin - camshaft
T2	892/01148	Timing pin - crankshaft
T3	General	Magnetic probe

Before Removing

1 Drain the oil from the engine, see ***Section 3 Routine Maintenance***.

2 Disconnect and remove the fuel lines from the injectors, see ***Section 7 Fuel System - Fuel Lines.***

3 Remove the rocker cover, see ***Rocker Cover - Removal and Replacement.***

4 Remove the fuel lift pump, see ***Section 7 Fuel System - Fuel Lift Pump***.

5 Remove the rocker assembly and push rods, see ***Rocker Assembly - Removal and Replacement.***

6 Remove the starter motor, see ***Section 10 Electrical System - Starter Motor.***

7 Remove the oil pan, see ***Section 9 Lubrication System - Oil Pan***.

8 Remove the flywheel, see ***Flywheel - Removal and Replacement***.

9 Remove the flywheel housing, see ***Flywheel Housing - Removal and Replacement.***

Note: *The engine must be inverted. DO NOT attempt to remove the camshaft and its drive gears with the engine upright. The tappets and push rods will fall into the engine and further dismantling will be required to retrieve them.*

Note: *The camshaft and crankshaft lock pins must be in position to lock the crankshaft and camshaft before removing the camshaft assembly.*

10 Rotate the crankshaft until the camshaft gear lock pin **T1** can be inserted through the gear **1** and into the aligning hole in the rear gear case.

11 Remove the taper blanking plug **3** and insert crankshaft locking pin **T2**.

12 Remove the fuel injection pump drive gear, see ***Drive Gear - Fuel Injection Pump - Removal and Replacement.***

Removal

Note: *The camshaft and its drive gears are a complete assembly. The gears are removed complete with the camshaft. The gears cannot be removed from the camshaft. If the gears or camshaft are worn or damaged the complete assembly must be renewed.*

1 Remove the camshaft gear lock pin **T1**.

2 Carefully withdraw the camshaft and gear assembly **1** from the cylinder block. Be sure to fully support the camshaft to prevent the lobes contacting the bearing surfaces in the cylinder block. The bearing surfaces can easilly be damaged by the sharp hard edges on the cam lobes.

3 Access the tappets **2** through the apertures in the cylinder block bed plate next to the crankshaft. Lift out the tappets from the cylinder block using a suitable magnetic probe. Label the tappets to ensure replacement in their original positions.

Inspection

1 Inspect the camshaft gear teeth for signs of damage or excessive wear.

2 Inspect the cam lobes for signs of excessive wear, scoring or pitting.

3 Inspect the cam bearing surfaces for signs of excessive wear, or scoring. Check that the dimensions are within service limits, see ***Section 1 Technical Data***.

4 Inspect the cam bearing surfaces inside the cylinder block for signs of excessive wear, or scoring. Check that the dimensions are within service limits, see ***Section 1 Technical Data***.

5 Inspect the bearing surfaces of the tappets for signs of excessive wear or damage. Check that the dimensions are within service limits, see ***Section 1 Technical Data***.

6 Inspect the tappet bores inside the cylinder block for signs of excessive wear or damage. Check that the dimensions are within service limits, see ***Section 1 Technical Data***.

7 If any of the camshaft bearings or lobes are worn or damaged then the relative oil feed galleries in the cylinder block and camshaft may be blocked. See ***Section 4 Systems Description - Lubrication System***. Make sure all oil ways are clear and free from debris.

Replacement

1 Lubricate the tappets **2** and tappet bores inside the cylinder block with clean engine oil.

2 Insert the tappets in their original positions in the cylinder block using a suitable magnetic probe **T2**.

3 Lubricate the camshaft bearing journals inside the cylinder block with clean engine oil.

4 Carefully insert the camshaft assembly **1** into the cylinder block as shown. Support the camshaft preventing the lobes contacting the bearing surfaces in the cylinder block. Before meshing the camshaft gear with the crankshaft gear, rotate the camshaft until the timing hole in the gear aligns with the dowel hole in the gearcasing. Insert the timing pin **T1** to lock the camshaft in this position.

After Replacing

1 Carry out the procedures listed under ***Before removing*** in reverse order. Note that fuel injection pump drive gear fixing nut is torque tightened as part of the fuel injection pump replacing procedure.

Timing Case - Rear

Removal and Replacement

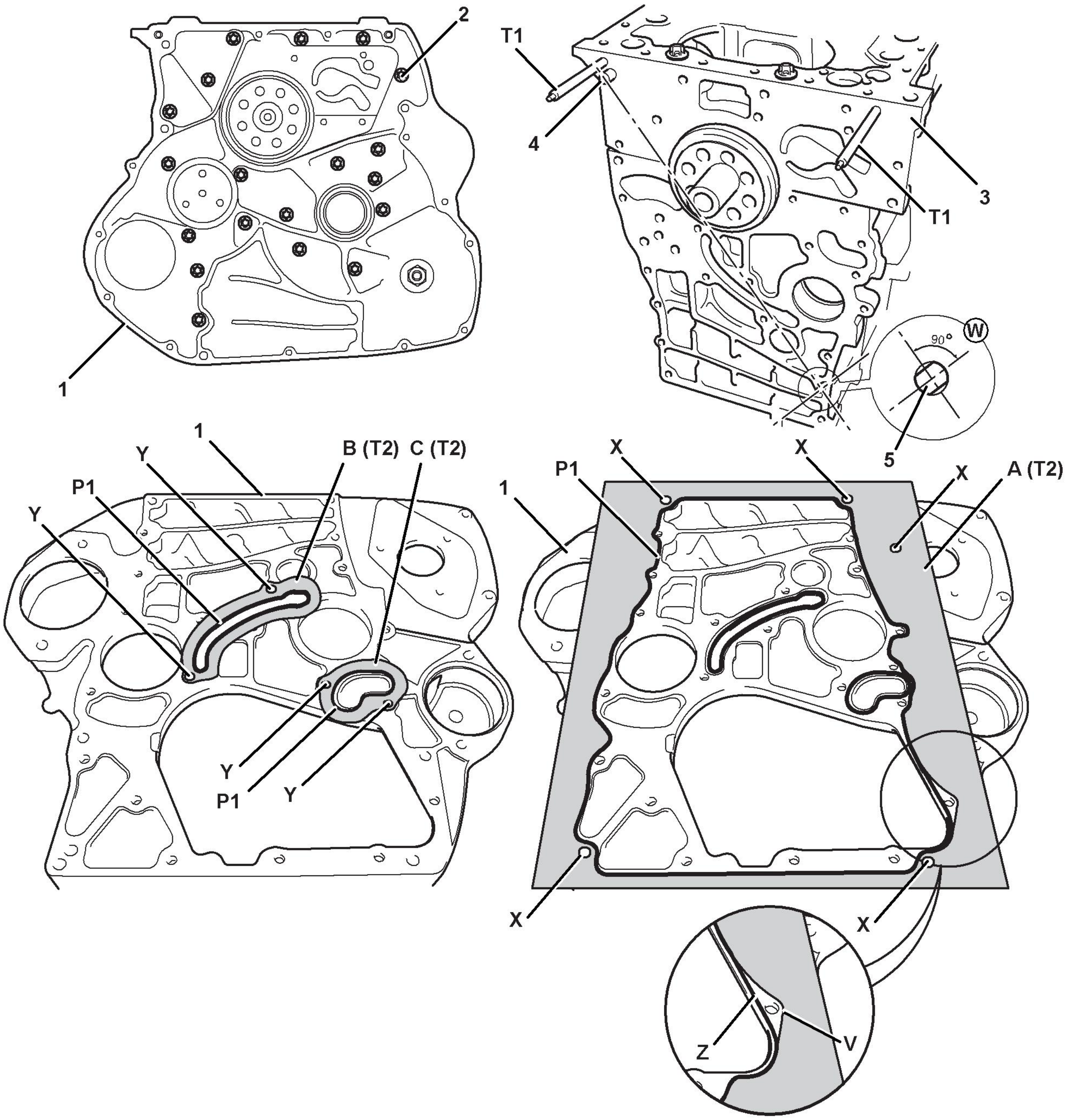


Fig 18.

Table 43. Component Identification

Fig 18. (12-36)	
1	Timing case - rear
2	Timing case fixing bolts (19 off)
3	Cylinder block/bed plate assembly
4	Dowel
5	Dowel - with flats

Table 44. Service Parts

P1	Anaerobic sealant

Table 45. Service Tools

Item	Part Number	Description
T1	General	Alignment pins (Locally manufacture)
T2	892/01176	Sealant template
	Comprising:	
	A	Main template
	B	Long gallery template
	C	Short gallery template

Before Removing

1 Drain the oil from the engine, see ***Section 3 Routine Maintenance.***

2 Disconnect and remove the fuel lines from the injectors, see ***Section 7 Fuel System - Fuel Lines***.

3 Remove the fuel injection pump, see ***Section 7 Fuel System - Fuel Injection Pump.***

4 Remove the fuel lift pump, see ***Section 7 Fuel System - Fuel Lift Pump***.

5 Remove the starter motor, see ***Section 10 Electrical System - Starter Motor.***

6 Remove the high duty PTO device (if fitted).

7 Remove the low duty PTO device (if fitted).

8 Remove the flywheel, see ***Flywheel - Removal and Replacement***.

9 Remove the flywheel housing, see ***Flywheel Housing - Removal and Replacement.***

10 Remove the fuel injection pump drive gear, see ***Drive Gear - Fuel Injection Pump - Removal and Replacement***.

11 Remove the oil pump, see ***Section 9 Lubrication System - Oil Pump***.

12 Remove the high duty PTO idler drive gear (if fitted), see ***Drive Gear - High Duty P.T.O. Idler - Removal and Replacement.***

13 Remove the crankshaft drive gear, see ***Drive Gear - Crankshaft - Removal and Replacement***.

14 Remove the camshaft, see ***Camshaft and Tappets - Removal and Replacement***.

Removal

1 Undo bolts **2** and then separate the timing case **1** from the cylinder block/bed plate assembly **3**. DO NOT use a lever to separate the timing case from the cylinder block/bed plate assembly.

Replacement

Important: *Anaerobic sealant will not start to cure whilst it is open to the atmosphere, however when air is excluded (for instance when the two parts are put together) it will immediately start to harden. Make sure that all the necessary tools, bolts etc are readily available prior to assembling the components. The parts must be fitted and torque tightened within 5 minutes (with a maximum permissible time of 15 minutes.).*

1 Carefully remove all traces of the old sealing compound from the timing case **1** and cylinder block/ bed plate assembly **3** mating faces. Make sure that the mating faces are clean and free from damage. Clean the inside of the case **1** using a suitable degreaser.

2 Fit two alignment pins **T1** to the cylinder head/bed plate assembly **3**.

3 Make sure that dowels **4** and **5** are correctly located in the cylinder block.

Note: *Dowel **5** has flats which must be positioned relative to dowel **4**, as shown **W**. This ensures correct alignment of the timing cover **1**.*

4 Sealant template **T2** comprises three pieces. Locate parts **B** and **C** using the holes in the templates and fixing bolts at positions **Y** as shown.

5 Using the templates **B** and **C** as a guide apply a continuous 1.5 mm (0.060 in.) bead of sealant **P1** to the case. Remove the bolts from positions **Y**. Remove the templates making sure not to smudge the sealant. Discard the templates.

6 Locate part **A** of the template **T2** using the holes in the template and fixing bolts at positions **X** as shown.

7 Using the template **A** as a guide apply a continuous 1.5 mm (0.060 in.) bead of sealant **P1** to the case. Do not follow the template at **V**, instead apply a continuous bead **Z** (inboard of the fixing hole). Remove the bolts from positions **X**. Remove the template making sure not to smudge the sealant. Discard the template.

8 Locate the timing case **1** on the alignment pins **T1** and fit the bolts **2** (remove pins **T1** to fit the final 2 bolts). Torque tighten the bolts **2**. ⇨ ***Table 46. Torque Settings (12-38)***.

Important: *If the parts have not been torque tightened within the maximum 15 minute time period, then the parts must be separated, thoroughly cleaned and fresh sealant applied*

Table 46. Torque Settings

Item	**Nm**	**lbf ft**
2	33	24

After Replacing

1 Replace all the components listed under ***Before removing*** in reverse order.

Pistons and Connecting Rods

Big End Bearing

Removal, Inspection and Assembly

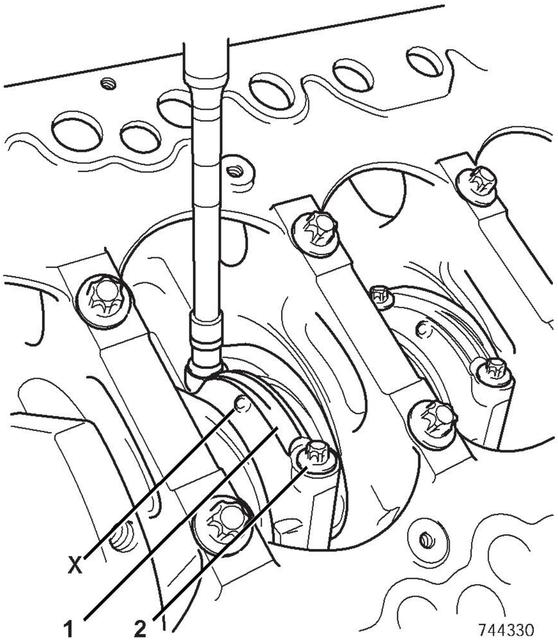


Fig 19.

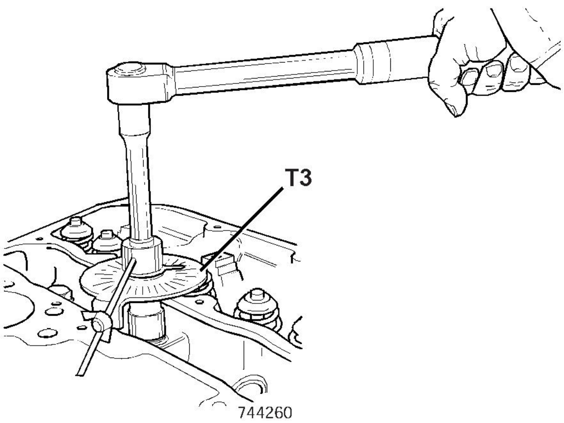


Fig 20.

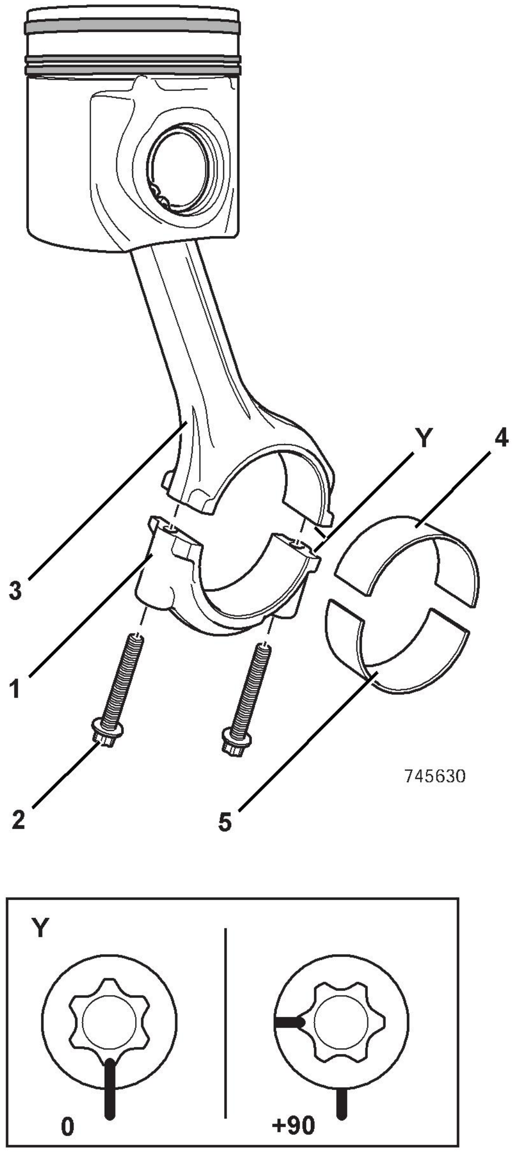


Fig 21.

