SERVICE MANUAL

Volume 1

Ford

Power Products

Ford Power Products

INDUSTRIAL PRODUCTS SERVICE MANUAL FOR 2720 RANGE ENGINES

VOL. 1 – BASE ENGINE

Naturally aspirated industrial or marine engines
2722 - 4 Cyl. 4,150 litre (254 cu in)
2723 - 6 Cyl. 5,950 litre (363 cu in)
2725 - 6 Cyl. 6,220 litre (380 cu in)

Turbocharged industrial or marine engine
2726T - 6 Cyl. 5,950 litre (363 cu in)

Turbocharged and intercooled marine engine
2728T - 6 Cyl. 5,950 litre (363 cu in)

CONTENTS

HEALTH & SAFETY

WARNING: The following health and safety recommendations should be carefully observed.

Carrying out certain operations and handling some substances can be dangerous or harmful to the operator if the correct safety precautions are not observed. Some such precautions are recommended at the appropriate points in this book.

Whilst it is important that these recommended safety precautions are observed, care near machinery is always necessary, and no list can be exhaustive. Always be on your guard!

The following recommendations are for general guidance:

1. Always wear correctly fitting protective clothing which should be laundered regularly.

Loose or baggy clothing can be extremely dangerous when working on running engines or machinery.

Clothing which becomes impregnated with oil or other substances can constitute a health hazard due to prolonged contact with the skin even through underclothing.

2. So far as practicable, work on or close to engines or machinery only when they are stopped. If this is not practicable, remember to keep tools, test equipment and all parts of the body well away from the moving parts of the engine or equipment - fans, drive belts and pulleys are particularly dangerous.

3. Avoid contact with exhaust pipes, exhaust manifolds and silencers when an engine is, or has recently been running; these can be very hot and can cause severe burns.

4. Many liquids used in engines or vehicles are harmful if taken internally or splashed into the eyes. In the event of accidentally swallowing gasoline (petrol), oil, diesel fuel, anti-freeze, battery acid etc., do NOT encourage vomiting and OBTAIN QUALIFIED MEDICAL ASSISTANCE IMMEDIATELY.

Wear protective goggles when handling liquids which are harmful to the eyes; these include ammonia and battery acid. If any of these substances are splashed in the eyes, wash out thoroughly with clean water and OBTAIN QUALIFIED MEDICAL ASSISTANCE IMMEDIATELY.

Some components on your engine and transmission, such as gaskets and friction surfaces (clutch discs or automatic transmission brake brands), may contain asbestos.

Breathing asbestos dust is dangerous to your health. You are therefore advised to have any maintenance or repair operations on such components carried out by a Ford Dealer. If, however, service operations are to be undertaken on parts containing asbestos, the essential precautions listed below must be observed.

- Work out of doors or in a well ventilated area.
- Dust found on the vehicle or produced during work on the vehicle should be removed by extraction not by blowing.
- Dust waste should be dampened, placed in a sealed container and marked to ensure safe disposal.
- If any cutting, drilling etc. is attempted on materials containing asbestos the item should be dampened and only hand tools or low speed power tools used.

For your further guidance, Ford and Motorcraft replacement parts which contain asbestos are identified by this symbol. If you are in any doubt, please consult your Ford Dealer.

FOREWORD

Where the terms 'Right' or 'Left' occur in this publication, they refer to the respective sides of the engine when viewed from the rear or flywheel end.

Pistons and valves are numbered from the front or timing cover end of the engine commencing at No. 1.

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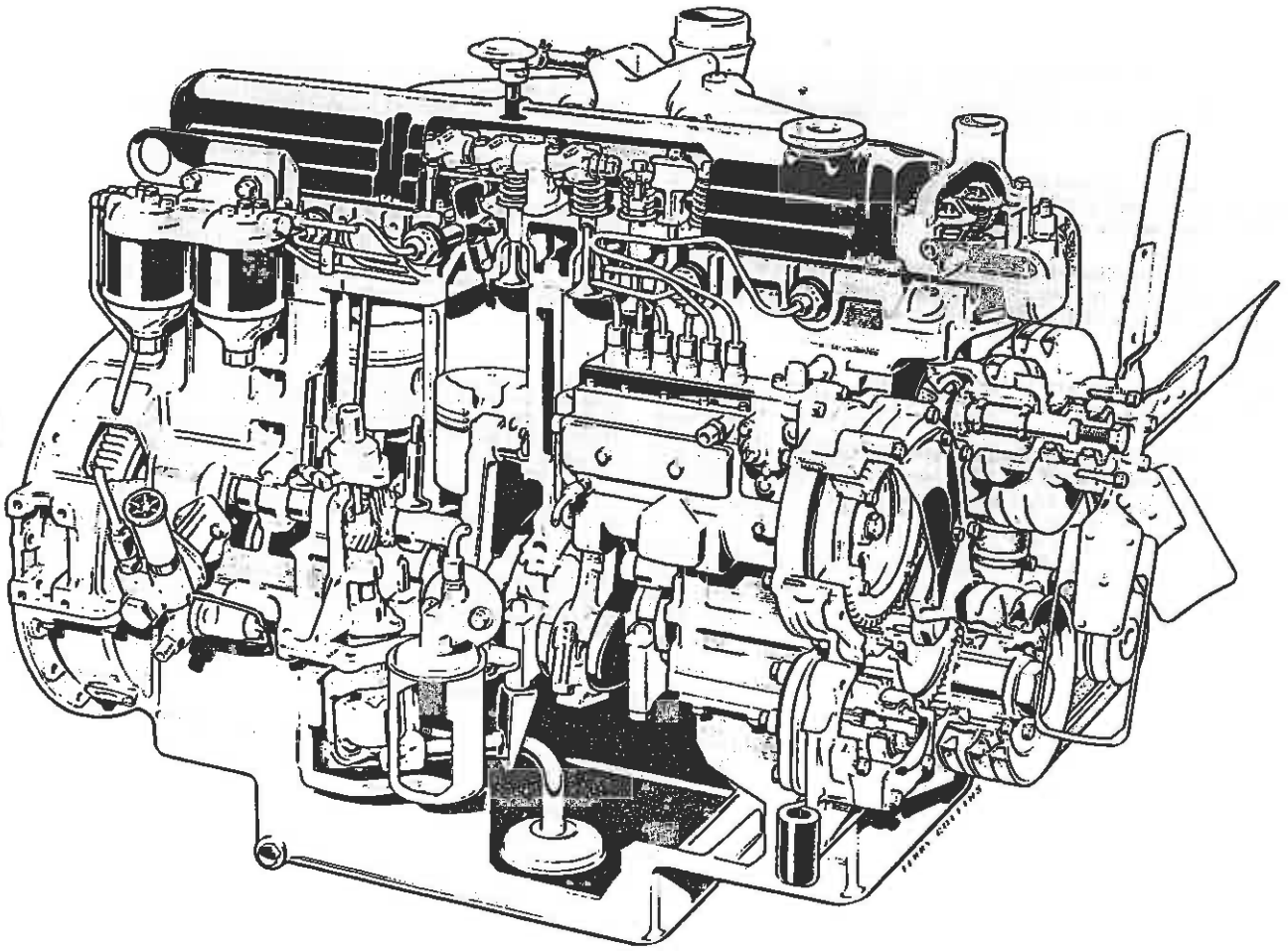


art Or Will Not Start

Remedy

a Check stop control cable or linkage and lever on injection pump. Rectify as necessary.

b Refill tank and bleed fuel system.

c Refer to Section 4.

d Check and adjust to specification.

e Carry out compression test to ascertain:
i) Leaking or damaged valves.
ii) Leaking cylinder head.
iii) Worn, damaged or broken pistons and/or piston rings.
Carry out complete or partial overhaul as required.

e Possibly Accompanied By Continuous Or Intermittent Vibration

Remedy

a Check all engine mounted components for security of mountings. Check security of flywheel. Tighten as necessary.

b Check security of engine mountings. Tighten or renew as necessary.

c Refer to Section 4.

