LISTER PETTER®

X90 Series Workshop Manual

Engine Type: 4X90 (Interim Edition)

P027-08218

The purpose of this manual is to give information, operating, maintenance and repair procedures for the current X90 series of engines.

The manual is designed primarily for use by qualified technicians with electrical and mechanical experience.

This work can only be carried out if the necessary hand and service tools are available. When the user has insufficient tools, experience or ability to carry out adjustments, maintenance and repairs then this work should not be attempted.

Where accurate measurements, or torque values, are required they can only be made using calibrated instruments.

Under no circumstances should makeshift tools or equipment be used, as their use may adversely affect safe working procedures and engine operation.

The specification details given apply to a range of engines and not to any one particular engine. In cases of difficulty the user should consult the local Lister-Petter Distributor or Dealer for further advice and technical assistance.

The information, specifications, illustrations, instructions and statements contained within this publication are given with our best intentions and are believed to be correct at the time of going to press. Our policy is one of continued development and we reserve the right to amend any technical information with or without prior notice.

Whilst every effort is made to ensure the accuracy of the particulars contained within this publication, neither the Manufacturer, Distributor or Dealer shall in any circumstances be held liable for any inaccuracy or the consequences thereof.

The information given is subject to the Company's current Conditions of Tender and Sale, is for the assistance of users and is based upon results obtained from tests carried out at the place of manufacture. This Company does not guarantee that the same results will be obtained elsewhere under different conditions.

Parts that have not been approved by the Lister-Petter organisation cannot be relied upon for correct material, dimensions or finish. This Company cannot therefore, be responsible for any damage arising from the use of such parts and the guarantee will be invalidated.

When purchasing parts or giving instructions for repairs users should, in their own interests, always specify Genuine Lister-Petter Parts and quote the Description of the Part and the Engine Serial Number.

Associated Publications

Operators Handbook
English P027-08200

Various technical/sales leaflets are available; please contact your Lister-Petter Distributor or Dealer for details.

Training

Comprehensive training in the correct operation, service and overhaul procedures of engines is available at the Lister-Petter International Product Training Centre.

Please contact Lister-Petter for details.

If Problems Occur

If problems occur with your engine, or any of the Lister-Petter approved accessories fitted to it, your local Lister-Petter Distributor should be consulted.

There are Lister-Petter Distributors in most countries of the world and details for these can be obtained from any one of the companies listed on the back cover.

How to Use this Workshop Manual

Each section title is given at the top of the relevant pages and each section has its own 'Contents' page.

A full cross reference 'Index' appears at the back of the manual.

It is recommended the individual steps contained in the various maintenance or repair operations are followed in the sequence in which they appear.

At times it may be necessary to refer to other parts of the section, or to a different section, for more specific or detailed information.

⚠ WARNING

Unauthorised adjustments to the emission compliant fuel injection pump may invalidate warranty claims.
In the USA, unauthorised adjustment of emission critical components is prohibited by Federal Law, incurring civil penalty.

Caution and Warning Symbols

When an engine is operating or being overhauled there are a number of associated practices which may lead to personal injury or product damage.

Your attention is drawn to the symbols shown and described below which are applied throughout this manual.

⚠ CAUTION

This caution symbol draws attention to special instructions or procedures which, if not correctly followed, may result in damage to, or destruction of, equipment.

⚠ WARNING

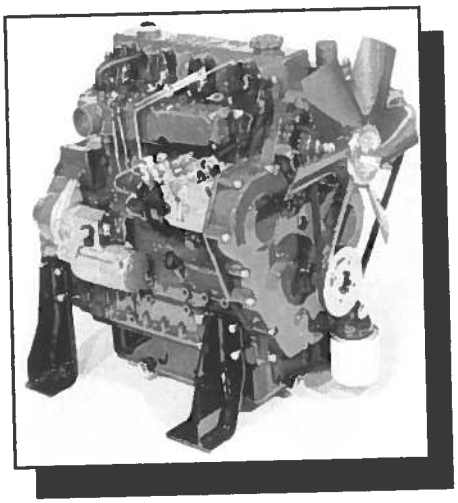
This warning symbol draws attention to special instructions or procedures which, if not strictly observed, may result in personal injury.

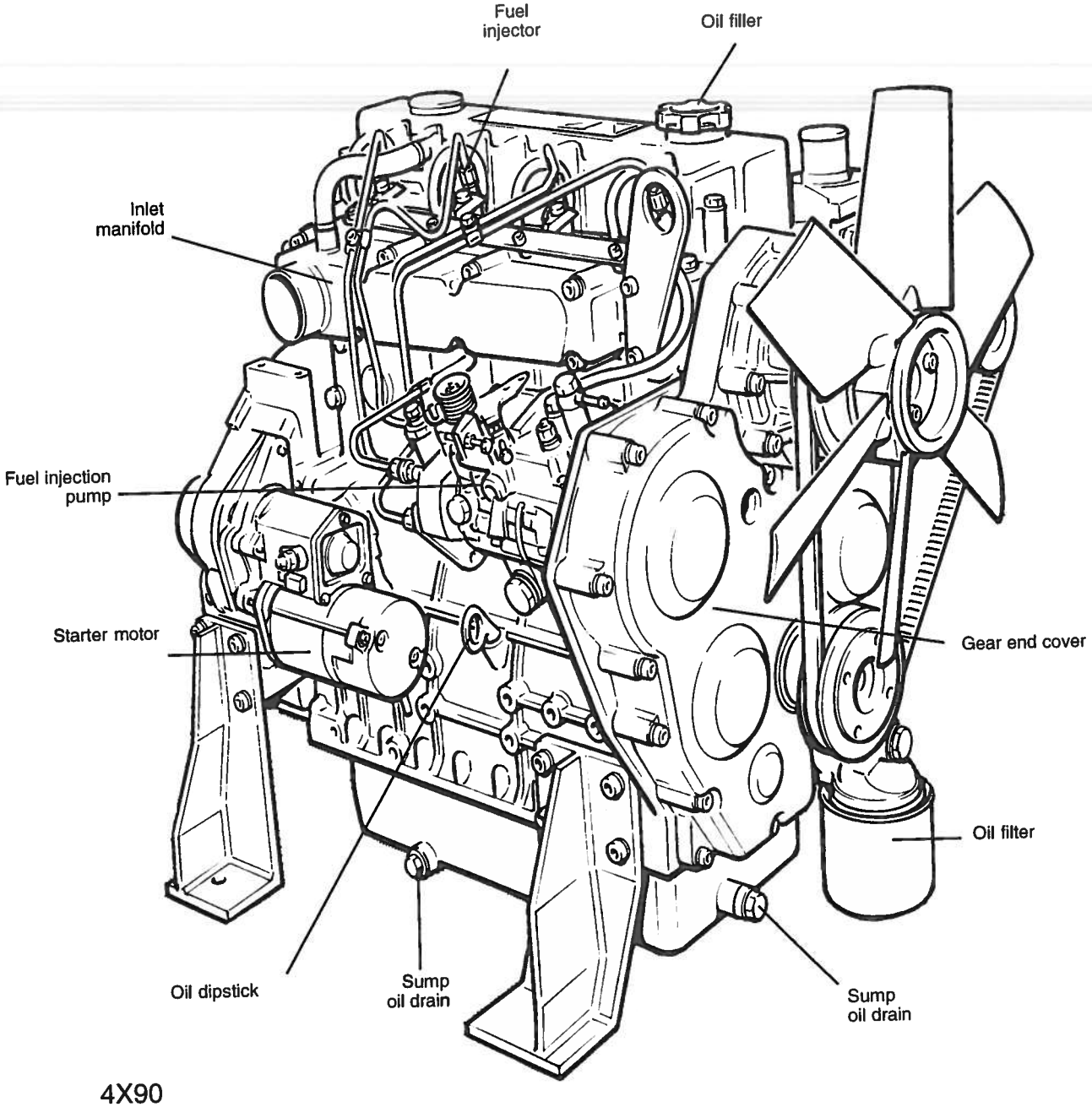
⚠ WARNING

A WARNING SYMBOL WITH THIS TYPE OF TEXT DRAWS ATTENTION TO SPECIAL INSTRUCTIONS OR PROCEDURES WHICH, IF NOT STRICTLY OBSERVED, MAY RESULT IN SEVERE PERSONAL INJURY, OR LOSS OF LIFE.

Note:
A note is used to draw your attention to additional or important information.

Manual Contents




Fuel injector
Oil filler
Inlet manifold
Fuel injection pump
Starter motor
Gear end cover
Oil filter
Oil dipstick
Sump oil drain
Sump oil drain

4X90

SECTION 1. GENERAL INFORMATION

CONTENTS

1.1 SAFETY PRECAUTIONS

The following safety precautions are of a general nature; more specific precautions appear where they are relevant.

⚠ WARNING

Starting any engine can be dangerous in the hands of inexperienced people. Engine operators must be instructed in the correct procedures before attempting to start any engine.

1.1.1 Before Starting Precautions

- Ensure the engine is free to turn without obstruction.
- Check that the water and lubricating oil levels are correct.

  The oil sump must be filled to the upper mark on the dipstick; do not overfill.
- Check that the fuel supply is adequate and the system is primed.
- Ensure that the battery is connected, fully charged and serviceable.
- Where possible, disengage the driven equipment while starting.

1.1.2 Alternator Precautions

The following points must be strictly observed when an alternator is fitted otherwise serious damage can be done.

- Never remove any electrical cable while the battery is connected in the circuit.
- Only disconnect the battery with the engine stopped and all switches in the OFF position.
- Always ensure that cables are fitted to their correct terminals.

  A short circuit or reversal of polarity will ruin diodes and transistors.
- Never connect a battery into the system without checking that the voltage and polarity are correct.
- Never flash any connection to check the current flow.
- Never experiment with any adjustments or repairs to the system.
- The battery and alternator must be disconnected before commencing any electric welding when a pole strap is directly or indirectly connected to the engine.

1.1.3 Starter Battery Precautions

- Do not smoke near the batteries.
- Keep sparks and flames away from the batteries.
- Batteries contain sulphuric acid - if the acid has been splashed on the skin, eyes or clothes flush it away with copious amounts of fresh water and seek medical aid.
- Keep the top of the battery well ventilated during charging.
- **Disconnect the battery negative (earth) lead first and reconnect last.**
- Switch off the battery charger before disconnecting the charger leads.
- Never 'flash' connections to check current flow.
- Never experiment with adjustments or repairs to the system.
- A damaged or unserviceable battery must never be used.

1.1.4 General Precautions

- Ensure the engine is securely mounted.
- Ensure that there is a generous supply of cooling and combustion air available.
- Keep the engine and surrounding area clean.
- Keep all safety guards in position.
- Keep the body and clothing clear of all moving or hot parts.
- Never allow any part of the body to come into contact with high pressure fuel; for example when testing fuel injection equipment.
- Thoroughly clean any lubricating or fuel oil from the skin as soon as practicable after contact.
- Rectify all fuel, water and oil leaks as soon as practicable and clean any spillages when they occur.
- If compressed air is ingested or enters the skin immediate medical assistance must be sought.

1.1.5 Lifting Precautions

The following points must be considered before attempting to lift the engine.

- Ensure the lifting equipment to be used has the correct capacity to lift the engine.
- When two engine lifting eyes are fitted suitable lifting equipment designed to give two vertical lifts from directly above the engine lifting eyes must be used.
- Check that the engine lifting eyes are not damaged and that they are secure.
- To prevent damage to the cylinder head cover ensure that there is clearance between the lifting equipment hooks and the cover.
- The lifting eyes fitted to the engine are suitable for lifting the engine, and gearbox if fitted, and accessory assemblies originally fitted by Lister-Petter.

⚠ WARNING

Engine lifting eyes must not be used to lift the complete plant.

1.1.6 Waste Disposal Precautions

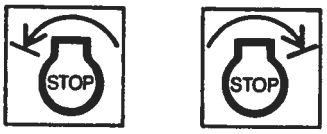
⚠ WARNING

Extreme care must be taken to ensure that waste oil, fuel, filter elements, coolant concentrate, battery electrolyte, solvents or other toxic wastes are disposed of in accordance with local regulations to prevent contamination.

1.2 SAFETY SYMBOLS

This section identifies the ISO 8999 symbols currently used by Lister-Petter.

Read the handbook



Stop control (on engine)

Diesel fuel fill

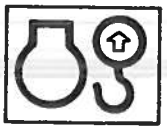
Engine oil fill

Engine oil level

Engine oil pressure

Anti-clockwise rotation

Clockwise rotation

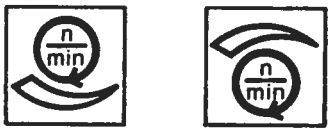


Lifting eye (engine only)

On

Off

Pre-heat

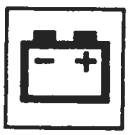


Rotational speed control

Linear speed control

Tachometer

Elapsed hours



Battery Charging

Engine cranking

General hot surface warning

Electrical hazards

Engine coolant pressure

Engine coolant fill

Engine coolant level

Engine coolant temperature

1.4 TECHNICAL DATA

		4X90
Type of fuel injection		Direct
Direction of rotation - looking on flywheel		Anti-clockwise
Nominal cylinder bore - these values are not to be used as machining tolerances	mm	90.00
	in	3.54
Stroke	mm	90.00
	in	3.54
Cylinder capacity - total	litre	2.29
	in^3	139.74
Compression ratio		18.5:1
Mean piston speed at 3000r/min	m/sec	9.0
	ft/min	1771.65
Firing order - (Number 1cylinder is at the gear end)		1 - 3 - 4 - 2
Number of flywheel ring gear teeth		96
Idling speed	r/min	900
Minimum full load speed	r/min	1500
Fuel lift pump maximum lift	mm	3048
	in	120
Fuel lift pump maximum head	mm	600
	in	23.6
Approximate dry engine weight - including starter motor and alternator. Refer to Lister-Petter for actual figure	kg	205
	lb	452
Maximum permissable intake restriction at full rated speed and load	mbar	25
	in H_2O	10.04
Maximum permissable exhaust back pressure	mbar	75
	in H_2O	30.11
Maximum radiator top hose temperature	° C	120
	° F	248
Fuel filter nominal rating	micron	5 - 7

1.5 NOMENCLATURE

4X90 four cylinder, direct injection, naturally aspirated water cooled diesel engine.

1.6 ENGINE SERIAL NUMBER

The engine serial number is stamped on a plate attached to the engine.

It is necessary to identify the type and build of each engine to enable the correct maintenance procedures, as described later in this publication, to be carried out.

1.7 SERIAL NUMBER PLATES

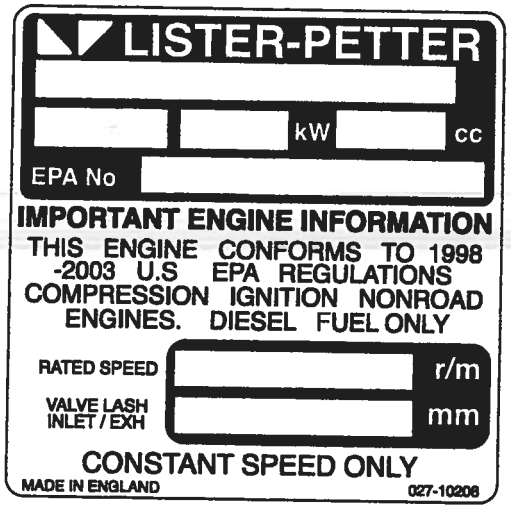


Figure 1.6.1 Constant Speed Plate

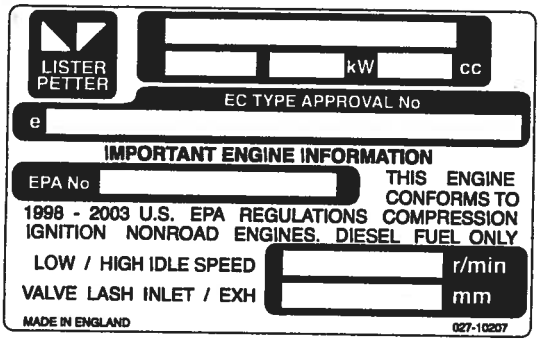


Figure 1.6.2 Variable Speed Plate

1.8 BUILD INFORMATION

The engines have been assembled to predetermined configurations.

Further details are given in "Section 7 Engine Variants".

1.9 THE KEY START

A key start may be fitted to connect the engine starter motor, fuel injection pump solenoid and other electrical equipment to the battery.

1.9.1 The Key Start Positions

STOP - when in this position the switch disconnects any auxiliary electrical equipment and the starting circuit from the battery and the key can be removed from the switch.

ON - in this position the alternator is given initial excitation by the battery and the warning lamp will be lit, serving as a reminder either to turn the key to the STOP position or continue to start the engine. Once the engine has been started the charge indicator light should, with the alternator charging, go out.

HEAT - in this position the cold start heater plugs are energised.

START - when the key is moved to this position the starter solenoid is energised and the starter motor cranks the engine.

The switch, when released, automatically returns to the ON position.

1.10 OPERATING INSTRUCTIONS

The following information is of a general nature and should be read in conjunction with, or substituted by, the equipment manufacturers instructions.

1.10.1 Preliminary Instructions

⚠ WARNING

Starting any diesel engine can be dangerous in the hands of inexperienced people.
Before attempting to start any engine the operator should read the "1.1 Safety Precautions" and be conversant with the use of the engine controls and the correct starting procedures.

⚠ CAUTION

ETHER BASED COLD START AIDS MUST NOT BE USED UNDER ANY CIRCUMSTANCES.

⚠ WARNING

EXHAUST GASSES CONTAIN CARBON MONOXIDE WHICH IS A COLOURLESS, ODOURLESS AND POISONOUS GAS THAT CAN CAUSE UNCONSCIOUSNESS AND DEATH.

1

1.10.2 Engine Control

The engine control (A) is automatically in the run position.

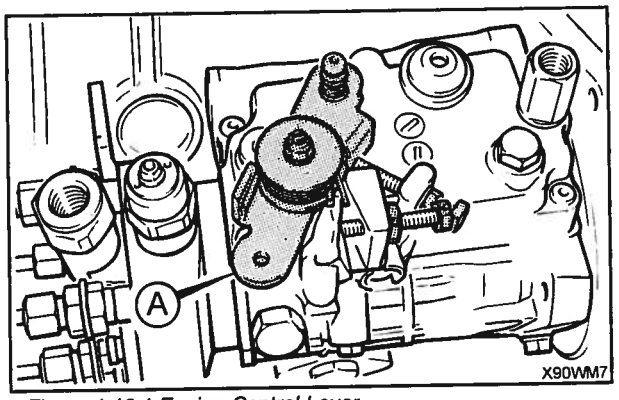


Figure 1.10.1 Engine Control Lever

1.10.3 The Key Switch

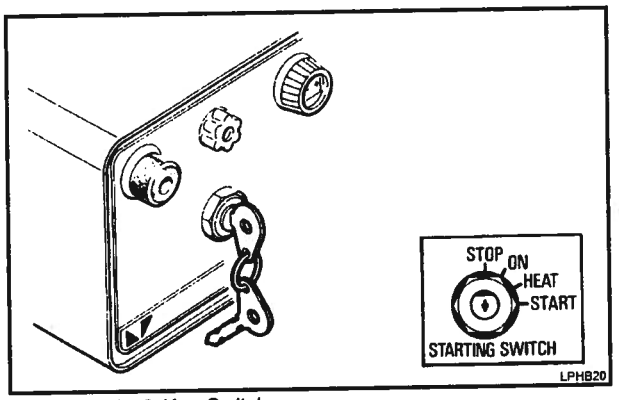


Figure 1.10.2 Key Switch

1.10.4 Starting

If an oil pressure switch bypass button is fitted it must be depressed during engine cranking and until the engine attains full speed.

The engine is fitted with a fuel pump solenoid. The solenoid is automatically energised by the start key during the starting procedure, and while the engine is running with the key in the 'ON' position.

If the engine fails to start within 30 seconds, release the key and attempt to restart after allowing sufficient time for all moving parts to stop.

1. On variable speed engines move the speed control to the fast position.
3. For ambient starting temperatures above -10°C (14°F) turn the key clockwise and hold it in the 'HEAT' position for 10 to 15 seconds before turning it to the 'START' position to energise the starter.
4. For ambient starting temperatures below -10°C (14°F) turn the key clockwise to the 'HEAT' position for 15 to 20 seconds before turning the key to the 'START' position to energise the starter.

   Immediately the engine starts the key must be moved anti-clockwise to the 'HEAT' position until the engine has attained full speed.

   When the engine has attained full speed release the key allowing it to return to the 'ON' position.

1.10.5 Stopping the Engine

1. If possible remove the load from the engine.
2. If a variable speed control is fitted reduce the engine speed.
3. Turn the key to the 'STOP' position.

1.11 THE STARTER BATTERY

Comprehensive details concerning the battery are given in "Section 6. The Electrical System".

1.12 ROUTINE MAINTENANCE

⚠ WARNING

Routine maintenance must be performed by qualified persons who are conversant with the hazards of fuels, electricity and machinery.
Read the Safety Precautions and observe all instructions and precautions in this publication.

1.12.1 Preliminary Instructions

This section is designed primarily for use by trained technicians but it does contain sufficient information, illustrations and detail to allow the operator to perform basic maintenance work.

This work can only be carried out if the necessary hand and service tools are available. When the user has insufficient tools, experience or ability to carry out adjustments, maintenance and repairs this work should not be attempted.

Where accurate measurements or torque values are required they can only be made using calibrated instruments.

Under no circumstances should makeshift tools or equipment be used as their use may adversely affect safe working procedures and engine operation.

These recommendations and instructions cover several engine models therefore they are of a general nature.

The engines are assembled to pre-determined builds and individual engines may include optional equipment not specifically covered in this book. More detailed information can be found in the Workshop Manual or any Lister-Petter Distributor or Dealer can be consulted.

- The engine should receive regular attention during the first 50 hours of its life from new and after a major overhaul.
- Long periods of light or 'no load' running early in the engine's life may lead to cylinder bore glazing and high oil consumption.
- The instructions given in "4.16 Maintenance Schedule" are based on average operating conditions and cover the minimum requirements to keep an engine running at peak performance with trouble free operation.
- Under very dusty conditions, air cleaners, lubricating oil and fuel filters will require more frequent attention
- Decarbonising may be required more often if the engine has been running on light loads for long periods.
- Before carrying out any maintenance work on an engine it is advisable to remove the battery.

  The battery and alternator must be disconnected before commencing any electric welding when a pole strap is directly or indirectly connected to the engine.
- It is essential to ensure that nuts and bolts are tightened to the torques specified in the Workshop Manual.
- When re-assembling an engine lubricate all moving parts with engine oil.
- Renew nuts and bolts that have been taken from high stress locations. In particular nuts and/or bolts from the connecting rods should be renewed.
- The fuel injector can only be checked and set off the engine using suitable specialist test equipment.

⚠ WARNING

ON NO ACCOUNT ALLOW ANY UNPROTECTED SKIN TO COME INTO CONTACT WITH THE INJECTOR SPRAY AS THE FUEL MAY ENTER THE BLOOD STREAM WITH FATAL RESULTS.

⚠ WARNING

SOME ENGINES MAY BE FITTED WITH SEALS OR 'O' RINGS MANUFACTURED FROM 'VITON' OR A SIMILAR MATERIAL.
WHEN EXPOSED TO ABNORMALLY HIGH TEMPERATURES, IN EXCESS OF 400°C (752°F), AN EXTREMELY CORROSIVE ACID IS PRODUCED WHICH CANNOT BE REMOVED FROM THE SKIN.
IF SIGNS OF DECOMPOSITION ARE EVIDENT, OR IF IN DOUBT, ALWAYS WEAR DISPOSABLE HEAVY DUTY GLOVES.

1.12.2 Precautions for Filters and Elements

- Used liquid filters and elements contain some of the filtered liquid and should be handled and disposed of with care.
- After handling new or used elements the users hands should be thoroughly washed, particularly before eating.

⚠ WARNING

Fuel and new or used lubricating oil may cause skin irritation

⚠ WARNING

The materials used in the manufacture and treatment of some filters and elements may cause irritation or discomfort if they come into contact with the eyes or mouth and they may give off toxic gasses if they are burnt.

⚠ WARNING

Care must be taken to ensure that waste fuel, oil, filter elements, acid and coolant concentrate, where applicable, are disposed of in accordance with local regulations to prevent contamination.

1.12.3 Initial Attention

To help assist engine running-in, X90 engines are despatched with an initial fill lubricating oil which must be changed after 100 hours. The oil filter must also be changed for the first time after 100 hours.

All subsequent oil and filter changes must be as specified in "1.12.5 Oil and Filter Change Periods".

It is recommended that the following receive attention after the engine has run 50 hours and again after 250 hours.

- Check and tighten nuts, bolts and unions paying particular attention to the fuel system.
- Check the drive belt tension.
- Check the lubricating oil level and top up if necessary.
- Check the radiator coolant level and top up if necessary. A 40% coolant concentration must be maintained at all times.

1.12.3 Crankcase Vacuum/Pressure

The vacuum, or pressure, is measured with a manometer at the lubricating oil dipstick hole with the engine running at any speed.

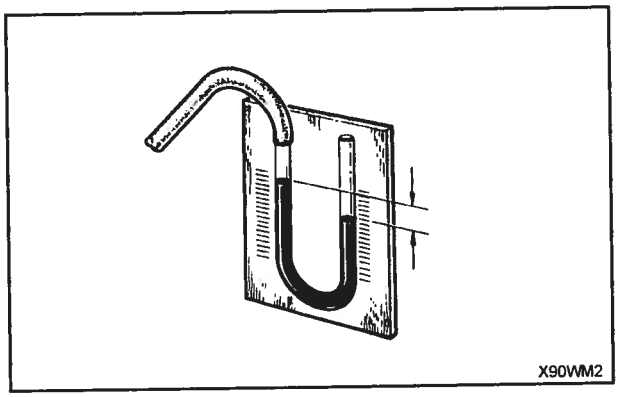


Figure 1.12.1 Manometer

Note:
The above illustration depicts a crankcase vacuum. A pressure would be indicated by the right hand level being above that of the left.