Table 47. Component Identification

⇒ Fig 19. (12-39), ⇒ Fig 21. (12-39)	
1	Bearing cap
2	Bearing cap fixing bolts (2 off)
3	Connecting rod
4	Big end bearing shell - upper
5	Big end bearing shell - lower
X	Cast pip
Y	Fracture split surfaces

Table 48. Service Parts

P1	Sealing compound
P2	Bearing cap fixing bolts
P3	Big end bearing shells

Table 49. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Torque wrench
T3	General	Angle gauge

Table 50. Torque Settings

Item	Nm	lbf ft	Angle	
2	35	25.8	-	1st stage
	65	47.9	-	2nd stage
	-	-	+90°	Final stage

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Disconnect and remove the fuel lines from the injectors, see ***Section 7 Fuel System - Fuel Lines***.

3 Remove the rocker cover, see ***Rocker Cover - Removal and Replacement***.

4 Remove the fuel injectors, see ***Section 7 Fuel System - Fuel Injectors (Atomisers)***.

5 Drain the oil from the engine, see ***Section 3 Routine Maintenance***.

6 Remove the oil pan, see ***Section 9 Lubrication System - Oil Pan***.

7 Position the engine upside down in a suitable jig or fixture, supported at the front of cylinder block.

Removal

1 It is recommended that the big end bearing caps are removed in pairs, cylinders **1** and **4** and cylinders **2** and **3**. Rotate the crankshaft so that the big end bearing caps on cylinders **2** and **3** are positioned as shown. Undo bolts **2** and lift off the bearing caps **1** from the connecting rods **3**. Note that the bolts MUST NOT be re-used. Discard the bolts **2**.

Important: *The connecting rod and bearing cap have been fracture split and must be kept together as a set. Utmost care must be taken to avoid contamination and / or damage to the fracture split surfaces* ***Y.***

2 Lift out the bearing shells **5** from the caps **1**. Carefully rotate the crank to disengage from the connecting rods and gain access to the upper bearing shells **4**. Lift out the upper bearing shells. It is recommended that the shells are renewed. If however they are to be reused, label the shells to ensure they are refitted in their original positions on assembly.

3 Carefully rotate the crankshaft to position the big end bearing caps of cylinders **1** and **4**. Make sure that the crank does not foul the connecting rods of cylinders **2** and **3**. Remove the bearing caps and bearing shells as described in steps **1** and **2** of Removal.

Inspection

1 Check the bearing shell surfaces for signs of damage and excessive wear.

2 Measure the crank pin diameters to confirm they are within service limits, see ***Section 1 Technical Data***.

Replacement

Replacement is the reverse of removal but note the following:

1 Ensure that all items are clean and free from damage and corrosion.

2 Fit the upper bearing shell **4** to the connecting rod **3**. Lubricate the bearing shell with clean engine oil.

3 Fit the lower bearing shell **5** to the bearing cap **1**. Lubricate the bearing shell with clean engine oil, then fit the bearing cap to the connecting rod. Ensure that the cast pip **X** on the bearing cap faces to the front of the engine.

Note: *Use compressed air to clean the fracture surfaces **Y** before assembly.*

4 Renew the fixing bolts. Torque tighten new bolts **2** in three stages, ⇨ ***Table 50. Torque Settings (🗋 12-40)***.

After Replacing

1 Carry out the procedures listed under ***Before removing*** in reverse order.

Piston and Connecting Rod Assembly

Removal and Replacement

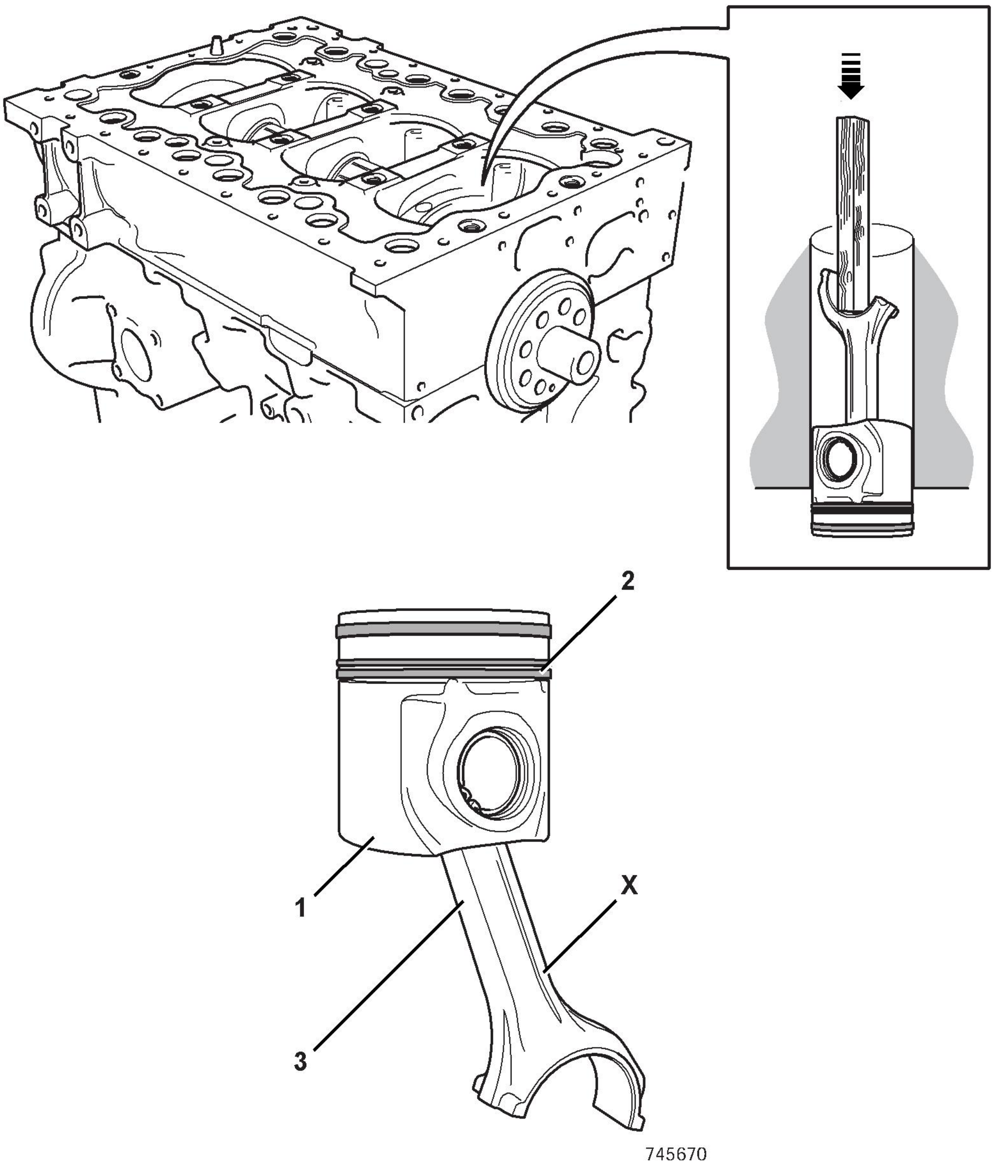


Fig 22.

Table 51. Component Identification

⇨ Fig 22. (12-42)	
1	Piston
2	Piston rings (3 off)
3	Connecting rod
X	Connecting rod - longest side

Table 52. Service Parts

P1	Piston rings

Table 53. Service Tools

Item	Part Number	Description
T1	General	Piston ring compressor

Before Removing

The following procedure is for one piston and connecting rod assembly. Note that each assembly must be replaced in the same cylinder bore. Label each piston and connecting rod assembly to ensure it is refitted in the correct position on assembly.

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Disconnect and remove the fuel lines from the injectors, see ***Section 7 Fuel System - Fuel Lines***.

3 Remove the rocker cover, see ***Rocker Cover - Removal and Replacement***.

4 Remove the fuel injectors, see ***Section 7 Fuel System - Fuel Injectors (Atomisers)***.

5 Remove the cylinder head assembly, see ***Cylinder Head Assembly - Removal and Replacement***.

6 Remove the oil pan, see ***Section 9 Lubrication System - Oil Pan***.

7 Remove the big end bearing caps, see ***Big End Bearing - Removal, Inspection and Replacement.***

Removal

The piston and connecting rod assemblies are removed through the top of the cylinder block.

1 Clean off the carbon deposits from around the top of the cylinder bore using a suitable scraper and wire wool. Take care not to scratch or damage the cylinder bore.

2 Tap the piston **1** from the connecting rod side using a hammer and a short length of wood to drive it out. Take care not to scratch or damage the cylinder bore or the connecting rod bearing surface.

Replacement

Replacement is the reverse of removal but note the following:

1 Ensure that all items are clean and free from damage and corrosion.

2 If the upper big end bearing shell has been removed replace it, see ***Big End Bearing - Replacement.***

3 Lubricate the cylinder bore with clean engine oil.

4 Use a suitable compressor tool to compress the piston rings **2**, see ***Service Tools.***

5 Insert the piston and connecting rod assembly into the cylinder bore making sure that the longest side **X** of the connecting rod is on the exhaust side of the cylinder block.

Note: *When guiding the connecting rod down the cylinder bore and over the crank pin diameter, take care not to damage the cooling jets.*

After Replacing

1 Refit the big end bearing caps, see ***Big End Bearing - Removal, Inspection and Replacement.***

2 Carry out the procedures listed under ***Before removing*** in reverse order.

Piston and Connecting Rod Assembly

Dismantling, Inspection and Assembly

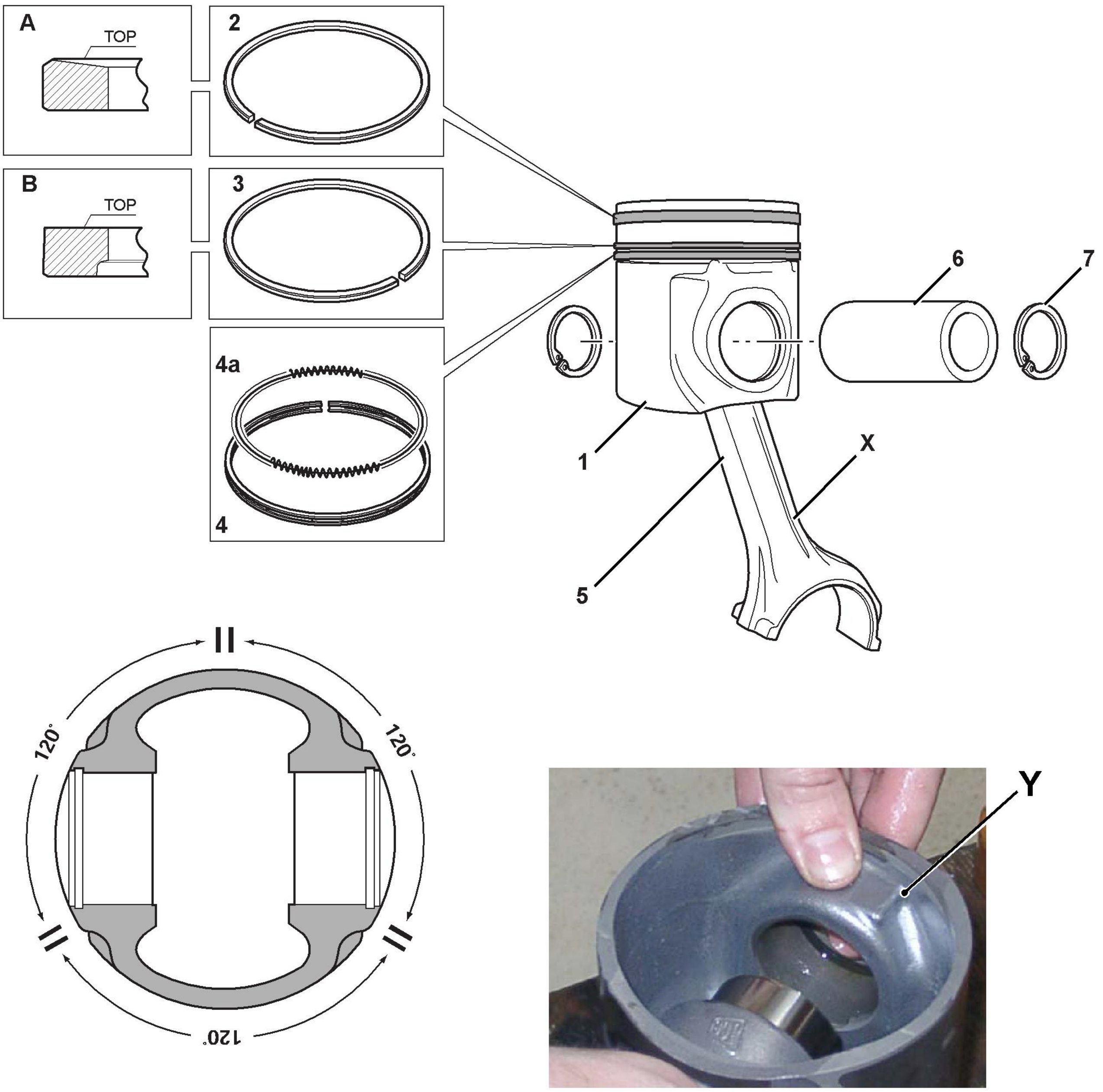


Fig 23.

Table 54. Component Identification

⇨ Fig 23. (12-44)	
1	Piston
2	Piston ring - compression No.1
3	Piston ring - compression No.2
4	Piston ring - oil control ring
4a	Spiral wire - oil control ring
5	Connecting rod
6	Piston pin
7	Retaining circlip (2 off)
X	Connecting rod - longest side
Y	Cast boss -piston

Table 55. Service Parts

P1	Piston
P2	Piston rings

Table 56. Service Tools

Item	Part Number	Description
T1	General	Piston ring expander
T2	General	Circlip pliers - Internal

Dismantling

1 Clamp the connecting rod **5** in a vice. Take care not to damage the connecting rod.

2 It is recommended that the piston rings are renewed. If however they are to be reused, label the rings to ensure they are refitted in the correct positions and the correct way up on assembly. Carefully remove the piston rings **2**, **3** and **4** from the piston **1**. To avoid damaging or distorting the rings use the piston ring expander tool, see ***Service Tools***. Note that oil control ring **4** is fitted with a spiral wire **4a**. Pull the wire apart and remove it.

3 Remove the circlips **7** and push out the piston pin **6**.

4 Using a suitable cleaning agent, clean the carbon deposits from the piston.

Inspection

1 Check the piston **1** for signs of damage and excessive wear. Measure the piston skirt diameter, piston pin bore and the clearance in the piston ring grooves to confirm they are within service limits, see ***Section 1 Technical Data.***

2 Check the piston pin **6** for signs of damage and excessive wear. Measure the pin diameter to confirm it is within service limits, see ***Section 1 Technical Data.***

The connecting rod small end bearing bush is not renewable. If the small end bearing bush is damaged or worn the connecting rod must be renewed as a complete assembly.

Assembly

Assembly is the reverse of dismantling but note the following:

1 Ensure that all items are clean and free from damage and corrosion.

2 Lubricate the piston pin **6** with clean engine oil. Assemble the connecting rod **5** to the piston **1** and insert the piston pin. Ensure that the long side **X** of the connecting rod is on the same side as the internal cast boss **Y** in the piston.

3 Fit new circlips **7**. Ensure they fit correctly in the groove in the piston.

4 Lubricate the piston with clean engine oil. Fit the piston rings to the piston in sequence as follows:

a Fit the spiral wire **4a** for the oil control ring **4** in the bottom groove and locate the locking wire inside both ends of the spiral as shown. Using a piston ring expander tool fit the oil control ring **4** in the bottom groove and locate the locking wire inside both ends of the spiral as shown. Ensure that the ring gap is positioned 180° to the locking wire.

b Fit the No.2 compression ring **3** into the middle groove. Note that new rings have a reference number etched on one face. Make sure that this face is fitted uppermost in the piston groove.