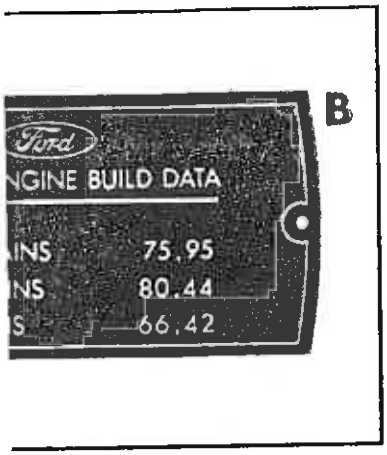
d Check that clearance exists between fan blades and cowl and/or radiator, that fan is not damaged or distorted and that no other component is fouling fan blades.

e Remove starter motor, check flywheel ring gear for damage and inspect and repair starter motor as detailed in Volume 2, Section 1.

f Check for noisy operation of: Air compressor, alternator, water pump, fuel injection pump, turbocharger (where fitted). Renew or repair as necessary.

g Check valve gear and rocker shaft for wear. Adjust valve clearances as necessary.

h Dismantle and check for worn or damaged timing gears, crankshaft and camshaft bearings, pistons and/or connecting rods. Overhaul or renew as necessary.



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examples illustrated in Fig. 4A

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ORIGINAL ENGINE BUILD DATA PLATE

During engine production, an original engine build data plate is fitted on the right hand side of the cylinder block on the flywheel housing (Fig. 2). This plate identifies in millimetres the crankshaft main journal diameter (crank mains), main bearing cap/cylinder block inside diameter (block mains), and the crankshaft big end journal diameter (crank pins).

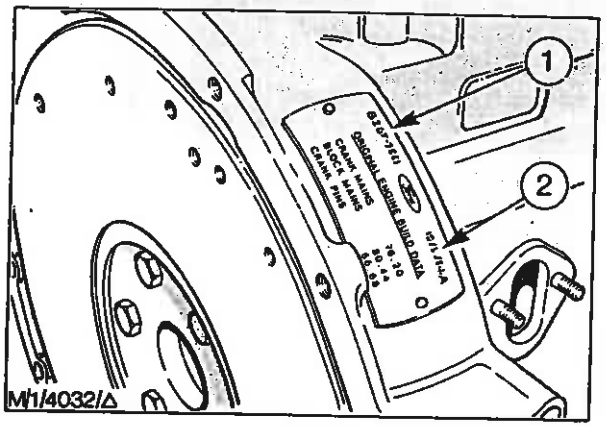


Fig. 2 - Location of Original Engine Build Data Plate
1. Engine Type 2. Build Date

Four possible combinations of sizes may be encountered, and these are identified by the colour of the plate and the dimensions on the plate – see Figs 3 and 4A.

SERVICE ENGINES

Service engines are fitted with a service cylinder data plate, giving dimensions in millimetres of crank main bearing diameter, crank big end bearing diameter, block main bearing diameter, and block cam bearing diameter - see Fig. 4.

The service cylinder data plate is fitted in place of the original engine build data plate.

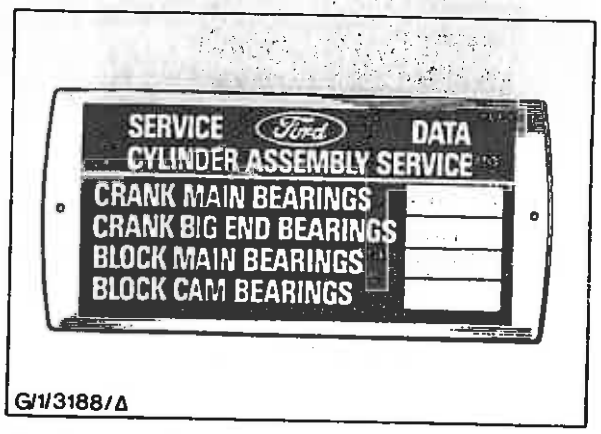


Fig. 4 - Service Cylinder Data Plate

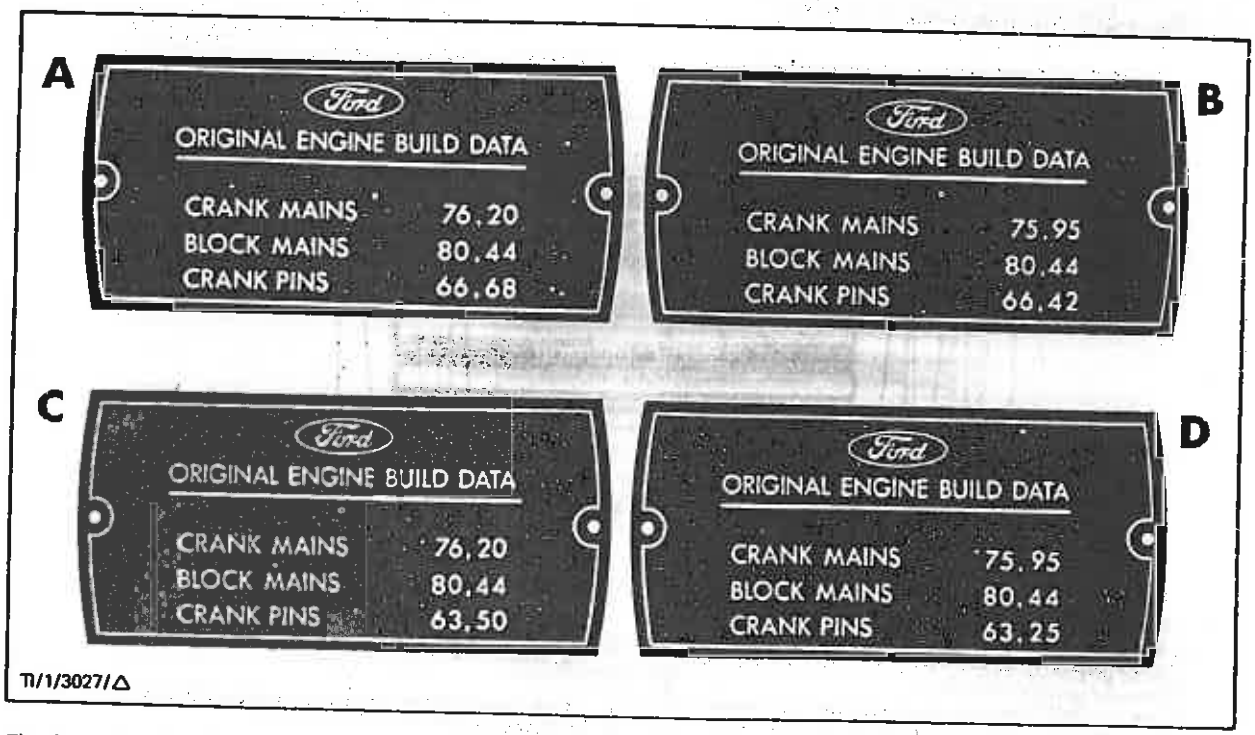


Fig. 3 – Original Engine Build Identification Plates for Engines Built Before October 1985
A. Green Plate – 2722, 2725, 2726T & 2728T
B. Blue Plate – 2722 & 2725
C. Black Plate – 2723
D. Orange Plate – 2723

NOTE: In the interests of clarity, the Engine Types and Build Dates are not shown on the examples illustrated in Fig. 3.

IMPORTANT: From October 1985, crankshafts were commonised with respect to crankpin diameters. These are now all 66,68 mm (size 1). In some circumstances, a crankshaft with crankpin diameters of 66,42 mm and main journal diameters of 75,95 mm (size 2) may be encountered on 2722, 2723 and 2725 engines only – see Fig. 4A overleaf.