1.12.4 Maintenance Schedule

Also refer to "1.12.5 Oil and Filter Change Periods".

⚠ WARNING

These engines meet the emission legislative requirements of EPA Tier 1 Regulations and EU NRMM Directive Stage 1.

UNDER NO CIRCUMSTANCES MUST ANY ATTEMPT BE MADE TO ADJUST OR DISMANTLE THE FUEL PUMP. THIS WORK MUST ONLY BE CARRIED OUT BY A LISTER-PETTER DISTRIBUTOR OR ACCREDITED FUEL PUMP SERVICE OUTLET.

Daily
Check the coolant level.
Check the supply and level of fuel.
Check the level and condition of the lubricating oil.
Clean the air cleaner if the engine is operating in very dusty conditions.

Every 125 Hours

The above and the following items.
Clean the air cleaner if the engine is operating in moderately dusty conditions.
Check for fuel, coolant and oil leaks.
Check the serviceability of the battery.

Every 250 Hours

The above and the following items.
Check the condition and tension of the radiator drive belt.
Check the radiator fins for contamination or blockage.
Renew the fuel filter element if the fuel is not perfectly clean.

Every 1000 Hours

The above and the following items.
Check all external nuts, bolts and unions for tightness.
Ensure that all guards are firmly attached and not damaged.
Replace the fuel lift pump diaphragm; see Note:
Clean the fuel injector nozzles if the exhaust is dirty.

Every 2000 Hours
The above and the following items.
Decarbonise, if performance has deteriorated, renewing all joints and seals as necessary.
Clean and check, or replace, the fuel injector nozzles.
Check the radiator fins and radiator fan blades for damage.
Replace the radiator fan drive belt irrespective of condition.
Check the lubricating oil pressure.
Renew the air cleaner element.
Every 6000 Hours
The previous items and give the engine a major overhaul, if necessary.

Every Year

Drain, flush and refill the cooling system adding new coolant concentrate to a 40% concentration.

Every Two Years

Replace the coolant hoses irrespective of their condition.

Note:
It is recommended that the fuel lift pump diaphragm is inspected at more frequent intervals if it is known the fuel is contaminated. It should also be inspected at regular intervals on engines in low duty cycle applications; for example, stand-by generating sets.

1.12.5 Oil and Filter Change Periods

Before attempting to change the lubricating oil or filter:

a. Read "1.12.2 Precautions for Filters and Elements".

b. Ensure the new oil meets the correct specification as given in "4.2 The Oil Specification".

Ambient Temperature	Periods in Hours
Up to 35°C	500
Above 35°C (see Note)	250

35°C = 95°F

Note:
The oil and filter change periods, given in hours, apply when engines are operating regularly at temperatures exceeding 35°C (95°F) at high speeds and duty factors.

1.12.6 Starting and Running Faults

This section is intended as a guide only.

Difficult Starting
Unsuitable lubricating oil (too heavy).
Incorrect fuel.
No fuel in the tank.
Choked fuel filter.
Air lock in the fuel system.
Discharged battery.
Fuel pump solenoid not energised.
Poor battery connections.

Excessive Carbon Deposits
Choked air filter.
Choked exhaust system.
Unsuitable fuel oil.
Unsuitable lubricating oil.
Continuous idling.

White Exhaust Smoke
Water entering the cylinder.
Faulty crankcase temperature switch - refer to Lister-Petter.
Faulty fuel pump - refer to Lister-Petter.

Light Blue Exhaust Smoke
Generally as a result of light load.

Heavy Blue Exhaust Smoke
Lubricating oil passing the piston rings .
Stuck, worn or broken piston rings.
Worn cylinder bore.
Overfull oil sump.

Black Exhaust Smoke
Overload.
Choked air filter.
Inlet air temperature too high.
Unsuitable fuel, or water in it.

Engine Stops
Lack of fuel.
Air or water in the fuel system.
Choked air or fuel filter.
Overload.
Overheating.
Loss of compression.
Loss of electrical supply to the fuel pump solenoid.
Automatic shutdown, if protective devices are fitted.

Loss of Power
Loss of compression.
Choked air filter.
Choked exhaust system.
Fuel injector dirty.
Choked fuel filter.
Worn engine.

Overheating
Radiator fan belt too slack.
Overload.
Lubricating oil level too low.
Radiator fan inlet obstructed.
Recirculation of exhaust gasses or cooling air.
Radiator cooling fins blocked.
Low level of coolant.
Cooling system obstructed.

1.12.7 Spanner Torques

The tolerance for all torque settings is ±10%. and for practical purposes the figures have been rounded.

	Nm	lbf ft
Air cleaner bracket bolt	21.0	15.5
Alternator bracket bolt	21.0	15.5
Camshaft gear bolt	81.0	60.0
Camshaft reataining plate bolt	21.0	15.5
Centre bearing bolt	21.0	15.5
Connecting rod bolts	35.0	26.0
Crankshaft pulley bolt	300	221
Cylinder head bolts - Stage 1	35.0	26.0
Cylinder head bolts - Stage 2	88.0	65.0
Cylinder head cover bolts	21.0	15.5
Gear endcover bolts	21.0	15.5
Exhaust manifold bolts	21.0	15.5
Feet to crankcase bolts	41.0	30.0
Flywheel retaining bolt	81.0	60.0
Flywheel housing bolts	81.0	60.0
Fuel lift pump bolts	21.0	15.5
Fuel injector pump bolts	21.0	15.5
Fuel injector pump gear nut	81.0	60.0
Glow plugs	15.0	11.0
Glow plug link bar nut	2.5	1.8
Idler gear stub shaft bolt	81.0	60.0
Inlet manifold adaptor bolt	21.0	15.5
Injector clamp capscrews	27.0	20.0
Injector pipe nuts	27.0	20.0
Lifting eye bolt	21.0	15.5
Main bearing housing bolts	27.0	20.0
Oil pump retaining bolts	9.0	6.5
Oil pump relief valve	21.0	15.5
Radiator fan retaining bolts	11.0	8.0
Rocker cover bolts	21.0	15.5
Starter motor bolts	41.0	30.0
Sump bolts	21.0	15.0
Thermostat housing bolts	21.0	15.5
Valve rocker lever retaining nut	27.0	20.0
Water pump bolt	21.0	15.5

SECTION 2 - THE BASIC ENGINE

CONTENTS

⚠ WARNING

Maintenance must be performed by qualified persons who are conversant with the hazards of fuels, electricity and machinery.
Read the Safety Precautions and observe all instructions and precautions in this publication.

2.1 DISMANTLING AND REBUILDING

When the engine is being dismantled all items must be identified and retained in their respective cylinder orientation and all related components must be treated similarly.

The instructions given in this section deal with individual components and it may be necessary to remove others before the relevant instructions can be carried out.

2.1.1 Preliminary Instructions

a. Disconnect or isolate any non-electric starting systems.
b. Disconnect and remove the battery.
c. Drain the diesel fuel and lubricating oil.
d. Drain the water.
e. Disconnect all services.
f. Remove any accessories or components that may be susceptible to damage when the engine is turned out of its normal plane.

⚠ WARNING

Do not attempt to remove the fuel injector pump without refering to "5.8 The Fuel Injection Pump".

⚠ WARNING

These engines are fitted with hydraulic tappets therefore it is important to follow the procedures given.

Because of the various engine configurations, and installations in which the engine can be fitted, it is not possible to give detailed instruction for each one.

Tightening torques are included in the text as necessary and in table format in "1.17.7 Spanner Torques".

When assembling the engine, use the same type of lubricating oil as used in the engine to spray all moving parts during assembly. All bearings and bushes must be well lubricated during assembly.

Renew all joints, gaskets, connecting rod nuts and bolts and the cylinder head bolts.

⚠ WARNING

In the majority of instances the bolts, capscrews and setscrews used on X90 engines are of the 'shoulder type' and must be replaced as such without washers, unless these were originally fitted.

2.2 THE CYCLONIC AIR CLEANER

The air cleaner can be remote or engine mounted and is connected to the engine by a moulded rubber hose secured by jubilee clips.

Care must be taken to ensure that the air cleaner draws air in at a temperature not exceeding:-

a. 12°C (54°F) above outside ambient in temperate climates.
b. 6°C (43°F) above outside ambient in tropical climates.

The air cleaner should receive regular maintenance as specified in "1.12.4 Maintenance Schedule".

2.2.1 Servicing the Air Cleaner

1. Regularly remove the dust cap (A) and empty all the dust.

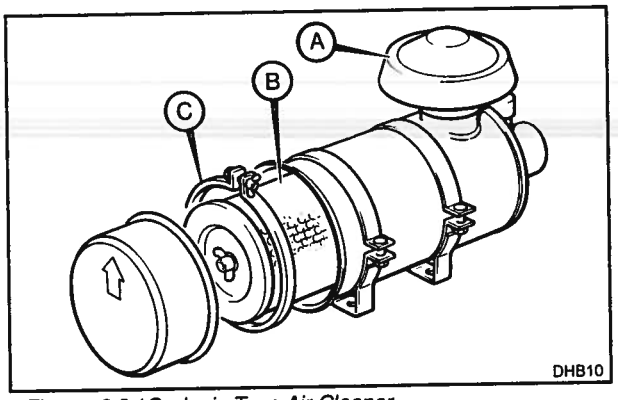


Figure 2.2.1 Cyclonic Type Air Cleaner

2. Access to the paper element (B) is gained by undoing the clamp (C) and removing the end cover.
3. Remove the element.
4. The element can be cleaned by directing a low pressure compressed air nozzle up and down the pleats from inside the element.
5. Inspect the element for damage by placing a suitable light source inside it. If the element is found to have any holes it must be replaced.
6. Replace the element, end cover and dust cap.

2.3 THE COLD START AID

To provide additional heating of the combustion air during starting a 12V heater plug is fitted for each cylinder as standard.

2.3.1 Replacing a Heater Plug

1. Isolate the battery and disconnect the wiring loom from the plugs.
2. Remove the plate (A) from the top of all the plugs.
3. Unscrew and lift out the heater plug (B).

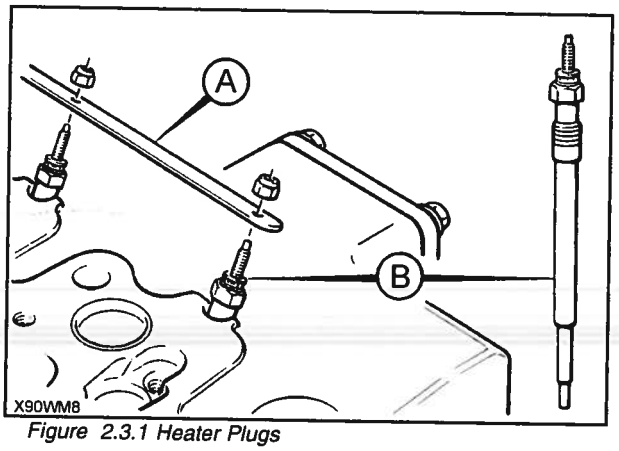


Figure 2.3.1 Heater Plugs

4. Screw the plug into the inlet manifold and torque it to 15.0 Nm (11.0lbf ft).
5. Replace the common link plate and reconnect the wiring loom and nuts finger tight.
6 Torque the link plate nuts to 2.5Nm (1.6lbf ft).

2.4 THE MANIFOLDS

The inlet manifold is an integral part of the cylinder head casting.

The exhaust manifold is secured by bolts which must be torqued to 21.0Nm (15.5lbf ft).

Whenever the manifold is replaced all traces of the old gasket must be removed and a new one fitted.

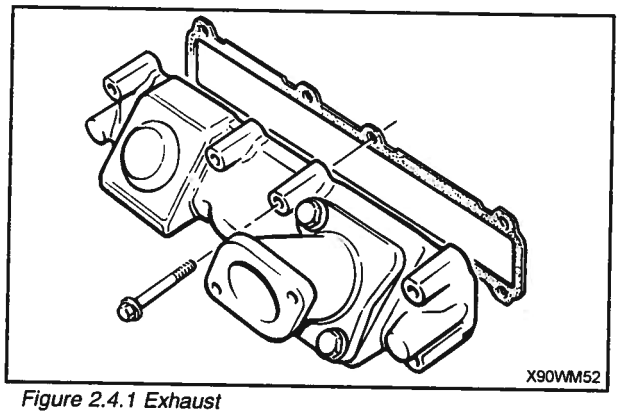


Figure 2.4.1 Exhaust

⚠ WARNING

EXHAUST GASSES CONTAIN CARBON MONOXIDE WHICH IS A COLOURLESS, ODOURLESS AND POISONOUS GAS THAT CAN CAUSE UNCONSCIOUSNESS AND DEATH.

⚠ CAUTION

Detrimental damage to the engine, or loss of performance, may be caused if exhaust gasses are sucked in by the air cleaner or the radiator fan.

2.4.1 Removing the Exhaust Manifold

1. Remove six of the eight retaining bolts; leaving one at each end.
2. Support the manifold and remove the remaining two bolts.
3. Lift the manifold away from the cylinder head.
4. Remove and discard all traces of the old gasket.
5. Fit a new gasket.
6. Replace the manifold and bolts.
7. Torgue the bolts to 21.0Nm (15.5lbf ft).

2.5 THE STARTER MOTOR

Unless it is necessary to remove the starter motor it can remain attached to the flywheel housing.

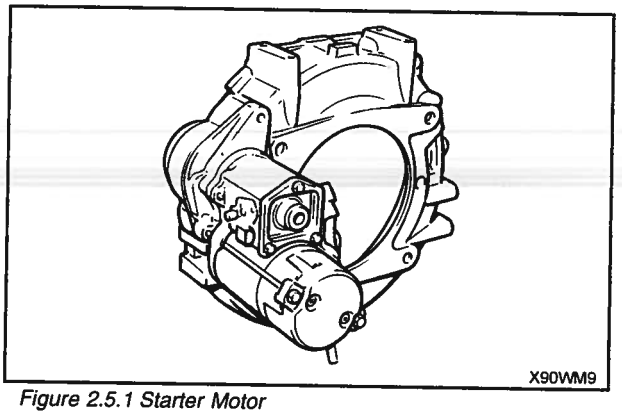


Figure 2.5.1 Starter Motor

2.5.1 Removing the Starter Motor

1. Isolate the battery.
2. Disconnect the electrical wiring loom from the starter.
3. Support the starter motor and remove the mounting bolts.

2.5.2 Replacing the Starter Motor

1. Support the starter motor and fit the mounting bolts finger tight.
2. Torque the bolts to 41.0Nm (30.0lbf ft).
3. Replace the cable loom connections.

2.6 THE ALTERNATOR

The alternator is belt driven at the gearcase end by a V-ribbed belt and the alternator to engine speed ratio and output is constant for all engines.

2.6.1 Terminal Identification

Terminal Identification	
B	Battery +
L	Warning light
P	Phase tap
R	Terminal reference

⚠ WARNING

The 'R' terminal is for the alternator reference circuit and must be wired into the circuit.

2

2.6.2 Removing the Alternator

1. Isolate the battery.
2. Remove the cable loom from the alternator
3. Slacken the alternator lower pivot bolt (A).
4. Slacken the two adjuster arm retaining bolts (B).
5. Place the palm of the hand under the alternator and lift it upwards until the alternator moves towards the crankcase sufficiently to remove the drive belt.
6. Support the alternator and remove the bolt from the slotted section of the adjusting arm.
7. Support the alternator and remove the lower pivot bolt.
8. Lift the alternator clear.

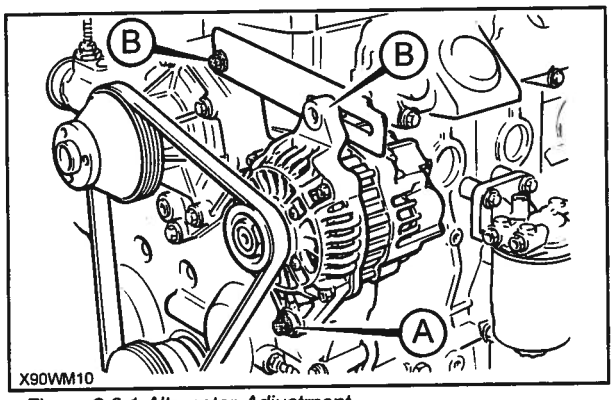


Figure 2.6.1 Alternator Adjustment

2.6.3 Replacing the Alternator

1. Hold the alternator in position and replace the lower pivot bolt finger tight.
2. Replace the alternator adjusting arm bolts finger tight.
3. Place the palm of the hand under the alternator and lift it upwards until the alternator moves towards the crankcase sufficiently to replace the drive belt by hand.
4. Move the alternator outwards as far as possible by hand and torque the pivot and adjusting arm bolts to 21.0Nm (15.5lbf ft).
5. Tension the drive belt as described in "2.7 Drive Belt Tension".

2.7 DRIVE BELT TENSION

It is important to ensure the drive belt is replaced every 2000 hours irrespective of its condition.

2.7.1 Tensioning the Drive Belt

The drive belt tension must be checked:

a. After the first 50 hours running.
b. After an overhaul.
c. After a new belt has been fitted.
d. As specified in "1.12.4 Maintenance Schedule".

When a new belt is correctly fitted and tensioned a force of 12N (2.7lbf) is required to deflect it a distance of 4.5mm (0.18in).

On subsequent checking and adjustment a force of 10.0N (2.2lbf) is required to deflect it a distance of 4.5mm (0.18in).

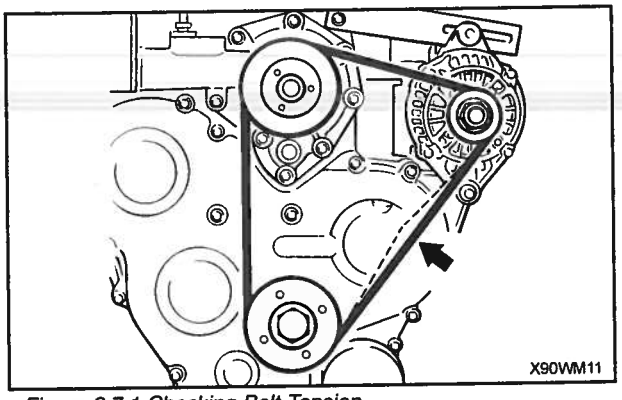


Figure 2.7.1 Checking Belt Tension

2.8 THE FUEL INJECTION PUMP

The fuel pump is of the rotary type and detailed instructions can be found in "5.8 The Fuel Injection Pump".

⚠ WARNING

Do not attempt to remove the fuel injector pump from the engine without refering to "5.8 The Fuel Injection Pump".

2.9 THE FUEL INJECTOR

Detailed instructions for removing, cleaning, setting and refitting the injectors can be found in "5.9 The Fuel Injector".

2.11 THE CYLINDER HEAD COVER

The 4X90 cylinder head cover is attached to the top of the cylinder head with ten shoulder bolts.

The cover is removed to give access to the valve rockers.

When the cylinder head cover has been removed a new joint should be fitted on re-assembly. Care must be taken to ensure the joint is correctly fitted with the straight edge on the exhaust manifold side.

The head cover bolts are torqued to 21.0Nm (15.5lbf ft) starting in the middle and working outwards.

2.12 THE CYLINDER HEAD

All engines have a monobloc head and gasket.

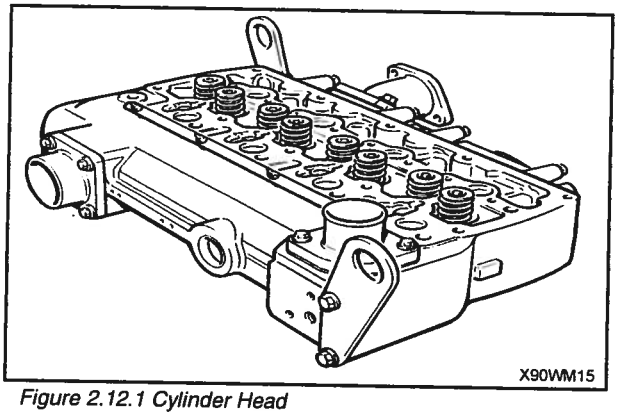


Figure 2.12.1 Cylinder Head

2.12.1. Removing the Cylinder Head

If it is necessary to remove the fuel injectors follow the instructions given in "5.9.2 Removing and Replacing an Injector".

1. Remove the exhaust manifold and cold start plugs.
2. Remove the cylinder head cover and gasket.
3. Remove the valve rocker retaining nuts and washers.
4. Remove the valve rockers.

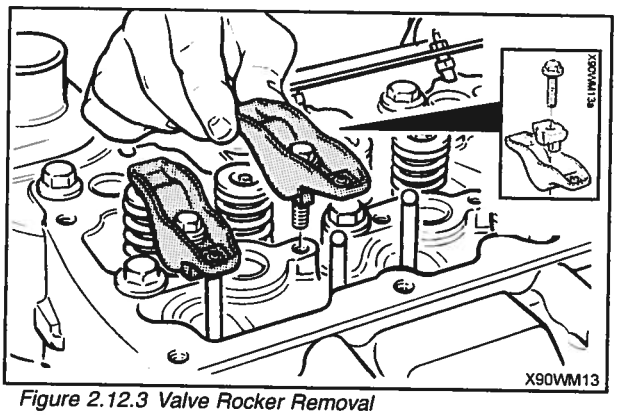


Figure 2.12.3 Valve Rocker Removal

5. Lift out the push rods, if necessary.

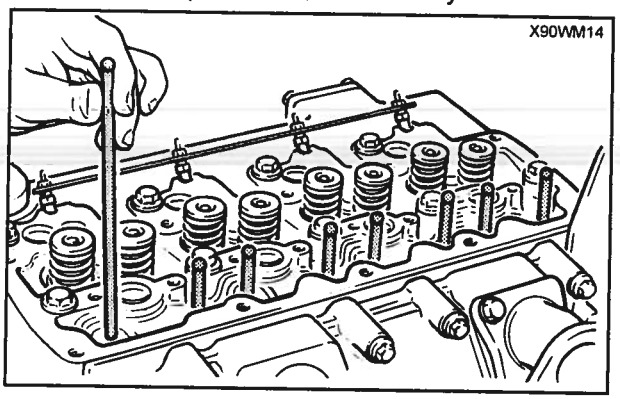


Figure 2.12.4 Removing a Pushrod

6. Slacken and remove the cylinder head retaining bolts
7. Lift off the cylinder head.
8. Remove the cylinder head gasket.

2.12.2 Refitting the Cylinder Head

The cylinder head clearance is factory set and adjustment is not possible.

A single gasket is fitted under the head.

It is strongly recommended that the cylinder head bolts and gasket are replaced every time the head is being refitted, except when checking the cylinder head clearance.

1. Ensure the hydraulic tappets have been replaced into the crankcase; refer to "2.16 The Hydraulic Tappets".
2. Check to ensure the two cylinder head locating dowels (A) are in position.

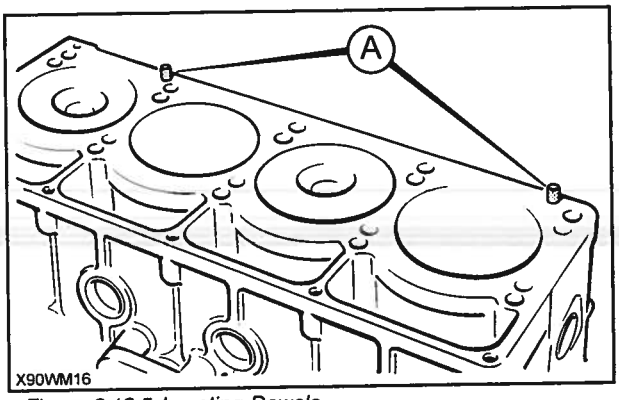


Figure 2.12.5 Locating Dowels

3. Place a new cylinder head gasket onto the crankcase taking care to ensure the holes in the gasket coincide with those in the crankcase and the gasket locates over the dowels (A).
4. Very carefully lower the cylinder head into position checking that the head locates over the two dowels (A).
5. Refer to the illustration and tighten down the cylinder head bolts evenly, in the sequence shown, to the final torque:

   Stage 1 - 35.0Nm (26.0lbf ft).

   Stage 2 - 88.0Nm (65.0lbf ft).

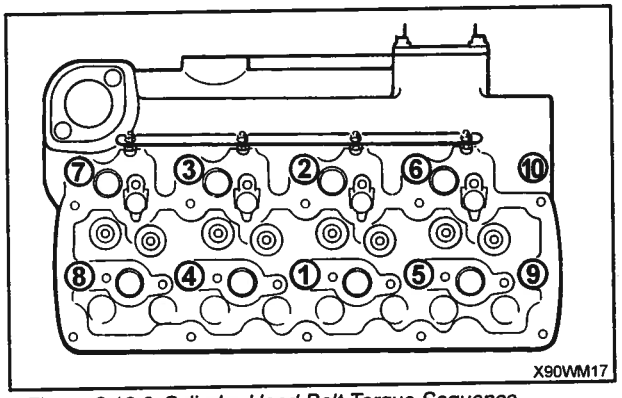


Figure 2.12.6 Cylinder Head Bolt Torque Sequence

6. Lightly oil the pushrods and replace them into the hydraulic tappets in the crankcase, taking extreme care to ensure they are correctly located; misalignment of the rods can cause serious damage.
7. Following the firing order (1 3 4 2), very slowly turn the crankshaft and press down on the top of the two push rods for the cylinder being worked on until they are at their lowest point of travel.
8. Replace the valve rocker, pivot and nut.