Note: *The correct ring orientation can also be determined from the profile shape of the ring as shown at* ***A****.*

c Fit the No.1 compresssion ring **2** into the top groove. Note that new rings have a reference number etched on one face. Make sure that this face is fitted uppermost in the piston groove.

Note: *The correct ring orientation can also be determined from the profile shape of the ring as shown at **B**.*

5 Rotate the piston rings so that the ring gaps are 120° apart as shown.

Crankshaft Assembly

Crankshaft Pulley

Removal and Replacement

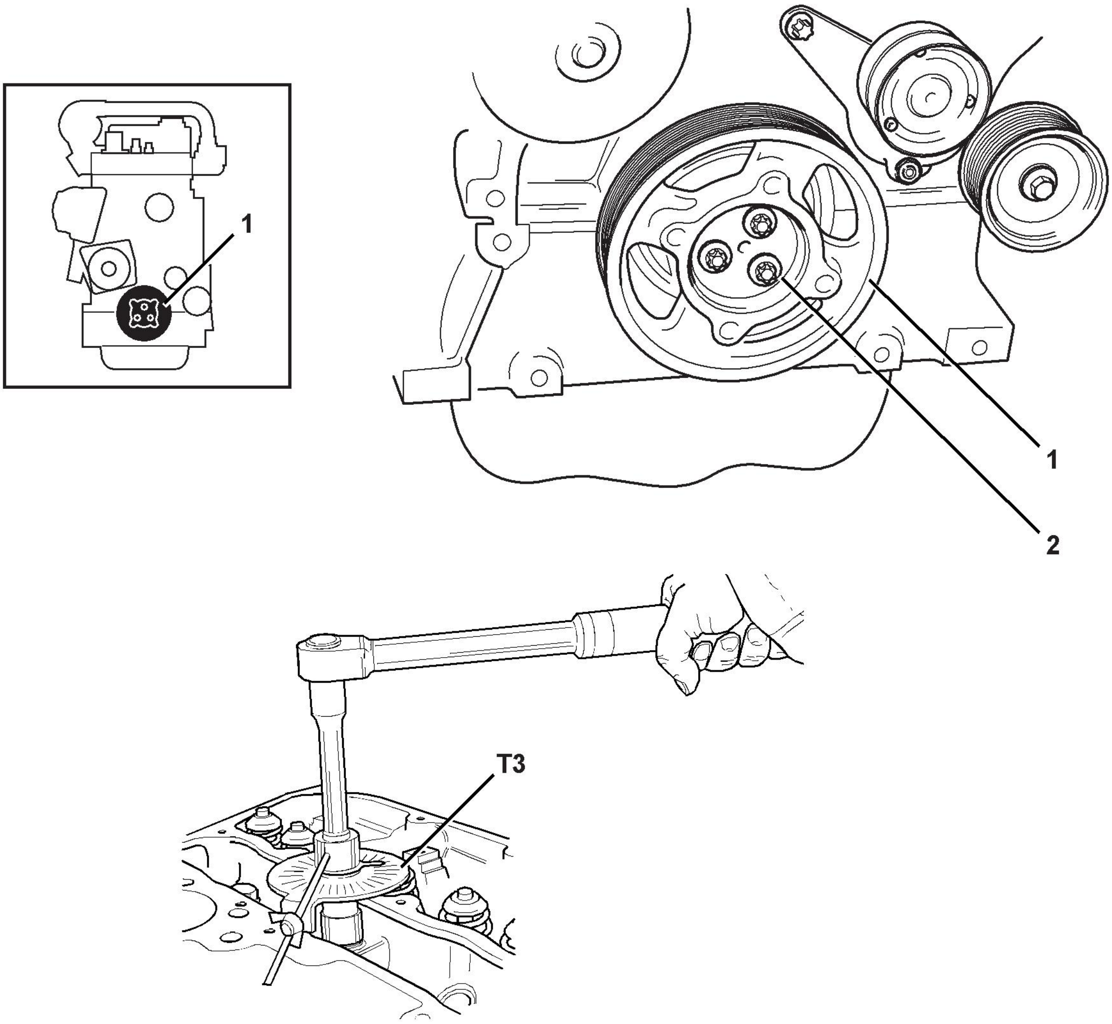


Fig 24.

Table 57. Component Identification

⇨ Fig 24. (12-47)	
1	Crankshaft pulley
2	Fixing bolts (3 off)

Table 58. Service Parts

P1	Fixing bolts

Table 59. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Dial gauge torque wrench
T3	General	Angle gauge

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Remove the accessory drive belt, see ***Section 3 Routine Maintenance.***

Removal

1 Undo bolts **2** and withdraw the pulley **1** from the crankshaft. Note that the bolts MUST NOT be re-used. Discard the bolts **2**.

Replacement

Replacement is the reverse of removal but note the following:

1 Ensure that all items are clean and free from damage and corrosion.

2 Renew the fixing bolts. Torque tighten new bolts **2** in three stages. ⇨ ***Table 60. Torque Settings (12-48)***.

Table 60. Torque Settings

Item	Nm	lbf ft	Angle	
2	30	22	-	1st stage
	75	56	-	2nd stage
	-	-	+180°	Final stage

After Replacing

1 Refit the accessory drive belt, see ***Section 3 Routine Maintenance.***

Rear Oil Seal

Removal and Replacement

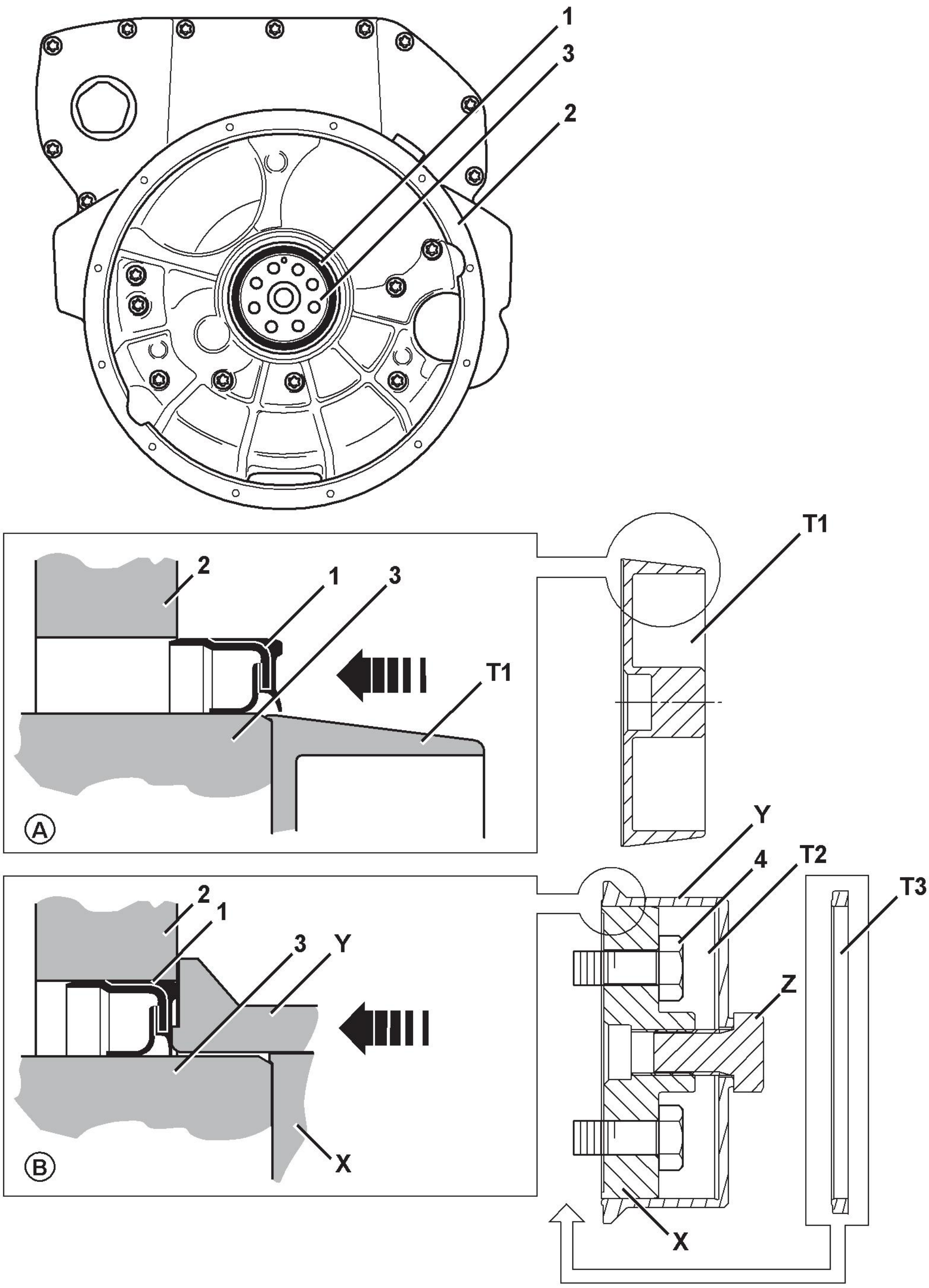


Fig 25.

Table 61. Component Identification

➩ *Fig 25. (12-49)*	
1	Crankshaft oil seal
2	Flywheel housing
3	Flywheel hub
4	Flywheel bolts (2 off)

Table 62. Service Parts

P1	Crankshaft oil seal - rear
P2	P80 lubricant

Table 63. Service Tools

Item	Part Number	Description
T1	892/01158	Mandrel
T2	892/01156	Seal fitting tool
comprises:		
X	Centre body	
Y	Outer sleeve	
Z	Screw	
T3 (1)	892/01259	Seal spacer ring (used to increase the seal insertion depth)

(1) *For use with specfic engine builds only - see the parts catalogue.*

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Remove the flywheel, see ***Flywheel - Removal and Replacement.***

Removal

Note: *Before removing the oil seal, identify the seal position in the counterbore. Some engines, have the front face of the seal flush with the edge of the counterbore as shown at **26V**, and some have the seal recessed as shown at **26W**.*

1 ➩ *Fig 25. (12-49)*. Carefully prise out the oil seal **1** from the counterbore in the flywheel housing **2** using a suitable lever behind the lip of the seal. Take care not to scratch or damage the counterbore or the flywheel hub **3**. Damaged or dirty sealing faces will cause the oil seal to fail.

Replacement

Important: *DO NOT touch the PTFE seal lips of the replacement crankshaft oil seal **1**.*

1 Ensure that the counterbore and the flywheel hub are clean and free from damage and corrosion.

2 To prevent the seal lip rolling over and becoming damaged, make sure you use the mandrel **T1** to initially install the oil seal **1** onto the flywheel hub **3**. Locate the mandrel over the end of the hub, then carefully push the oil seal over the mandrel and onto the crankshaft diameter. Make sure that the seal is fitted the correct way round as shown at **A**.

3 Apply lubricant P80 around the seal outer rubber diameter.

4 Dismantle the fitting tool **T2**. Bolt the centre body **X** onto the flywheel hub, using two flywheel bolts **4**. Assemble the outer sleeve **Y** (and spacer ring **T3** if applicable) onto the centre body and fit the screw **Z**.

5 Turn the screw **Z** to push the seal squarely into the counterbore until the outer sleeve comes up against the front edge of the counterbore. When correctly fitted, the front face of the seal (or the spacer ring **T3** if applicable) should be flush with the edge of the counterbore within 0.5 mm (0.020 in.) as shown at **B**. Make sure the seal is in the correct position as identified in ***Removal*** (see ***Note:***).

6 Remove the seal fitting tool.

After Replacing

1 Refit the flywheel, see ***Flywheel - Removal and Replacement.***

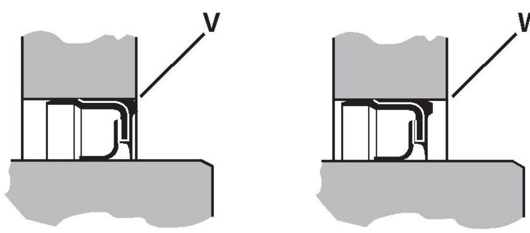


Fig 26.

Front Oil Seal

Removal and Replacement

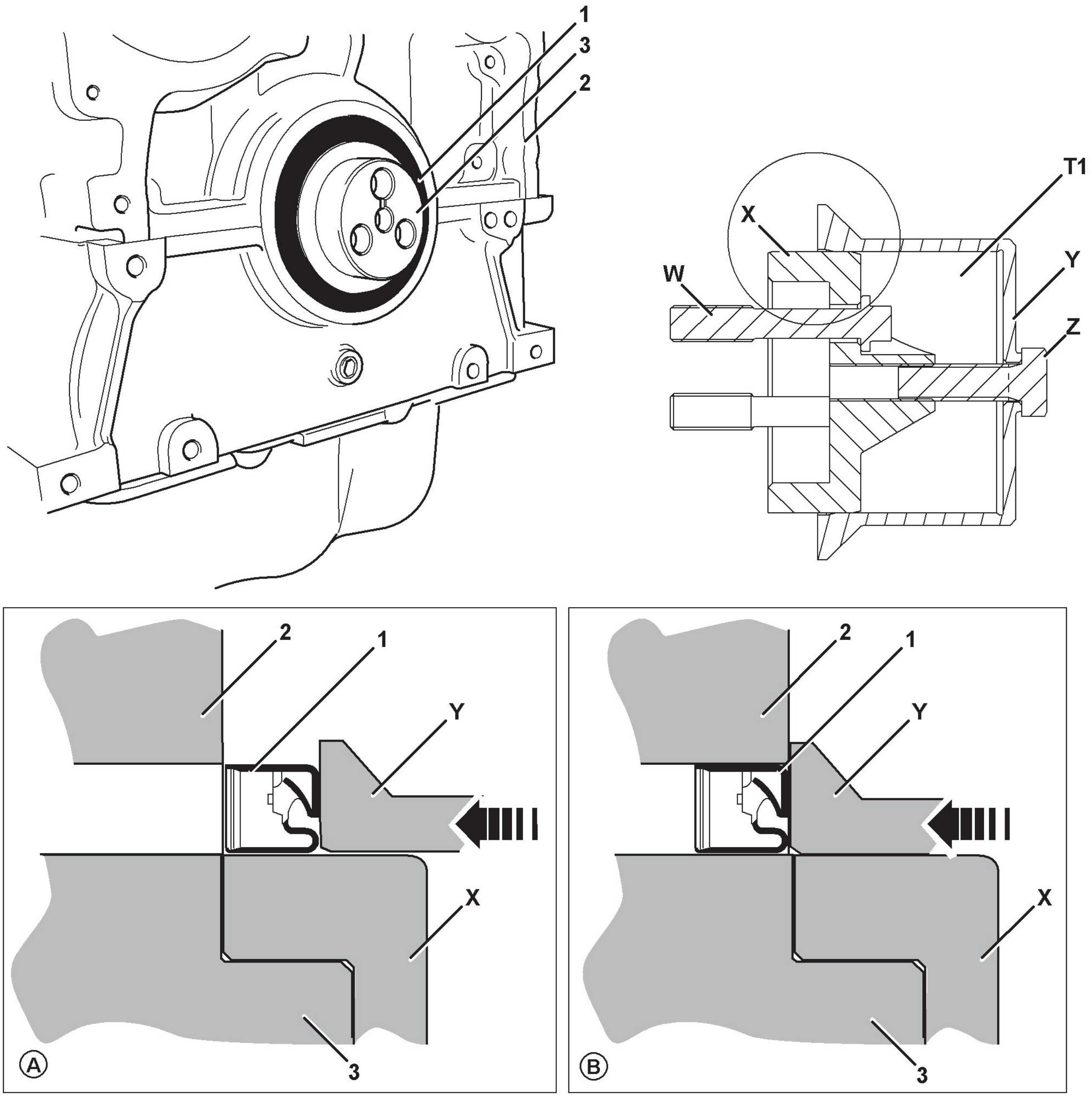


Fig 27.