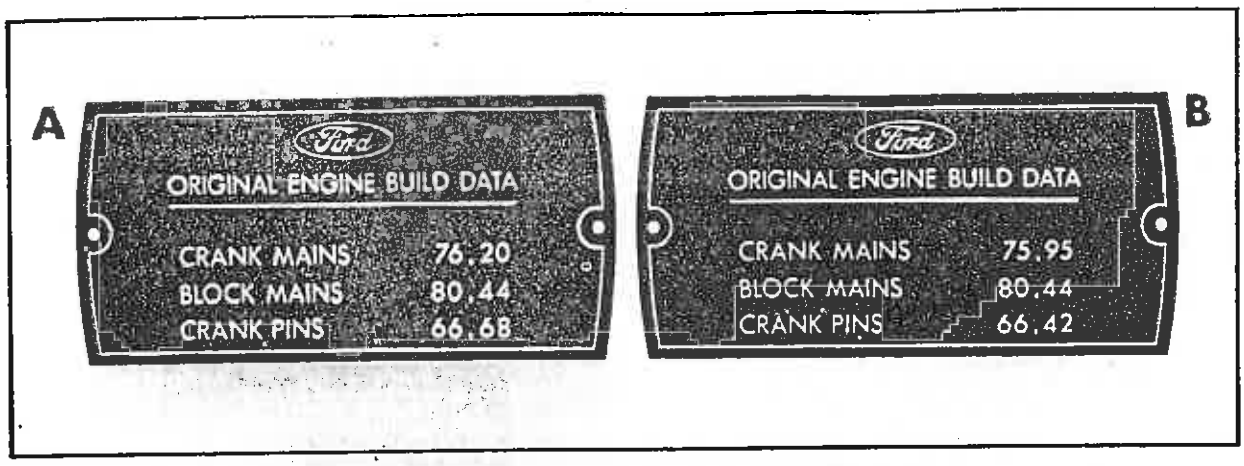


Fig. 4A – Original Engine Build Identification Plates for Engines Built Since October 1985
A. Green Plate – 2722, 2723, 2725, 2726T & 2728T
B. Blue Plate – 2722, 2723 & 2725 only

NOTE: In the interests of clarity, the Engine Types and Build Dates are not shown on the examples illustrated in Fig. 4A

SERVICE IDENTIFICATION PLATE

This plate (Fig. 5) is fixed to the top surface of the engine rocker cover. Positions 1 to 11 on the plate refer to various engine details as listed.

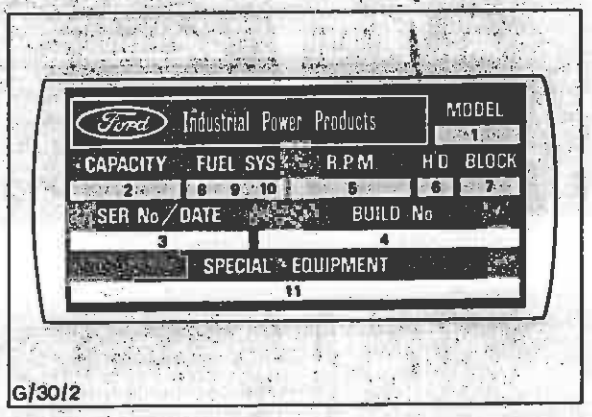


Fig. 5 - Service Identification Plate
1. Engine Model Identification
2. Engine Capacity in Litres
3. Engine Serial Number/Date
4. Selective Build Number indicates the complete engine specification. The digit to the extreme right-hand side, is the Build Chart Issue Number
5. Engine Operating rpm. An asterisk denotes speed set by customer
6. Cylinder Head Type:
7. Block Type:
   A Standard with Standard 28,5 Nm PTO
   B Standard with Heavy Duty 142 Nm PTO
   C Intercooled with Standard 28,5 Nm PTO
8. Injection Pump Manufacturer:
   A CAV/Simms
   B Bosch
9. Type of Governor Fitted to Injection Pump
   A General Purpose
   B Class 'A'
   C Automotive
   D Combine Harvester
10. Special Injection Equipment Fitted
11. This box is provided for Equipment Manufacturers' use when extra equipment is fitted outside the Ford Motor Company. Reference should be made to the Equipment Manufacturer for any information or parts required.

FAULT DIAGNOSIS

The following fault diagnosis procedures have been devised as a methodical guide when the cause of a fault is not obvious. It is not intended that the procedures should necessarily be followed in sequence.

This section covers the diagnosis of engine faults but it may also be necessary to refer to other sections of the manual for fault diagnosis procedures covering fuel, electrical, cooling and starting systems.

Before commencing, observe the symptoms and ask the following questions:

1. Did the fault occur suddenly or 'grow' over a period of time?
2. Were there any warning signs?
3. Has this fault occurred before on the same machine?
4. Could any previous repair or maintenance have contributed to the fault?
5. Is the fault caused indirectly by a malfunction in some other system or component?
6. If the engine still runs, is it safe to continue to make further checks?

Begin by eliminating the most obvious causes - these are usually the ones that can be seen or checked easily without, or by minimum removal of components.

Recheck for an easily overlooked solution before commencing complex or lengthy dismantling procedures.

1. Engine Fails To Crank Or Cranks Sluggishly

	Possible Causes		Remedy
a	Faulty battery or loose connections	a	Refer to Volume 2, Section 2.
b	Faulty starter motor or electrical circuit	b	Refer to Volume 2, Section 1.
c	Engine prevented from turning by mechanical seizure or hydraulic lock	c	Attempt to turn the engine backwards. If it will turn, then turn it forwards again and if it comes to a sudden stop check for a hydraulic lock caused by presence of oil in a cylinder bore; or a mechanical lock caused by such as a broken or damaged valve or valve gear. If the engine will not turn either way check for; engine seizure, starter motor jammed in mesh with the flywheel, or mechanical lock caused by broken or damaged engine components.
d	Laborious cranking at low temperatures caused by thick or incorrect grade of engine oil, partial seizure or high residual load	d	Drain and refill with correct specified grade of engine oil suitable for ambient temperatures.

2. Engine Cranks Satisfactorily But Is Difficult to Start Or Will Not Start

	Possible Causes		Remedy
a	Engine stop control not fully disengaged.	a	Check stop control cable or linkage and lever on injection pump. Rectify as necessary.
b	Fuel tank empty.	b	Refill tank and bleed fuel system.
c	Fuel system fault.	c	Refer to Section 4.
d	Incorrect valve timing and/or valve clearances.	d	Check and adjust to specification.
e	Wear or internal fault in engine.	e	Carry out compression test to ascertain: i) Leaking or damaged valves. ii) Leaking cylinder head. iii) Worn, damaged or broken pistons and/or piston rings. Carry out complete or partial overhaul as required.

3. Engine Knocks Or Has Abnormal Mechanical Noise Possibly Accompanied By Continuous Or Intermittent Vibration

	Possible Causes		Remedy
a	Loose engine component or flywheel.	a	Check all engine mounted components for security of mountings. Check security of flywheel. Tighten as necessary.
b	Engine mountings are loose or worn.	b	Check security of engine mountings. Tighten or renew as necessary.
c	Fuel system fault, uneven running or engine misfiring.	c	Refer to Section 4.
d	Cooling fan blades fouling or damaged.	d	Check that clearance exists between fan blades and cowl and/or radiator, that fan is not damaged or distorted and that no other component is fouling fan blades.
e	Starter motor stuck in engagement.	e	Remove starter motor, check flywheel ring gear for damage and inspect and repair starter motor as detailed in Volume 2, Section 1.
f	Worn or damaged engine driven component.	f	Check for noisy operation of: Air compressor, alternator, water pump, fuel injection pump, turbocharger (where fitted). Renew or repair as necessary.
g	Worn or maladjusted valve gear.	g	Check valve gear and rocker shaft for wear. Adjust valve clearances as necessary.
h	Excessive wear or internal damage in engine.	h	Dismantle and check for worn or damaged timing gears, crankshaft and camshaft bearings, pistons and/or connecting rods. Overhaul or renew as necessary.