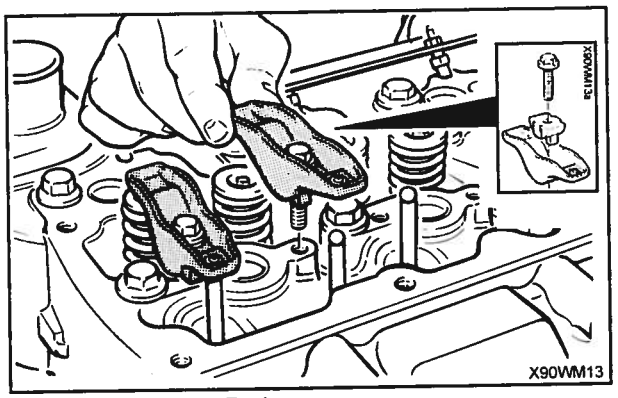


Figure 2.12.7 Valve Rocker

9. Depress the push rod end of the rocker arm and torque the rocker lever nut to 27.0Nm (20.0lbf ft).

   Alternatively torque the rocker lever nut to 27.0Nm (20.0lbf ft) and wait for the lubricating oil to 'bleed down':

   Up to 90 seconds on a new tappet.
   Up to 45 minutes on a used tappet.

⚠ CAUTION

During the waiting period the crankshaft must not be turned.

10. Fit a new cylinder head cover joint and torque the bolts to 21.0Nm (15.5lbf ft) starting in the middle and working outwards.
11. If the fuel injectors were removed, follow the instructions given in "5.9.2 Removing and Replacing an Injector".

2.13 CYLINDER HEAD CLEARANCE

The cylinder head clearance is factory set and adjustment is not possible.

The following instructions are included for reference.

1. Remove the cylinder head and push rods.
2. Place a new cylinder head gasket onto the crankcase taking care to ensure the holes in the gasket coincide with those in the crankcase and the gasket locating dowels.
3. Using two pieces of lead wire 1.6mm (0.06in) diameter and 50mm (1.9in) long form two 'U' loops.

⚠ CAUTION

To ensure accurate measurements are made multicore solder must not be used.

4. Twist the open tails of the loops together to form four or five coils.
5. Refer to 'Figure 2.13.1' and using a very small amount of high melting point grease place the two pieces of wire (A) onto the piston crown (B) at either side of the gudgeon pin axis and 90° to the centre line.

   The two wires should just touch the cylinder bore and care should be taken to ensure they are not placed over any markings on the piston crown.

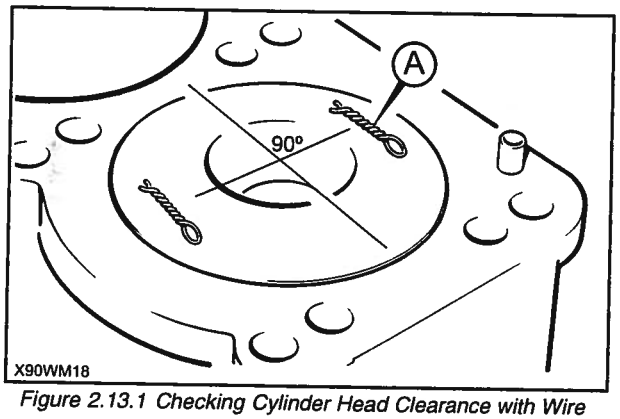


Figure 2.13.1 Checking Cylinder Head Clearance with Wire

6. Replace the cylinder head and torque the bolts in stages:

   Stage 1 - 35.0Nm (26.0lbf ft).

   Stage 2 - 88.0Nm (65.0lbf ft).
7. Rotate the engine by hand for two complete revolutions.
8. Remove the cylinder head and measure the thickness of the lead wire.

   The mean measurement of the two pieces of lead wire is the actual cylinder head clearance.
9. Replace the push rods and cylinder head after referring to "2.12.2 Refitting a Cylinder Head".

2.14 THE VALVES

The valves are pre-finished and therefore no lapping or further processing is required and they are sunk below the combustion surface of the head to the figures given in "2.14.3 The Valve Seats".

Care must be taken to ensure that all valve associated items are retained in their respective cylinder orientation.

2.14.1 Removing a Valve

⚠ CAUTION

It is advisable to wear suitable eye protection when carrying out this procedure.

1. Lay the head upright on a bench and place a suitable circular block of wood under the head of the valve.
2. Fit the adaptor (A) onto the valve spring carrier with the two indentations facing outwards.
3. Fit the tool (B) into the two plate indentations.

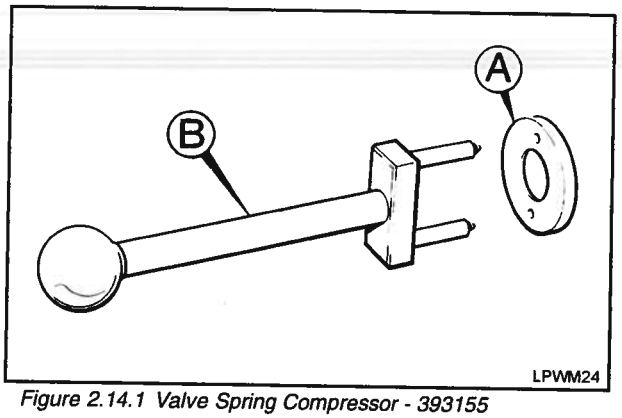


Figure 2.14.1 Valve Spring Compressor - 393155

4. Push down on the tool to compress the valve spring until the collets can be removed.
5. Gently release the tool and remove the carrier, valve spring and valve stem sealing ring.
6. Turn the cylinder head over and remove the valve.

2.14.2 Refitting a Valve

It is recommended that all valves and springs are replaced during a major overhaul.

A valve stem sealing ring is fitted to the top of the valve guides and it is recommended that a new seal is fitted whenever the valves are being refitted or renewed.

If more than one valve was removed ensure they are replaced in their respective cylinders.

⚠ CAUTION

It is advisable to wear suitable eye protection when carrying out this procedure.

1. Replace the valve if it is pitted or damaged.
2. Lightly lubricate the valve stem and insert the valve.
3. Lay the head upright on the bench and place a circular block of wood under the head of the valve being replaced.

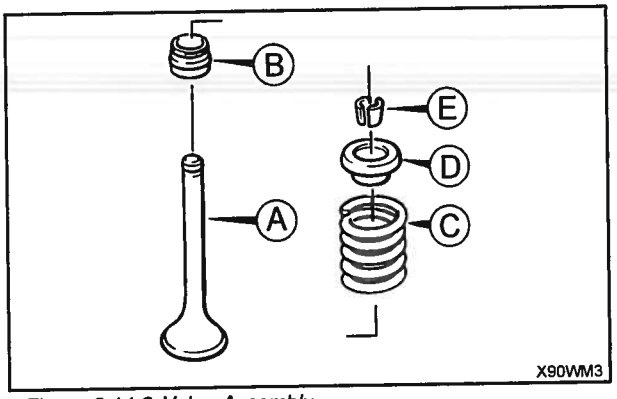


Figure 2.14.2 Valve Assembly
A - Valve
B - Valve Stem Seal
C - Valve Spring
D - Valve Spring Plate
E - Collets

4. Fit new valve stem seals (B), see "2.15 The Valve Guides", to the valve guides taking care to ensure they are correctly located and not distorted.

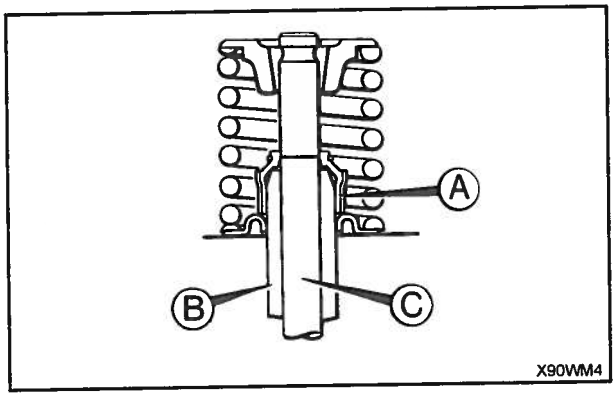


Figure 2.14.3 Valve Guide Seal Location
A - Valve Guide Seal
B - Valve Guide
C - Valve Stem

5. Replace the valve spring (C) and spring carrier (D).
6. Fit the adaptor (A), see 'Figure 2.14.1', over the valve spring carrier with the two indentations facing outwards.
7. Push down on the tool lever until the collets (E) can be replaced in position with their tops slightly sunk in the valve spring carrier.
8. Gently release the tool and check that the collets are correctly located.

2.14.3 The Valve Seats

The valve seats must be precision ground so that the valves are sunk below the combustion surface of the head as shown in the table.

	Valve Seat Depth	
	Inlet Seat	Exhaust Seat
mm	0.95-1.26	1.33-1.64
in	0.0374-0.0496	0.0524-0.0646

The seats are cut at a 45° angle and a 1° interference angle between the face and the seat provides a high-contact-pressure seal. The main consideration is that the installed valve spring tension will be reduced if valve recession is excessive. Good automotive machine shop practice should be followed in all cases, using spring shims if required to restore correct installed height.

2.14.4 Valve Seat and Recess Cutting

Specialized equipment is required to re-finish the valve seats which are cut at a 45° angle.

1. Fit the correct adjustable mandrel (A) into the valve guide and turn the adjuster until the flutes just bind onto the guide.

⚠ CAUTION

The valve guide will be damaged if the mandrel is adjusted too much when it is located in the guide and care must be taken to ensure an even, gentle downward pressure is applied when using the cutter to prevent the removal of too much metal.

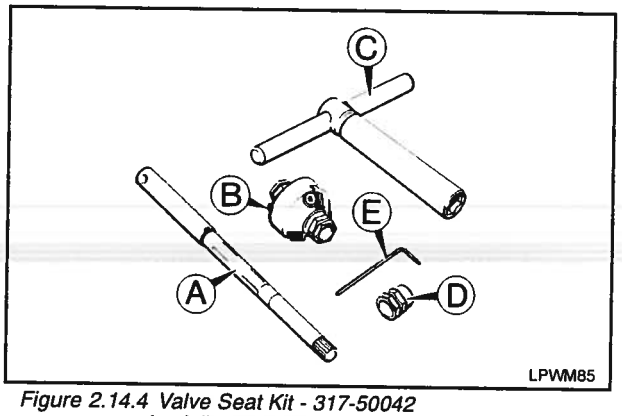


Figure 2.14.4 Valve Seat Kit - 317-50042
A - Adjustable Mandrel
B - Cutting Tool
C - 'T' Handle
D - Adaptor
E - Allen Key

2. Select the necessary cutting tool (B) and assemble it to the handle (C).
3. Place the cutter over the mandrel and adjust the three individual blades, using the Allen Key, if necessary.
4. Rotate the tool in a clockwise direction until the valve seat or recess finish is satisfactory.

2.15 THE VALVE GUIDES

The valve guides are an integral part of the cylinder head and are therefore not serviceable.

2.16 THE HYDRAULIC TAPPETS

No adjustment is necessary or possible and removal of any part of the valve gear will allow the hydraulic tappet to extend and hydraulically lock.

When new hydraulic tappets have been fitted the engine must be cranked for at least 15 seconds before attempting to start it.

The tappets can be removed, and replaced, by careful use of a suitable magnetic tipped tool.

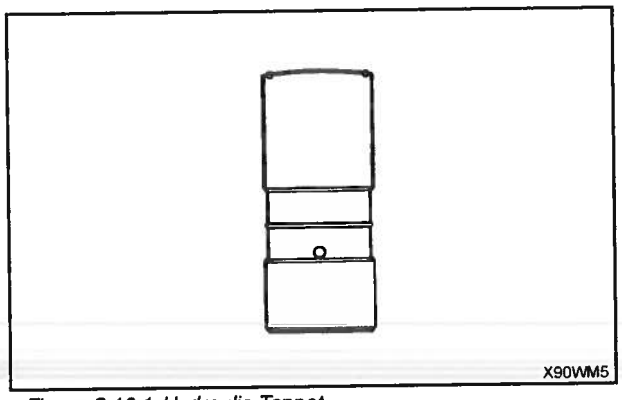


Figure 2.10.1 Hydraulic Tappet

When fitting the cylinder head, valve to piston contact can be avoided when tightening the valve rocker lever nut by depressing the push rod end of the rocker lever using a suitable tappet compressing tool.

⚠ CAUTION

Extreme care must be taken not to bend the push rod by using excessive force with the tool.

If the tappet compressing tool is not available torque the rocker lever nut to 27.0Nm (20.0lbf ft) to open the valve and wait for up to 45 minutes for the lubricating oil in the tappet to 'bleed down', and so allow the valve to seat in the head.

⚠ CAUTION

No piston must be at TDC when the head is replaced. During the 'bleed down' waiting period the crankshaft must not be turned.

2.17 THE GEAR END COVER

The gear end cover is located on two dowels and secured to the crankcase by bolts.

If the two dowels are being replaced care must be taken to ensure the flat end enters the crankcase fully; the taper end provides engagement with the end cover.

The two oil seals are of the lip type and a joint is fitted between the end cover and the crankcase face.

Care must be taken to protect the oil seals when the end cover is either removed or replaced.

2.17.1 Removing the End Cover

1. Fit the flywheel locking tool, 317-50057, into the flywheel gear ring by screwing it into the tapped hole in the flywheel housing.

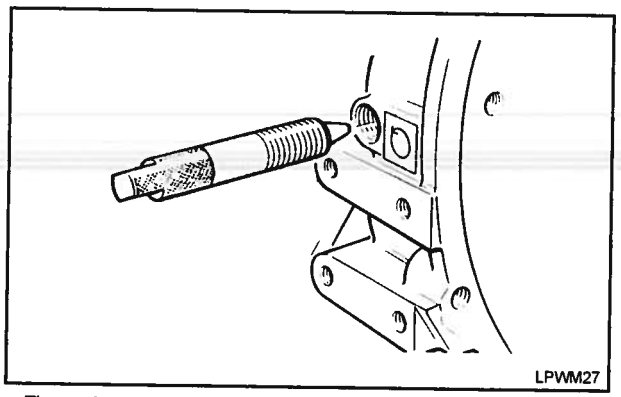


Figure 2.17.1 Fitting the Flywheel Locking Tool

2. Ensure the locking tool is fully engaged into a flywheel ring gear tooth by attempting to turn the flywheel.

   If the locking tool is not available wedge the crankshaft with a suitable piece of hardwood to prevent it turning.

3. Slacken the alternator pivot bolts (A) and (B) and move the alternator towards the crankcase sufficiently to allow removal of the drive belt.

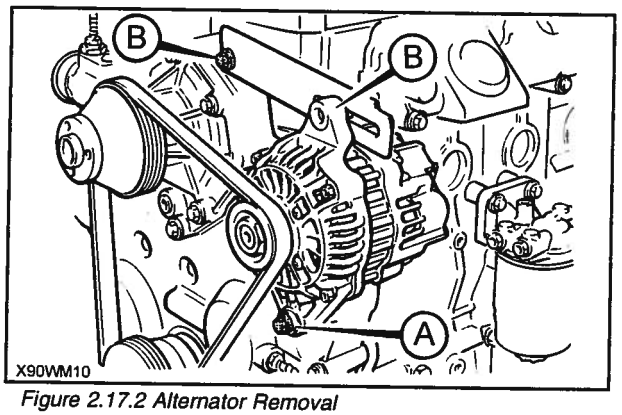


Figure 2.17.2 Alternator Removal

4. Remove the alternator.
5. Use a suitable socket and wrench and unscrew the right hand thread crankshaft pulley bolt and remove the pulley.
6. Remove the flywheel locking tool, or wood wedge.
7. Renove the oil filter/adaptor and the oil pressure relief valve.

Note:
The oil filter/adaptor must be removed to enable the removal of an end cover bolt fitted behind it.

8. Remove the end cover retaining bolts.
9. Remove the end cover.

   To avoid possible damage do not use a screwdriver on the cover or crankcase mating faces.

10. Clean all traces of the old joint from the crankcase and cover.
11. If necessary push out the two oil seals from the end cover using a suitable plug press.

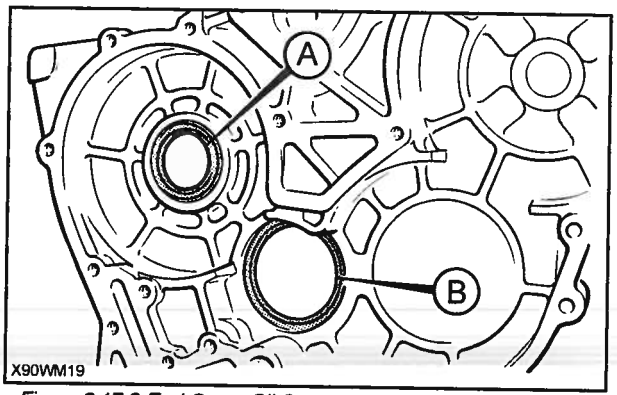


Figure 2.17.3 End Cover Oil Seals (shown from inside the cover)
A - Camshaft Seal
B - Crankshaft Seal

2.17.2 Fitting New End Cover Oil Seals

1. Lightly grease the sealing lip of the new seal.
2. Place a new seal into the outside neck of the end cover, lip side first, and position it squarely on the shoulder of the seal boss.
3. Using a suitable plug press drive the seal into position in the end cover.

   In an emergency, if the tool is not available a suitable plug, preferably hard wood, can be used.

2.17.3 Fitting the End Cover

1. Clean all traces of the old joint from the crankcase and cover.
2. Smear a very small amount of grease to the crankcase; sufficient to hold a new joint in position.
3. Place a new joint, which must be fitted dry, over the two dowels and onto the crankcase.
4. Replace the end cover, taking care to ensure the oil seals are not damaged and the cover is correctly located over the dowels.
5. Replace the retaining bolts finger tight.
6. Following the sequence shown torque the bolts to 21.0Nm (15.5lbf ft).

   The bolts shown as (A) are water pump retaining bolts.

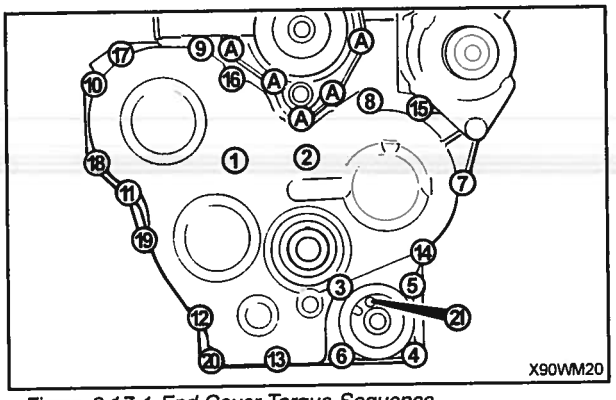


Figure 2.17.4 End Cover Torque Sequence

7. Replace the oil pressure relief valve into the end cover and torque it to 21.0Nm (15.5lbf ft).
8. Replace the oil filter/adaptor.
9. Replace the crankshaft pulley and torque the retaining bolt to 300.0Nm (221.0lbf ft).
10. Replace the alternator.
11. Replace and tension the drive belt as in "2.7 Drive Belt Tension".

2.18 THE GEAR TRAIN

Access to the gear train is possible by removing the gear end cover.

The illustration shows all the gears with their respective timing marks aligned.

Removal of the various gears is given in the relevant sections.

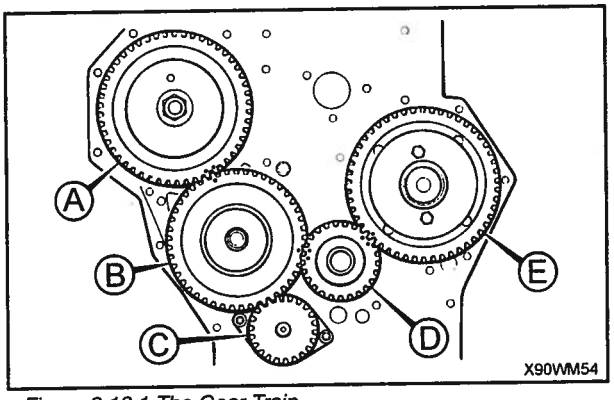


Figure 2.18.1 The Gear Train
A - Fuel Pump Gear
B - Idler Gear
C - Oil Pump Gear
D - Crankshaft Gear
E - Camshaft Gear

2.19 THE CAMSHAFT

The chilled cast iron camshaft is carried in a bearing bush at the gear end and has a thrust plate fitted behind the cam gear.

A locating dowel is fitted to the inside face of the camshaft pinion gear which locates at approximately the '7 -o-clock' position on the camshaft.

Cams on the camshaft operate the hydraulic tappets and the fuel lift pump.

2.19.1 Removing the Camshaft

1. Remove the gear end cover.
2. Remove the cylinder head and push rods.
3. Refer to "5.5 The Fuel Lift Pump" and remove the fuel lift pump and push rod.
4. Lift out the hydraulic tappets using a magnet.

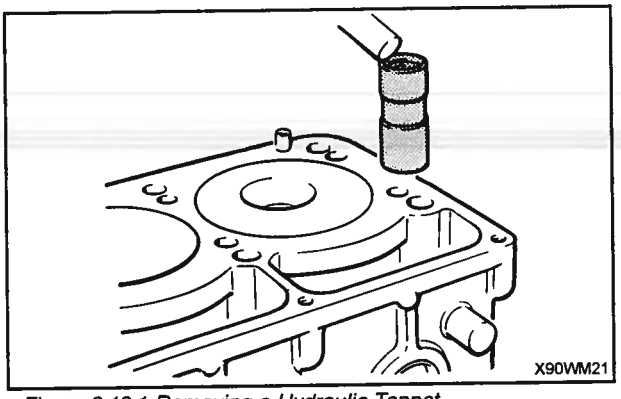


Figure 2.19.1 Removing a Hydraulic Tappet

5. Turn the crankshaft until the crankshaft and camshaft gear timing marks all align.

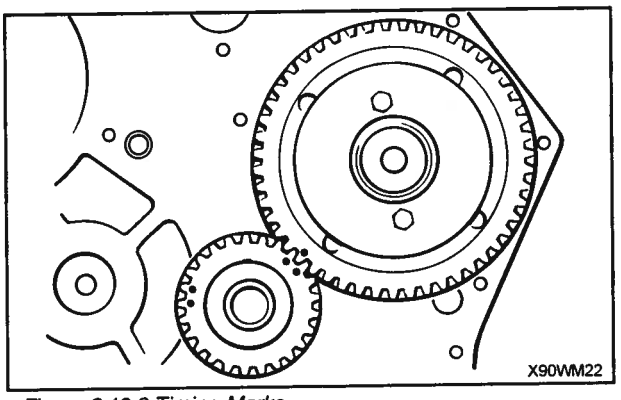


Figure 2.19.2 Timing Marks

6. Fit the flywheel locking tool, 317-50057, into the flywheel gear ring by screwing it into the tapped hole in the flywheel housing.

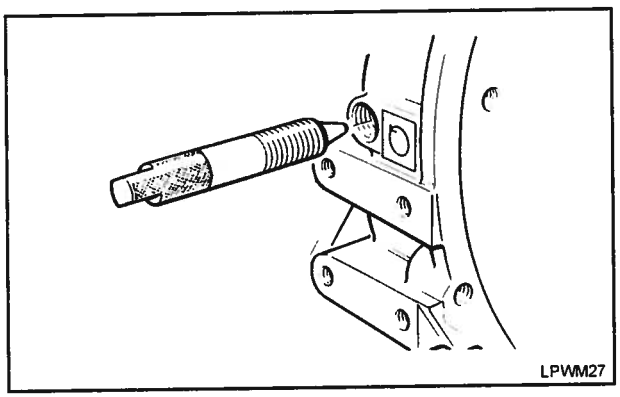


Figure 2.19.3 Fitting the Flywheel Locking Tool

7. Ensure the locking tool is fully engaged into a flywheel ring gear tooth by attempting to turn the flywheel.

   If the locking tool is not available wedge the crankshaft with a suitable piece of hardwood to prevent it turning..

8. With the flywheel locked remove the camshaft gear centre bolt (A). Do not remove the two outside bolts (B).

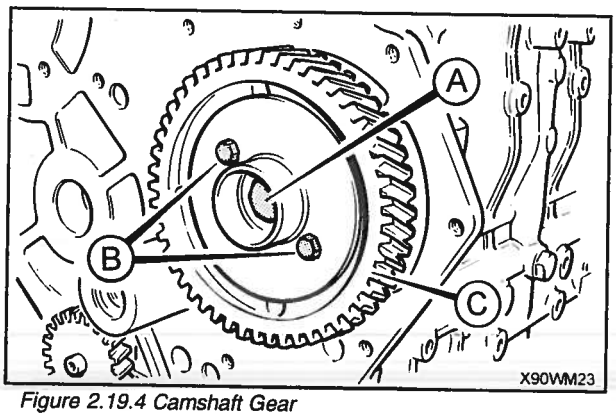


Figure 2.19.4 Camshaft Gear

9. Support the camshaft gear (C) and remove it from the shaft.
10. Mark the position of the camshaft locating dowel hole on the crankcase with a scribed line; this will be approximately in the '7 -o-clock' position.