Table 64. Component Identification

⇒ *Fig 27.* (12-51)	
1	Crankshaft oil seal
2	Cylinder block
3	Crankshaft hub

Table 65. Service Parts

P1	Crankshaft oil seal - front

Table 66. Service Tools

Item	Part Number	Description
T1	892/01157	Seal fitting tool
comprises:		
W	Fixing bolts (3 off)	
X	Centre body	
Y	Outer sleeve	
Z	Screw	

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Remove the accessory drive belt, see ***Section 3 Routine Maintenance***.

3 Remove the crankshaft pulley, see ***Crankshaft Pulley - Removal and Replacement.***

Removal

1 Carefully prise out the oil seal **1** from the counterbore in the cylinder block **2** using a suitable lever behind the lip of the seal. Take care not to scratch or damage the counterbore or the crankshaft hub **3**. Damaged or dirty sealing faces will cause the oil seal to fail.

Replacement

1 Ensure that the counterbore and the crankshaft hub are clean and free from damage and corrosion. Use a suitable degreasing agent to clean all traces of oil and grease from the counterbore.

Important: *The oil seal has a special coating and MUST be fitted `dry' without lubricant.*

2 Dismantle the seal fitting tool **T1**. Bolt the centre body **X** to the crankshaft hub, using bolts **W**, see ***Service Tools***.

3 Install the oil seal onto the centre body **X**. Make sure that the seal is fitted the correct way round. Assemble the outer sleeve **Y** onto the centre body and fit the screw **Z**. Shown at **A**.

4 Turn the screw **Z** to push the seal squarely into the counterbore until the outer sleeve comes up against the front edge of the counterbore. When correctly fitted, the front face of the seal should be flush with the edge of the counterbore within +/- 0.5 mm (+/- 0.020 inch). Shown at **B**.

5 Remove the seal fitting tool.

After Replacing

1 Refit the crankshaft pulley, see ***Crankshaft Pulley - Removal and Replacement.***

2 Refit the accessory drive belt, see ***Section 3 Routine Maintenance.***

Crankshaft

Removal and Replacement

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Remove the accessory drive belt, see ***Section 3 Routine Maintenance***.

3 Remove the crankshaft pulley, see ***Crankshaft Pulley - Removal and Replacement.***

4 Remove the oil pan, see ***Section 9 Lubrication System - Oil Pan.***

5 Disconnect and remove the fuel lines from the injectors, see ***Section 7 Fuel System - Fuel Lines.***

6 Remove the rocker cover, see ***Rocker Cover - Removal and Replacement.***

7 Remove the fuel injectors, see ***Section 7 Fuel System - Fuel Injectors (Atomisers).***

8 Remove the rocker assembly including the push rods, see ***Rocker Assembly - Removal and Replacement***.

9 It is not necessary to remove the cylinder head assembly to remove the crankshaft. If however the cylinder head needs to be removed for other reasons (for piston and connecting rod removal for example) remove it now, see ***Cylinder Head Assembly - Removal and Replacement.***

10 Remove the fuel injection pump, see ***Section 7 Fuel System - Fuel Injection Pump***.

11 Remove the starter motor, see ***Section 10 Electrical System - Starter Motor.***

12 Remove the high duty PTO device (if fitted) see ***Section 13 Auxiliary Equipment - High Duty P.T.O***.

13 Position the engine upside down in a suitable jig or fixture, supported at the front of cylinder block.

14 Remove the flywheel, see ***Flywheel - Removal and Replacement.***

15 Remove the flywheel housing, see ***Flywheel Housing - Removal and Replacement.***

16 Remove the fuel injection pump drive gear, see ***Drive Gear - Fuel Injection Pump - Removal and Replacement.***

17 Remove the oil pump, see ***Section 9 Lubrication System - Oil Pump***.

18 Remove the high duty PTO idler drive gear (if fitted), see ***Drive Gear - High Duty P.T.O. Idler - Removal and Replacement.***

19 Remove the crankshaft drive gear, see ***Drive Gear - Crankshaft - Removal and Replacement.***

20 Remove the camshaft, see ***Camshaft and Tappets - Removal and Replacement***.

21 Remove the rear timing case, see ***Timing Case - Rear - Removal and Replacement***.

22 If the pistons and connecting rods have not been removed, undo and remove the big end bearing caps, see ***Pistons and Connecting Rods - Big End Bearing.***

Removal, Bedplate

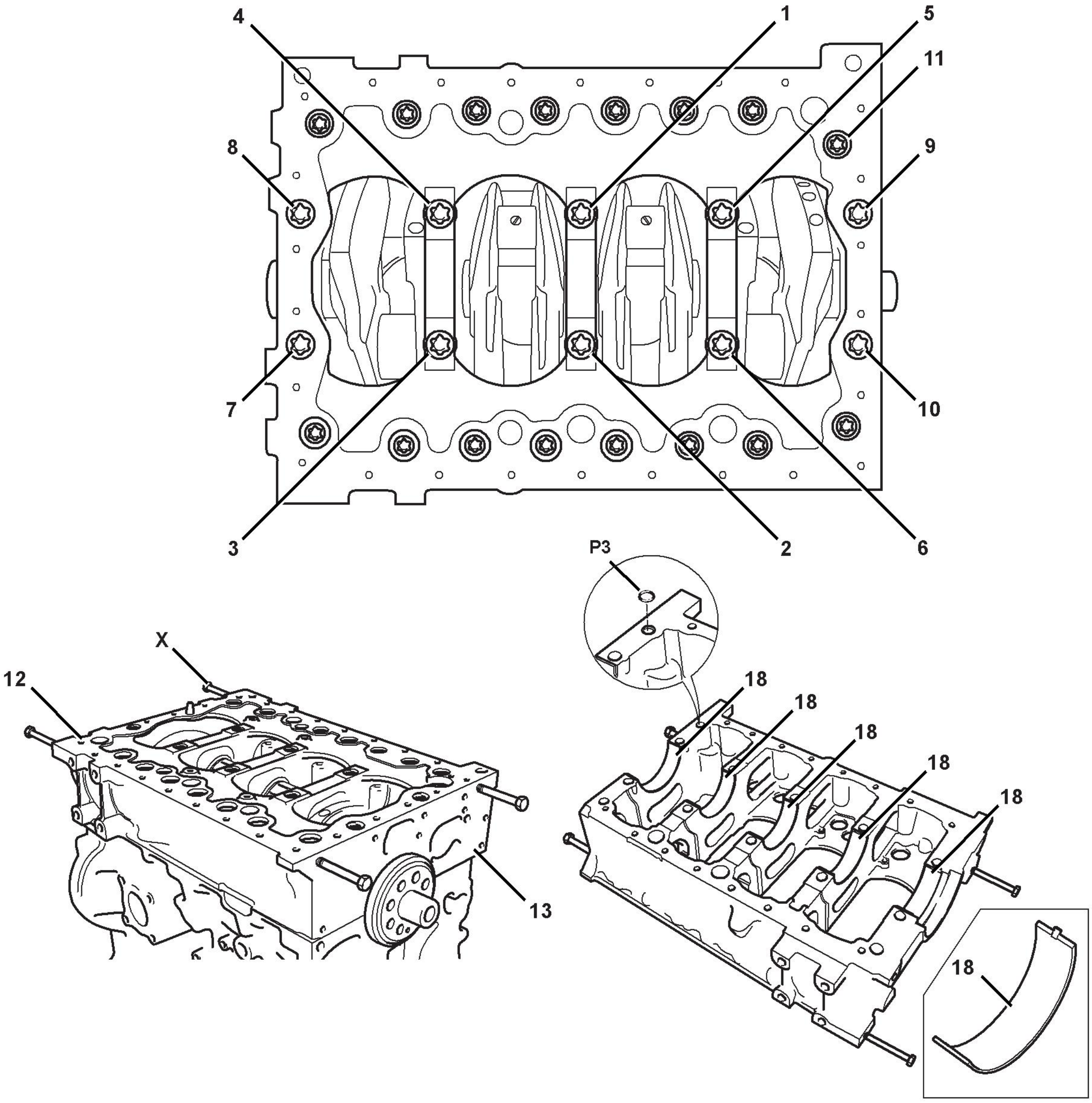


Fig 28.

Table 67. Component Identification

⇒ *Fig 28. (12-54)*	
1-10	Main bearing bolts (10 off)
11	Bedplate peripheral bolts (16 off)
12	Bedplate
13	Cylinder block
18	Upper bearing shell (5 off)

Table 68. Service Parts

P3	O-ring (if fitted))

Table 69. ServiceTools

T1	Lifting bolts (4 off Locally manufactured)

1. Undo the bedplate peripheral bolts **11**.
2. Progressively undo the main bearing bolts **1-10** in reverse order starting at bolt **10**. The bolts MUST NOT be re-used. Discard the bolts **1-10**.
3. Fit four temporary lifting bolts **T1**. Carefully separate the bedplate **12** from the cylinder block **13**. Use suitable lifting equipment (if the bedplate is lifted manually, two people will be required). DO NOT use a lever to separate the bedplate.
4. Remove and discard the O-ring **P3** (if fitted).
5. Carefully remove the upper bearing shells **18** from the bedplate.

Removal, Crankshaft

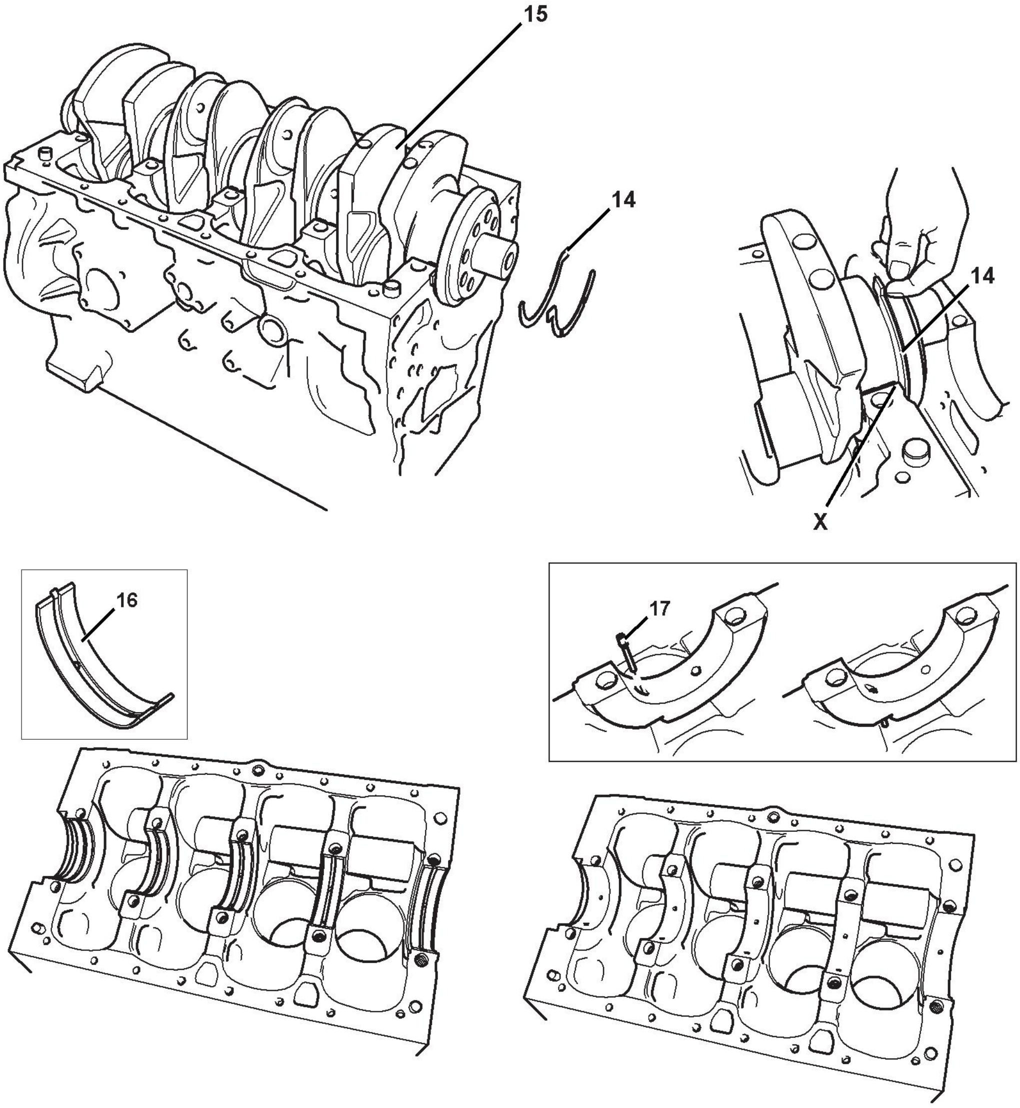


Fig 29.

Table 43. Component Identification

⇒ Fig 18. (12-36)	
1	Timing case - rear
2	Timing case fixing bolts (19 off)
3	Cylinder block/bed plate assembly
4	Dowel
5	Dowel - with flats

Table 44. Service Parts

P1	Anaerobic sealant

Table 45. Service Tools

Item	Part Number	Description
T1	General	Alignment pins (Locally manufacture)
T2	892/01176	Sealant template
	Comprising:	
	A	Main template
	B	Long gallery template
	C	Short gallery template

Before Removing

1 Drain the oil from the engine, see ***Section 3 Routine Maintenance.***

2 Disconnect and remove the fuel lines from the injectors, see ***Section 7 Fuel System - Fuel Lines***.

3 Remove the fuel injection pump, see ***Section 7 Fuel System - Fuel Injection Pump.***

4 Remove the fuel lift pump, see ***Section 7 Fuel System - Fuel Lift Pump***.

5 Remove the starter motor, see ***Section 10 Electrical System - Starter Motor.***

6 Remove the high duty PTO device (if fitted).

7 Remove the low duty PTO device (if fitted).

8 Remove the flywheel, see ***Flywheel - Removal and Replacement***.

9 Remove the flywheel housing, see ***Flywheel Housing - Removal and Replacement.***

10 Remove the fuel injection pump drive gear, see ***Drive Gear - Fuel Injection Pump - Removal and Replacement***.

11 Remove the oil pump, see ***Section 9 Lubrication System - Oil Pump***.

12 Remove the high duty PTO idler drive gear (if fitted), see ***Drive Gear - High Duty P.T.O. Idler - Removal and Replacement.***

13 Remove the crankshaft drive gear, see ***Drive Gear - Crankshaft - Removal and Replacement***.

14 Remove the camshaft, see ***Camshaft and Tappets - Removal and Replacement***.

Removal

1 Undo bolts **2** and then separate the timing case **1** from the cylinder block/bed plate assembly **3**. DO NOT use a lever to separate the timing case from the cylinder block/bed plate assembly.

Replacement

Important: *Anaerobic sealant will not start to cure whilst it is open to the atmosphere, however when air is excluded (for instance when the two parts are put together) it will immediately start to harden. Make sure that all the necessary tools, bolts etc are readily available prior to assembling the components. The parts must be fitted and torque tightened within 5 minutes (with a maximum permissible time of 15 minutes.).*

1 Carefully remove all traces of the old sealing compound from the timing case **1** and cylinder block/bed plate assembly **3** mating faces. Make sure that the mating faces are clean and free from damage. Clean the inside of the case **1** using a suitable degreaser.

2 Fit two alignment pins **T1** to the cylinder head/bed plate assembly **3**.

3 Make sure that dowels **4** and **5** are correctly located in the cylinder block.

Note: *Dowel **5** has flats which must be positioned relative to dowel **4**, as shown **W**. This ensures correct alignment of the timing cover **1**.*

4 Sealant template **T2** comprises three pieces. Locate parts **B** and **C** using the holes in the templates and fixing bolts at positions **Y** as shown.

5 Using the templates **B** and **C** as a guide apply a continuous 1.5 mm (0.060 in.) bead of sealant **P1** to the case. Remove the bolts from positions **Y**. Remove the templates making sure not to smudge the sealant. Discard the templates.

6 Locate part **A** of the template **T2** using the holes in the template and fixing bolts at positions **X** as shown.

7 Using the template **A** as a guide apply a continuous 1.5 mm (0.060 in.) bead of sealant **P1** to the case. Do not follow the template at **V**, instead apply a continuous bead **Z** (inboard of the fixing hole). Remove the bolts from positions **X**. Remove the template making sure not to smudge the sealant. Discard the template.