4. Engine Lacks Power

	Possible Causes	Remedy
a	Accelerator linkage prevented from attaining maximum fuel setting.	Check accelerator pedal and linkage and injection pump controls for full and free movement. Rectify as necessary.
b	Fuel or air intake system fault, including turbocharger (where fitted).	Refer to Section 4.
c	Exhaust system restriction.	Check the exhaust pipes and silencer for blockage or damage. Renew or repair as necessary.
d	Engine operating temperature incorrect.	Refer to Section 3.
e	Incorrect valve timing and/or valve clearances	Check and adjust to Specification.
f	Low compression pressures.	Carry out compression test to identify fault.
	ONE OR TWO ISOLATED LOW PRESSURES:	
	i) Incorrect valve clearances.	i) Check and adjust clearances to specification. Repeat compression test.
	ii) Leaking cylinder head gasket. (May cause two adjacent low pressures).	ii) Check for pressure blow past into adjacent cylinders or for pressurisation of the cooling system. Repair as necessary.
	iii) Burnt or damaged valves. Holed or badly damaged piston. (Usually causes heavy blue exhaust smoke).	iii) Pour some clean engine oil into the affected cylinder to act as a temporary seal and repeat the compression test. If the pressure does not rise significantly, remove the cylinder head. Check and repair as necessary.
	iv) Sticking or broken piston rings.	iv) Repeat the compression test with oil in the cylinder. If the pressure rises significantly, remove the cylinder head to verify the fault. Repair or overhaul as necessary and locate and rectify cause.
	ALL COMPRESSIONS LOW BUT EVEN:	
	Worn pistons, rings and/or cylinder bores. Sticking piston rings. Usually accompanied by increased engine smoke. If not a high mileage engine, could be caused by lubrication or cooling system fault.	Repeat the compression test with oil in the cylinders. If the pressure rises significantly, this indicates a loss of pressure past the pistons. Repair or overhaul as necessary and locate and rectify cause of fault if applicable.

5. Excessive Exhaust Smoke

	Possible Causes		Remedy
	BLACK SMOKE		
a	Fuel system fault.	a	Refer to Section 4.
	WHITE SMOKE		
a	Fuel system fault (usually indicated by pungent smell).	a	Refer to Section 4.
b	Coolant leak into cylinder/s.	b	Check cylinder head gasket for leaks or damage. Check cylinder head and block for cracks or damage. Repair or renew as necessary.
	BLUE SMOKE (indicates engine is burning lubricating oil).		
a	Engine oil level too high.	a	Reduce to the correct level. Refer to Fault No. 6 if high level was not caused by overfilling.
b	Worn engine or damaged components.	b	Carry out compression test to check for worn or damaged pistons and/or piston rings. Check valves, valve guides and inlet valve stem seals for wear and/or damage. Repair or overhaul as necessary.
c	Incorrect grade of engine oil.	c	Drain and refill with correct specified grade of oil.
d	On turbocharged engines a blocked or restricted air intake can cause the turbocharger to suck engine oil past its seals into the air intake.	d	Overhaul air cleaner or remove restriction.

6. Increase in Engine Oil Level Possibly Accompanied By Smell Of Fuel Oil

	Possible Causes		Remedy
a	Prolonged running at below engine normal operating temperature.	a	Cooling system fault. Refer to Section 3. Change engine oil and filter.
b	Prolonged operation at idle speed	b	Change engine oil and filter. Revise operating procedures or increase frequency of oil changes.
c	Injectors faulty, loose, damaged or not seating correctly. (Can also cause uneven running and/or black smoke).	c	Renew or overhaul injectors as required.
d	Injector leak-off rail leaking, damaged or fractured.	d	Refer to 'Injector Leak-off Rail Pressure Test' in Section 4. Repair or renew as necessary.
e	Coolant leakage into lubricating system.	e	Check cylinder head gasket for leaks. Check oil cooler (where fitted) for internal leaks or damage. Rectify as necessary.

7. Engine Oil Pressure Low

Possible Causes	Remedy
a Low oil level.	a Top up with engine oil of the specified grade. Inspect the engine for signs of leakage. If no leakage is evident and the engine exhaust shows blue smoke, refer to Fault No. 5.
b Oil pressure gauge faulty.	b Check oil pressure using a master pressure gauge. Refer to Section 2 if gauge is faulty.
c Engine oil dirty and filter blocked.	c Change oil and renew filter.
d Oil diluted with fuel oil.	d Refer to Fault No. 6.
e Badly worn crankshaft bearings. Usually indicated by knocking or increased engine noise. May result from adverse operating conditions or from faulty oil pump.	Remove oil pan, check condition of crankshaft and bearings. Check condition of oil pump. Overhaul or renew as necessary.

8. High Oil Consumption

The oil consumption of an engine free from defects will vary depending on operating conditions. It is not possible, therefore, to predict what the 'normal' oil consumption of an engine should be. However, once the engine is 'bedded-in' oil consumption should remain constant. As the engine wears, this consumption may gradually increase until such time as it is considered unacceptable and corrective action is necessary. If a previously stable oil consumption increases rapidly, a fault is indicated.

	Possible Causes		Remedy
a	Oil level too high.	a	Check and adjust oil level. If high level was not due to overfilling, refer to Fault No. 6.
b	Oil leakage	b	Steam clean the engine and stand the machine over a clean area. Run the engine until it is thoroughly warm. Check for leaks. It is sometimes difficult to identify the true source of oil leaks. Meticulous attention should be paid to obtaining a correct identification before commencing dismantling. Particular attention should be paid to apparent rear crankshaft seal leaks to ensure that the source is not behind the flywheel.
c	Incorrect grade or type of oil.	c	Drain oil, and refill with oil to the correct specification. Recheck oil consumption.
d	Inlet valve stem seals worn, damaged or displaced.	d	Remove rocker cover, check and renew seals as necessary.
e	Engine wear and/or damage.	e	Engine damage which causes increased oil consumption, normally also results in increased engine noise and can readily be identified, i.e. broken piston and/or rings. Carry out a compression test to identify fault and overhaul as necessary.
f	Air compressor passing oil (usually indicated by presence of oil in air pressure circuits).	f	Remove and overhaul or renew the compressor.

In order to determine an oil consumption level where high consumption is suspected, carry out the following procedure:

i) Carry out the Fault Diagnosis steps above to eliminate oil leaks or obvious faults as reason for excessive consumption.

ii) Start and run the engine to obtain normal operating temperature. Switch off and allow to stand for 10 minutes. Adjust the oil level carefully and exactly to the 'full' mark on the dipstick.

iii) Run the engine in normal service for a minimum of 20 hours keeping an accurate record of quantities of oil added.

iv) Check and correct the engine oil level as in (ii) and, using the service hours run and quantity of oil added, calculate the average oil consumption.

NOTE: High oil consumption caused by engine wear or component damage allowing the engine to burn oil is usually indicated by considerable blue exhaust smoke.

ENGINE TESTING
(Engine in vehicle/installation)

Compression Test Using Dieseltune "Diestester' (or equivalent)

In order to check the engine compression pressures, it is necessary to remove all the injectors. Fuel injection equipment is machined to extremely fine limits, and every precaution should be taken to avoid damage to the injectors when they are removed.

The following procedure details the use of the Dieseltune "Diestester'. If other equipment is used, follow the manufacturer's instructions.

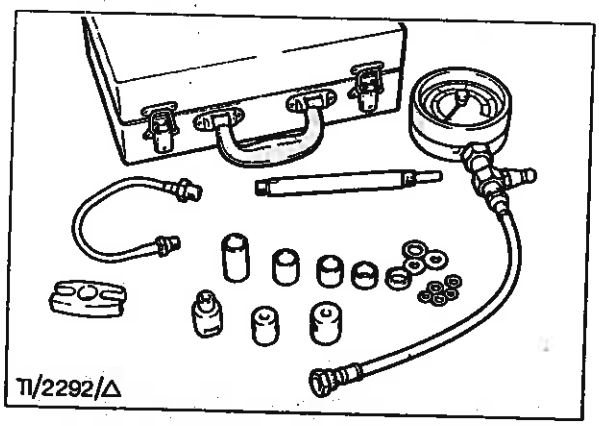


Fig. 6 - Dieseltune 'Diestester' Equipment

The 'Diestester' equipment consists of a pressure gauge assembly, a stem, and a series of spacers and adaptors - see Fig. 6.