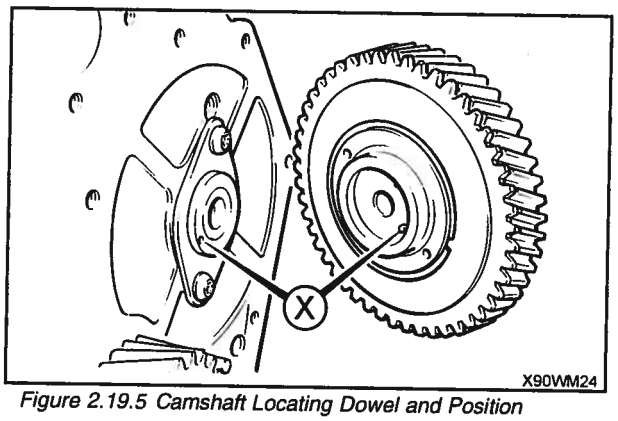


Figure 2.19.5 Camshaft Locating Dowel and Position

11. Remove the two thrust plate screws (D).

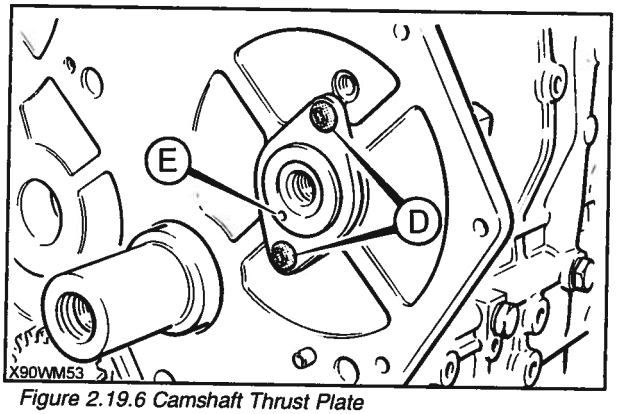


Figure 2.19.6 Camshaft Thrust Plate

12. Remove the thrust plate (E).
13. Gently ease the camshaft (F) out of the crankcase keeping it square at all times.

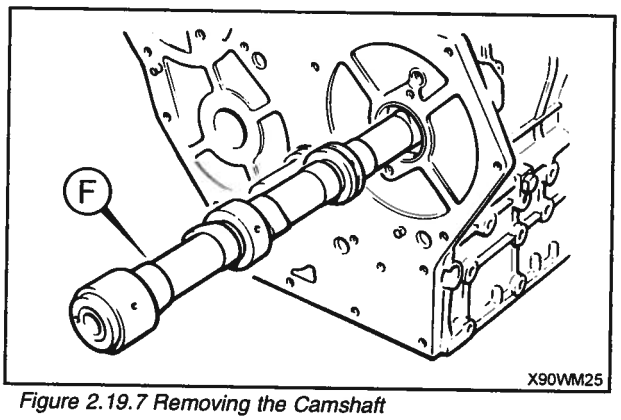


Figure 2.19.7 Removing the Camshaft

2.19.2 Inspection of the Camshaft

a. Examine the camshaft bush for scars or wear.
b. Check the camshaft gearwheel and crankshaft pinion teeth for wear.
c. Ensure the cams are not chipped or damaged.
d. Check the hydraulic tappets for scars or damage to the contact face.

2.19.3 Replacing the Camshaft

1. Lightly oil the camshaft.
2. Keeping the camshaft square at all times carefully replace it into the crankcase .
2. If necessary, turn the camshaft until the dowel hole is in line with the previously scribed line.
3. Replace the thrust plate and the two thrust plate screws finger tight.
4. Torque the two screws to 21.0Nm (15.5lbf ft).
5. Carefully replace the camshaft cam gear ensuring that on final assembly:
   a. The dowel on the back of the gear will mate with its hole in the end of the camshaft.
   b. The timing marks on the crankshaft and camshaft pinion gears will be exactly aligned.

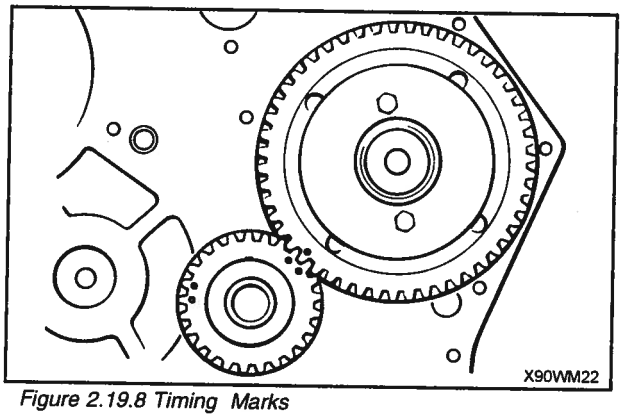


Figure 2.19.8 Timing Marks

6. With the flywheel locked replace the pinion gear centre bolt and torque it to 81.0Nm (60.0lbf ft).
7. Remove the flywheel locking tool.
8. Check the endfloat as described in "2.19.4 Camshaft Endfloat"
9. Refer to the relevant instructions and replace the hydraulic tappets, push rods, cylinder head, fuel lift pump and tappet and gear end cover.

2.19.4 Camshaft Endfloat

The camshaft endfloat is factory set and cannot be adjusted.

The following instructions are included for reference.

If the endfloat is greater than that given the camshaft must be replaced.

1. Remove the gear end cover.
2. Push the camshaft towards the flywheel end.
3. Fix a clock gauge in position against the camshaft gear.

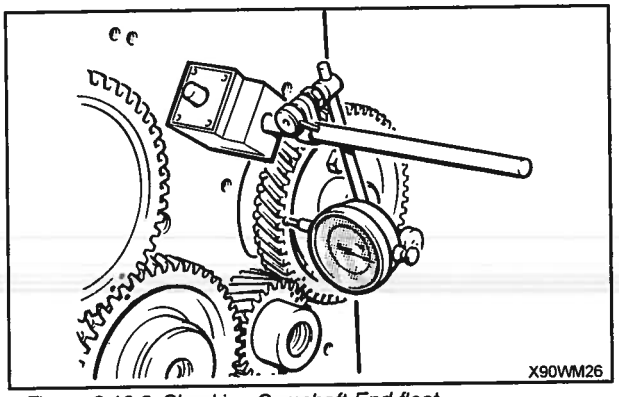


Figure 2.19.9 Checking Camshaft End float

4. Zero the gauge.
5. Move the camshaft as far as it will go towards the gear end.

   The movement recorded on the gauge is the endfloat.

2.19.5 Removing the Camshaft Bearing

1. Fit the guide (A) into the bearing shells from inside the crankcase.
2. Fit the slide hammer (B) onto the guide threads.
3. Use the slide hammer to remove the shells.

⚠ WARNING

Care must be taken to ensure that any part of the hand is not likely to become trapped between the two parts of the slide hammer while it is being used.

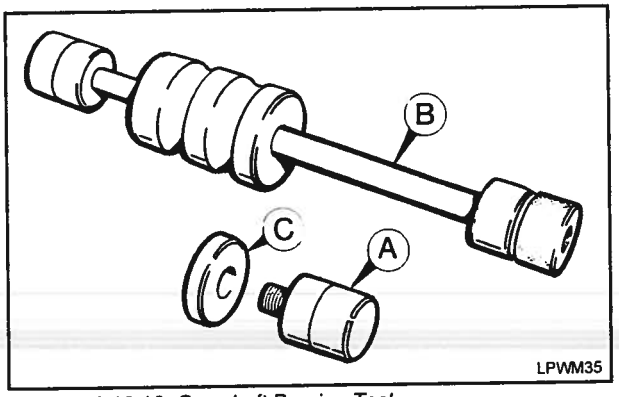


Figure 2.19.10 Camshaft Bearing Tool

2.24.2 Fitting a New Bearing

Before fitting new camshaft bearing shells the outside diameters must be lightly oiled with new engine lubricating oil before assembly.

1. Fit the new bearing shells over the guide threads.
2. Screw on the depth plate (C); see the above illustration.
3. Fit the slide hammer onto the guide threads.
4. Place the assembly squarely into the crankcase bore from the outside of the crankcase.
5. Use the slide hammer to replace the bearing shells.

⚠ WARNING

Care must be taken to ensure that any part of the hand is not likely to become trapped between the two parts of the slide hammer while it is being used.

2.20 THE PISTON

The piston is manufactured from a low expansion alloy with a recessed combustion chamber in the crown and is fitted with three rings.

The piston crown is stamped 'Camshaft Side' to ensure the piston is correctly assembled to the engine.

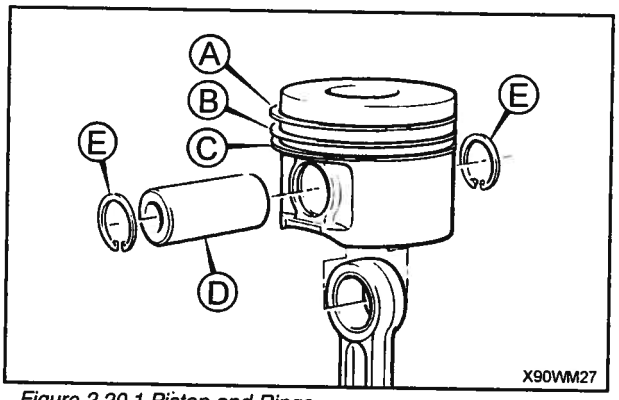


Figure 2.20.1 Piston and Rings
A - Firing Ring
B - Compression Ring
C - Oil Control Ring
D - Gudgeon Pin
E - Gudgeon Pin Retaining Circlip

2.20.1 The Piston Rings

Piston rings are only available as sets and it is recommended that they are only fitted as a set.

Firing Ring - top

A barrel lapped chrome ring is situated at the top of the piston, one surface is marked 'TOP' and the ring must be fitted the correct way up.

Compression Ring - centre

The compression ring has a tapered face in contact with the barrel, one surface is marked 'TOP' and the ring must be fitted the correct way up.

Oil Control Ring - bottom

A conformable type, with a spring expander, is fitted above the gudgeon pin.

2.20.2 Removing a Piston

1. Remove the cylinder head and lubricating oil sump.
2.. Rotate the crankshaft sufficiently to give access to the connecting rod bearing cap bolts.
3. Remove the two bearing cap bolts and the bearing cap.

⚠ CAUTION

To avoid possible injury, due to the sharp edges of the machined crankcase face, use a drive socket and not a spanner.

4. Carefully scrape any build up of carbon from the top of the cylinder bore.
5. Rotate the crankshaft until the piston is at either TDC or BDC; whichever is the most convenient.
6. Using a suitable brass drift, taking care not to damage the crankshaft journal, push out the piston and connecting rod until they are sufficiently clear of the top of the cylinder bore to allow them to be pulled clear.
7. Replace the bearing cap onto the connecting rod.
8. By using a standard ring expander the piston rings can be removed.
9. The gudgeon pin may be removed by releasing the circlip from one end and pushing out the pin.

⚠ CAUTION

It is recommended that suitable eye porotection is worn when removing the circlip.

2.20.3 Inspecting and Servicing the Piston

1. Thoroughly clean the cylinder barrel and check for scoring and wear.
2. Clean the piston, removing all traces of carbon from both the upper and underside of the crown and the ring grooves.
3. Clean the connecting rod.
5. Examine the small end bearing shells for wear.
6. If the big end has been dismantled because of metal failure, the oil passages in the crankshaft must also be examined for obstruction and fragments of metal.

2.20.4 Fitting a Piston

The pistons with rings and connecting rods assembled, must be submerged in oil just before fitting into the cylinder. After submersion drain both ways so that no oil is left in the combustion chamber or inside the piston.

1. Fit the piston to the connecting rod with the wording 'Camshaft Side' on the piston crown to the same side as the identification marks on the connecting rod big end and cap.

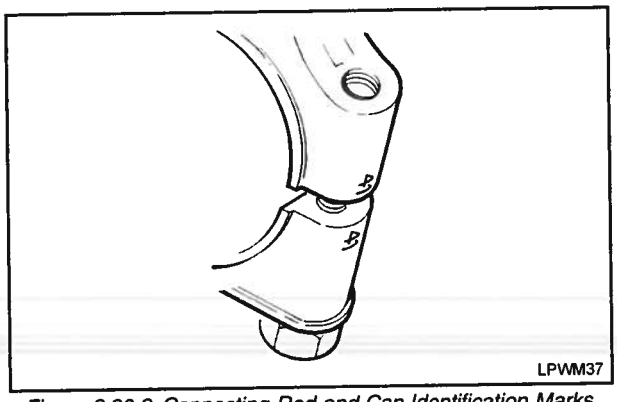


Figure 2.20.2 Connecting Rod and Cap Identification Marks

2. Place the connecting rod into the piston and Insert the gudgeon pin and circlips into the piston. Special care must be taken to ensure the circlips are correctly and securely located.

⚠ CAUTION

It is recommended that suitable eye porotection is worn when replacing the circlips.

3. Fit the piston rings, using a piston ring expander, taking care to ensure they are fitted in the correct order; refer to "2.20.1 The Piston Rings".
4. Turn the crankshaft journal to TDC.

   If necessary, fit new connecting rod big end bearing shells ensuring the tab (A) is correctly located in both the connecting rod and cap.

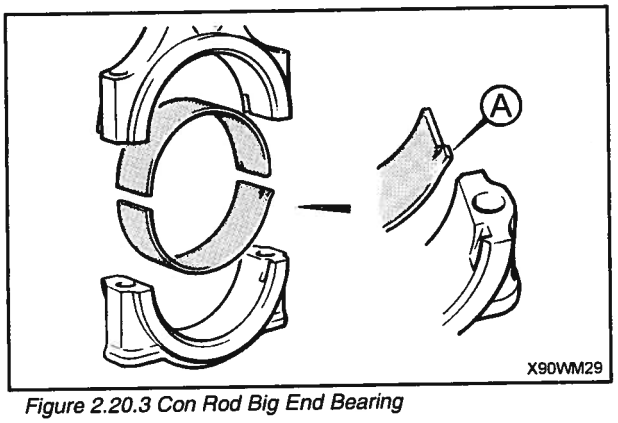


Figure 2.20.3 Con Rod Big End Bearing

5. Stagger the piston ring gaps as shown at 'X' in the illustration.

   Each ring gap must be set at 90° to the adjacent rings and 45° from the gudgeon pin axis.

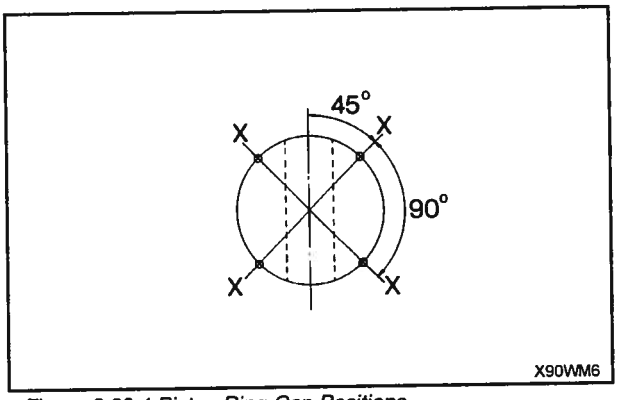


Figure 2.20.4 Piston Ring Gap Positions

6. Fit the piston and connecting rod into the cylinder while compressing the piston rings using a suitable piston ring compressor.

   Ensure the identification marks on the connecting rod will be facing towards the camshaft on final assembly.

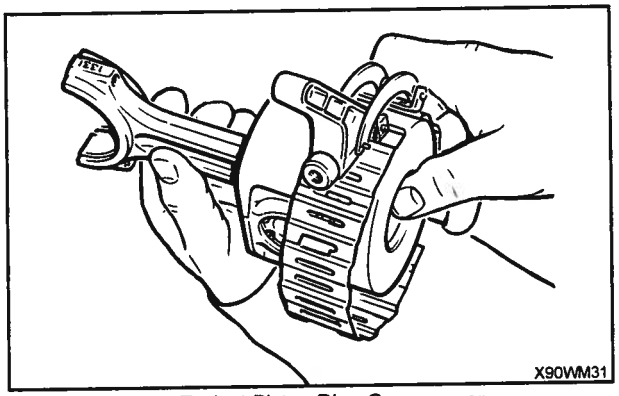


Figure 2.20.5 A Typical Piston Ring Compressor

7. Push down on the piston crown to ensure the connecting rod is fully located on the crankshaft journal.

The connecting rod cap can be replaced at either TDC or BDC depending on preference.

8. If necessary push down on the piston crown and turn the crankshaft until the big end is at BDC.
9. Ensure the identification marks on the connecting rod cap and rod are identical and replace the cap.

   Fit two new bolts and nuts and torque them to 35.0Nm (26.0lbf ft).

   It is recommended that the bolts are replaced at every major overhaul.

⚠ CAUTION

To avoid possible injury, due to the sharp edges of the machined crankcase face, use a drive socket and not a spanner

2.21 THE GUDGEON PIN

The gudgeon pin is a clearance fit in the piston and is retained by two circlips. It runs in bearing shells in the small end of the connecting rod.

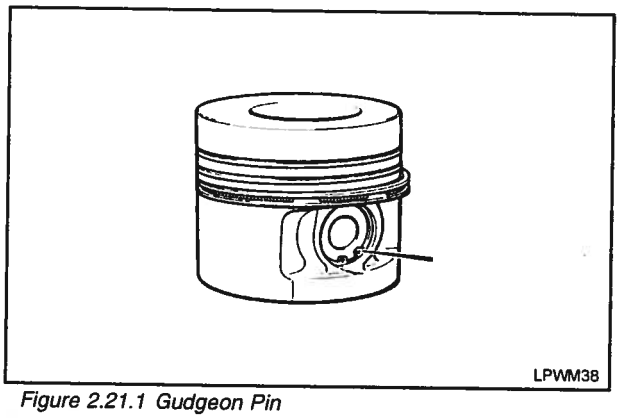


Figure 2.21.1 Gudgeon Pin

2.22 THE CONNECTING ROD

The connecting rod is connected to the crankpin by the big end bearing cap held in position by two bolts torqued to 35.0Nm (26.0lbf ft).

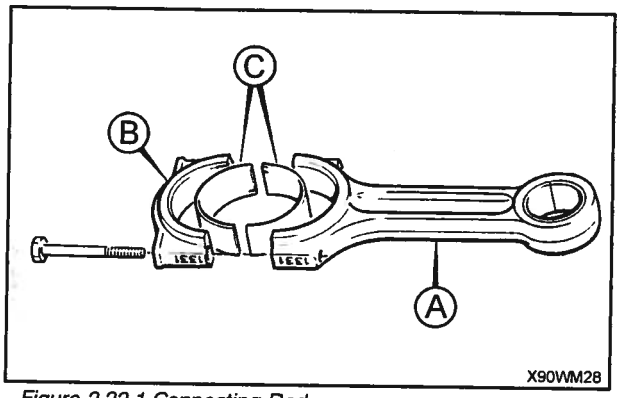


Figure 2.22.1 Connecting Rod
A - Con Rod
B - Bearing Cap
C - Big End Bearing Shells

The two halves of the big end bearing shells are steel backed aluminium/tin and should not be scraped or touched up in any way. The bearing shells are plain and without circumferential grooves but they do have locating tabs (A) to ensure they are correctly seated.

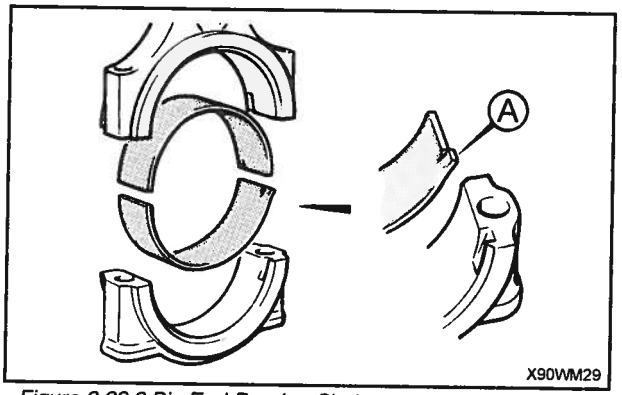


Figure 2.22.2 Big End Bearing Shells

The connecting rod must be assembled to the piston so that when it is in the engine 'Camshaft Side' on the piston crown is correctly positioned and the rod and cap identification numbers will be facing towards the camshaft; refer to "2.20.4 Fitting a Piston".

2.22.1 Checking Bearing Clearance

1. Place a piece of the correct size 'Plastigauge' approximately 6.35mm (0.25in) off-centre across the full width of one bearing shell.

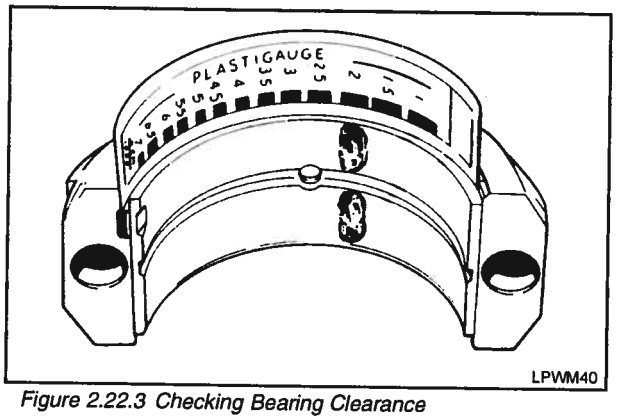


Figure 2.22.3 Checking Bearing Clearance

2. Replace the bearing and torque the bolts to 35.0Nm (26.0lbf ft).

⚠ CAUTION

Care must be taken to ensure the crankshaft is not turned when the 'Plastigauge' is in place, and all traces of it must be removed before final assembly of the bearing.

3. Remove the bearing shell and use the scale to check the width of the flattened 'Plastigauge'; the width at the widest point establishes the minimum clearance and at the narrowest point the maximum clearance.

   The difference between the two readings is the journal to bearing clearance.

2

2.23 THE FLYWHEEL

The flywheel rotates within the flywheel housing aperture and the type fitted depends on the engine and variant.

All flywheels are fitted with a ring gear for electric starting.

The flywheel is located in position with six bolts and the tolerance for spigot and mounting face run-out must be within 0.25mm (0.010in) T.I.R.

Timing degree marks are not shown on the flywheel.

⚠ CAUTION

It is strongly recommended that suitable lifting equipment and storage facilities are used when removing, handling or replacing the flywheel.

2.23.1 Removing the Flywheel

To aid re-assembly it is suggested that the crankshaft is turned to TDC for number 1 cylinder and the flywheel and flywheel housing are marked with a scribed line.

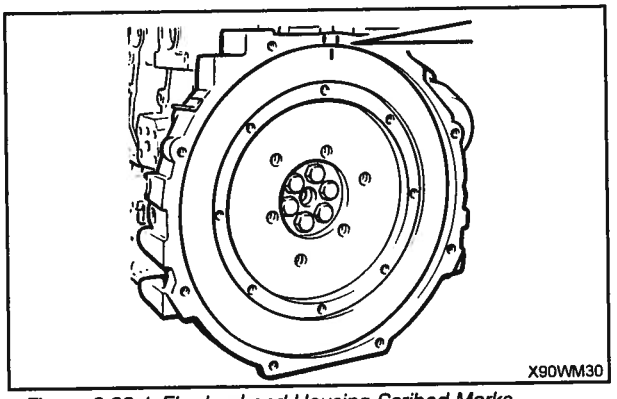


Figure 2.23.1 Flywheel and Housing Scribed Marks

1. Disconnect the driven equipment and the battery.
2. Fit the flywheel locking tool (B) through the flywheel housing into the flywheel gear ring, ensuring that it locates by attempting to turn the flywheel.

   If the locking tool is not available wedge the crankshaft with a suitable piece of wood to prevent it turning.

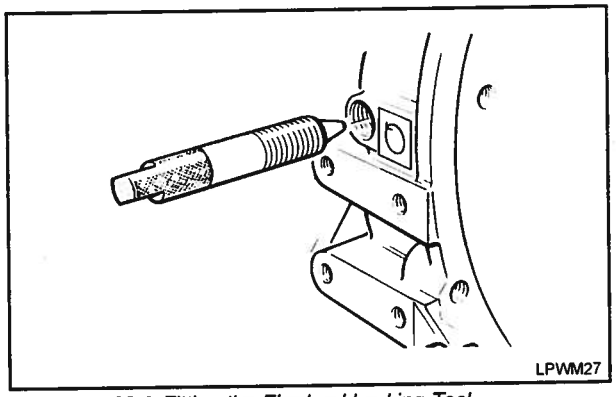


Figure 2.23.2 Fitting the Flywheel Locking Tool

3. Slacken the flywheel retaining bolts two turns.
4. Remove the locking tool.
5. Bolt the puller plate (A) to the flywheel and turn the tool centre bolt clockwise sufficiently to loosen the flywheel.

   If the puller plate is not available, remove the starter motor and use a suitable brass drift or piece of hardwood through the starter motor aperture to slacken the flywheel.

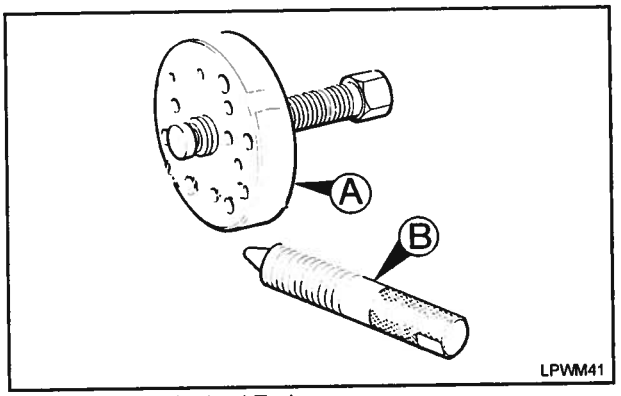


Figure 2.23.3 Flywheel Tools

6. Remove the service tool and the flywheel bolts.
7. Support the flywheel at all times and, keeping it square lift it off of the crankshaft and out of the housing.

2.23.2 Refitting the Flywheel

1. Turn the crankshaft to TDC for number 1 cylinder
2. Position the flywheel, off the engine, with the previously scribed mark on it in a similar position to the mark on the flywheel housing.
3. Lift the flywheel, supporting and keeping it square at all times, into the flywheel housing and onto the crankshaft.
4. Support the flywheel and push it fully into position and replace the retaining bolts finger tight.
5. Fit the flywheel locking tool (B) through the flywheel housing into the flywheel gear ring, ensuring that it locates by attempting to turn the flywheel.
6. Torque the retaining bolts, diagonally, to 81.0Nm (60.0lbf ft).
7. Remove the flywheel locking tool.