8 Locate the timing case **1** on the alignment pins **T1** and fit the bolts **2** (remove pins **T1** to fit the final 2 bolts). Torque tighten the bolts **2**. ⇨ *Table 46. Torque Settings (12-38)*.

Important: *If the parts have not been torque tightened within the maximum 15 minute time period, then the parts must be separated, thoroughly cleaned and fresh sealant applied*

Table 46. Torque Settings

Item	Nm	lbf ft
2	33	24

After Replacing

1 Replace all the components listed under ***Before removing*** in reverse order.

Pistons and Connecting Rods

Big End Bearing

Removal, Inspection and Assembly

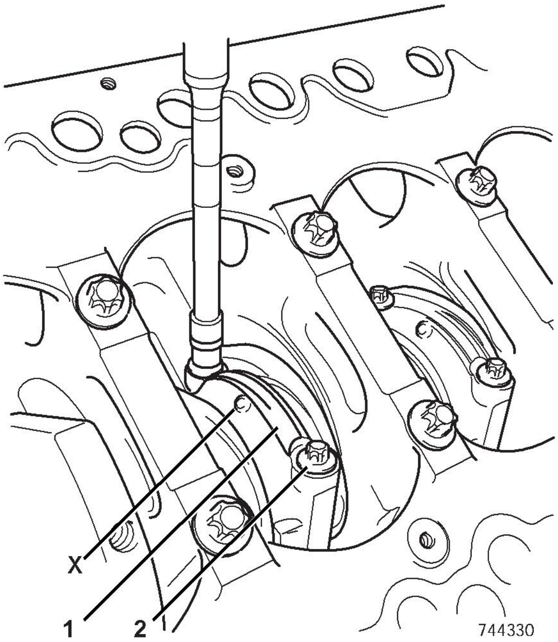


Fig 19.

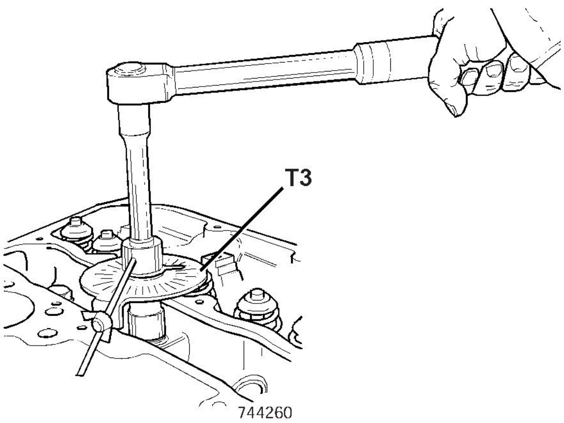
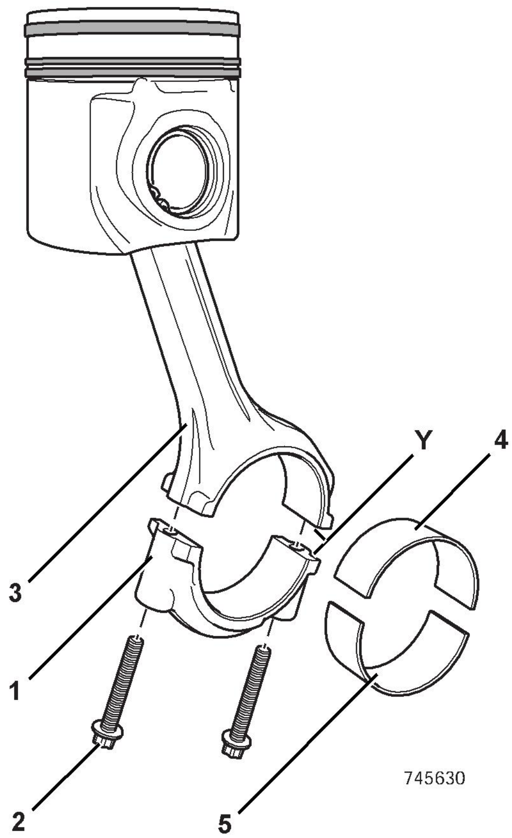


Fig 20.



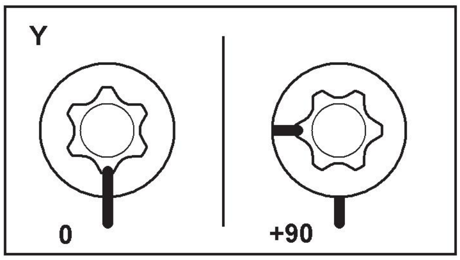


Fig 21.

Table 47. Component Identification

⇨ Fig 19. (12-39), ⇨ Fig 21. (12-39)	
1	Bearing cap
2	Bearing cap fixing bolts (2 off)
3	Connecting rod
4	Big end bearing shell - upper
5	Big end bearing shell - lower
X	Cast pip
Y	Fracture split surfaces

Table 48. Service Parts

P1	Sealing compound
P2	Bearing cap fixing bolts
P3	Big end bearing shells

Table 49. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Torque wrench
T3	General	Angle gauge

Table 50. Torque Settings

Item	Nm	lbf ft	Angle	
2	35	25.8	-	1st stage
	65	47.9	-	2nd stage
	-	-	+90°	Final stage

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Disconnect and remove the fuel lines from the injectors, see ***Section 7 Fuel System - Fuel Lines***.

3 Remove the rocker cover, see ***Rocker Cover - Removal and Replacement***.

4 Remove the fuel injectors, see ***Section 7 Fuel System - Fuel Injectors (Atomisers)***.

5 Drain the oil from the engine, see ***Section 3 Routine Maintenance***.

6 Remove the oil pan, see ***Section 9 Lubrication System - Oil Pan***.

7 Position the engine upside down in a suitable jig or fixture, supported at the front of cylinder block.

Removal

1 It is recommended that the big end bearing caps are removed in pairs, cylinders **1** and **4** and cylinders **2** and **3**. Rotate the crankshaft so that the big end bearing caps on cylinders **2** and **3** are positioned as shown. Undo bolts **2** and lift off the bearing caps **1** from the connecting rods **3**. Note that the bolts MUST NOT be re-used. Discard the bolts **2**.

Important: *The connecting rod and bearing cap have been fracture split and must be kept together as a set. Utmost care must be taken to avoid contamination and / or damage to the fracture split surfaces* ***Y.***

2 Lift out the bearing shells **5** from the caps **1**. Carefully rotate the crank to disengage from the connecting rods and gain access to the upper bearing shells **4**. Lift out the upper bearing shells. It is recommended that the shells are renewed. If however they are to be reused, label the shells to ensure they are refitted in their original positions on assembly.

3 Carefully rotate the crankshaft to position the big end bearing caps of cylinders **1** and **4**. Make sure that the crank does not foul the connecting rods of cylinders **2** and **3**. Remove the bearing caps and bearing shells as described in steps **1** and **2** of Removal.

Inspection

1 Check the bearing shell surfaces for signs of damage and excessive wear.

2 Measure the crank pin diameters to confirm they are within service limits, see ***Section 1 Technical Data***.

Replacement

Replacement is the reverse of removal but note the following:

1 Ensure that all items are clean and free from damage and corrosion.

2 Fit the upper bearing shell **4** to the connecting rod **3**. Lubricate the bearing shell with clean engine oil.

3 Fit the lower bearing shell **5** to the bearing cap **1**. Lubricate the bearing shell with clean engine oil, then fit the bearing cap to the connecting rod. Ensure that the cast pip **X** on the bearing cap faces to the front of the engine.

Note: *Use compressed air to clean the fracture surfaces* ***Y*** *before assembly.*

4 Renew the fixing bolts. Torque tighten new bolts **2** in three stages, ⇨ ***Table 50. Torque Settings (🗋 12-40)***.

After Replacing

1 Carry out the procedures listed under ***Before removing*** in reverse order.

Piston and Connecting Rod Assembly

Removal and Replacement

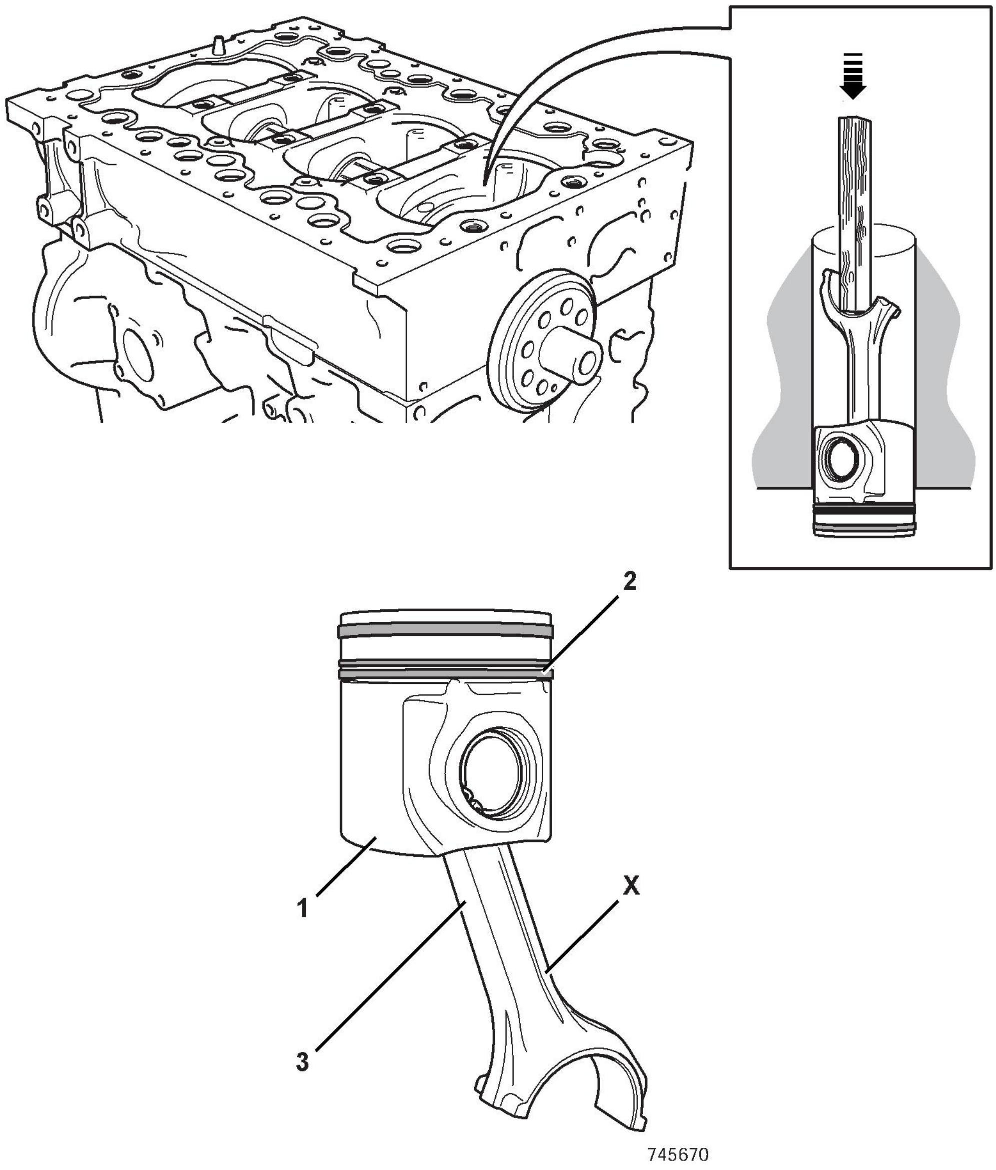


Fig 22.

Table 51. Component Identification

⇨ Fig 22. (12-42)	
1	Piston
2	Piston rings (3 off)
3	Connecting rod
X	Connecting rod - longest side

Table 52. Service Parts

P1	Piston rings

Table 53. Service Tools

Item	Part Number	Description
T1	General	Piston ring compressor

Before Removing

The following procedure is for one piston and connecting rod assembly. Note that each assembly must be replaced in the same cylinder bore. Label each piston and connecting rod assembly to ensure it is refitted in the correct position on assembly.

1. This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.
2. Disconnect and remove the fuel lines from the injectors, see ***Section 7 Fuel System - Fuel Lines***.
3. Remove the rocker cover, see ***Rocker Cover - Removal and Replacement***.
4. Remove the fuel injectors, see ***Section 7 Fuel System - Fuel Injectors (Atomisers)***.
5. Remove the cylinder head assembly, see ***Cylinder Head Assembly - Removal and Replacement***.
6. Remove the oil pan, see ***Section 9 Lubrication System - Oil Pan***.
7. Remove the big end bearing caps, see ***Big End Bearing - Removal, Inspection and Replacement.***

Removal

The piston and connecting rod assemblies are removed through the top of the cylinder block.

1. Clean off the carbon deposits from around the top of the cylinder bore using a suitable scraper and wire wool. Take care not to scratch or damage the cylinder bore.
2. Tap the piston **1** from the connecting rod side using a hammer and a short length of wood to drive it out. Take care not to scratch or damage the cylinder bore or the connecting rod bearing surface.

Replacement

Replacement is the reverse of removal but note the following:

1. Ensure that all items are clean and free from damage and corrosion.
2. If the upper big end bearing shell has been removed replace it, see ***Big End Bearing - Replacement.***
3. Lubricate the cylinder bore with clean engine oil.
4. Use a suitable compressor tool to compress the piston rings **2**, see ***Service Tools.***
5. Insert the piston and connecting rod assembly into the cylinder bore making sure that the longest side **X** of the connecting rod is on the exhaust side of the cylinder block.

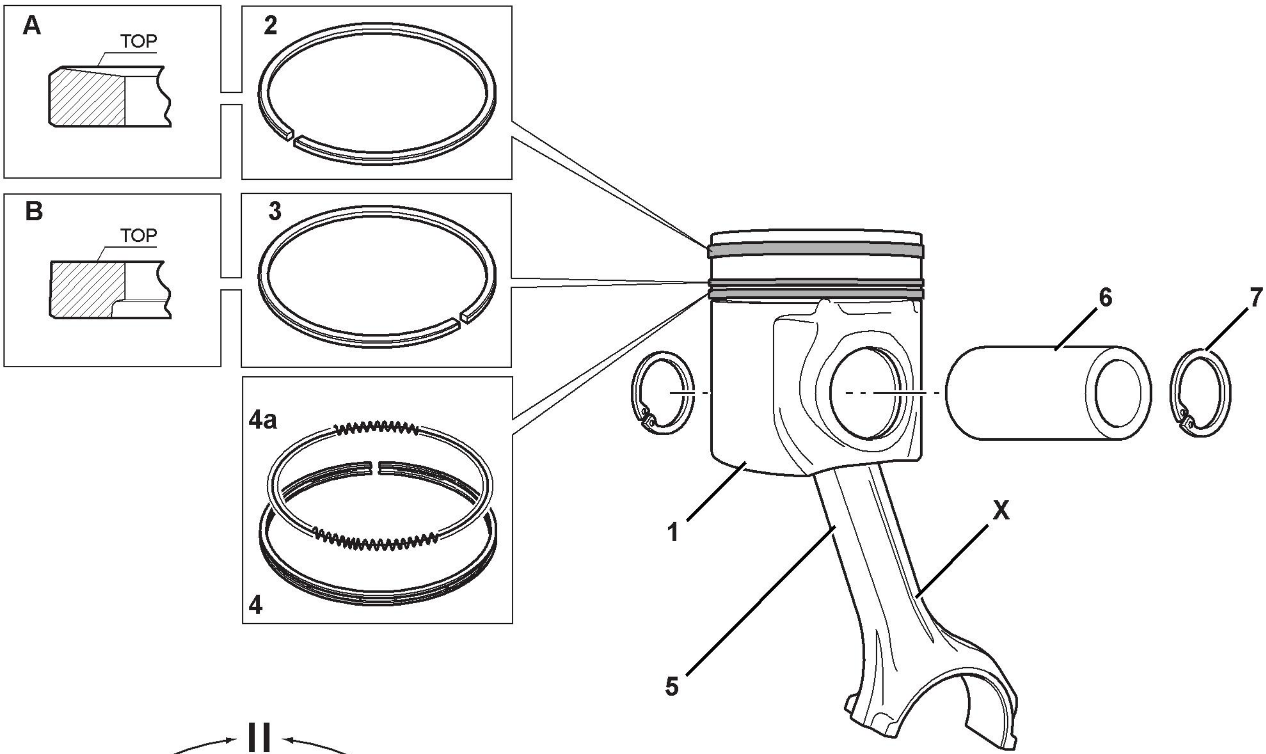
Note: *When guiding the connecting rod down the cylinder bore and over the crank pin diameter, take care not to damage the cooling jets.*

After Replacing

1. Refit the big end bearing caps, see ***Big End Bearing - Removal, Inspection and Replacement.***
2. Carry out the procedures listed under ***Before removing*** in reverse order.