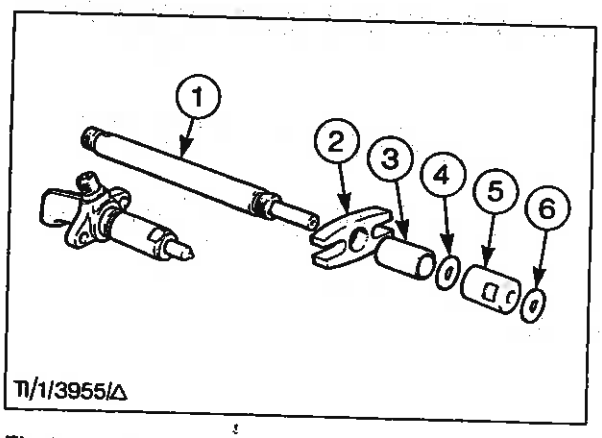


Fig. 7 - Tester Components
1. Stem Assembly
2. Clamping Plate
3. 38 mm (1,5 in) Spacer
4. Sealing Washer
5. 25 mm (1,0 in) Adaptor
6. Sealing Washer

1. If the engine will start, run it and allow it to reach normal operating temperature.

2. Stop the engine and remove all the injectors as detailed in Section 4.

3. Select the 25 mm (1,0 in) long x 20 mm ($^{13}/_{16}$ in) diameter adaptor, and the 38 mm (1,5 in) long spacer. Select a suitable copper sealing washer for the stem assembly, and for the adaptor. Assemble the components as shown in Fig. 7 and check:

a) That the overall length of the assembly (from clamping plate to end of adaptor) is approximately the same as the injector body - see Fig. 8.

b) That the length of stem protruding from the adaptor is less than the length of the injector nozzle - see Fig. 8.

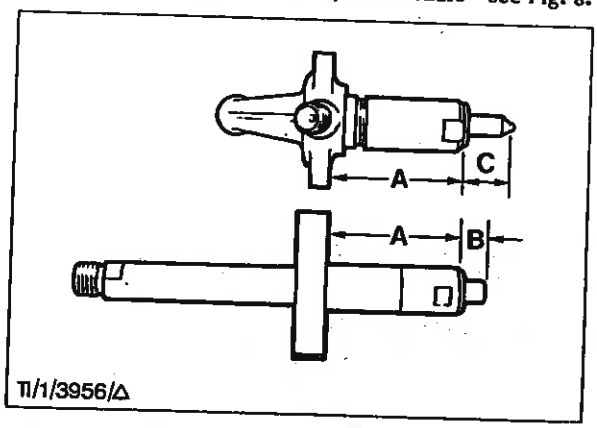


Fig. 8 - Assembling Tester Components
Dimension 'A' to be approximately equal - Dimension 'B' to be less than 'C'

4. Fit the stem and adaptor assembly into the first injector aperture, and tighten the clamping plate securely. Connect the pressure gauge assembly to the stem, and tighten securely.

5. Secure the engine stop control lever on the injection pump in the 'no delivery' position.

6. Crank the engine by the starter, and continue to 'crank' until the pressure gauge is indicating a steady pressure. Note the pressure obtained.

7. Repeat the operation for the remaining cylinders.

8. Compare the pressure readings obtained from each cylinder with those specified. If the pressure variation is outside the specified limits, or if all cylinder pressures are low, engine damage or wear is indicated (see Fault Diagnosis).

NOTE: Specified compression pressures are for normal atmospheric conditions at sea level. At altitudes considerably above sea level, proportionally lower compression pressures will be obtained.

9. Remove and dismantle the test equipment.

10. Check the injector apertures to ensure that they are clean and free from any carbon deposits.

11. Refit the injectors and bleed the system as detailed in Section 4 and refit the valve cover.

12. Start the engine and allow it to run for a short period. Check for oil or fuel leaks. Rectify any leakage as necessary.

CHECKING ENGINE OIL PRESSURE

WARNING: Prolonged and repeated contact with used engine oils can be injurious to health – refer to the statement 'Used Engine Oils' at the beginning of the section headed 'Dismantling The Basic Engine' on page 18.

The following procedure details the use of the Churchill '500X' Pressure Gauge which is a multiple gauge unit. If other equipment is used, follow the manufacturer's instructions.

If the vehicle/installation is equipped with a reliable and accurate oil pressure gauge, only operations 3 to 5 inclusive need be carried out.

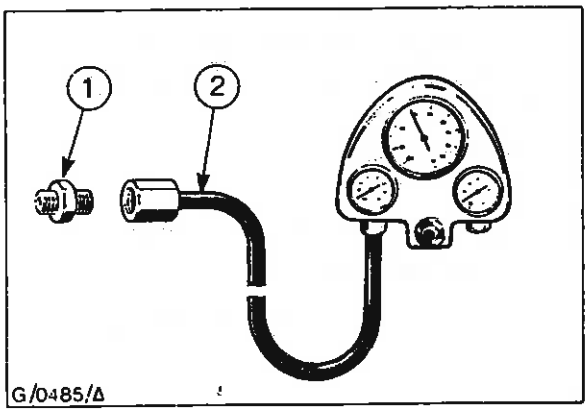


Fig. 9 - Multiple Gauge Unit '500X'
1. Adaptor
2. Flexible Hose

1. Check that the engine oil level is above the 'MIN' mark on the dipstick.

2. Disconnect the electrical connection from the oil pressure sender unit, remove the sender unit from the cylinder block (some oil may drain), connect the gauge unit into the block using a suitable adaptor and connecting pipe.

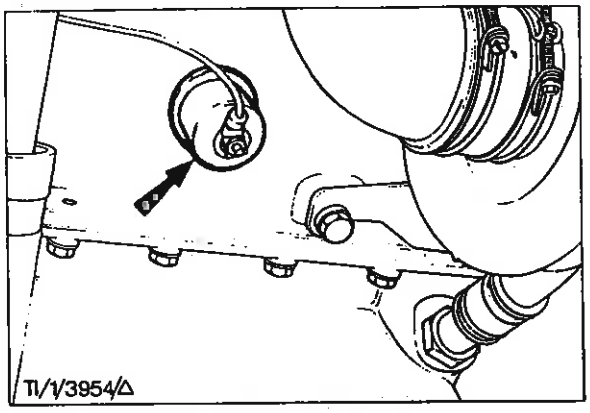


Fig. 10 - Oil Pressure Sender Unit and Electrical Connection

3. Start the engine and allow it to attain normal operating temperature. Increase the engine speed to maximum 'no load' speed and note the indicated engine oil pressure.

4. Allow the engine to idle for a few seconds and repeat the test.

5. Compare the results with the specified pressure and if it is not within the specified limits refer to Fault Diagnosis to establish the likely cause(s). Rectify as necessary.

6. Stop the engine. Disconnect the gauge and remove the adaptor from the engine. Mop up any oil spillage and clean the tapped hole.

7. Refit the oil pressure sender unit and tighten to the specified torque. Refit the electrical connection.

8. If the pressure readings are satisfactory, check the engine oil level and 'top-up' with fresh specified grade engine oil if necessary.

DISMANTLING THE ENGINE
(Engine Removed from Vehicle/Installation)

In order to give the maximum amount of information, Figs. 11 to 16 inclusive cover a wide range of engine types and optional equipment. Consequently, some items such as dipsticks may be shown on both the left hand and right hand side of engines - this is brought about by the different types of oil pans illustrated.