2.24 THE FLYWHEEL HOUSING

The flywheel housing locates on the flange of the main bearing housing and is not dowelled to the crankcase therefore, before attempting to remove it scribe a line on its rear face and the crankcase to ensure it is replaced in its original orientation.

There are two flywheel housing width options, 81mm and 98mm wide, with both having an SAE5 flange face.

2.24.1 Removing the Flywheel Housing

Unless it is considered necessary there is no need to remove the starter motor from the flywheel housing.

1. Remove the flywheel.
2. Remove the four housing retaining bolts.
3. Lift off the housing.

2.24.2 Fitting the Flywheel Housing

1. Lift the housing into position;
2. Replace the bolts finger tight.
3. Align the previously scribed marks.
4. Torque the retaining bolts to 81.0Nm (60.0lbf ft).

2.25 REAR MAIN BEARING HOUSING

The two halves of the main bearing are steel backed aluminium/tin and should not be scraped or touched up in any way. The bearing shells are plain and without circumferential grooves.

The bearing housing is secured to the crankcase at the flywheel end and has an oil drain which must be located at the bottom of the housing when it is refitted.

An oil seal is fitted to the centre bore of the housing and the bearing oil feed enters a drilling in the side of the bearing housing which aligns with a similar one in the crankcase.

2.25.1 Removing the Main Bearing Housing

⚠ CAUTION

Failure to remove the centre bearing dowels may result in distorting them, if the rear main bearing housing is levered off, making it difficult to remove them at a later stage.

1. Remove each centre bearing locating dowel securing screw (A) from the side of the crankcase.
2. Screw a suitable new or clean M6 bolt into the dowel (B).

   Pull the bolt and dowel out of the crankcase and leave the bolt in the dowel until it is refitted to ensure the dowel is refitted the correct way round.

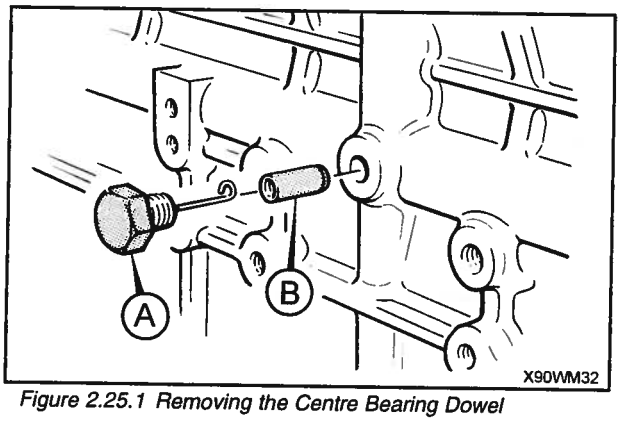


Figure 2.25.1 Removing the Centre Bearing Dowel

3. Remove the seven bolts securing the main bearing housing.
4. Remove the bearing housing.

   If the housing is tight, lever it off with a suitable screwdriver using the recesses in the '3 o-clock' and '9 o-clock' positions.
5. If necessary, drift out the oil seal taking care not to damage the bearings.

2.25.2 Refitting the Main Bearing Housing

If the bearing shells have been replaced before refitting the housing check that the oil supply holes in the bearing shells and the housing align.

⚠ CAUTION

Striking the crankshaft may displace the thrust washers and damage the bearing locating dowels if they have not been removed.

1. Lightly grease the steel back of the thrust washers and position them in the housing.

   Ensure the tab (A) is correctly located in the recess and the grooved faces will be towards the crankshaft.

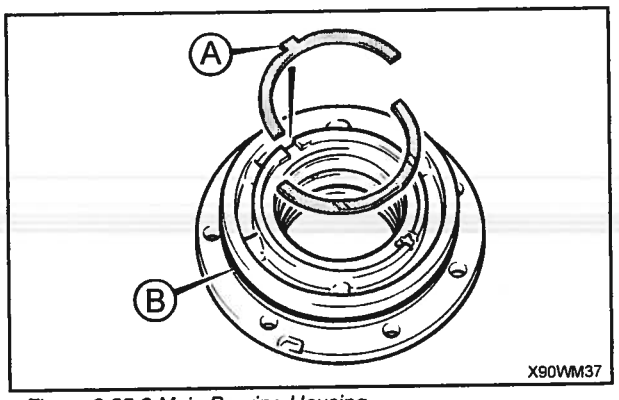


Figure 2.25.2 Main Bearing Housing

2. It is recommended that a new 'O' ring (B) is fitted.

   Lightly oil, or grease, the ring before fitting the housing.

3. With the oil seal removed, refit the housing ensuring it is kept square and the oil drain will be located towards the bottom of the crankcase on final assembly.

⚠ CAUTION

Take care to ensure the the 'O' ring is not being damaged as the housing is fitted.

4. Torque the housing bolts to 27.0Nm (20.0lbf ft) in the sequence shown.

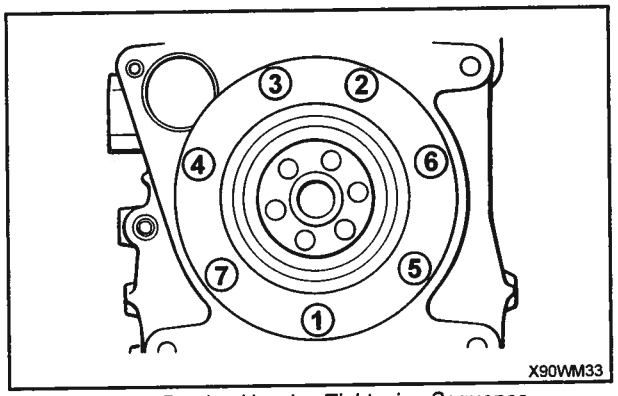


Figure 2.25.3 Bearing Housing Tightening Sequence

5. Check the crankshaft endfloat as described in "2.31 Crankshaft Endfloat".
6. Replace the oil lip seal.
   a. Lightly grease the sealing lip of the new seal.
   b. Place a new seal into the outside neck of the bearing housing, lip side first, and position it squarely on the shoulder of the seal boss.
   c. Using a suitable plug drive the seal into position in the housing.
7. With a suitable 6mm bolt inserted in the centre bearing dowels, insert the dowels through the crankcase wall and into the centre bearing housings.

⚠ CAUTION

Ensure the dowel is fully seated and not in the housing capscrew head recess (B).

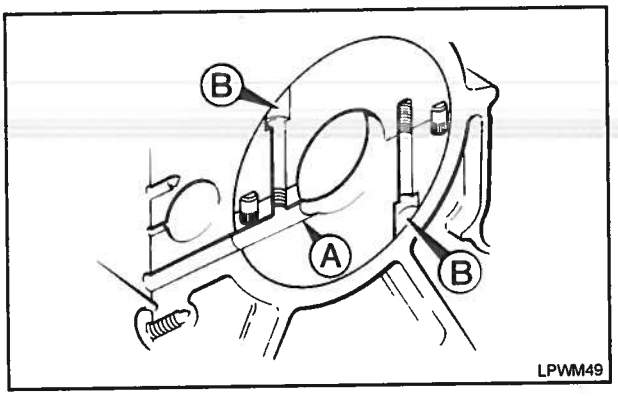


Figure 2.25.4 Dowel Hole Alignment
A - Bearing Housing Dowel Hole
B - Capscrew Head Recess

8. Remove the bolts from the dowels and refit the retaining screws with new copper washers.

2.26 CRANKSHAFT MAIN BEARINGS

The procedure for removing and fitting both main bearings is identical except smaller tool components are used at the gear end.

It is recommended that all bearings are replaced at the same time.

2.26.1 Removing the Bearing Shells

Before attempting to remove the bearings from the main bearing housing it should be firmly held in a soft-jawed vice.

1. Remove the oil seal by drifting or pressing it out from inside the bearing housing.
2. Place the bolt (A) through the plain dolly (B).

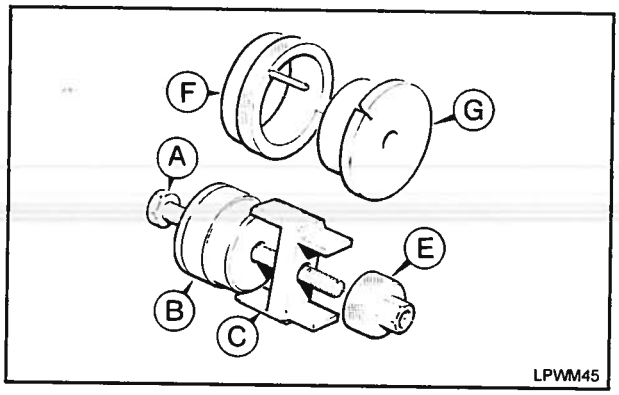


Figure 2.26.1 Main Bearing Tool

3. Fit the bolt and dolly into the bearing from the oil seal side (crankcase outside face).
4. Fit the bridge (C) over the bolt threads until the two legs are against the housing face (crankcase at the gear end)
5. Fit the nut (E) onto the bolt.
6. Using a suitable spanner tighten the nut until the bearing shells are withdrawn.

2.26.2 Fitting New Bearing Shells

Before attempting to replace the bearings in the main bearing housing it should be firmly held in a soft-jawed vice.

1. Place the large tapered collar (F) on a bench with the spigot facing upwards.
2. Place the new bearing shells into the collar ensuring that one oil feed hole is in line with the spigot and the end of the shell is in line with the mark on the collar face.
3. Place the driver (G) onto the collar (F) with the cutout on the driver located over the collar spigot.
4. Push the driver sufficiently until the bearings come out the other side of the collar to provide a lead-in.
5. Scribe a pencil line in line with the oil hole (X) on the outside face of the housing (crankcase at the gear end).

   Care must be taken to align the spigot with the inner oil hole; see (X) in the illustration.
6. Fit the assembly into the housing from the oil seal side (crankcase outside face at the gear end) with the spigot in line with the pencil line on the housing (crankcase at the gear end).

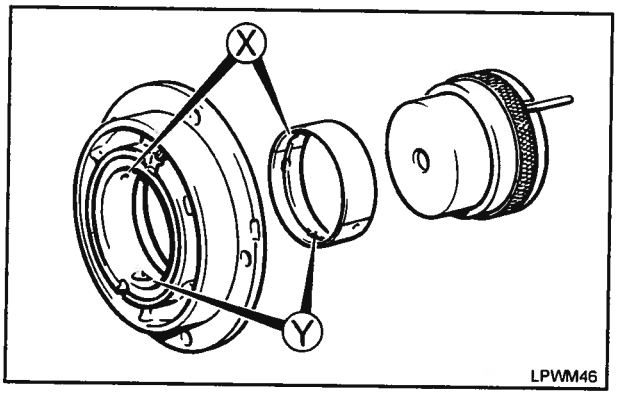


Figure 2.26.2 Main Bearing Housing Oil Hole

7. Place the bolt (A) through the assembly.
8. Fit the bridge (C) and the nut (E) onto the bolt.
9. Tighten the nut until the driver (G) is against the face of the collar (F).
10. Remove the tool.
11. Check that the elongated oil hole (X) and the small oil hole (Y) in the bearing shell is correctly aligned with the oil feed holes in the housing (crankcase).

2.27 REAR MAIN BEARING OIL SEAL

⚠ CAUTION

Before fitting an oil seal refer to '3.12 Oil Seals'.

1. Place the new seal (A) squarely into the housing (B).

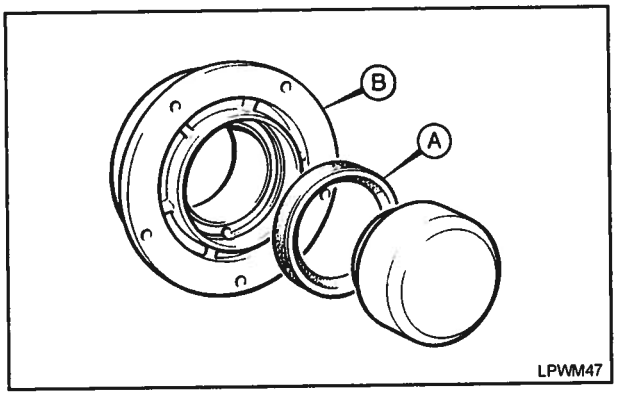


Figure 2.27.1 Oil Seal Tool

2. Hold a suitable dolly firmly onto the outside face of the seal and drive the seal into the bearing housing until it is flush with the outside face of the housing.

2.28 THE CRANKSHAFT CENTRE MAIN BEARING

The two halves of the main bearing are steel backed aluminium/tin and should not be scraped or touched up in any way.

The bearing shells both have circumferential grooves and are contained within the two halves of the housing which are dowelled and secured by two capscrews.

The housing is located by a hollow dowel fitted through the crankcase.

2.28.1 Replacing Centre Bearing Shells

1. Remove the crankshaft.
2. Remove the two retaining capscrews and lift the housing halves away.
3. Slide out the bearing shells and fit the new ones taking care to ensure the oil holes in the shells and housing align.
4. Fit the bearing housing to the crankshaft ensuring the two halves correctly align on the dowels and the words 'Flywheel End' face the correct way.
5. Replace the capscrews and torque them to 21.0Nm (15.5lbf ft).

2.29 THE CRANKSHAFT PULLEY

The crankshaft and driven pulleys must have a smooth finish to the grooves, and be aligned within 1.6mm (0.061in), measured at the centre of the grooves.

The pulley is retained by a right hand thread bolt torqued to 300Nm (221lbf ft).

2.29.1 Removing the Crankshaft Pulley

1. Remove the drive belt.
2. Remove the right hand thread pulley retaining bolt (A).
3. Pull the pulley (B) off the crankshaft.

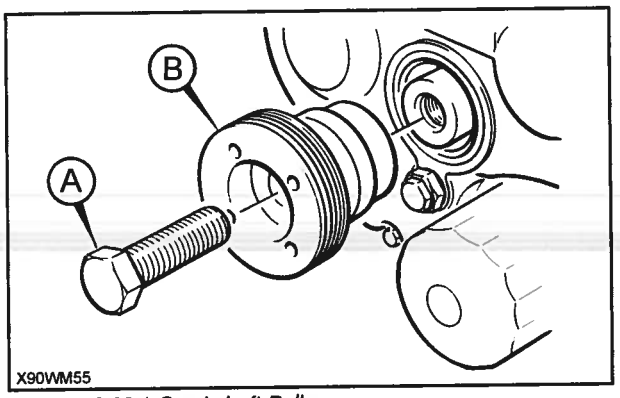


Figure 2.29.1 Crankshaft Pulley

2.29.2 Refitting the Crankshaft Pulley

1. Ensure the pulley boss is clean.
2. Keeping the pulley square push it onto the crankshaft taking care not to damage the oil seal.
3. Replace the pulley bolt and torque it to 300Nm (221lbf ft).
4. Replace and tension the drive belt.

2.30 THE CRANKSHAFT

The crankshaft is carried in steel backed aluminium/tin faced main bearings which are located in the crankcase at the gear end, the flywheel end main bearing housing and the centre main bearing housings.

The two halves of the flywheel end main bearing shells are plain with no circumferential grooves but both halves have an oil feed hole. Two grooved half bearing shells are fitted in the crankcase at the gear end and the centre bearing housings.

An interference fit pinion gear is keyed onto the gear end of the crankshaft and engages with the camshaft and idler gears.

The balance weights are an integral part of the shaft and the centre bearing housing is in two halves secured by two capscrews.

End thrust is taken on steel backed aluminium/tin faced split thrust washers fitted at the gear end of the crankcase and in the flywheel end main bearing housing.

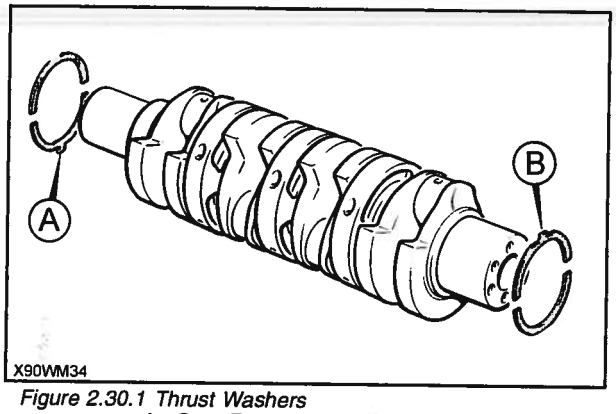


Figure 2.30.1 Thrust Washers
A - Gear End (in crankcase)
B - Flywheel End (in main bearing housing)

2.30.1 Removing the Crankshaft

1. Remove the crankshaft pulley and gear end cover.
2. Remove the pistons and connecting rods.
3. Remove the flywheel, flywheel housing and main bearing housing.
4. Remove the camshaft.
5. Remove each centre bearing locating dowel securing screw (A) from the side of the crankcase.
2. Screw a suitable new or clean M6 bolt into the dowel (B).

   Pull the bolt and dowel out of the crankcase and leave the bolt in the dowel until it is refitted to ensure the dowel is refitted the correct way round.

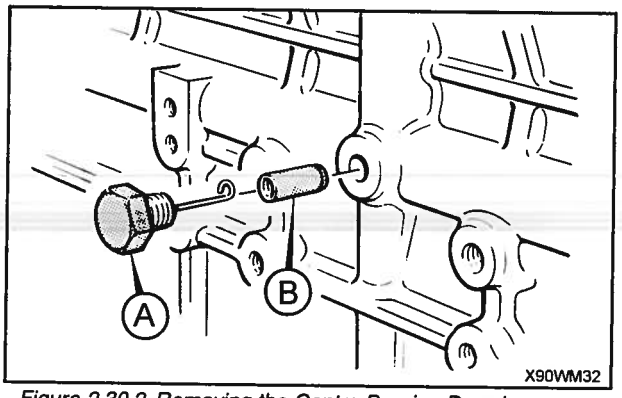


Figure 2.30.2 Removing the Centre Bearing Dowel

6. Use a suitable three legged puller to remove the crankshaft gear.
7. Gently withdraw the crankshaft through the flywheel end of the crankcase.

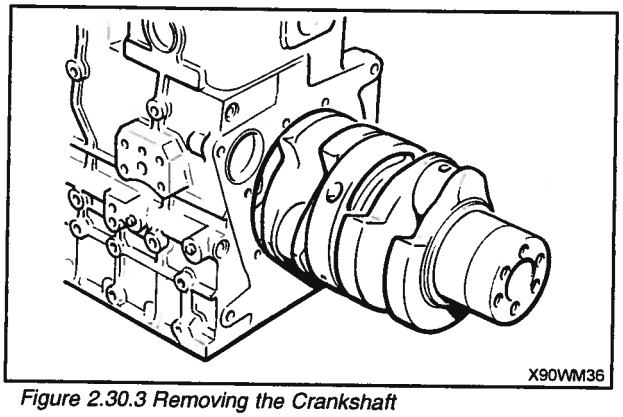


Figure 2.30.3 Removing the Crankshaft

8. Remove the two capscrews and dismantle the centre bearing housing/s.
9. Remove the thrust washers from the gear end of the crankcase and the flywheel end main bearing housing.

2.30.2 Inspecting the Crankshaft

a. Inspect the main bearings for scoring or wear.
b. If the connecting rod big end has been dismantled because of failure of the bearing, the oil passages in the crankshaft must also be examined for obstruction and fragments of metal.
c. Check the clearance between the crankshaft and journals, the main bearings and crankpins and also the connecting rod bearings.
d. Examine all bearing surfaces for scoring and wear.
e. Examine the thrust washers for damage and wear.

2.30.3 Refitting the Crankshaft

1. If necessary, fit new bearing shells to the main bearing housing, centre bearing housings and the gear end crankcase main bearing.
2. Re-assemble the centre main bearing housings around the crankshaft and torque the capscrews to 21.0Nm (15.5lbf ft).

   Ensure 'Flywheel End', stamped on the two housing halves, will be facing towards the flywheel after assembly.
3. Smear a small amount of grease to the steel side of the thrust washers and place them in the gear end of the crankcase; ensure the tab is correctly located in the recess and the grooved face will be towards the crankshaft.
4. Fit the crankshaft into the crankcase from the flywheel end, taking care to ensure the centre bearing dowel holes will in alignment with the holes in the crankcase on final assembly.

2

⚠ CAUTION

Take special care when passing the crankshaft through the gear end bearing as it is quite easy to score the bearing shell with the crankshaft.

5. With a suitable 6mm bolt inserted in the centre bearing dowels, insert the dowels through the crankcase wall and into the centre bearing housings.

⚠ CAUTION

Ensure the dowel is fully seated and not in the housing capscrew head recess (B).

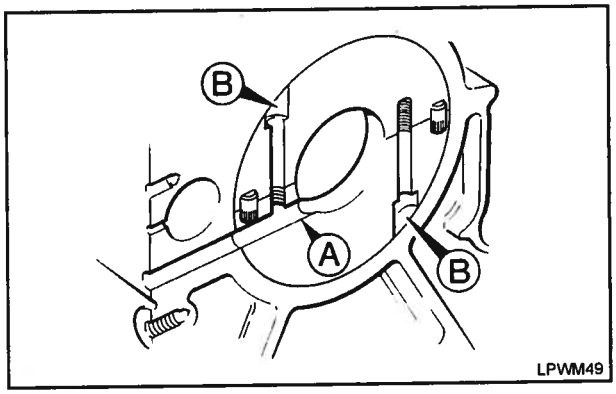


Figure 2.30.4 Dowel Hole Alignment
A - Bearing Housing Dowel Hole
B - Capscrew Head Recess

6. Remove the bolts from the dowels, refit the retaining screws with new copper washers.
7. Replace the rear main bearing housing and oil seal as described in "2.25.2 Refitting the Main Bearing Housing".
8. Check that the crankshaft is free to rotate.
9. Fit the Woodruff key at the gear end of the crankshaft if it was removed.
10. Heat the crankshaft gear to a straw yellow colour (approximately 100°C (212°F)) and fit it to the crankshaft ensuring the timing mark is facing outwards.

    Insufficient heat or delay in fitting could cause the gear to become jammed on the crankshaft, whereas overheating may cause softening of it.
11. Check the crankshaft end float as described in "2.30.1 Checking Crankshaft Endfloat".

2.31 CRANKSHAFT ENDFLOAT

The endfloat tolerance is factory set and is not adjustable.

The following instructions are included for reference.

2.31.1 Checking Crankshaft Endfloat

1. Set a dial test indicator so that the actuating plunger makes contact with the end face of the crankshaft.

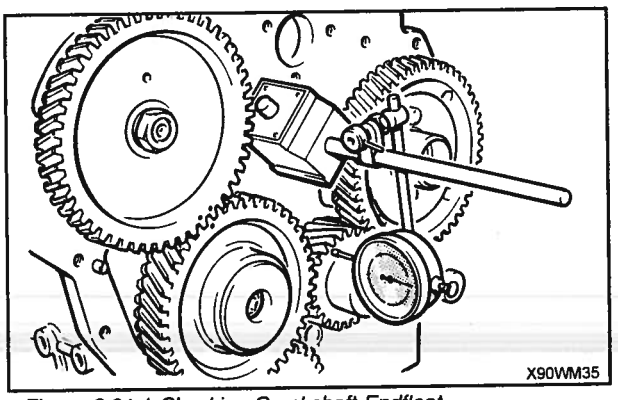


Figure 2.31.1 Checking Crankshaft Endfloat

2. Push the crankshaft firmly towards the gear end of the engine and zero the indicator.
3. Push the crankshaft firmly towards the flywheel end of the engine and check the measurement on the indicator which will be the endfloat.

2.32 THE IDLER GEAR

The idler gear is fitted to a stub shaft and provides an indirect drive from the crankshaft to the fuel pump.

2.32.1 Removing the Idler Gear

1. Turn the crankshaft to align the fuel pump (A) idler (B), crankshaft (C) and camshaft (D) gear timing marks as shown in 'Figure 2.18.1'.

⚠ CAUTION

Take care to ensure the crankshaft is not turned If no further dismantling is envisaged.

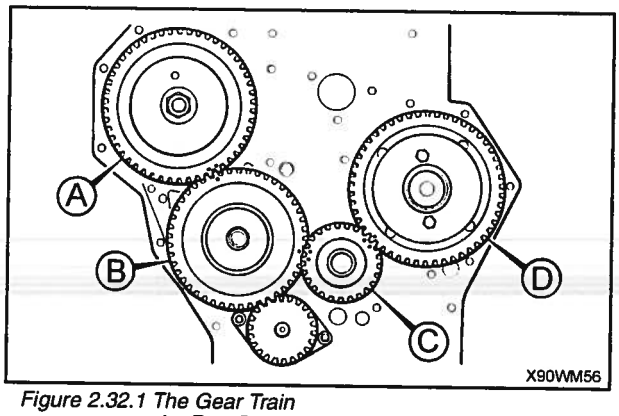


Figure 2.32.1 The Gear Train
A - Fuel Pump Gear
B - Idler Gear
C - Crankshaft Gear
D - Camshaft Gear

2. Remove the centre retaining bolt (A).
3. Slide out the stub shaft (B).
4. Pull the idler gear (C) away from the crankcase.

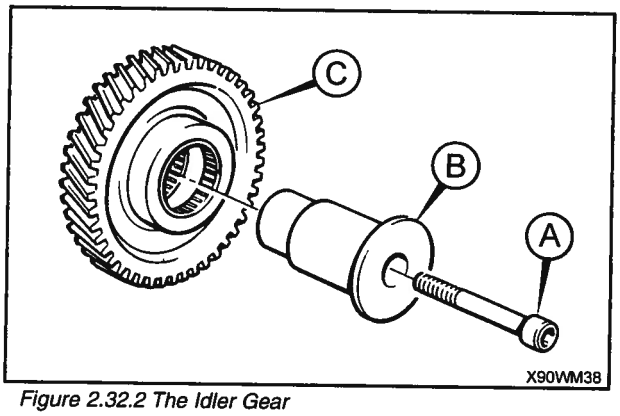


Figure 2.32.2 The Idler Gear

2.32.2 Replacing the Idler Gear

1. If the crankshaft was turned after the idler was removed, turn the it to align the camshaft and crankshaft gear timing marks.
2. Offer the idler gear to the crankshaft gear with the timing marks of both aligned.
3. With a sideways movement towards the crankshaft, firmly push the gear into position.
4. Fit the idler gear stub shaft assembly (B) through the gear into the crankcase.
5. Fit the centre bolt (A) and torque it to 81.0Nm (60.0lbf ft).
6. Check all the timing marks are correctly aligned.