Piston and Connecting Rod Assembly

Dismantling, Inspection and Assembly



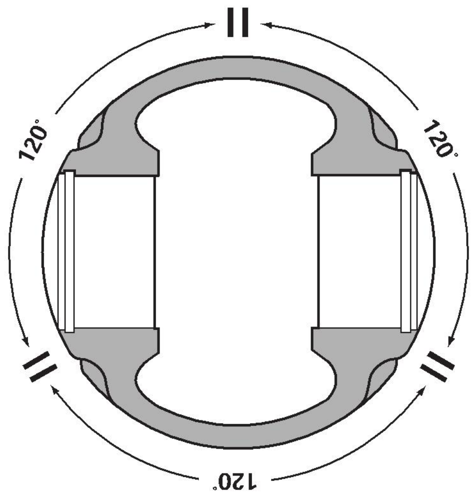


Fig 23.

Table 54. Component Identification

⇨ *Fig 23. (12-44)*	
1	Piston
2	Piston ring - compression No.1
3	Piston ring - compression No.2
4	Piston ring - oil control ring
4a	Spiral wire - oil control ring
5	Connecting rod
6	Piston pin
7	Retaining circlip (2 off)
X	Connecting rod - longest side
Y	Cast boss -piston

Table 55. Service Parts

P1	Piston
P2	Piston rings

Table 56. Service Tools

Item	Part Number	Description
T1	General	Piston ring expander
T2	General	Circlip pliers - Internal

Dismantling

1 Clamp the connecting rod **5** in a vice. Take care not to damage the connecting rod.

2 It is recommended that the piston rings are renewed. If however they are to be reused, label the rings to ensure they are refitted in the correct positions and the correct way up on assembly. Carefully remove the piston rings **2**, **3** and **4** from the piston **1**. To avoid damaging or distorting the rings use the piston ring expander tool, see ***Service Tools***. Note that oil control ring **4** is fitted with a spiral wire **4a**. Pull the wire apart and remove it.

3 Remove the circlips **7** and push out the piston pin **6**.

4 Using a suitable cleaning agent, clean the carbon deposits from the piston.

Inspection

1 Check the piston **1** for signs of damage and excessive wear. Measure the piston skirt diameter, piston pin bore and the clearance in the piston ring grooves to confirm they are within service limits, see ***Section 1 Technical Data.***

2 Check the piston pin **6** for signs of damage and excessive wear. Measure the pin diameter to confirm it is within service limits, see ***Section 1 Technical Data.***

The connecting rod small end bearing bush is not renewable. If the small end bearing bush is damaged or worn the connecting rod must be renewed as a complete assembly.

Assembly

Assembly is the reverse of dismantling but note the following:

1 Ensure that all items are clean and free from damage and corrosion.

2 Lubricate the piston pin **6** with clean engine oil. Assemble the connecting rod **5** to the piston **1** and insert the piston pin. Ensure that the long side **X** of the connecting rod is on the same side as the internal cast boss **Y** in the piston.

3 Fit new circlips **7**. Ensure they fit correctly in the groove in the piston.

4 Lubricate the piston with clean engine oil. Fit the piston rings to the piston in sequence as follows:

- **a** Fit the spiral wire **4a** for the oil control ring **4** in the bottom groove and locate the locking wire inside both ends of the spiral as shown. Using a piston ring expander tool fit the oil control ring **4** in the bottom groove and locate the locking wire inside both ends of the spiral as shown. Ensure that the ring gap is positioned 180° to the locking wire.

- **b** Fit the No.2 compression ring **3** into the middle groove. Note that new rings have a reference number etched on one face. Make sure that this face is fitted uppermost in the piston groove.

Note: *The correct ring orientation can also be determined from the profile shape of the ring as shown at **A**.*

- **c** Fit the No.1 compresssion ring **2** into the top groove. Note that new rings have a reference number etched on one face. Make sure that this face is fitted uppermost in the piston groove.

Note: *The correct ring orientation can also be determined from the profile shape of the ring as shown at **B**.*

5 Rotate the piston rings so that the ring gaps are 120° apart as shown.

Crankshaft Assembly

Crankshaft Pulley

Removal and Replacement

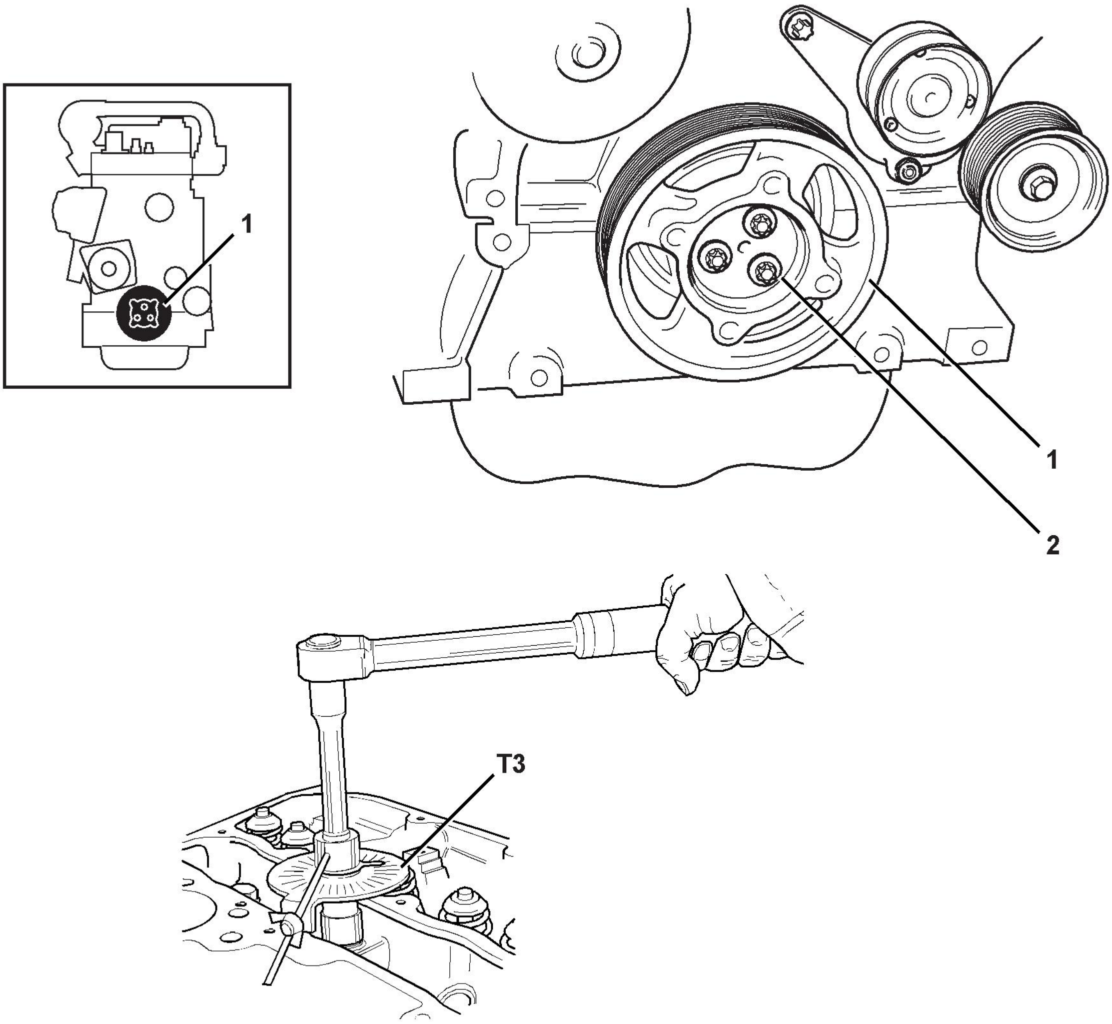


Fig 24.

Table 57. Component Identification

⇨ *Fig 24. (12-47)*	
1	Crankshaft pulley
2	Fixing bolts (3 off)

Table 58. Service Parts

P1	Fixing bolts

Table 59. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Dial gauge torque wrench
T3	General	Angle gauge

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Remove the accessory drive belt, see ***Section 3 Routine Maintenance.***

Removal

1 Undo bolts **2** and withdraw the pulley **1** from the crankshaft. Note that the bolts MUST NOT be re-used. Discard the bolts **2**.

Replacement

Replacement is the reverse of removal but note the following:

1 Ensure that all items are clean and free from damage and corrosion.

2 Renew the fixing bolts. Torque tighten new bolts **2** in three stages. ⇨ ***Table 60. Torque Settings (12-48)***.

Table 60. Torque Settings

Item	Nm	lbf ft	Angle	
2	30	22	-	1st stage
	75	56	-	2nd stage
	-	-	+180°	Final stage

After Replacing

1 Refit the accessory drive belt, see ***Section 3 Routine Maintenance.***

Rear Oil Seal

Removal and Replacement

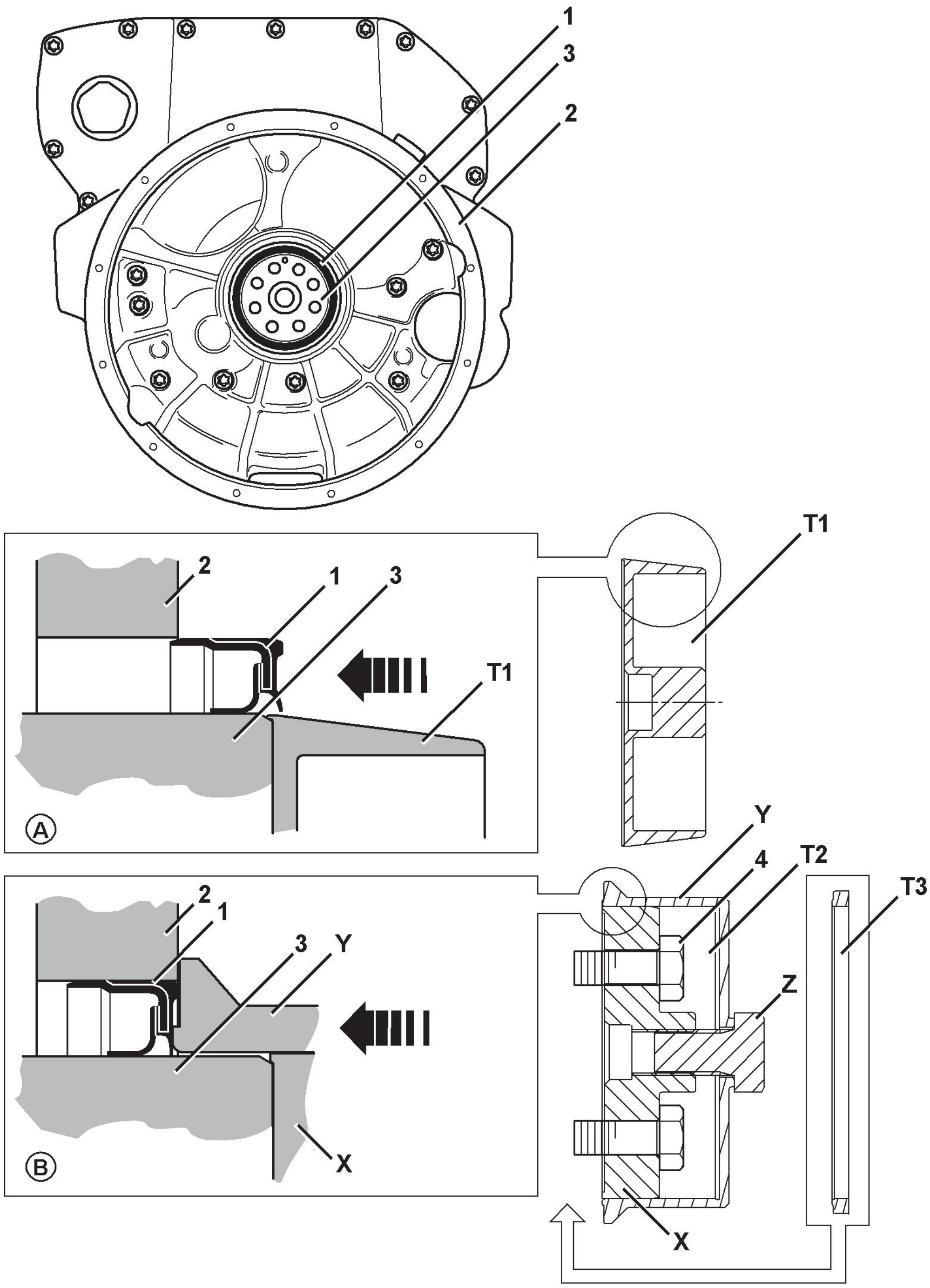


Fig 25.

Table 61. Component Identification

⇨ *Fig 25. (12-49)*	
1	Crankshaft oil seal
2	Flywheel housing
3	Flywheel hub
4	Flywheel bolts (2 off)

Table 62. Service Parts

P1	Crankshaft oil seal - rear
P2	P80 lubricant

Table 63. Service Tools

Item	Part Number	Description
T1	892/01158	Mandrel
T2	892/01156	Seal fitting tool
comprises:		
X	Centre body	
Y	Outer sleeve	
Z	Screw	
T3 (1)	892/01259	Seal spacer ring (used to increase the seal insertion depth)

(1) For use with specfic engine builds only - see the parts catalogue.

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Remove the flywheel, see ***Flywheel - Removal and Replacement.***

Removal

Note: *Before removing the oil seal, identify the seal position in the counterbore. Some engines, have the front face of the seal flush with the edge of the counterbore as shown at **26V**, and some have the seal recessed as shown at **26W**.*

1 ⇨ *Fig 25. (12-49)*. Carefully prise out the oil seal **1** from the counterbore in the flywheel housing **2** using a suitable lever behind the lip of the seal. Take care not to scratch or damage the counterbore or the flywheel hub **3**. Damaged or dirty sealing faces will cause the oil seal to fail.

Replacement

Important: *DO NOT touch the PTFE seal lips of the replacement crankshaft oil seal **1**.*

1 Ensure that the counterbore and the flywheel hub are clean and free from damage and corrosion.

2 To prevent the seal lip rolling over and becoming damaged, make sure you use the mandrel **T1** to initially install the oil seal **1** onto the flywheel hub **3**. Locate the mandrel over the end of the hub, then carefully push the oil seal over the mandrel and onto the crankshaft diameter. Make sure that the seal is fitted the correct way round as shown at **A**.

3 Apply lubricant P80 around the seal outer rubber diameter.

4 Dismantle the fitting tool **T2**. Bolt the centre body **X** onto the flywheel hub, using two flywheel bolts **4**. Assemble the outer sleeve **Y** (and spacer ring **T3** if applicable) onto the centre body and fit the screw **Z**.

5 Turn the screw **Z** to push the seal squarely into the counterbore until the outer sleeve comes up against the front edge of the counterbore. When correctly fitted, the front face of the seal (or the spacer ring **T3** if applicable) should be flush with the edge of the counterbore within 0.5 mm (0.020 in.) as shown at **B**. Make sure the seal is in the correct position as identified in ***Removal*** (see ***Note:***).