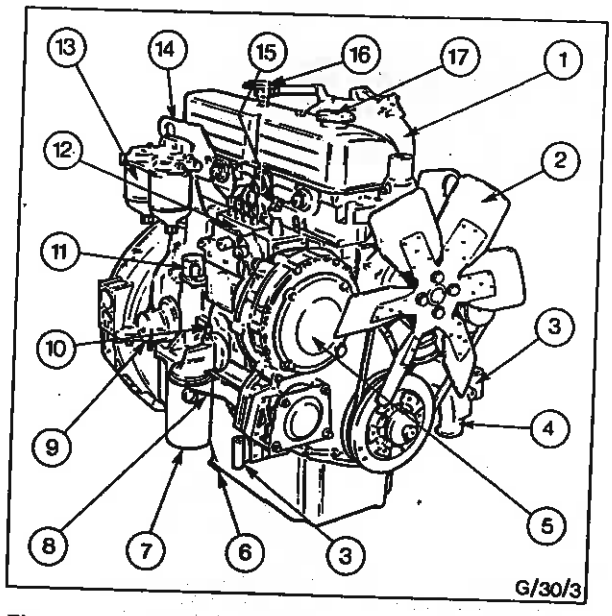


Fig. 11 - 4 Cylinder Naturally Aspirated Engine
1. Inlet Manifold
2. Fan
3. Mounting Bracket
4. Water Inlet Extension Tube
5. Timing Adjustment Cover Plate
6. Oil Drain Plug
7. Oil Filter
8. Dipstick
9. Fuel Lift Pump
10. Injection Pump Oil Feed Pipe
11. Mechanical Hourmeter
12. Injection Pump
13. Fuel Filter
14. Lifting Bracket
15. High Pressure Pipe Clamp
16. Crankcase Ventilation Valve
17. Oil Filler Cap

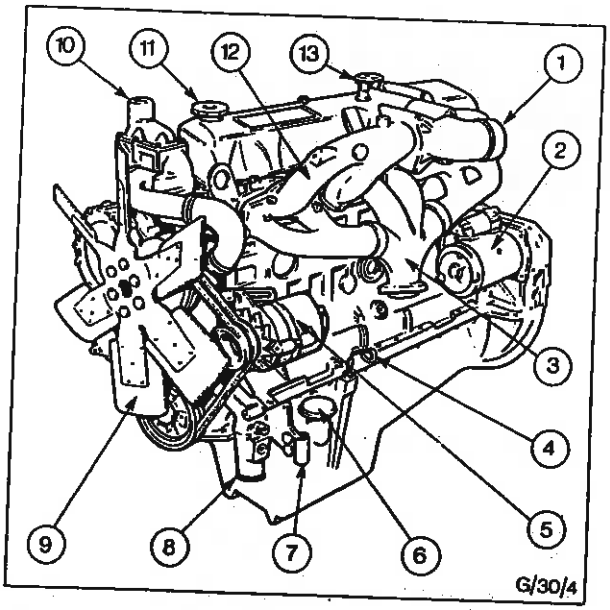


Fig. 12 - 6 Cylinder Naturally Aspirated Engine
1. Inlet Manifold Adaptor
2. Starter Motor
3. Exhaust Manifold
4. Dipstick
5. Alternator
6. Low Level Oil Filler
7. Mounting Bracket
8. Water Inlet Extension Tube
9. Fan
10. Water outlet connection
11. Oil Filler
12. Inlet Manifold
13. Crankcase Ventilation Valve

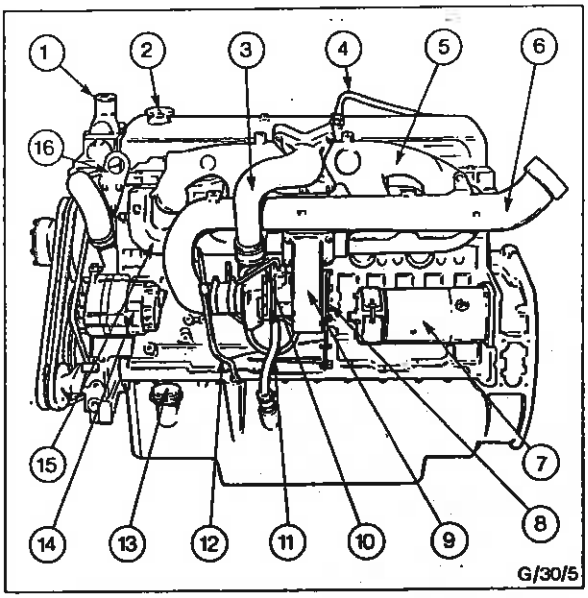


Fig. 13 - 6 Cylinder Turbocharged Industrial Engine

1. Water Outlet Connection
2. Oil Filler
3. Inlet Manifold Adaptor
4. Crankcase Ventilation Pipe
5. Inlet Manifold
6. Air Inlet Pipe
7. Starter Motor
8. Turbocharger Support plate
9. Turbocharger
10. Turbocharger Oil Feed Pipe
11. Turbocharger Oil Drain Pipe
12. Dipstick Tube
13. Low Level Oil Filler
14. Alternator
15. Exhaust Pipe
16. Lifting Bracket

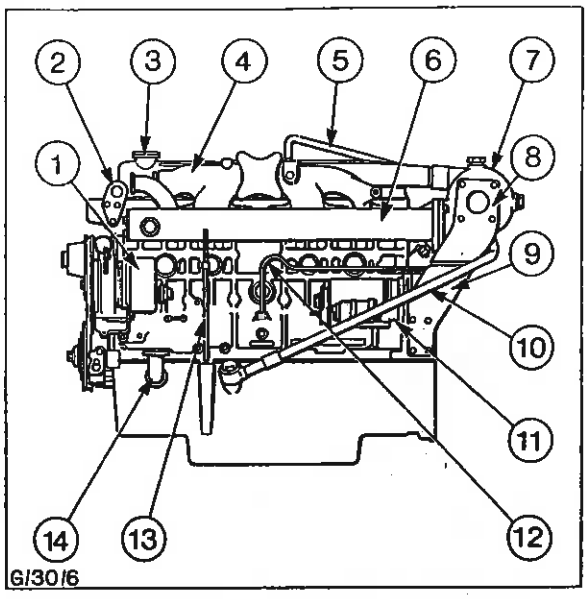


Fig. 14 6 Cylinder Turbocharged Marine Engine

1. Alternator
2. Lifting Bracket
3. Oil Filler Cap
4. Inlet Manifold
5. Crankcase Ventilation Pipe
6. Exhaust Manifold
7. Turbocharger
8. Turbocharger Support Plate
9. Turbocharger Mounting Bracket
10. Turbocharger Oil Drain Pipe
11. Starter Motor
12. Turbocharger Oil Feed Pipe
13. Dipstick Tube
14. Low Level Oil Filler

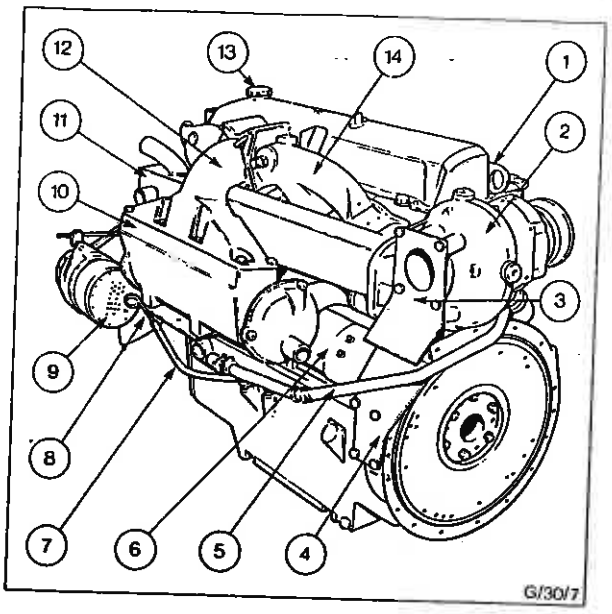


Fig. 15 - 6 Cylinder Intercooled Marine Engine

1. Lifting Bracket
2. Turbocharger
3. Turbocharger Support Plate
4. Turbocharger Mounting Bracket
5. Turbocharger Oil Drain Pipe
6. Starter Motor
7. Dipstick Tube
8. Dipstick
9. Alternator
10. Intercooler
11. Exhaust Manifold
12. Inlet Manifold Adaptor
13. Oil Filler
14. Inlet Manifold