2.33 DECARBONISING

Decarbonising should be carried out after 2000 hours running, or if the engine shows loss of compression or blow-by past the piston.

Thoroughly clean and examine the following items for damage or wear and renew any defective parts as necessary.

a. Piston.
b. Piston rings, grooves and oil holes.
c. Combustion chamber in the top of the piston.
d. Valve ports, valves and valve seats.
e. Exhaust manifold, piping and silencer.
f. Injector nozzle.

2.34 LAYING-UP PROCEDURE

The following routine should be carried out when it is known that the engine will not be required for some months.

If the following procedure is not carried out the engine should be run on full load for approximately 45 minutes once a month.

⚠ CAUTION

As a direct result of combustion the lubricating oil may contain harmful acids and therefore it should not be left in the sump if it is known that the engine will not be used for extended periods.

a. Fill a suitable small slave fuel tank with a small supply of suitable inhibition fluid.
b. Drain the lubricating oil from the sump and refill with new oil.
c. Run the engine for a period to circulate the oil through the system and to ensure the inhibition fluid is passed through the fuel pumps and injectors.
d. Stop the engine, drain the cooling system and drain the lubricating oil from the sump.

   The crankshaft should NOT be turned until the engine is again required for service.

   The inhibition fluid should be left in the fuel system.
e. Seal all openings on the engine with tape.
f. Remove the batteries and store them fully charged after coating the terminals with petroleum jelly.
g. Grease all external bright metal parts and the speed control linkage.
h. Tie labels on the engine clearly stating what steps have been taken to inhibit the engine during storage.

SECTION 3 - THE LUBRICATING OIL SYSTEM

CONTENTS

3.1 DESCRIPTION AND OPERATION

The pressed steel lubricating oil sump has two drain plugs; one at either the flywheel end or gear end and the other on the side of the sump.

The oil filler is fitted to the cylinder head cover and the dipstick on the opposite side of the crankcase to the fuel pump.

The oil pump, shown in "Figure 3.9.3", is gear driven from the idler gear and is fitted with a removable strainer.

The oil relief valve setting is pre-set and is not adjustable.

Oil in the sump is drawn into the pump through the oil strainer and is then delivered through a drilling in the crankcase to the full flow cartridge type oil filter.

Filtered pressure oil passes through the centre of the filter into the oil gallery from where it is delivered to the crankshaft and bearings.

The connecting rod big end bearings are pressure fed through internal drillings in the crankshaft from the supply to the main bearings.

Oil is also fed to the gear train, camshaft and hydraulic tappets.

3.2 OIL AND FILTER PRECAUTIONS

- Particular attention is drawn to the instructions given later in this section for replacing filters.
- Used oil filters and elements contain some of the filtered liquid and should be handled and disposed of with care.
- After handling new or used elements the users hands should be thoroughly washed, particularly before eating.

⚠ WARNING

New lubricating oil may cause skin irritation.
Contact with used lubricating oil can cause cancer, birth defects or other reproductive harm.

⚠ WARNING

The materials used in the manufacture and treatment of some filters and elements may cause irritation or discomfort if they come into contact with the eyes or mouth and they may give off toxic gasses if they are burnt.

⚠ WARNING

Extreme care must be taken to ensure that waste oil, filter elements, solvents or other toxic wastes are disposed of in accordance with local regulations to prevent contamination.

⚠ CAUTION

As a direct result of combustion the lubricating oil may contain harmful acids and therefore it should not be left in the sump if it is known that the engine will not be used for extended periods.

3.3 ENGINE LUBRICATING OIL CLASSIFICATION SYSTEM

The information contained in this section has been extracted from "Lubricant and Fuel Performance", with the permission of 'The Lubrizol Corporation'.

⚠ CAUTION

Some of the following classifications may not be available in your country. In cases of difficulty, it is suggested contact be made with a reputable oil supplier or any Lister-Petter Distributor.

Note:
US 'S' grade oils are for gasolene engines and are not recommended for Lister-Petter diesel engines.

3.3.1.1 European Oil Specifications

ACEA specifies the following:

Gasolene engines: A1-96, A2-96, A3-96.

Light duty diesel engine operation: B1-96, B2-96, B3-96.

Heavy duty and commercial vehicle diesel engine operation: E1-96, E2-96, E3-96.

3.3.2 Past and Current US API Grade Oils

API Service Category CA:

Service typical of diesel engines operated in mild to moderate duty with high-quality fuels; occasionally has included gasoline engines in mild service.

Oils designed for this service provide protection from bearing corrosion and ring-belt deposits in some naturally aspirated diesel engines when using fuels of such quality that they impose no unusual requirements for wear and deposit protection.

They were widely used in the 1940s and 1950s but should not be used in any engine unless specifically recommended by the equipment manufacturer.

API Service Category CB:

Service typical of diesel engines operated in mild to moderate duty, but with lower quality fuels, which necessitate more protection from wear and deposits; occasionally has included gasoline engines in mild service.

Oils designed for this service were introduced in 1949. They provide necessary protection from bearing corrosion and from high-temperature deposits in naturally aspirated diesel engines with higher sulphur fuels.

API Service Category CC:

Service typical of certain naturally aspirated diesel engines operated in moderate to severe-duty service, and certain heavy-duty gasoline engines.

Oils designed for this service provide protection from high-temperature deposits and bearing corrosion in diesel engines, and also from rust, corrosion, and low-temperature deposits in gasoline engines. These oils were introduced in 1961.

API Service Category CD:

Service typical of certain naturally aspirated, turbocharged or supercharged diesel engines where highly effective control of wear and deposits is vital, or when using fuels with a wide quality range (including high-sulphur fuels).

Oils designed for this service were introduced in 1955 and provide protection from high-temperature deposits and bearing corrosion in these diesel engines.

API Service Category CD-11:
Severe duty two-stroke

Service typical of two-stroke cycle diesel engines requiring highly effective control of wear and deposits.

Oils designed for this service meet all performance requirements of API Service Category CD.

API Service Category CE - 1983:

Service typical of certain turbocharged or supercharged heavy-duty diesel engines, manufactured since 1983 and operated under both low speed, high load and high speed, high load conditions.

Oils designated for this service may also be used when API Service Category CD is recommended for diesel engines.

API Service Category CF-4 -1990:

Service typical of high-speed, four-stroke cycle diesel engines.

API CF-4 oils exceed the requirements for the API CE category, providing improved control of oil consumption and piston deposits.

These oils should be used in place of API CE oils. They are particularly suited for on-highway, heavy-duty truck applications. When combined with the appropriate 'S' category, they can also be used in gasoline and diesel powered personal vehicles - i.e., passenger cars, light trucks, and vans - when recommended by the vehicle or engine manufacturer.

API Service Category CF:
Indirect injection

Service typical of indirect-injected diesel engines and other diesel engines that use a broad range of fuel types, including those using fuel with high sulphur content; for example, over 0.5% weight.

Effective control of piston deposits, wear and copper-containing bearing corrosion is essential for these engines, which may be naturally aspirated, turbocharged or supercharged.

Oils designated for this service have been in existence since 1994 and may be used when API Service Category CD is recommended.

API Service Category CF-2:
Severe duty, two-stroke cycle

Service typical of two-stroke cycle diesel engines requiring highly effective control over cylinder and ring-face scuffing and deposits.

Oils designed for this service have been in existence since 1994 and may also be used when API Engine Service Category CD-11 is recommended.

These oils do not necessarily meet the requirements of API CF or CF-4 unless they pass the test requirements for these categories.

API Service Category CG-4 - 1994:
Severe duty

API Service Category CG-4 describes oils for use in high-speed four-stroke-cycle diesel engines used in both heavy-duty on-highway (0.05% weight sulphur fuel) and off-highway (less than 0.5% weight sulphur fuel) applications.

CG-4 oils provide effective control over high-temperature piston deposits, wear, corrosion, foaming, oxidation stability, and soot accumulation.

These oils are especially effective in engines designed to meet 1994 exhaust emission standards and may also be used in engines requiring API Service Categories CD, CE, and CF-4. Oils designed for this service have been in existence since 1994.

3.4 LUBRICATING OIL SPECIFICATION

To help assist engine running-in, all engines are despatched with an initial fill lubricating oil which must be changed after 100 hours.

All subsequent oil changes must be as specified in "3.6 Oil and Filter Change Periods".

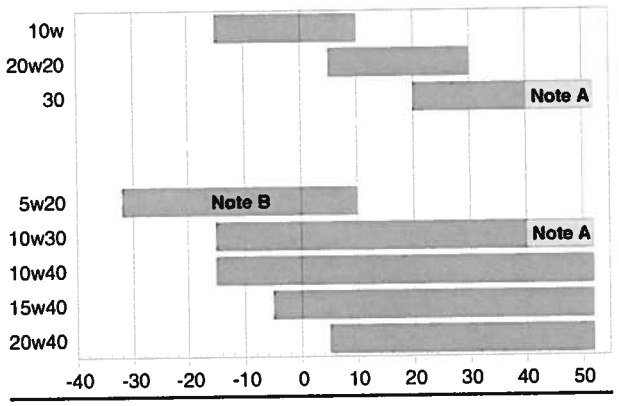
1. The temperatures mentioned in the tables are the ambient temperatures at the time when the engine is started. However, if monograde oils are used and running ambient temperatures are significantly higher than starting temperatures, a higher viscosity oil should be selected subject to satisfactory starting performance. Multigrade oils may be used to overcome the problem.
2. Where it is not practical to continually change oils to suit varying ambient temperatures a suitable multigrade oil is recommended to ensure adequate starting performance at the lowest temperature likely to be encountered.
3. X90 Series engines must be run on heavy duty lubricating oils. Straight mineral oils are not suitable, neither are oils of less detergency than specified.
4. API CD, Series 3 or MIL-L-2104C/D oils must be used in all X90 engines.

⚠ CAUTION

API CD, API CE, API CF-4 or MIL-L-2104C/D/E oils can inhibit the running-in process in new or reconditioned engines and are not suitable for engines running on low duty cycles.

5. For engines in long running installations Lister-Petter should be consulted.

3.4.1 Oil Viscosity



Notes:

A. Intermittent running.

B. Synthetic oils only.

°F = (1.8 x °C) + 32.

1. *SAE 5W-20 oils are recommended on the basis that they are fully synthetic, and are technically suitable for use up to 25°C (77°F). Non synthetic oils at very low temperatures will suffer from wax crystallisation.*

   Monograde SAE 5W is not normally available as a synthetic oil and therefore is not quoted.

2. *In order to maintain the cold starting characteristics of any recommended grade it is essential that oil changes are made within the Lister-Petter recommendations.*

   An oil change is recommended immediately if the engine fails to reach its normal cold start cranking speed due to excessive oil viscosity.

   Fuel dilution of the lubricating oil will adversely affect cold starting and oil consumption.

3. *SAE 30 and 10W-30 oils may be used at up to 52°C (126°F) but oil consumption may be affected.*

   10W-40, 15W-40 and 20W-40 multigrades are recommended for continuous full load operation at this temperature.

4. *Monograde SAE 40 oils are not recommended.*

3.5 THE OIL DIPSTICK

Extreme care must be taken to ensure the correct dipstick is returned to the engine.

3.6 OIL AND FILTER CHANGE PERIODS

Before attempting to change the lubricating oil it is essential to identify the type of engine and ensure the new oil meets the correct specification as given in "3.4 The Lubricating Oil Specification".

To help assist engine running-in, all engines are despatched with an initial fill lubricating oil which must be changed, with the filter, after 100 hours. All subsequent oil and filter changes must be as specified below.

Ambient Temperature	Periods in Hours
Up to 35°C	500
Above 35°C (see Note)	250

35°C = 95°F

Note:
The oil and filter change periods, given in hours, apply when engines are operating regularly at temperatures exceeding 35°C (95°F) at high speeds and duty factors.

3.7 THE OIL FILTER

The full flow oil filter is a spin-on cartridge type located on the gear end cover.

Only filters approved by Lister-Petter should be used as these have the correct bypass valve pressure to match the oil pump relief valve, high temperature joints, adequate filter paper characteristics and a rigid case.

The fact that a proprietary filter may have the same external dimensions and thread as the genuine one is no guarantee that it will not fail in service.

3.7.1 Changing the Oil Filter

The oil filter should be changed as specified in "3.6 Oil and Filter Change Periods".

Before changing the filter read "3.2 Precautions for Filters and Elements".

1. Use a band type gripping tool to remove the filter (A) from the engine.

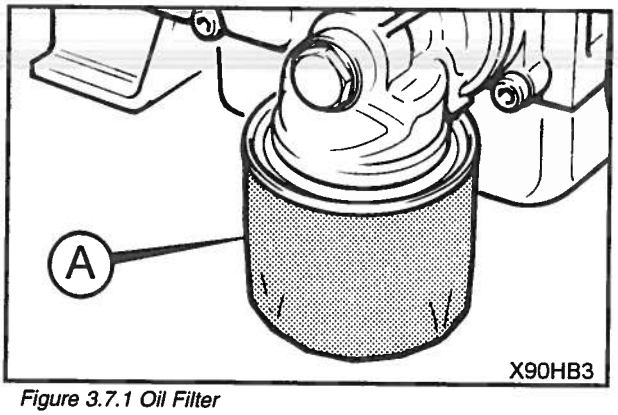


Figure 3.7.1 Oil Filter

2. Lightly grease or oil the face of the rubber joint on the new filter.
3. Screw the new filter onto the gear end cover filter adaptor until the rubber joint just makes contact with the crankcase facing.
4. Screw the filter on a further quarter to half of a turn.
5. Start the engine and run it for a few minutes to circulate the oil.
6. Stop the engine and allow time for the oil to drain down and check the level on the dipstick.
7. Add more oil if necessary.

3.8 THE OIL SUMP

The pressed steel oil sump is fitted with two drain plugs and the orientation of the sump will determine the location of the drain plugs. One plug is located on one side of the sump and the other will be either at the gear end, or flywheel end.

3.8.1 Draining the Oil Sump

If the engine has been run immediately before draining, the warm oil will drain quicker.

The oil should be changed as specified in "3.6 Oil and Filter Change Periods".

Before draining the oil read "3.2 Precautions for Filters and Elements".

1. Remove the oil filler cap.
2. Remove the most convenient drain plug (A) and allow the oil to run into a suitable retainer.

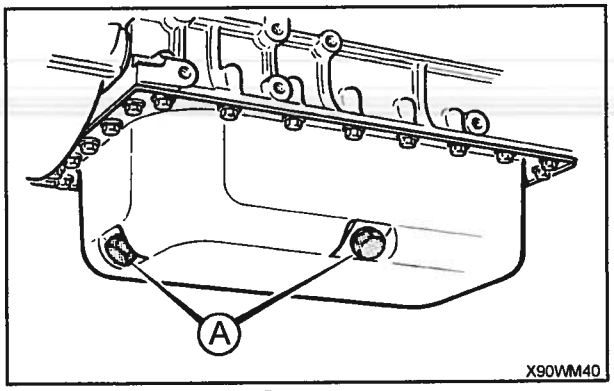


Figure 3.8.1 Sump Drain Plugs

3. Clean the drain plug threads, fit a new copper washer, replace the plug and tighten it.

3.8.2 Filling the Oil Sump

Before refilling the oil sump ensure the new oil meets the specification and viscosity as given in "3.4 Lubricating Oil Specification".

⚠ CAUTION

Do not overfill with oil. The oil must only be poured into the filler at a rate which enables it to drain into the crankcase.

1. If the sump has been drained ensure the drain plug has been securely replaced.
2. Fill the sump through the oil filler (A) on the top of the valve rocker cover to the upper mark on the dipstick.

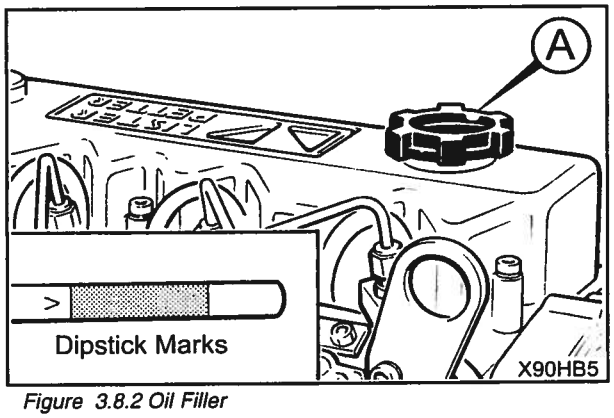


Figure 3.8.2 Oil Filler

3. Start the engine and run it for a few minutes to circulate the oil.
4. Stop the engine and allow time for the oil to drain down and check the level on the dipstick.
5. Add more oil if necessary.

3.8.3 The Oil Sump Capacity

⚠ CAUTION

Do not overfill with lubricating oil as this may have a detrimental effect on engine performance.

	litres	pts	US qts
4X90	6.5	11.4	6.9

3.8.4 Capacity Between Dipstick Marks

	litres	pts	US qts
4X90	1.0	1.7	1.0

3.8.5 Removing the Oil Sump

Before attempting to remove the sump make a note as to the position of the drain plugs to ensure it is correctly replaced.

1. Drain the oil and replace the oil drain plug (A) with a new copper washer.

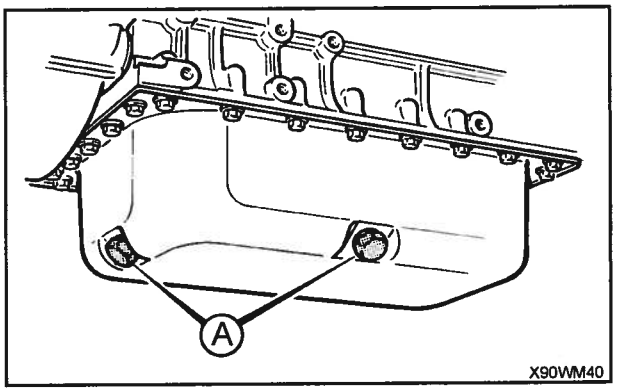


Figure 3.8.3 Sump Drain Plugs

⚠ CAUTION

With the engine level and the sump drained, some oil will remain in the sump. Care must be taken to ensure this is taken into account when the sump is being removed.

2. Slacken four of the sump corner retaining bolts.
3. Remove the remaining bolts.
4. Support the sump and remove the remaining four bolts.
5. If necessary, clean the inside of the sump with a suitable cleaning liquid, or material that will not leave particles or fibres that could eventually block the oil system.

3.8.6 Replacing the Oil Sump

1. Remove all traces of the old joint.
2. Place a new joint onto the sump or crankcase ensuring the holes are aligned.
3. Support the sump in position and replace four corner bolts hand tight.
4. Replace the remaining bolts and torque all of them to 21.0Nm (15.5lbf ft).

3.9 THE OIL STRAINER AND PUMP

Access to the oil pump and strainer is only possible after removing the oil sump.

The pump is a positive displacement type gear driven from the idler gear.

3.9.1 Removing the Oil Pump

1. Remove the oil sump, gear end cover and idler gear.

⚠ CAUTION

Before removing the idler gear refer to "2.32.1 Removing the Idler Gear".

2. Remove the oil strainer bracket bolt (A).

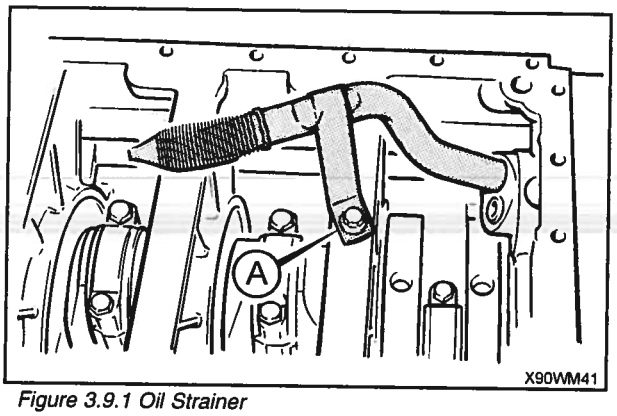


Figure 3.9.1 Oil Strainer

3. Pull the strainer away from the oil pump assembly.
4. Remove the two pump retaining bolts.
5. Ease the pump out of the crankcase.

⚠ CAUTION

To avoid possible damage to the pump flanges do not use a screwdriver or other tool to lever the pump out.

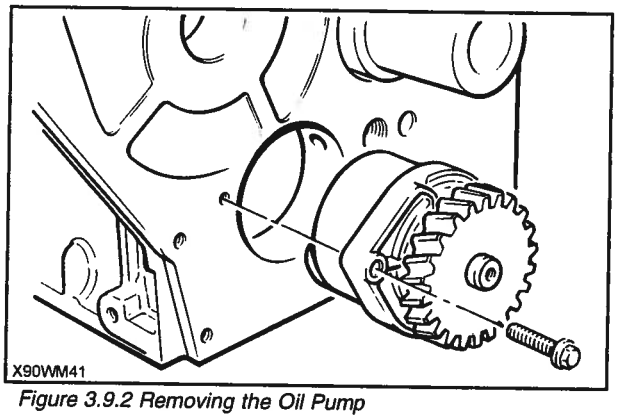


Figure 3.9.2 Removing the Oil Pump

6. A quick check can be made to see if the pump is working by turning the pump gear while holding the palm of the hand over the two ports and listen for a sucking/pumping sound.
7. Check the pump impeller vanes and lobes for damage.

3.9.1 Replacing the Oil Pump

1. Carefully align the impeller vanes and assemble to the pump housing.

   The locating dowels are off-centre and care must be taken to ensure the two parts are correctly fitting together.

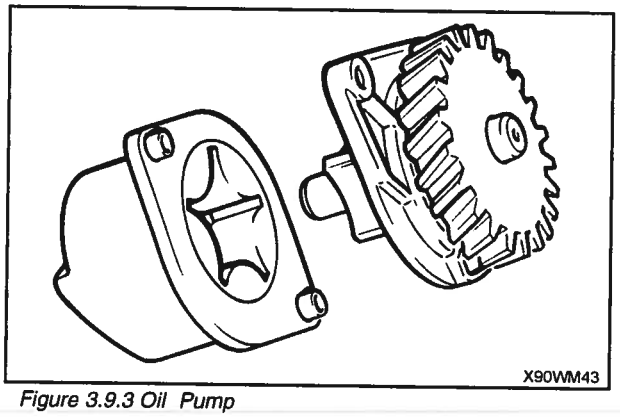


Figure 3.9.3 Oil Pump

2. Replace the pump into the crankcase and torque the two retaining bolts to 9Nm (6.5lbf ft).
3. Lightly grease the 'O' ring and push the oil strainer pipe into the pump.
4. Align the bolt hole in the strainer mounting bracket with the corresponding hole in the crankcase and replace the bolt finger tight.
5. Torque the bracket retaining bolt to 21.0Nm (15.5lbf ft)..
6. Replace the idler gear, gear end cover and sump.

⚠ CAUTION

Before refitting the idler gear refer to "2.32.2 Fitting the Idler Gear".

3.10 THE OIL PRESSURE RELIEF VALVE

The oil pressure relief valve is fitted at the gear end of the crankcase. The pressure relief setting is pre-set and is not adjustable.

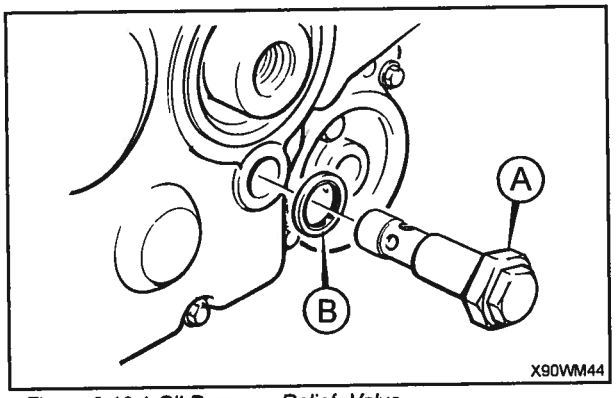


Figure 3.10.1 Oil Pressure Relief Valve

3.10.1 Removing the Relief Valve

Access to the relief valve is only possible after the crankshaft pulley has been emoved.

1. Remove the gear end coverand crankshaft pulley.
2. Unscrew and remove the valve (A) from the ctrankcase.
3. Screw the valve into the crankcase after fitting a new seal (B).
4. Torque the valve to 21.0Nm (15.5lbf ft).

3.11 OIL SEALS

⚠ WARNING

SOME ENGINES MAY BE FITTED WITH SEALS OR 'O' RINGS MANUFACTURED FROM 'VITON' OR A SIMILAR MATERIAL.
WHEN EXPOSED TO ABNORMALLY HIGH TEMPERATURES, IN EXCESS OF 400°C (752°F), AN EXTREMELY CORROSIVE ACID IS PRODUCED WHICH CANNOT BE REMOVED FROM THE SKIN.
IF SIGNS OF DECOMPOSITION ARE EVIDENT, OR IF IN DOUBT, ALWAYS WEAR DISPOSABLE HEAVY DUTY GLOVES.

Lip type oil seals are fitted to the gear end cover and the flywheel end main bearing housing and are fitted without any jointing compound being applied.

The lip seals used must be the approved type as supplied by Lister-Petter; ordinary rubber seals may quickly harden in use, rapidly wear the shaft, or not even seal on fitting and therefore must not be used.

A lip type seal will not seal if the shaft is scratched or bruised within 5mm either side of the path of the lip of the seal.