6 Remove the seal fitting tool.

After Replacing

1 Refit the flywheel, see ***Flywheel - Removal and Replacement.***

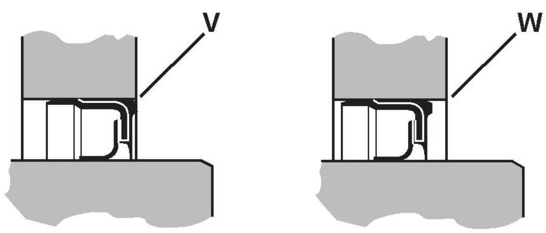


Fig 26.

Front Oil Seal

Removal and Replacement

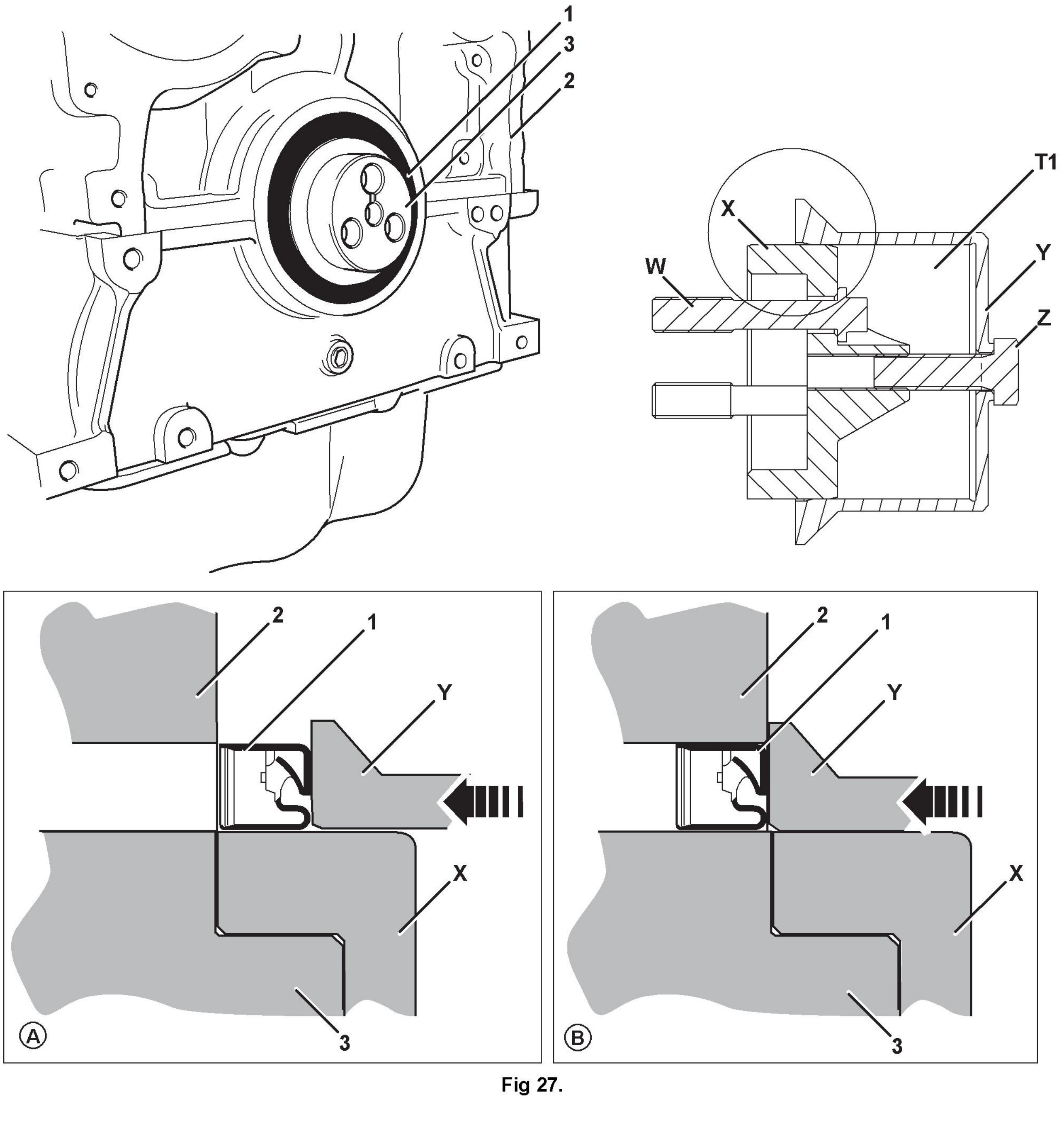


Fig 27.

Table 64. Component Identification

⇨ Fig 27. (12-51)	
1	Crankshaft oil seal
2	Cylinder block
3	Crankshaft hub

Table 65. Service Parts

P1	Crankshaft oil seal - front

Table 66. Service Tools

Item	Part Number	Description
T1	892/01157	Seal fitting tool
comprises:		
W	Fixing bolts (3 off)	
X	Centre body	
Y	Outer sleeve	
Z	Screw	

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Remove the accessory drive belt, see ***Section 3 Routine Maintenance***.

3 Remove the crankshaft pulley, see ***Crankshaft Pulley - Removal and Replacement.***

Removal

1 Carefully prise out the oil seal **1** from the counterbore in the cylinder block **2** using a suitable lever behind the lip of the seal. Take care not to scratch or damage the counterbore or the crankshaft hub **3**. Damaged or dirty sealing faces will cause the oil seal to fail.

Replacement

1 Ensure that the counterbore and the crankshaft hub are clean and free from damage and corrosion. Use a suitable degreasing agent to clean all traces of oil and grease from the counterbore.

Important: *The oil seal has a special coating and MUST be fitted `dry' without lubricant.*

2 Dismantle the seal fitting tool **T1**. Bolt the centre body **X** to the crankshaft hub, using bolts **W**, see ***Service Tools***.

3 Install the oil seal onto the centre body **X**. Make sure that the seal is fitted the correct way round. Assemble the outer sleeve **Y** onto the centre body and fit the screw **Z**. Shown at **A**.

4 Turn the screw **Z** to push the seal squarely into the counterbore until the outer sleeve comes up against the front edge of the counterbore. When correctly fitted, the front face of the seal should be flush with the edge of the counterbore within +/- 0.5 mm (+/- 0.020 inch). Shown at **B**.

5 Remove the seal fitting tool.

After Replacing

1 Refit the crankshaft pulley, see ***Crankshaft Pulley - Removal and Replacement.***

2 Refit the accessory drive belt, see ***Section 3 Routine Maintenance.***

Crankshaft

Removal and Replacement

Before Removing

1 This procedure requires service parts. Make sure you have obtained the correct service parts before you start, see ***Service Parts***.

2 Remove the accessory drive belt, see ***Section 3 Routine Maintenance***.

3 Remove the crankshaft pulley, see ***Crankshaft Pulley - Removal and Replacement.***

4 Remove the oil pan, see ***Section 9 Lubrication System - Oil Pan.***

5 Disconnect and remove the fuel lines from the injectors, see ***Section 7 Fuel System - Fuel Lines.***

6 Remove the rocker cover, see ***Rocker Cover - Removal and Replacement.***

7 Remove the fuel injectors, see ***Section 7 Fuel System - Fuel Injectors (Atomisers).***

8 Remove the rocker assembly including the push rods, see ***Rocker Assembly - Removal and Replacement***.

9 It is not necessary to remove the cylinder head assembly to remove the crankshaft. If however the cylinder head needs to be removed for other reasons (for piston and connecting rod removal for example) remove it now, see ***Cylinder Head Assembly - Removal and Replacement.***

10 Remove the fuel injection pump, see ***Section 7 Fuel System - Fuel Injection Pump***.

11 Remove the starter motor, see ***Section 10 Electrical System - Starter Motor.***

12 Remove the high duty PTO device (if fitted) see ***Section 13 Auxiliary Equipment - High Duty P.T.O***.

13 Position the engine upside down in a suitable jig or fixture, supported at the front of cylinder block.

14 Remove the flywheel, see ***Flywheel - Removal and Replacement.***

15 Remove the flywheel housing, see ***Flywheel Housing - Removal and Replacement.***

16 Remove the fuel injection pump drive gear, see ***Drive Gear - Fuel Injection Pump - Removal and Replacement.***

17 Remove the oil pump, see ***Section 9 Lubrication System - Oil Pump***.

18 Remove the high duty PTO idler drive gear (if fitted), see ***Drive Gear - High Duty P.T.O. Idler - Removal and Replacement.***

19 Remove the crankshaft drive gear, see ***Drive Gear - Crankshaft - Removal and Replacement.***

20 Remove the camshaft, see ***Camshaft and Tappets - Removal and Replacement***.

21 Remove the rear timing case, see ***Timing Case - Rear - Removal and Replacement***.

22 If the pistons and connecting rods have not been removed, undo and remove the big end bearing caps, see ***Pistons and Connecting Rods - Big End Bearing.***

Removal, Bedplate

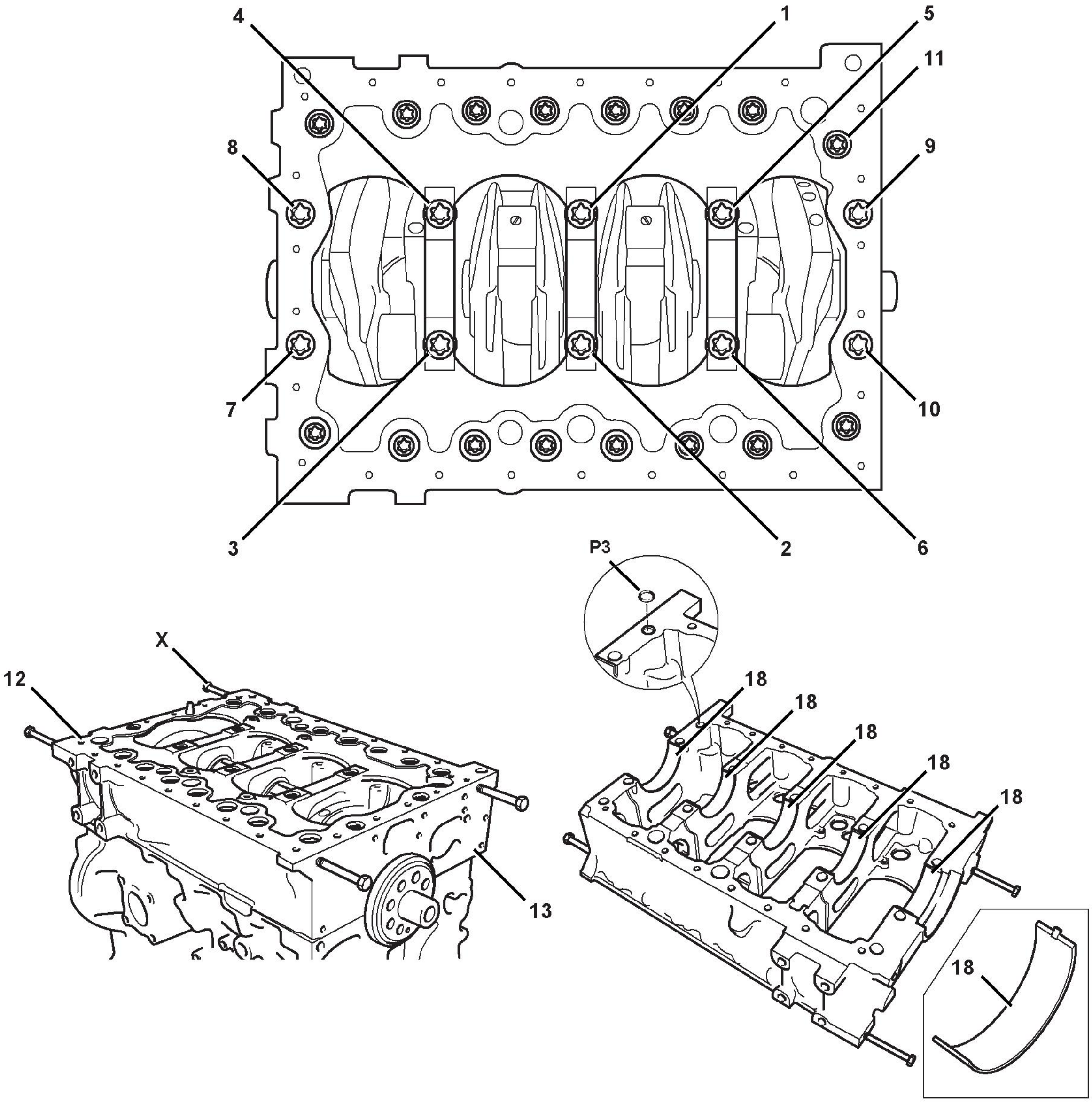


Fig 28.

Table 67. Component Identification

⇨ Fig 28. (12-54)	
1-10	Main bearing bolts (10 off)
11	Bedplate peripheral bolts (16 off)
12	Bedplate
13	Cylinder block
18	Upper bearing shell (5 off)

Table 68. Service Parts

P3	O-ring (if fitted))

Table 69. ServiceTools

T1	Lifting bolts (4 off Locally manufactured)

1 Undo the bedplate peripheral bolts **11**.

2 Progressively undo the main bearing bolts **1-10** in reverse order starting at bolt **10**. The bolts MUST NOT be re-used. Discard the bolts **1-10**.

3 Fit four temporary lifting bolts **T1**. Carefully separate the bedplate **12** from the cylinder block **13**. Use suitable lifting equipment (if the bedplate is lifted manually, two people will be required). DO NOT use a lever to separate the bedplate.

4 Remove and discard the O-ring **P3** (if fitted).

5 Carefully remove the upper bearing shells **18** from the bedplate.

Removal, Crankshaft

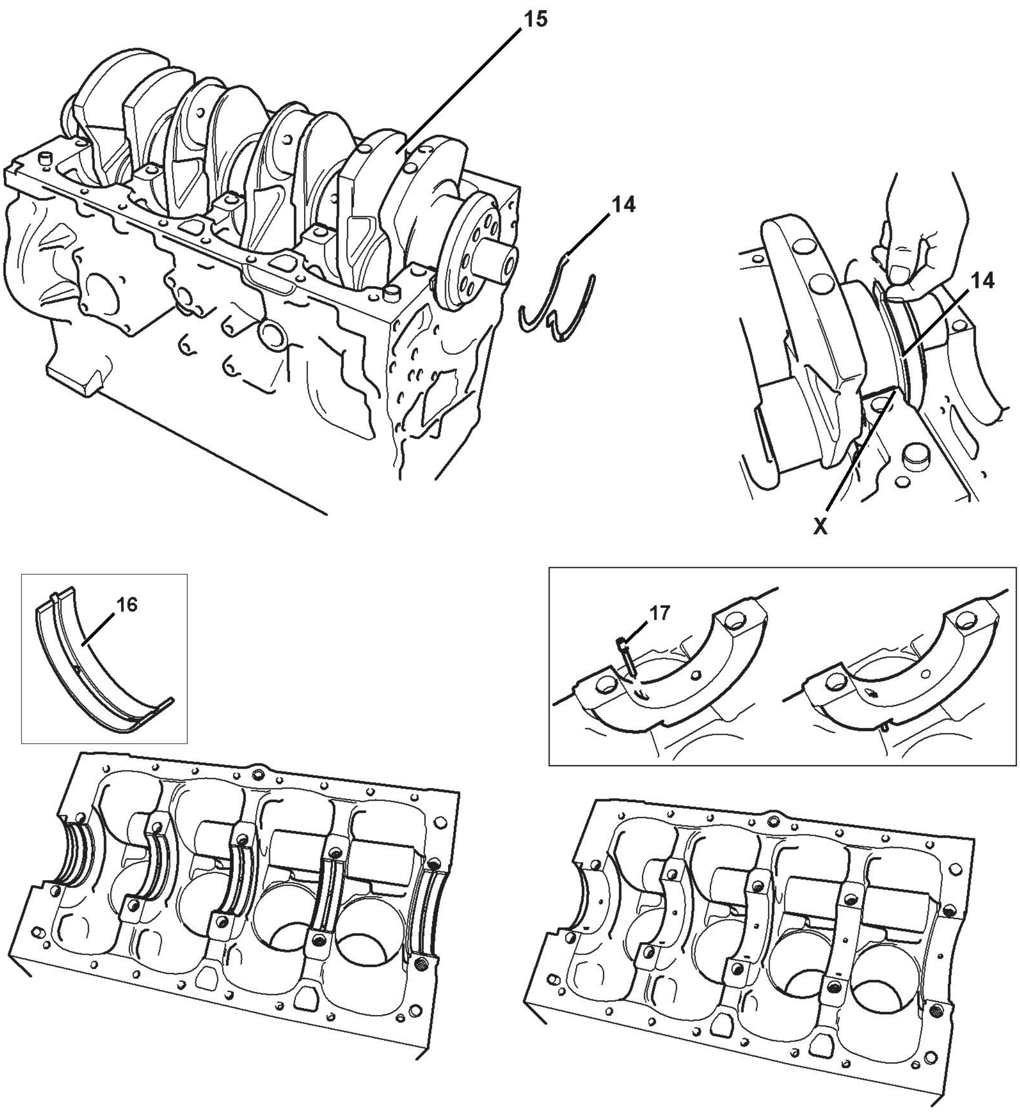


Fig 29.