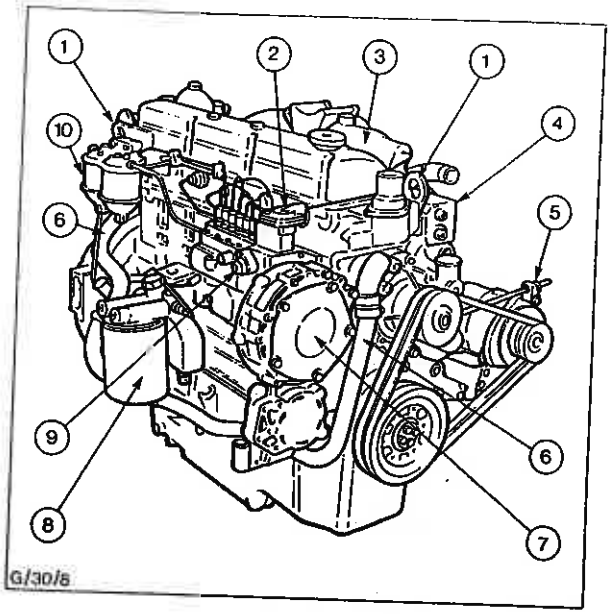


Fig. 16 - 6 Cylinder Intercooled Marine Engine

1. Lifting Brackets
2. Injection Pump Boost Control
3. Inlet Manifold
4. Water Cooled Exhaust Manifold
5. Alternator Drive Belt adjuster
6. Split Flow Water Tube
7. Injection Pump Timing Aperture Cover
8. Oil Filter
9. Injection Pump Automatic Excess Fuel Solenoid
10. Fuel Filter

The dismantling sequence assumes that the following equipment (where applicable) has been removed from the engine:

a) Equipment (other than alternator or water pumps) driven from the crankshaft pulley, flywheel or timing gear PTO including associated air and water pipes.

b) Exhaust pipe/silencer, air cleaner, clutch and flywheel housing adaptor.

NOTE: Some engine ancillaries such as fuel filters, fan, starter motor, alternator, etc. may already have been detached from the engine during its removal from the vehicle/installation.

REMOVING ENGINE ANCILLARIES - Refer to Figs. 11 to 16 inclusive

WARNING: Prolonged and repeated contact with used engine oils can be injurious to health – refer to the statement 'Used Engine Oils' at the beginning of the section headed 'Dismantling The Basic Engine'.

1. Disconnect and remove the turbocharger oil feed pipe and oil return pipe. Detach pipe connecting injection pump boost control and inlet manifold.

2. Slacken clips securing hose between turbocharger and inlet manifold adaptor. On the turbocharged industrial engine, slacken clips securing hose between turbocharger and air inlet pipe, unscrew securing bolts and remove the pipe.

3. Remove nuts securing turbocharger to support plate and detach the exhaust outlet elbow; on marine engines the nuts securing the turbocharger to the support plate would have been removed when the exhaust pipe was detached from the engine. Discard gasket(s).

Remove turbocharger support plate and bracket from cylinder block. Remove nuts securing turbocharger to exhaust manifold and detach the turbocharger. Protect turbocharger from ingress of dirt and foreign bodies.

4. Remove inlet manifold and, on inter-cooled engines, the inter-cooler complete with mounting bracket. Discard all gaskets.

5. Remove exhaust manifold and discard gaskets.

6. Remove starter motor.

7. Fit engine mounting bracket 21-535 to the engine as shown in Fig. 17. Lift engine with a suitable hoist, using the cylinder head lifting brackets and mount the engine on the stand (200B) as illustrated.

8. Withdraw dipstick and, in the case of a high level dipstick, remove the dipstick tube from the oil pan. Unscrew and discard the oil filter canister.

9. Remove low pressure fuel pipes connecting fuel lift pump, fuel filters and injection pump.

10. Remove fuel lift pump and (where fitted) the pre-filter unit.

11. Remove fuel filters complete with mounting bracket.

12. Loosen or remove the high pressure fuel pipe clamps as necessary to enable the large oil seal nuts to be slackened off.

13. Unscrew the gland nuts from the injectors and the injection pump and remove the high pressure fuel pipes.

14. Fit blanking plugs/caps to all injection equipment apertures, including pipe ends.

15. Where applicable, detach oil feed pipe from between oil filter head and injection pump. Remove filter head from cylinder block and discard gasket. Remove oil pressure sender unit.

16. Where fitted, detach the lead connecting injection pump automatic excess fuel solenoid to temperature sensitive switch on the thermostat housing.

17. Unscrew the three retaining bolts and remove the injection pump.

18. Slacken and remove fan securing bolts while gripping fan pulley drive belt(s) and detach the fan. On 'Low Loss' Fan Drive System, also detach the bearing retainer outer plate which is retained by the fan securing bolts.

NOTE: On single belt drives, the pulley can be removed at the same time.

19. Remove water pump drive belt(s) and detach water hose(s). On turbocharged inter-cooled marine engines, remove the complete split flow tube assembly connecting the water pump to the rear of the cylinder block.

20. Remove water pump securing bolts/nuts and detach pump from engine. Discard the gasket.

On 2728T engines, remove the centre bolt and detach the pump back plate; discard the gasket. On marine engines, remove the raw water pump from the PTO drive at the rear of the timing gear housing.

21. Remove alternator. Remove the water pump extension tube (where fitted) together with the engine mounting bracket or spacers, as applicable.

DISMANTLING THE BASIC ENGINE

USED ENGINE OILS

WARNING: Prolonged and repeated contact may cause serious skin disorders including dermatitis and skin cancer.

Avoid excessive contact – wash thoroughly after contact. Keep out of the reach of children.

PROTECT THE ENVIRONMENT: It is illegal to pollute drains, water courses or soil. Use authorised facilities for disposal. If in doubt, contact your Local Authority for advice.

22. Remove thermostat housing and lift out the thermostat(s).

23. Remove oil pan drain plug(s) and drain off the engine oil into a suitable receptacle.

24. Remove the rocker cover.

25. Slacken each rocker shaft pedestal retaining bolt approximately one turn at a time until all are loose, then remove them.

26. Tie the two end rockers in position to keep the complete assembly together, then lift off rocker shaft assembly complete.

27. Remove push rods in sequence and mark them to ensure that they are replaced in their original positions when assembling them later. Do not dislodge the valve stem caps.

REMOVING INJECTORS - Refer to Fig. 18

28. Remove banjo bolts from leak-off pipe, then unscrew gland nut and remove leak-off pipe from cylinder head.

29. Unscrew two retaining bolts and remove each injector. Discard 'O' ring. Remove copper sealing washers from recesses in cylinder head and discard them.

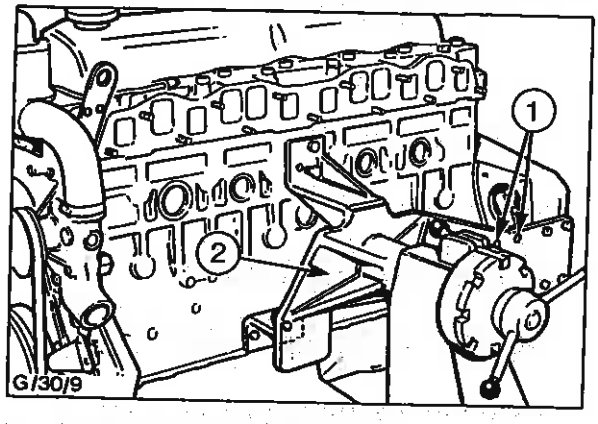


Fig. 17 - Engine Mounted on Stand (200B)
1. Holes for Mounting 4 Cylinder Engine
2. Mounting Bracket (21-535)

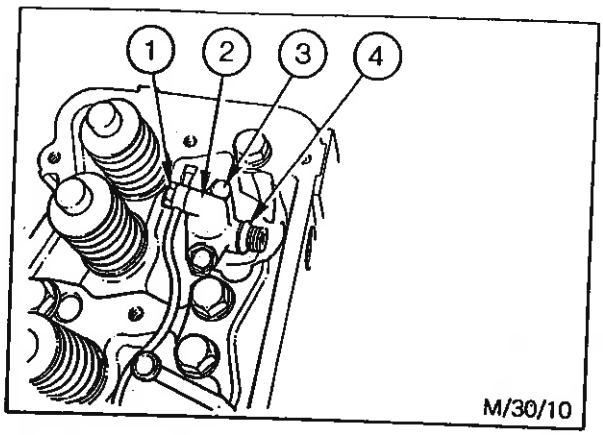


Fig. 18 - Removing Injectors
1. Leak-Off Pipe Banjo Bolt
2. Injector
3. Injector Retaining Bolt
4. 'O' Ring

REMOVING CYLINDER HEAD

30. Slacken each cylinder head bolt a little at a time in the reverse order to the tightening sequence shown in Fig. 19, then remove all bolts.