A finely and accurately ground shaft without chatter marks and with a surface finish of 0.4-0.6 microns Ra is required. Emery cloth of any grade must not be used on the shaft in the area of the lip.

3.12.1 Fitting Replacement Oil Seals

The fitting of oil seals is described in "2.21.2 Fitting a New End Cover Oil Seal" and "2.32 The Rear Main Bearing Oil Seal".

SECTION 4 - THE WATER COOLING SYSTEM

CONTENTS

4.1 GENERAL DESCRIPTION

The basic engine is supplied with a belt driven freshwater circulation pump but the radiator and cooling fan are specified as accessories and can be engine mounted or supplied loose depending on the engine application.

The system is designed to allow the engine to operate in ambient temperatures up to 52°C (125°F).

4.2 COOLANT CONCENTRATE

Traditionally the term 'antifreeze' has been used to describe the concentrate which is added to the cooling system. However, this term takes into account only the frost-protective role of the product, so implying that its use is a seasonal requirement, and ignores its function as a heat exchange medium which is designed to protect the system from corrosion and damage under all operating conditions.

The term 'engine coolant concentrate' embraces all these requirements.

A 40% concentration must be used under all operating conditions.

⚠ WARNING

Coolant concentrate must not be allowed to come into contact with the skin; adhere to the manufacturers instructions and precautions.

⚠ WARNING

Extreme care must be taken to ensure that coolant concentrate, solvents or other toxic wastes are disposed of in accordance with local regulations to prevent contamination.

4.2.1 Coolant Concentrate Specification

The specification of the coolant concentrate should comply with one of the following:

BS6580 : 1992

MIL-A-11755D

MIL-A-46153/B

4.3 ENGINE COOLANT CAPACITY

To obtain the total capacity of the cooling system, the cylinder block capacities shown must be added to the capacity of the radiator and hoses.

	litre	pint	US qts
4X90	1.135	2.0	1.2

4.4 DRAINING THE COOLING SYSTEM

⚠ WARNING

The cooling system is pressurised and extreme care must be taken when removing the radiator cap if the engine is hot.

A coolant drain plug is fitted to the water pump just below the water pump pulley.

1. If a drain plug is fitted to the radiator, place a suitable container under both it and the water pump drain plug.

   If a radiator drain plug is not fitted, place a suitable container under the radiator bottom hose, slacken the clips of the hose and slide the hose off
2. Open the drain plug/s.
3. Remove the radiator filler cap.
4. Allow sufficient time for the system to drain.

4.4.1 Flushing the Cooling System

a. Radiator

1. With the top and bottom hose, or drain plug, removed from the radiator flush the radiator through the filler with clean fresh water, preferably using a hose pipe, until clean water emerges from the bottom.
2. Replace the hoses and drain plug.

b. Cylinder Block

1. With the drain plug and the top hose from the radiator removed, flush the engine block with clean fresh water, preferably using a hose pipe, until clean water emerges from the drain plug.
2. Replace the hose and drain plug.

4.4.2 Filling the Cooling System

⚠ CAUTION

Under some circumstances an airlock can occur when filling the system causing a false level indication.

1. Ensure all the hoses and drain plugs, have been replaced.
2. Refill the system with clean fresh water, and coolant concentrate to a 40% concentration, while bleeding air from the system at a suitable point.

   The radiator should be filled to within 13.0mm-25.0mm (0.5-1.0in) below the neck of the radiator filler.
3. Run the engine for a short time and check the coolant level.

4.5 THE THERMOSTAT

4.5.1 Removing the Thermostat

1. Remove the two cover retaining bolts.
2. Lift off the cover.
3. Lift out the thermostat.
4. Clean any debris and the old seal from the thermostat housing.

4.5.2 Testing the Thermostat

1. With the thermostat removed from the engine submerge it in a suitable container of warm water.
2. Raise the water temperature and check when the thermostat begins to open and when it is fully open.
3. Compare the results with the figures given in the table and if they are outside those given the thermostat must be replaced.

	°C	°F
Starts to Open	72-76°	162-169°
Fully Open	85-88°	185-190°

4.5.3 Fitting the Thermostat

1. With all surfaces clean and dry, fit a new gasket to the thermostat housing.
2. Replace the thermostat into the housing.
3. Replace the cover in the correct plane and torque the housing bolts to 21.0Nm (15.5lb/ft).

4.6 THE RADIATOR

Care must be taken to ensure the air flow is unobstructed and has not been re-circulated from the driven equipment.

The radiator fins should be checked for damage every 2000 hours, or more frequently if the application demands.

4.6.1 The Radiator Cap

A 15.0lb/in² cap is used on all radiators originally fitted by Lister-Petter.

4.6.2 Radiator Coolant Capacity

There are a number of radiator options available for X90 engines including some which may not have been originally fitted by Lister-Petter.

For these reasons it is advisable to ascertain the radiator capacity which must then be added to that given in "4.4 Engine Coolant Capacity" before determining the amount of coolant concentrate to be added to maintain a 40% concentration.

An additional amount must also be taken into consideration for the capacity of the hoses on remote radiator applications.

4.6.3 Removing the Radiator

1. Drain the radiator.
2. Slacken the clip at the radiator end of the bottom hose and slide the hose off the radiator.
3. Slacken the clip at the radiator end of the top hose and slide the hose off the radiator.
4. Remove the two radiator stay bots.
5. Support the radiator and remove the bolts from both bottom radiator support brackets.
6. Lift the radiator off taking care not to damage the fan or radiator core fins.

4.6.4 Replacing the Radiator

1. Support the radiator and bolt the two bottom radiator support brackets to the radiator mounting bracket (F).
2. Tighten the two top flexible mountings and stay hooks.
3. Replace the two radiator hoses.
4. Refill the system ensuring there is a 40% concentration of coolant concentrate.

4.7 THE RADIATOR FAN DRIVE BELT

The belt is made of special materials and construction, and no other belt than that specified must be used.

The crankshaft and driven pulleys must have a smooth finish to the grooves, and be aligned within 1.6mm (0.061in), measured at the centre of the grooves.

⚠ CAUTION

The belt must be slackened and fitted to the pulleys by hand, under no circumstances must it be levered or wound on. The belt must be replaced every 2000 hours, irrespective of its condition.

4.7.1 Removing the Drive Belt

1. Slacken the alternator pivot bolt and nut.
2. Slacken the bolts at both ends of the adjuster arm.
3. Place the palm of the hand under the jockey pulley or alternator and lift it upwards towards the crankcase sufficiently to remove the drive belt.

4.7.2 Refitting the Drive Belt

1. Move the alternator towards the crankcase and replace the drive belt by hand.
2. Move the alternator outwards as far as possible by hand and tighten the pivot bolt and adjusting arm bolts.
3. Tension the drive belt.

   After every adjustment rotate the drive until the belt has travelled through 360° then check the deflection to ensure the tension is correct.

4.7.3 Drive Belt Tension

It is important that the tension of the " drive belt is checked after:

a. After the first 50 hours running.
b. After an overhaul.
c. After a new belt has been fitted.
d. As specified in "1.12.4 Maintenance Schedule".

When a new belt is correctly fitted and tensioned a force of 12N (2.7lbf) is required to deflect it a distance of 4.5mm (0.18in).

On subsequent checking and adjustment a force of 10N (2.2lbf) is required to deflect it a distance of 4.5mm (0.18in).

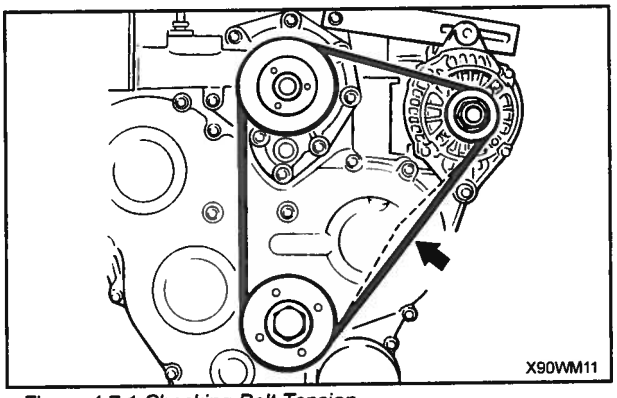


Figure 4.7.1 Checking Belt Tension

4.8 THE RADIATOR FAN

Radiator fans are available with pusher or puller options and it is suggested that where possible pusher fans are used, especially in encapsulated installations, as this arrangement draws radiated heat from the enclosure. The drive ratio of all fans is 1:1.

The fan blades should be checked for damage every 2000 hours, or more frequently if the application demands.

Fans originally fitted, or supplied, by Lister-Petter are marked with an arrow on each blade showing the direction of rotation. When viewed from facing the gear end of the engine, the arrows should point in a clockwise direction.

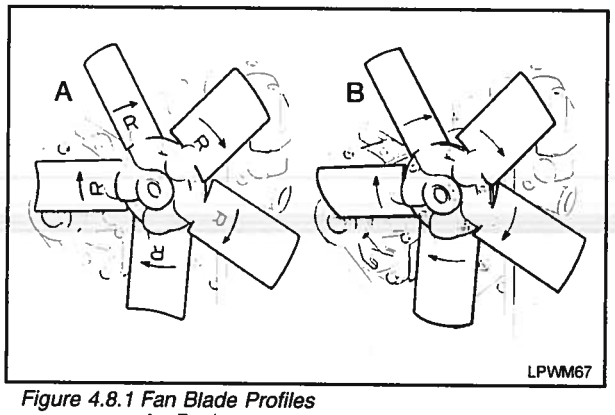


Figure 4.8.1 Fan Blade Profiles
A - Pusher
B - Puller

4.8.1 Removing and Fitting the Fan

1. Remove the radiator.
2. Remove the fan drive belt.
3. Support the fan and remove the three retaining bolts.
4. Lift off the fan.
5. Replace the fan taking care to align the mounting holes.
6. Replace and torque the three bolts to 11.0Nm (8.0lbf ft).
7. Replace the fan drive belt and tension it.
8. Replace the radiator.
9. Refill the system ensuring there is a 40% concentration of coolant concentrate.

4.9 THE WATER CIRCULATING PUMP

A coolant drain plug (A) is fitted to the water pump just below the water pump pulley.

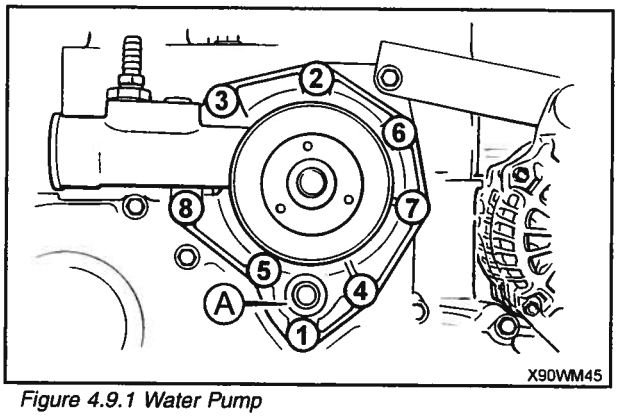


Figure 4.9.1 Water Pump

4.9.1 Removing the Water Pump

1. Remove the radiator and fan.
2. Remove the fan drive belt.
3. Remove the bolts from the pump assembly.
4. Lift off the pump assembly.
5. Clean any debris and old seal from the pump assembly and the pump mounting face on the crankcase.

4.9.2 Fitting the Water Pump

1. With all surfaces clean and dry fit a new gasket.
2. Replace the pump assembly and torque the bolts to 21.0Nm (15.5lbf ft).
3. Replace the fan drive belt and tension it.
4. Replace the fan and radiator.
5. Refill the system with clean fresh water and coolant concentrate to a 40% concentration.

SECTION 5 - THE DIESEL FUEL SYSTEM

CONTENTS

5.1 DESCRIPTION AND OPERATION

The fuel system is of the high pressure, re-entrant bowl, direct injection type.

The system comprises a multi-cylinder rotary type fuel injection pump, an injector for each cylinder, a fuel lift pump and filter with a water trap.

The injectors are held in position by clamps on all engines.

From the filter, fuel flows to the fuel injection pump which feeds high pressure fuel to the injectors.

A common leak-off pipe from the individual injectors carries the leak-off enabling it to be fed back to the inlet side of the fuel injection pump, the fuel filter or back to the fuel tank.

⚠ WARNING

Extreme care must be taken to ensure that waste fuel, filter elements, solvents or other toxic wastes are disposed of in accordance with local regulations to prevent contamination.

5.2 FUEL SYSTEM PRECAUTIONS

⚠ WARNING

Unauthorised adjustments to the emission compliant fuel injection pump may invalidate warranty claims.
In the USA, unauthorised adjustment of emission critical components is prohibited by Federal Law, incurring civil penalty.

- When priming or checking the fuel injection pump timing, care must be taken to wipe spilled fuel from the outside of the engine.
- Always fit a new joint when a union has been disturbed.
- Special care must be taken to see that there is no leakage from the joints of the fuel pipe connection to the pump.
- When tightening or loosening the fuel injection pump delivery connections, use two spanners to prevent the unsealing of the fuel pump delivery valve holders.
- When refitting the fuel pipe from the pump to injector, the connection to the injector must be tightened before the connection to the fuel pump.

  This procedure will ensure that there is no leakage from these joints.
- It is most important that all fuel joints are tight and leak proof.
- Always fill the fuel tank through a fine strainer, preferably at the end of the engine work period.

  If any sediment is stirred up during the process this has time to settle before the engine is used again, this will minimise the risk of condensation contaminating the fuel.

  If cans are used, avoid tipping out the last few drops.
- Funnels are very difficult to keep clean in dusty conditions.

  Wash them before and after use and wrap them up when not required, or fill the tank direct from a small mouthed screw capped fuel can.

5.3 FUEL FILTER PRECAUTIONS

- Some of the materials used in the manufacture of fuel filters could give off toxic gasses if they are burnt.
- Used filters contain some of the filtered fuel and should be handled and disposed of with care.
- The materials used in the manufacture and treatment of some filters may cause irritation or discomfort if they come into contact with the eyes or mouth.
- After handling new, or used filters the users hands should be thoroughly washed, particularly before eating.

5.4 THE FUEL SPECIFICATION

The engine must only be used with diesel fuel oil which conforms to one of the following:-

a. BS 2869:1988 Class A2.
b. BS EN590:1995 Class A1.
c. USA Specification ASTM D-975-77 Grades No.1-D and 2-D.
d. BSMA 100 Class M1 for marine use.

The fuel must be a distillate, and not a residual oil or blend.

Vaporising oils are not suitable as fuels for Lister-Petter engines.

The user is cautioned that although the engines may operate on fuels outside the above specifications, such operation may well result in excessive wear and damage.

⚠ CAUTION

The fuel injection equipment is manufactured to very accurate limits and the smallest particle of dirt will destroy its efficiency. Fuel free from water and contaminants is of the utmost importance.

5.5 THE FUEL LIFT PUMP

A fuel lift pump is fitted to the engine as standard and is operated from the camshaft by a push rod.

The pump has a maximum lift of approximately 3m (10ft) and a maximum head of 600mm (2ft).

Note:
It is recommended that the fuel lift pump diaphragm is inspected at more frequent intervals than specified in "1.12.4 Maintenance Schedule" if it is known the fuel is contaminated. It should also be inspected at regular intervals on engines in low duty cycle applications; for example, stand-by generating sets.

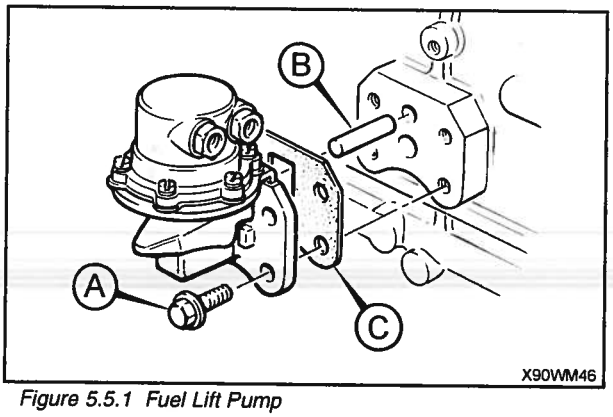


Figure 5.5.1 Fuel Lift Pump

5.5.1 Replacing the Fuel Lift Pump

The distance from the camshaft to the pump tappet is not adjustable.

Care must be taken to ensure that only one joint is fitted between the pump and crankcase.

1. Remove the fuel inlet and outlet pipes from the pump.
2. Remove the four pump retaining bolts (A).
3. Lift off the pump.
4. Pull out the pump push rod (B) from the crankcase.
5. Remove all traces of the old joint (C).
6. Ensure the pump and crankcase mating surfaces are clean and dry before fitting a new joint.
7. Fit the push rod into the crankcase.
8. Push the push rod inwards until it is at its lowest position while slowly turning the crankshaft.
9. Refit the pump and bolts finger tight.
10. Torque the four bolts to 21.0Nm (15.5lbf ft).
11. Replace the fuel inlet and outlet pipes.

5.6 THE FUEL FILTER

The fuel filter is an essential part of the engine and it must never be run without a filter which should be changed as specified in "1.12.4 Maintenance Schedule".

The filter is fitted on the opposite side of the engine to the fuel injector pump.

5.6.1 Replacing the Fuel Filter Cartridge

Water can be drained from the filter by gently unscrewing (B) a few turns.

Before changing the fuel filter read "5.3 Fuel Filter Precautions".

1 Loosen the bleed screws (A) and (B) to drain the fuel.

2. Unscrew the cartridge retainer (B) sufficiently for the element cartridge to be removed from the filter head.

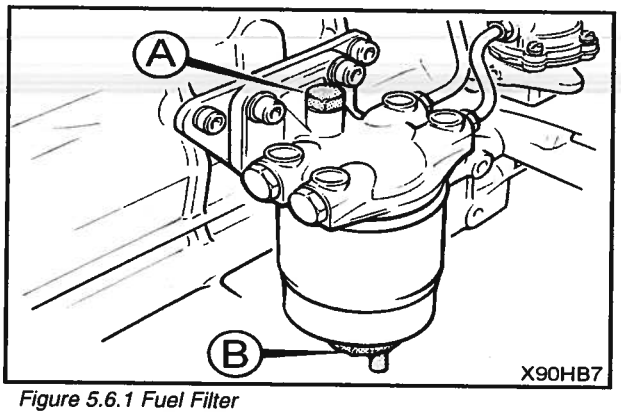


Figure 5.6.1 Fuel Filter

3. Push a new cartridge securely onto the head and tighten the retainer.
4. Prime the fuel system.
5. Start the engine and run it for a few minutes to check for leaks.

5.7 PRIMING THE FUEL FILTER

The fuel system is self-bleed but should priming be necessary follow the instructions below.

⚠ CAUTION

Care must be taken to contain any spilt fuel while carrying out this procedure.

1. Ensure there is sufficient fuel.
2. Loosen the bleed screw (B) to drain any water and then re-tighten it.
3. Release the bleed screw (A) and re-tighten when no further air bubbles are expelled.

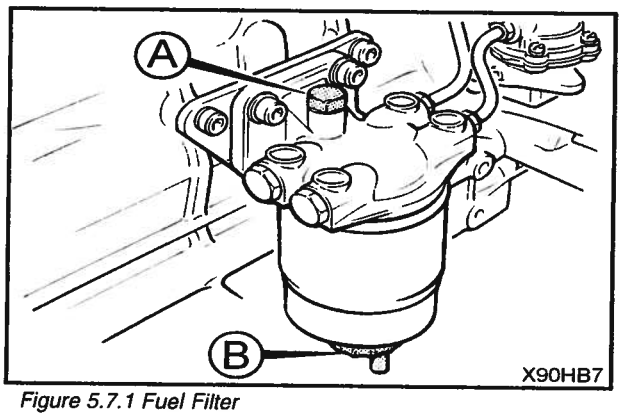


Figure 5.7.1 Fuel Filter

5.8 THE FUEL INJECTION PUMP

The rotary fuel pump is secured to the crankcase by three bolts torqued to 21.0Nm (15.5lbf ft).

The pump is self-lubricating by an internal feed of fuel and is fitted with an electrically operated solenoid which is energised by the key starting system before the engine starts.

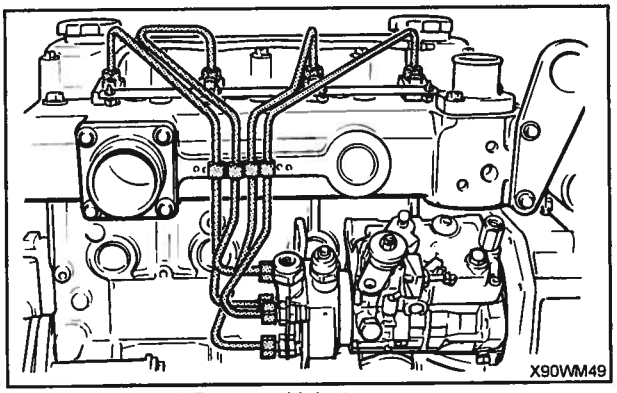


Figure 5.8.1 Fuel Pump and Injectors

⚠ WARNING

These engines meet the emission legislative requirements of EPA Tier 1 Regulations and EU NRMM Directive Stage 1.

UNDER NO CIRCUMSTANCES MUST ANY ATTEMPT BE MADE TO ADJUST OR DISMANTLE THE FUEL PUMP. THIS WORK MUST ONLY BE CARRIED OUT BY A LISTER-PETTER DISTRIBUTOR OR ACCREDITED FUEL PUMP SERVICE OUTLET.

5.8.1 Fitting a New Fuel Pump

⚠ CAUTION

When slackening, or tightening, the high pressure fuel pipes hold the fuel pump delivery valve holder with a spanner to prevent it turning.

1. Remove the gear end cover.
2. Gently turn the crankshaft until the crankshaft, idler and fuel pump pinion gear timing marks are all aligned.
3. Insert a suitable 6mm diameter spindle through the gear into a similar hole in the crankcase.

   It may be necessary to slightly move the crankshaft to align the two holes.

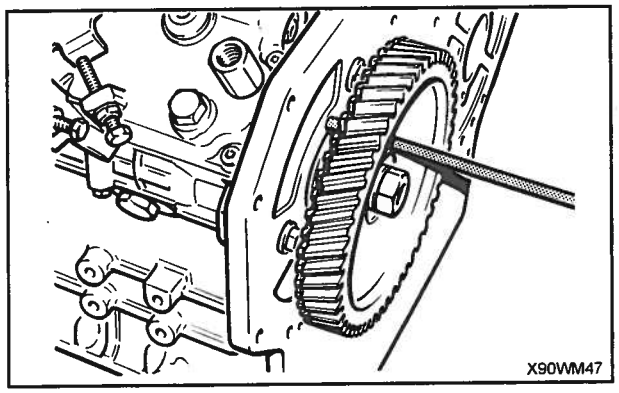


Figure 5.8.1 Locking the Fuel Pump Gear

4. Lock the fuel pump by slackening the 10mm bolt (A) and moving the plate upwards.

   Retighten the bolt.

⚠ CAUTION

Ensure the plate is correctly engaged with the bolt.

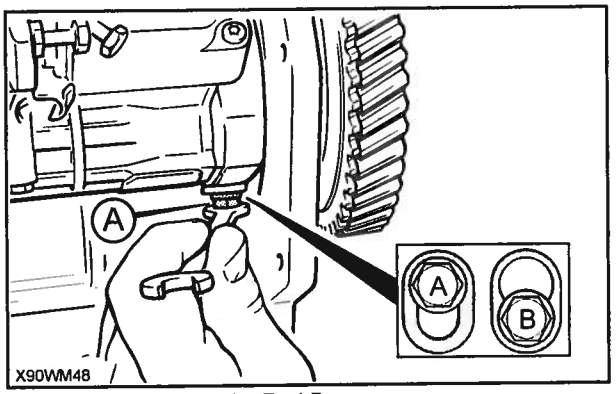


Figure 5.8.3 Locking the Fuel Pump
A - Plate down - pump locked
B - Plate up - pump unlocked

5. Unscrew the pump gear retaining nut.
6. Pull the gear off the pump shaft using a suitable gear puller.
7. Support the pump and remove the three pump mounting bolts from the gear end of the crankcase.
8. Bolt the new pump to the crankcase and torque the three mounting bolts to 21Nm (15.5lbf ft).

⚠ WARNING

Under no circumstances slacken the pump locking bolt at this stage.

9. Insert the service tool through the pump gear into the hole in the crankcase.

   It may be necessary to slightly move the crankshaft to align the two holes.
10. Fit the gear to the pump shaft with both the pump and idler gear timing marks aligned.
11. Replace the pump gear retaining nut and torque it to 10Nm (7.5lbf ft).
12. Unlock the fuel pump by slackening the 10mm bolt (A) and moving the plate downwards.

    Retighten the bolt.

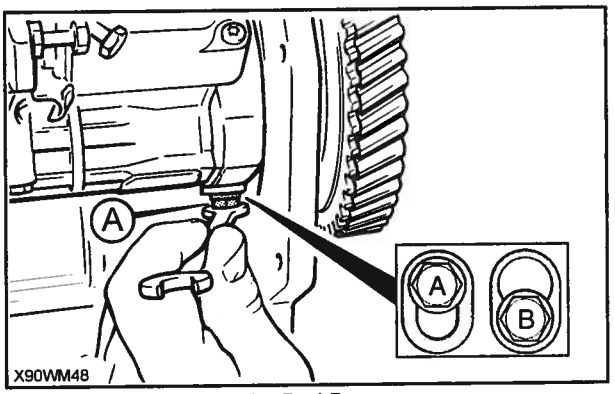


Figure 5.8.4 Unlocking the Fuel Pump
A - Plate down - pump locked
B - Plate up - pump unlocked

13. Torque the pump gear to 81.0Nm (60.0lbf ft).
14. Remove the service tool, or 6mm spindle.
15. Replace the gear end cover.