Table 70. Component Identification

⇨ *Fig 29. (12-56)*	
1-10	Main bearing bolts (10 off)
11	Bedplate peripheral bolts (16 off)
12	Bedplate
13	Cylinder block
18	Upper bearing shell (5 off)

1 Remove the bedplate. ⇨ ***Removal, Bedplate (12-54)***.

2 Remove the thrust washers **14** between crankshaft and cylinder block rear main journal **X**. Label the thrust washers to ensure they are refitted in the correct positions on assembly.

3 Carefully lift the crankshaft **15** from the cylinder block. Use suitable lifting equipment (if the crankshaft is lifted manually, two people will be required).

4 Carefully lift out the bearing shells **16**. It is recommended that the shells are renewed. If however they are to be re-used, label the shells to ensure they are refited in their original positions on assembly.

Inspection

1 Check the bearing surfaces for damage and excessive wear.

2 Measure the crankshaft diameters to confirm they are within service limits, see ***Section 1 Technical Data***.

3 Check that the oil way cross drillings in the crankshaft are clear and free from debris. Blocked or restricted oil ways will cause oil starvation at the big end bearings.

4 Check that the piston cooling jets **17** are clear. If the jets cannot be cleared, push them out of the cylinder block and discard them.

Before Replacing

1 Clean off all traces of the old sealant compound from the cylinder block and bedplate mating faces.

2 Carefully clean the main bearing saddles in the bedplate and cylinder block using a suitable degreasing agent. Take care not to block the oil ways or the piston cooling jets.

Important: *Cleanliness is of the utmost importance. Blocked oil ways or oil jets* ***17*** *will cause engine failure. Before fitting the crankshaft make sure that ALL oil ways and jets are clear and free from debris.*

Replacement, Crankshaft

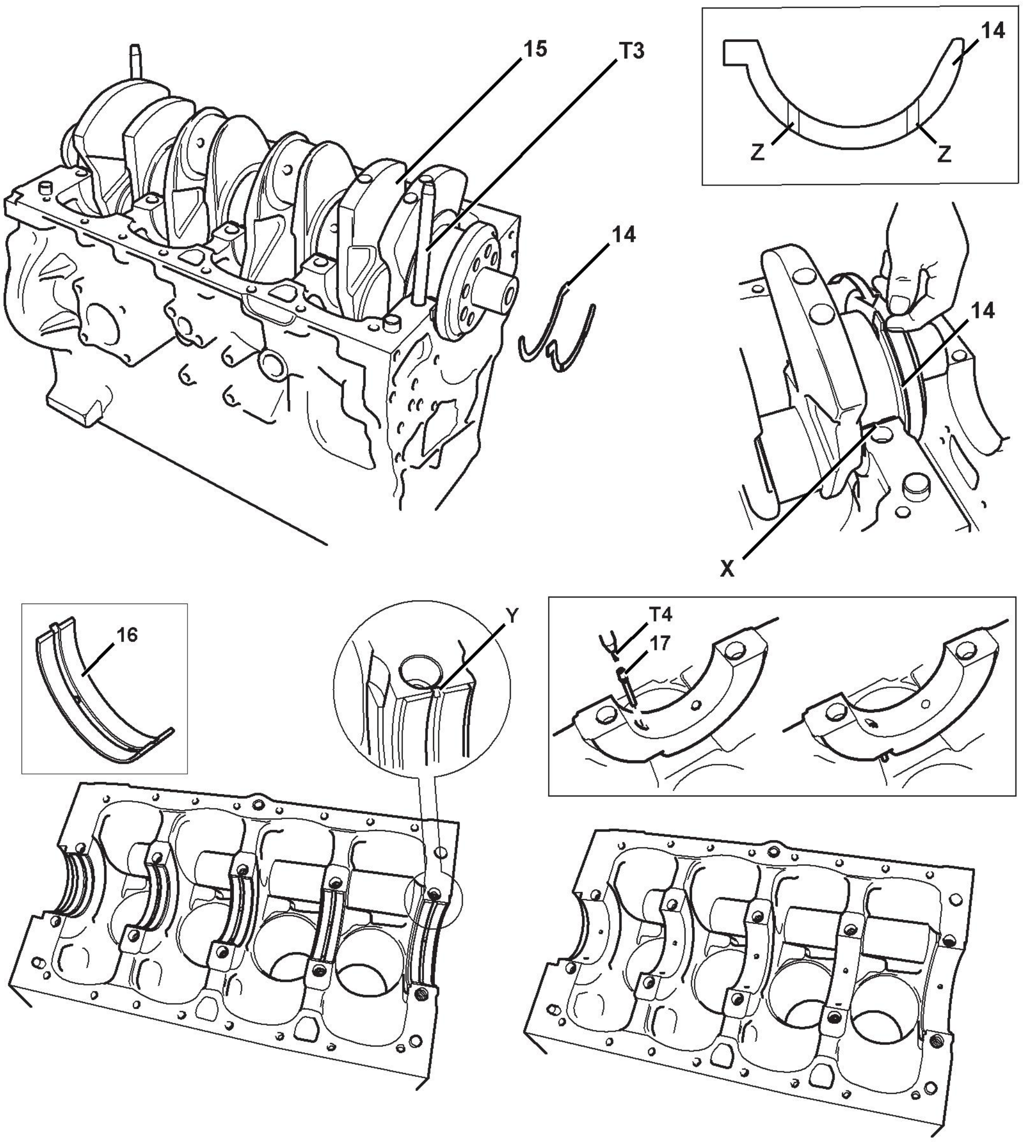


Fig 30.

Table 71. Component Identification

⇒ *Fig 30. (12-58)*	
14	Thrust washers (2 off)
15	Crankshaft
16	Upper bearing shells (5 off)
17	Cooling jets (4 off)
X	Rear main bearing journal
Y	Bearing location tab
Z	Oil slot - thrust washers

Table 72. Service Tools

Item	Part Number	Description
T3	General	Guide pins (Locally manufacture)
T4	General	Insertion tool (Locally manufacture)

1 If the cooling jets have been removed or a new cylinder block is being fitted, insert cooling jets **17** into the holes in the main bearing saddles as shown. Use service tool **T4** to avoid damaging the jets.

Note: *There are different types of cooling jets fitted depending on the engine application. The jets are colour coded. Be sure to fit the correct jets. See the relevant parts information for correct cooling jet identification.*

2 Make sure the surface of the upper bearing shells **16** are clean using a suitable degreasing agent.

3 Assemble the shells **16** into the cylinder block bearing saddles. Ensure the location tab **Y** engages in the slot as shown, ensuring that the oil way holes in the bearing saddles align with the holes in the shell.

Important: *Ensure that the oil way holes in the bearing saddles align with the holes in the shell. If the holes are even partially misaligned the piston cooling oil jet will be restricted, causing the engine to fail.*

4 Lubricate the upper bearing shells with clean engine oil and carefully lower the crankshaft **15** into the cylinder block. Use suitable lifting equipment (if the crankshaft is lifted manually, two people will be required). DO NOT rotate the crankshaft, the bearing shells **16** can become dislodged, see step **3**.

5 Slide the thrust washers **14** between crankshaft and cylinder block rear main journal. Ensure they are fitted in the correct positions, with the two slots **Z** facing outwards from the bearing saddle. If necessary, push the crankshaft forward and then back to obtain clearance to fit the washers. DO NOT rotate the crankshaft, the bearing shells **16** can become dislodged, see step **3**.

6 Check that the crankshaft end float is within service limits, see ***Section 1 Technical Data***.

Replacement, Bedplate

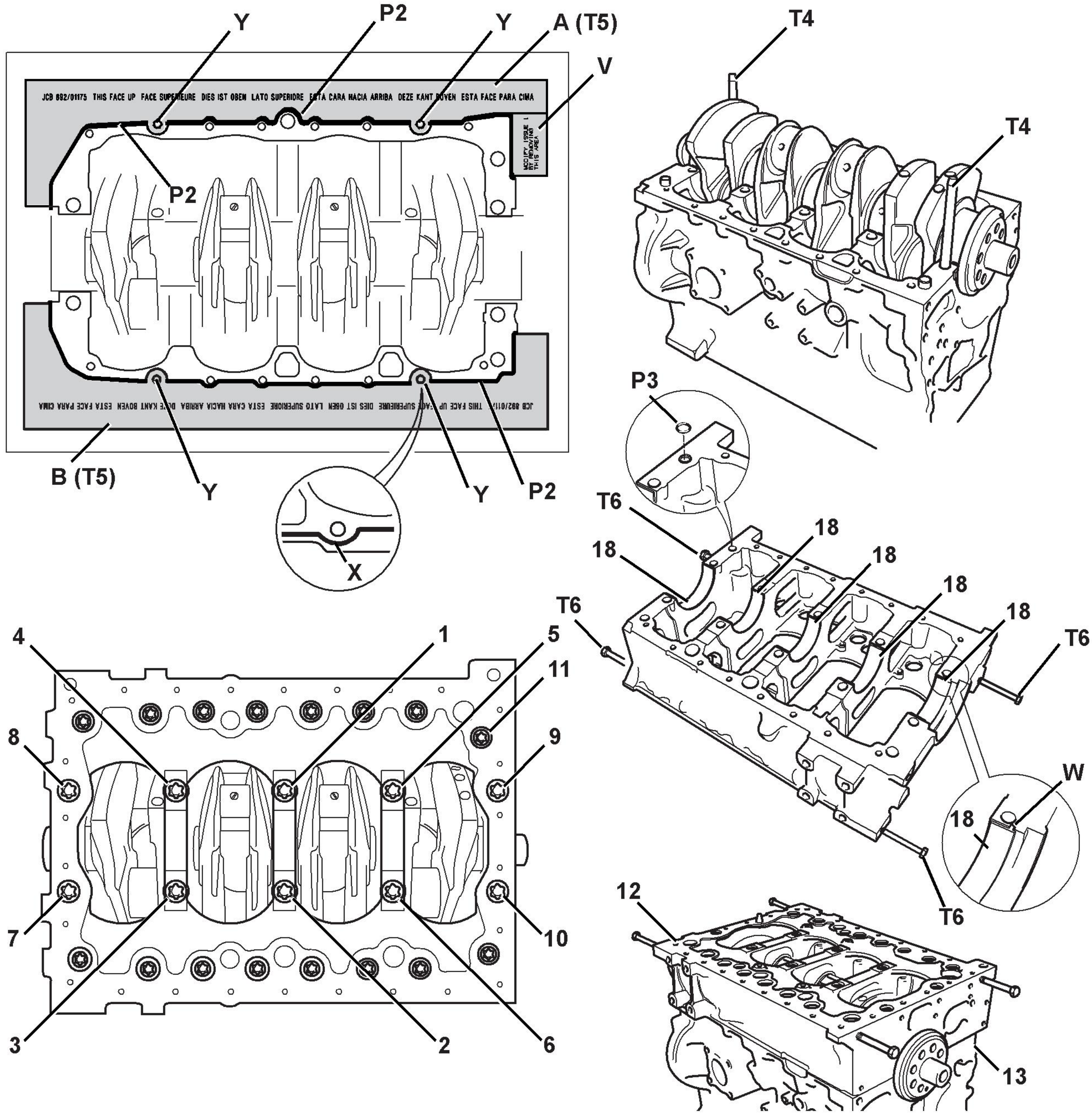


Fig 31.

Table 73. Component Identification

⇨ Fig 31. (12-60)	
1-10	Main bearing bolts (10 off)
11	Bedplate peripheral bolts (16 off)
12	Bedplate
13	Cylinder block
18	Lower bearing shells (5 off)
W	Bearing tab

Table 74. Service Parts

P1	Main bearing bolts (10 off)
P2	Anaerobic Sealant
P3	O-ring

Table 75. Service Tools

Item	Part Number	Description
T1	General	Star drive socket
T2	General	Socket wrench
T3	General	Angle gauge
T4	General	Guide pins (Locally manufacture)
T6	General	Lifting bolts (4 off Locally manufacture)
T5	892/01175	Sealant template
Comprises:		
A		Left side template
B		Right side template

Important: *Anaerobic sealant will not start to cure whilst it is open to the atmosphere, however when air is excluded (for instance when the two parts are put together) it will immediately start to harden. Make sure that all the necessary tools, bolts etc are readily available prior to assembling the components. The parts must be fitted and torque tightened within 5 minutes (with a maximum permissible time of 15 minutes).*

Important: *BEFORE fitting the bedplate: DO NOT rotate the crankshaft . Ensure that the upper main bearing shells are flush with the bottom face of the cylinder block.*

1 Fit two guide pins **T4** to the cylinder block bedplate fixing holes as shown.

2 Fit four lifting bolts **T6** to the bedplate as shown.

3 Fit a new O-ring **P3** at the bedplate **12**.

4 Use a suitable degreasing agent to clean both sides of the lower bearing shells **18**. Assemble the lower bearing shells into the bedplate. Lubricate the lower bearing shells with clean engine oil.

Note: *Ensure the location tab **W** engages in the slot as shown.*

Note: *Sealant template **T5** is used on the cylinder block **13**, NOT the bedplate **12**.*

5 The sealant template **T5** comprises of two pieces, **A** and **B**. Modify template **A** by removing portion **V**.

6 Locate the holes in the templates **A** and **B** using four fixing bolts at positions **Y**. Using the templates as a guide apply 1.5 mm (0.060 in.) beads of sealant **P2** around the cylinder block/bedplate mating face as shown.

7 Remove the four fixing bolts at positions **Y**. Remove the templates **A** and **B**, making sure not to smudge the sealant. Discard the templates.

8 Add beads of sealant **P2** around the four bolt holes at positions **Y**, so as to join the sealant beads as shown at **X**.

9 Make sure that the location guide pins **T4** are in position in the cylinder block. Assemble the bedplate to the cylinder block using the alignment guide pins.

Note: *The bedplate is heavy. Two people will be requred to lift and rotate the bedplate safely onto the block.*

10 Fit new main bearing bolts **1-10**. Torque tighten the bolts in pairs, starting in the centre and working outwards (in sequence 1-10) to the 1st stage pre-torque. ⇨ Table 76. Torque Settings (12-62).

11 Fit the bedplate peripheral bolts **11**. Torque tighten the bolts. ⇨ Table 76. Torque Settings (12-62).

12 After fitting and torque tightening the bedplate peripheral bolts, further tighten the main bearing bolts in pairs, starting in the centre and working outwards (in sequence 1-10) to the 2nd stage pre-torque. ⇨ Table 76. Torque Settings (12-62).

13 Finally, angle tighten the main bearing bolts in pairs, starting in the centre and working outwards (in

sequence 1-10). ⇨ *Table 76. Torque Settings (12-62)*.

Important: *If the parts have not been torque tightened within the maximum 15 minute time period, then the parts must be separated, thoroughly cleaned and fresh sealant applied.*

Table 76. Torque Settings

Item	**Nm**	**lbf ft**	**Angle**	
1-10	50	37	-	1st stage
	115	85	-	2nd stage
	-	-	+180°	Final stage
11	24	18		

After Replacing

1 Check that the crankshaft can be freely rotated by hand. Remove the bedplate lifting bolts **T6**.

2 Carry out the procedures listed under ***Before removing*** in reverse order.