5.9 THE FUEL INJECTOR

It is important to maintain the fuel injection equipment, all pipes and unions between the fuel supply outlet filter and the injector absolutely clean. A minute particle of dirt can easily block an injector nozzle hole and this will give rise to a dirty exhaust, difficult starting and running problems.

5.9.1 Fuel Injector Settings

	bar	atmos	lbf/in²
4X90	250-258	247-255	3626-3742

5.9.2 Removing and Replacing an Injector

⚠ CAUTION

When slackening, or tightening, the high pressure fuel pipes hold the fuel pump delivery valve holder with a spanner to prevent it turning.

1. Pull off the injector leak-off pipe from the injector body stub pipe.
2. Slacken the pump to injector pipe nuts at both ends and remove the pipe.

   Hold the fuel pump delivery valve holder with a spanner while slackening the pump pipe nuts.

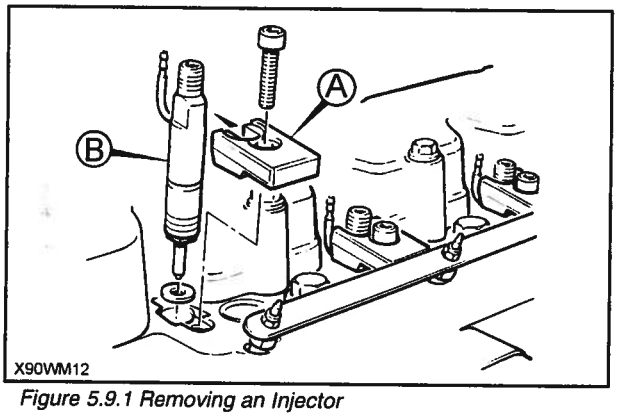


Figure 5.9.1 Removing an Injector

3. Unscrew the injector clamp bolt and remove the injector clamp (A).
4. Lift out the injector (B).
5. If the injector sealing washer is not on the injector, carefully remove it from the cylinder head taking care not to damage the seating area.
6. Ensure the seating in the cylinder head is clean and smooth.
7. Lightly smear a very small amount of high melting point grease to one side of a new injector sealing washer and place it over the injector nozzle, greased side first.

⚠ CAUTION

If the injector sealing washer has been used more than once it may become compressed causing a leak or damage to the injector seat.

8. Replace the injector and clamp and hand tighten the clamp bolt.
9. Replace the pump to injector pipe and hand tighten the nuts.
10. Torque the injector clamp bolt to 27.0Nm (20.0lbf ft).
11. Torque the fuel pipe nuts to 27.0Nm (20.0lbf ft).
12. Replace the leak-off pipe onto the injector.

5.9.2 Cleaning and Servicing the Injector

⚠ WARNING

IF HIGH PRESSURE FUEL IS INGESTED OR PENETRATES THE SKIN IT CAN HAVE FATAL RESULTS. IMMEDIATE MEDICAL ADVICE AND TREATMENT MUST BE OBTAINED.

To ascertain if the injector is in good condition, it is removed from the engine and connected to a fuel injector test rig.

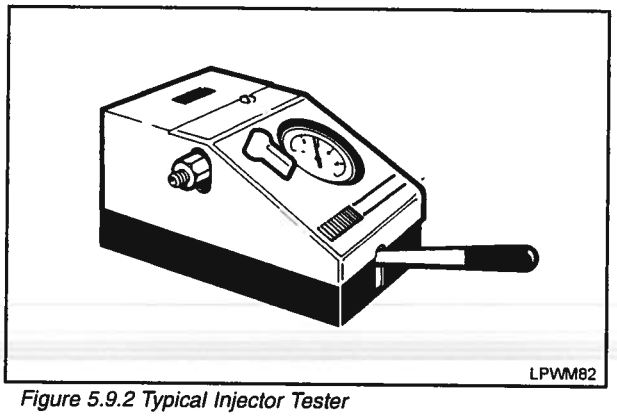


Figure 5.9.2 Typical Injector Tester

If a test rig is not available, it becomes necessary to replace the complete injector by a new or a serviced one. A serviced injector must have a clean nozzle and be set to the correct pressure. The complete faulty injector should then be sent to an accredited service depot for reconditioning.

All sprays on injectors should have the same appearance and the same length of penetration in the air. If one spray is shorter or weaker than the others this indicates that the corresponding hole is partially blocked and best engine performance results will not be obtained. If one hole is totally blocked or the nozzle dribbles it must be replaced.

If the nozzle only is replaced, the injector spring pressure must be reset and this cannot be done without the test rig.

5.9.3 Injector Back Leakage

The leak-off rate is 10-40 seconds between 152-101bars (150-100atmos) on an injector tester using Calibration C fluid, at a temperature of 15.5°C (60°F).

5.10 THE GOVERNOR

The governor is contained within the fuel pump and no attempt must be made to adjust it.

⚠ WARNING

These engines meet the emission legislative requirements of EPA Tier 1 Regulations and EU NRMM Directive Stage !

UNDER NO CIRCUMSTANCES MUST ANY ATTEMPT BE MADE TO ADJUST OR DISMANTLE THE FUEL PUMP. THIS WORK MUST ONLY BE CARRIED OUT BY A LISTER-PETTER DISTRIBUTOR OR ACCREDITED FUEL PUMP SERVICE OUTLET.

5.11 ADJUSTING THE ENGINE SPEED

⚠ WARNING

If tamperproof devices are fitted no adjustment should be attempted.

5.11.1 Variable Speed Adjustment

1. Hold the engine control lever (A) at the required idling speed and adjust the setscrew (C) until it makes contact with the engine control lever and then lock it in this position.
2. Hold the engine control lever (A) at the required maximum speed and ajust the setscrew (B) until it makes contact with the engine control lever and then lock it in this position.
3. Make any minor adjustment as necessary.

Note:
The minimum idling speed is 900r/min.

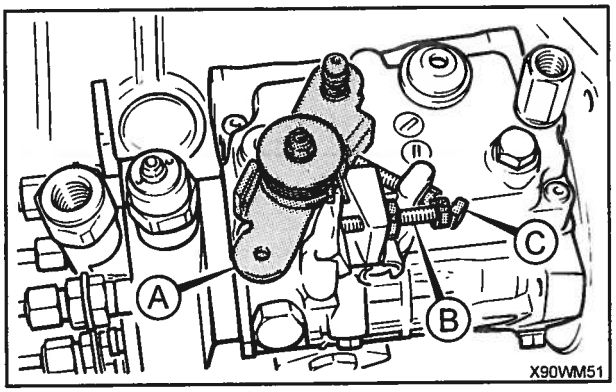


Figure 5.11.1 Speed Adjustment

5.11.2 Fixed Speed Adjustment

1. Hold the engine control lever (A) at the required speed and ajust the setscrews (B) and (C) until both make contact with the engine control lever and then lock both in this position.
2. Make any minor adjustment as necessary.

Note:
The minimum full load speed is 1500r/min.

SECTION 6 - THE ELECTRICAL SYSTEM

CONTENTS

6.1 THE STARTER MOTOR

Details for removing and refitting the starter motor are given in "2.5 The Starter Motor".

6.2 THE ALTERNATOR

Refer to "2.6 The Alternator".

6.3 THE STARTER BATTERY

6.3.1 Starter Battery Precautions

- Do not smoke near the batteries.
- Keep flames and sparks away from the batteries.
- Batteries contain sulphuric acid - if the acid has been splashed on the skin, eyes or clothes flush it away with copious amounts of fresh water and seek medical aid.
- Keep the top of the battery well ventilated during charging.
- Disconnect the battery negative (earth) lead first and reconnect last.
- Switch off the battery charger before disconnecting the leads.
- Never 'flash' connections to check current flow.
- Never experiment with adjustments or repairs to the system.
- A damaged or unserviceable battery must never be used.
- Check the electrolyte level at regular intervals and adjust by adding distilled or de-ionized water.

  Do not use impure water.
- Keep the top of the battery clean and dry.
- Inspect the battery terminals and if necessary clean and coat them with petroleum jelly.
- Do not allow metal objects to short circuit the cells.
- Take special care when using tools near a battery.
- The battery and alternator must be disconnected before commencing any electric welding when a pole strap is directly or indirectly connected to the engine.

6.3.2 Battery Polarity

The electrical system for all engines is 12 or 24 volt negative earth.

6.3.3 Preparing a Battery for Use

The following procedure should be used to prepare a battery with factory sealed charge.

1. Where necessary remove the flash seal in each vent plug hole.
2. Fill with battery grade sulphuric acid of specific gravity 1.260 (1.200 for tropical climates - see Note). The temperature of this acid should not be above 30°C (90°F) before filling. The correct level is 6mm (0.25in) above the separator guards.
3. Stand the filled battery for one hour and adjust the acid to the correct level by adding more acid where necessary.
4. Charge the battery at 6-12 amps for a minimum period of 4 hours.
5. At the end of this charge period the specific gravity of the acid in any cell should not be less than 1.260 (1.200 for tropical climates).

   If the specific gravity readings are uneven or the specific gravity low, continue charging until two consecutive half hourly readings of specific gravity and charge voltage are approximately the same.

   Discontinue charging and allow the battery to cool if the temperature rises above 40°C (110°F).

Note:
Tropical climates apply to those countries or areas where the average temperature of any month of the year exceeds 27°C (80°F).

6.3.4 Connecting Batteries

It is most important to ensure that the starter battery, or batteries, are properly connected and all connections are tight.

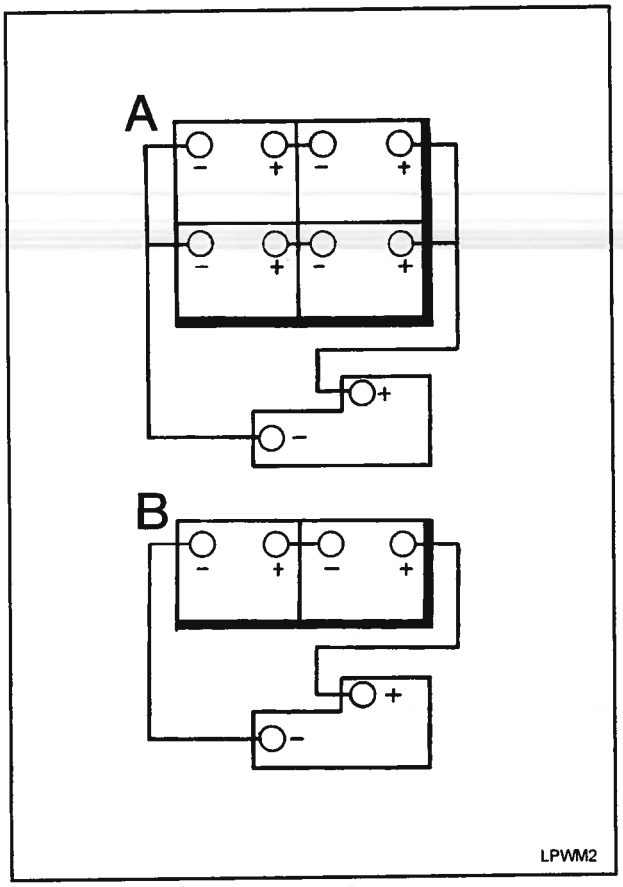


Figure 6.3.1 Battery Connections
A - 12 (24) volt system using four 6 (12) volt batteries connected in series-parallel.
B - 12 (24) volt system using two 6 (12) volt batteries connected in series.

6.3.5 Cold Cranking Battery Requirement

The cold cranking battery requirement is usually defined as being to BS3911 or IEC95-1.

The recommended minimum cold cranking performance is required from lead acid batteries, when tested at an ambient temperature of -18°C (0°F).

The recommendations made assume that the engine is filled with the recommended type and grade of lubricating oil and is not required to start against high inertia loads such as concrete mixers, tar boilers, hydraulic pumps, screw pumps and similar. In these applications, wherever possible, means should be provided to overcome such loads by the inclusion of clutches and unloading valves, etc.

6.3.6 Recommended Battery Type

Heavy Duty Batteries to BS3911:982 or IEC95-1 are recommended for all X90 engine applications.

For temperatures below -18°C (0°F), high discharge, low resistance Arctic or Alkaline batteries must be used.

Lister-Petter recommends that a battery should provide a minimum cranking period of 60 seconds from a 70% charged 12 volt battery, with a minimum voltage at the end of the cranking period of 8.4 volts (16.8 volts on a 24 volt system).

SECTION 7 - ENGINE VARIANT DETAILS

CONTENTS

7.1 GENERAL INFORMATION

When new parts are required for X90 engines it is important to quote the full engine number which is stamped onto the relevant serial number plate; see the example plates below.

7.2 EMISSIONS CERTIFICATION

The X90 engines meet the emission legislative requirements of EPA Tier 1 Regulations and EU NRMM Directive Stage 1. The relevant details will be stamped on the serial number plate; see the example plates below.

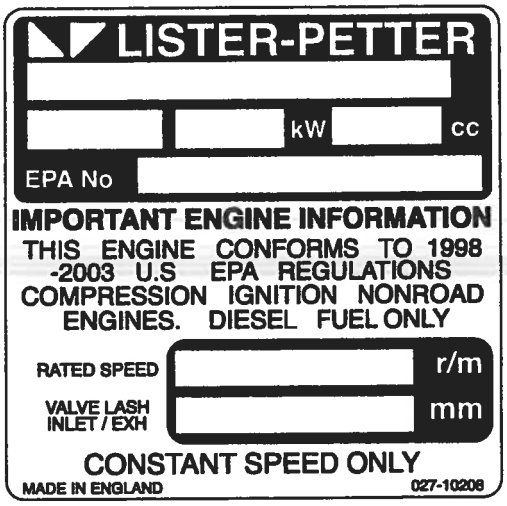


Figure 7.2.1 Constant Speed Plate

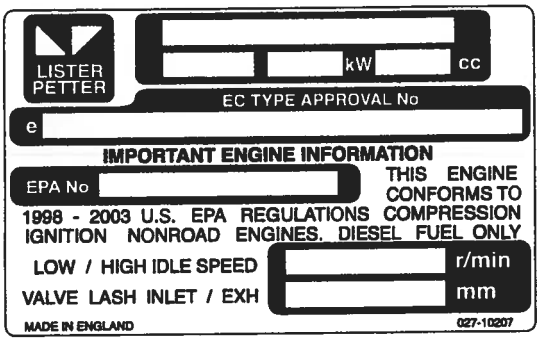


Figure 7.2.2 Variable Speed Plate

7.3 RATING DETAILS

Declarations of power are to ISO 3046 and apply to fully run-in engines without a radiator, fan or power absorbing accessories.

Variable Speed - Fuel Stop (IOFN).
Fixed Speed - Continuous (ICXN).

7.3.1 Derating

Any derating for site conditions must be in accordance with ISO 3046.

The figures below are approximate and are given for guidance only, they must not be used to obtain actual derate values.

Altitude:
Approximately 4% for every 300m higher than 100m above sea level.

Temperature:
Approximately 2% for every 5°C above 25°C.

7.4 ENGINE VARIANTS

Fixed and variable speed variants are available and details will be published in a later edition.

SECTION 8. FORMULAE AND CONVERSIONS

CONTENTS

8.1 FORMULAE

8.1.1 BMEP

Bar = $\frac{\text{kW x 60000 x 20000}}{\text{Cylinders x r/min x bore area (mm}^2\text{) x stroke (mm)}}$

lbf/in² = $\frac{\text{bhp x 792000}}{\text{Cylinders x r/min x bore area (in}^2\text{) x stroke (in)}}$

8.1.2 Torque

Nm = $\frac{\text{kW x 9549}}{\text{r/min}}$ x load factor

lbf ft = $\frac{\text{bhp x 5252}}{\text{r/min}}$ x load factor

Load factor:
No overload = 1,0
10% overload = 1,1

8.1.3 Fuel Consumption

A Specific Gravity of 0.84 is assumed

l/h = $\frac{\text{g/kWh x kW}}{840}$ x load factor

pt/h = $\frac{\text{lb/bhp h x bhp}}{1.05}$ x load factor

Load Factor - Naturally aspirated engines
100% = 1.0 50% = 0.58
75% = 0.78 25% = 0.40

Load Factor - Turbocharged engines
100% = 1.0 50% = 0.55
75% = 0.76 5% = 0.38

8.1.4 Oil Consumption

A Specific Gravity of 0.886 is assumed

litres/24hours = $\frac{\text{g/kWh x kW}}{4922}$

pints/24hours = $\frac{\text{lb/bhp h x bhp}}{0.15}$

8.1.5 Piston Speed

metres/second = $\frac{\text{stroke (mm) x r/min}}{30000}$

feet/minute = $\frac{\text{stroke (in) x r/min}}{6}$

8.1.6 Mechanical Efficiency

% = $\frac{\text{bhp}}{\text{ihp}}$ x 100

8.1.7 Cyclic Irregularity

$\frac{\text{max flywheel speed - min flywheel speed}}{\text{mean flywheel speed}}$

8.1.8 Power

kW = $\frac{\text{r/min x torque(Nm)}}{9549}$

bhp = $\frac{\text{r/min x torque(lb ft)}}{5252}$

8

8.2 CONVERSION FACTORS

The conversion tables in this section have been derived from BS350

To use the tables the left hand base unit is multiplied by the relevant conversion factor given in one of the right hand columns.

For example:
To convert 6.28 metres to inches using Table 13.2.1

6.28 x 39.3701 (factor from third column) = 247.244 inches.

It is not good practice to round-up the conversion factors given.

8.2.1 Length

	metre m	inch in	foot ft	yard yd
1 metre		39.3701	3.2808	1.0936
1 inch	0.0254		0.0833	0.0278
1 foot	3.038	12.0000		0.3333
1 yard	0.9144	36.0000	3.0000	

1in = 25.4mm
1mm = 0.03937in

8.2.2 Liquid Capacity

	litre l	UK pint [1] pt	UK gallon [2] gal	US pint US pt
1 litre		1.7598	0.2199	2.1134
1 UK pint	0.5683		0.1250	1.2009
1 UK gallon	4.5464	8,0000		9.6076
1 US pint	0.4732	0.8327	0.1041	

[1] Also known as the imperial pint
[2] Also known as the imperial gallon
1 UK gallon = 1.2009 US gallon
1 US gallom = 0.8325UK gallon

8.2.3 Volume

	cubic metre m^3	litre l	cubic inch in^3	cubic foot ft^3
1 cubic metre		1000.0	61023.8	35.3147
1 litre	0.0010		61,0238	0.0353
1 cubic inch	1.6387×10^{-5}	0.0164		5.7870×10^{-4}
1 cubic foot	0.0283	28.3168	1728.0	

1 dm^3 = 1litre
1 in^3 = 16.3871cm^3

8.2.4 Linear Velocity

	metre per second m/sec	foot per second ft/sec	foot per minute ft/min	inch per second in/sec
1 metre per second		3.2808	196.850	39.3701
1 foot per second	0.3048		60.0000	12.0000
1 foot per minute	0.0051	0.0167		0.2000
1 inch per second	0.0254	0.0833	5.0000	

8.2.5 Rate of Flow - Mass

	kilogram per second	kilogram per hour	pound per second	pound per hour
1 kilogram/second		3600.0	2.2046	7936.6
1 kilogram/hour	2.7777×10^{-4}		6.1239×10^{-4}	2.2046
1 pound/second	0.4535	1632.9		3600.0
1 pound/hour	1.2599×10^{-4}	0.4535	2.777×10^{-4}	

8.2.6 Rate of Flow - Volume

	cubic metre per second - m^3/sec	litre per second l/sec	cubic foot per second - ft^3/sec	UK gallon per second - gal/sec
1 m^3/sec		1000.0	35.3147	219.969
1 l/sec	0.0010		0.0353	0.2200
1 ft^3/sec	0.0263	28.3168		6.2288
1 UK gal/sec	4.5460×10^{-3}	4.5461	0.1605	

1 UK gallon = 1.2009 US gallon

8.2.7 Pressure - Table 1

	newton per square millimetre N/mm^2	kilogram-force per square centimetre kgf/cm^2	pound-force per square inch lbf/in^2	pound-force per square foot lbf/ft^2
1 N/mm^2		10.1972	145.038	20885.4
1 kgf/cm^2	9.8066×10^{-2}		14.2233	2048.16
1 lbf/in^2	6.8947×10^{-3}	0.0703		144.000
1 lbf/ft^2	4.7880×10^{-5}	4.8824 x 10-4	6.9444×10^{-3}	

8.2.8 Pressure - Table 2

	bar bar	atmosphere atm	kilogram-force per square centimetre kgf/cm^2	pound-force per square in lbf/in^2
1 bar		0.9869	1.0197	14.5038
1 atm	1.0132		1.0332	14.6959
1 kgf/cm^2	0.9807	0.9678		14.2233
1 lbf/in^2	0.0689	0.0680	0.073	

8.2.9 Pressure - Table 3

	inch of water in H_2O	foot of water ft H_2O	millimetre of mercury - mm Hg	inch of mercury in Hg
1 in H_2O		0.0833	1.8683	0.0735
1 ft H_2O	12.000		22.4198	0.8827
1 mm Hg	0.5352	0.0446		0.0394
1 in Hg	13.5951	1.1329	25.400	

1in H_2O = 0.00248 bar

8.2.10 Torque (Moment of Force)

	newton metre Nm	kilogram-force metre - kgf m	pound-force foot lbf ft	pound-force inch lbf in
1 Nm		0.1020	0.7376	8.8507
1 kgf m	9.8066		7.230	86.8507
1 lbf ft	1.3558	0.1382		12.000
1 lbf in	0.1130	0.0115	0.0833	

The kilogram is known as the kilopond (kp) in Germany. 1 kgf m = 1 kp m

8.2.11 Force (Mass x Acceleration)

	newton N	kilogram-force kgf	pound-force lbf	poundal pdl
1 newton		0.1019	0.2248	7.2230
1 kilogram-force	9.8066		2.2046	70.9316
1 pound-force	4.4482	0.4536		32.1740
1 poundal	0.1382	0.0141	0.0311	

The kilogram is known as the kilopond (kp) in Germany. 1 kgf m = 1 kp m
1 pdl = 1 lb ft/s^2
1 N = 1 kg m/s^2

8.2.12 Energy - Table 1

	kilowatt hour kWh	kilogram-force metre - kgf m	foot-pound force ft lbf	horsepower hour hp h
1 kWh		3.6709×10^{5}	2.6552×10^{6}	1,3410
1 kgf m	2.7240×10^{-6}		7.2330	3.6530×10^{-6}
1 ft lbf	3.7661×10^{-7}	0.1382		5.0505
1 hp h	0.7457	2.7373×10^{6}	1.98×10^{6}	

8.2.13 Energy - Table 2

	joule J	horsepower hour hp h	calorie cal	British thermal unit Btu
1 joule		3.7250×10^{-7}	0.2388	9.4781×10^{-4}
1 hp h	2.6846×10^{6}		641186	2544.43
1 cal	4.1868	1.5596×10^{-6}		3.9683×10^{-3}
1 Btu	1055.06	3.9301×10^{-4}	251.996	

8.2.14 Power - Table 1

	kilowatt kW	metric horsepower CV	brake horsepower bhp	British thermal unit per hour Btu h
1 kW		1.3596	1.3410	3412.14
1 CV	0.7355		0.9863	2509.63
1 bhp	0.7457	1.0139		2544.43
1 Btu h	0.00029	3.9846×10^{-4}	3.9301×10^{-4}	

8.2.15 Power - Table 2

	watt W	kilo calorie per hour k cal/h	British thermal unit Btu
1 watt		0.08598	3.4121
1 k cal/h	1.1630		3.9683
1 Btu	0.2930	0.2519	

8.2.16 Specific Fuel Consumption

	pounds per horesepower hour lb/hp h	pounds per Cheval Vapeur hour lb/CV h	grams per kilowatt hour g/kW h	gramsper Cheval Vapeur hour g/CV h
1 lb/hp h		0.9862	608.27	447.33
1 lb/CV h	1.0140		616.80	453.59
1 g/kW h	1.6440×10^{-3}	1.621×10^{-3}		0.7354
1 g/CV h	2.235×10^{-3}	2.205×10^{-3}	1.3600	

The Cheval Vapeur (CV) is also known as the metric horsepower (1CV = 1CH = 1PS)
1 lb = 453.592 grams

8.2.17 Temperature

The temperature unit in most practical use in many countries is the degree Celsius (°C), however the terms Centigrade (°C) and Fahrenheit (°F) are still in use. The Fahrenheit scale is not formally defined but it is generally recognised that the temperature difference of 1°F is equal to five ninths of the temperature difference of one degree °C.

$$1°C = \frac{5}{9} °F - 32$$

$$1°F = \frac{9}{5} °C + 32$$

The refinements of temperature scales are abstruse, but for most practical purposes the following relationships apply.

For the same temperature, if t and Ø represent the temperature on the Fahrenheit or Celsius scales, similarly r and T the Rankine (absolute Fahrenheit °R) and Kelvin (absolute Celsius K) temperatures, respectively, then

$$Ø = \frac{9}{5} (t - 32)$$

$$T = \frac{9}{5} (t + 459.67)$$

$$r = t + 459.67$$

The temperature at the triple point of water (where water, ice and water vapour are in equilibrium) is very slightly removed from the temperature of the melting point of ice at atmospheric pressure (the ice point).

8.2.18 Calorific Value of Fuel

kJ/kg - 42800

Btu/lb - 18400

8.2.19 Air Density

= 1.205kg/m^3 = 0.0752lb/ft^3

8.2.20 Continuous Power

1bhp = 1.014CV = 0.746kW

1kW = 1.340bhp = 1.359CV

1CV = 0.986bhp = 0.736kW

1CV = 1CH = 1PS

8.2.21 Intermittent Power

1.1bhp = 1.115CV = 0.821kW

1.1kW = 1,474bhp = 1.495CV

1.1CV = 1.085bhp = 0.810kW

1CV = 1CH = 1PS

SECTION 9 - INDEX

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