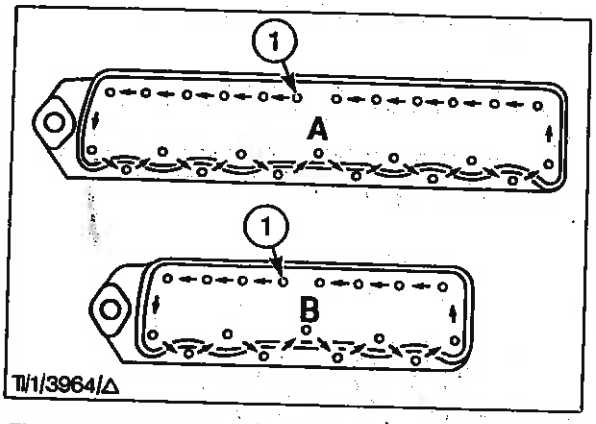


Fig. 19 - Cylinder Head Bolts Tightening Sequence
A. 6 Cylinder Engines
B. 4 Cylinder Engines
1. Start here when tightening
Reverse sequence to slacken

31. Using a hoist attached to the cylinder head lifting brackets, remove the cylinder head carefully, taking care not to damage the head and block mating faces. Valve and guide removal is detailed under 'Cylinder Head Overhaul'.

REMOVING CRANKSHAFT PULLEY

32. On all engines except 2728T, remove the crankshaft pulley retaining bolt, and remove the crankshaft pulley, using a suitable puller if necessary - see Fig. 20.

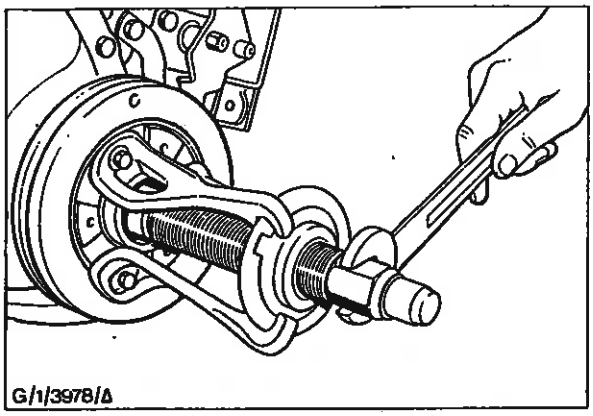


Fig. 20 - Removing Crankshaft Pulley - All Engines Except 2728T

33. On 2728T engines remove the four bolts retaining the crankshaft pulley locking sleeve and remove the locking sleeve. Strike the face of the pulley a firm blow with a soft faced mallet to release the Ringfeder locking mechanism and remove the pulley, the locking rings and the spacer ring - see Fig. 21.

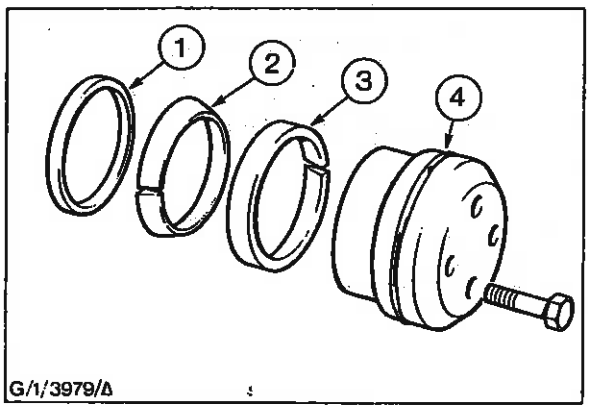


Fig. 21 - Crankshaft Pulley Retaining Components - 2728T Engine (Ringfeder Locking Mechanism)
1. Spacer Ring
2. Internal Locking Ring
3. External Locking Ring
4. Locking Sleeve

REMOVING FLYWHEEL

34. Remove the flywheel retaining bolts and, using two suitable bolts in the threaded holes as pullers, tighten the bolts evenly one turn at a time and withdraw the flywheel off the crankshaft - see Fig. 22.

CAUTION: ENSURE THAT THE FLYWHEEL IS ADEQUATELY SUPPORTED DURING REMOVAL.

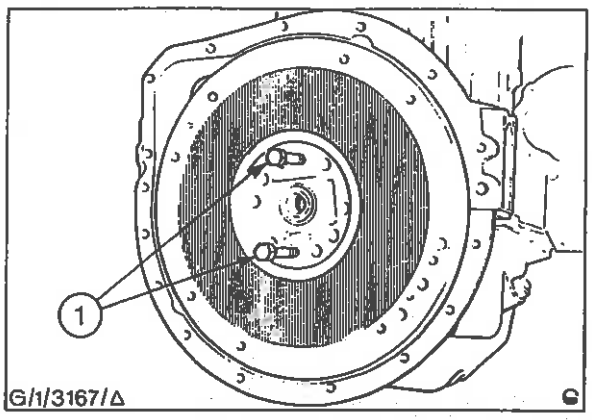


Fig. 22 - Removing Flywheel
1. Flywheel Withdrawal Bolts

REMOVING OIL PUMP

35. Ensure the oil pan has been completely drained of engine oil and invert the engine on the stand.

36. Slacken and remove the bolts and nuts and carefully separate the oil pan from the cylinder block.

2722, 2723, 2725 & 2726T Engines not fitted with high inclination oil pans.

37. Bend up the lock tabs securing the oil pick-up pipe union nut to the oil pump, and unscrew the union - see Fig. 23. Remove the pick up pipe support bracket bolt from the main bearing cap and withdraw the pick up pipe from the pump. Remove the bolts securing the pump to the cylinder block and carefully withdraw the pump.

2728T intercooled engines only

38. Unscrew the bolts securing the delivery pipe flange to the block, then remove the pipe and adaptor, (Fig. 24). Remove the bolts from the pick-up pipe flange and bracket and detach the pipe, complete with spacer, from the oil pump. Remove the nuts securing the oil pump to the front main bearing cap and carefully remove the pump and idler gear assembly.

Oil pump overhaul is detailed in Section 2, 'Lubrication System'.

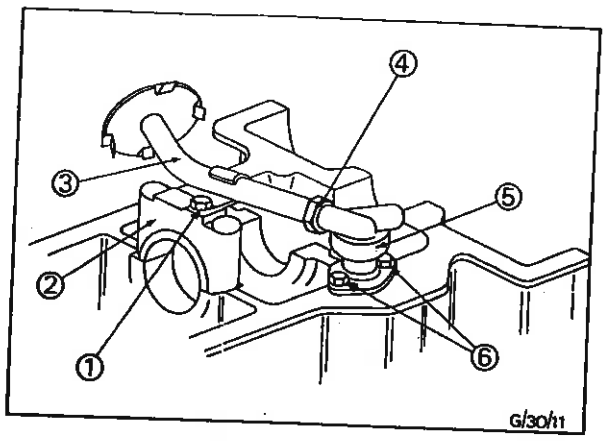


Fig. 23 - Oil Pump Removal/Replacement - 2722, 2723, 2725 and 2726T Engines not fitted with High Inclination Oil Pans

1. Support Bracket Bolt
2. Main Bearing Cap
3. Pick-up Pipe
4. Pick-up Pipe Union
5. Oil Pump
6. Oil Pump Securing Bolt

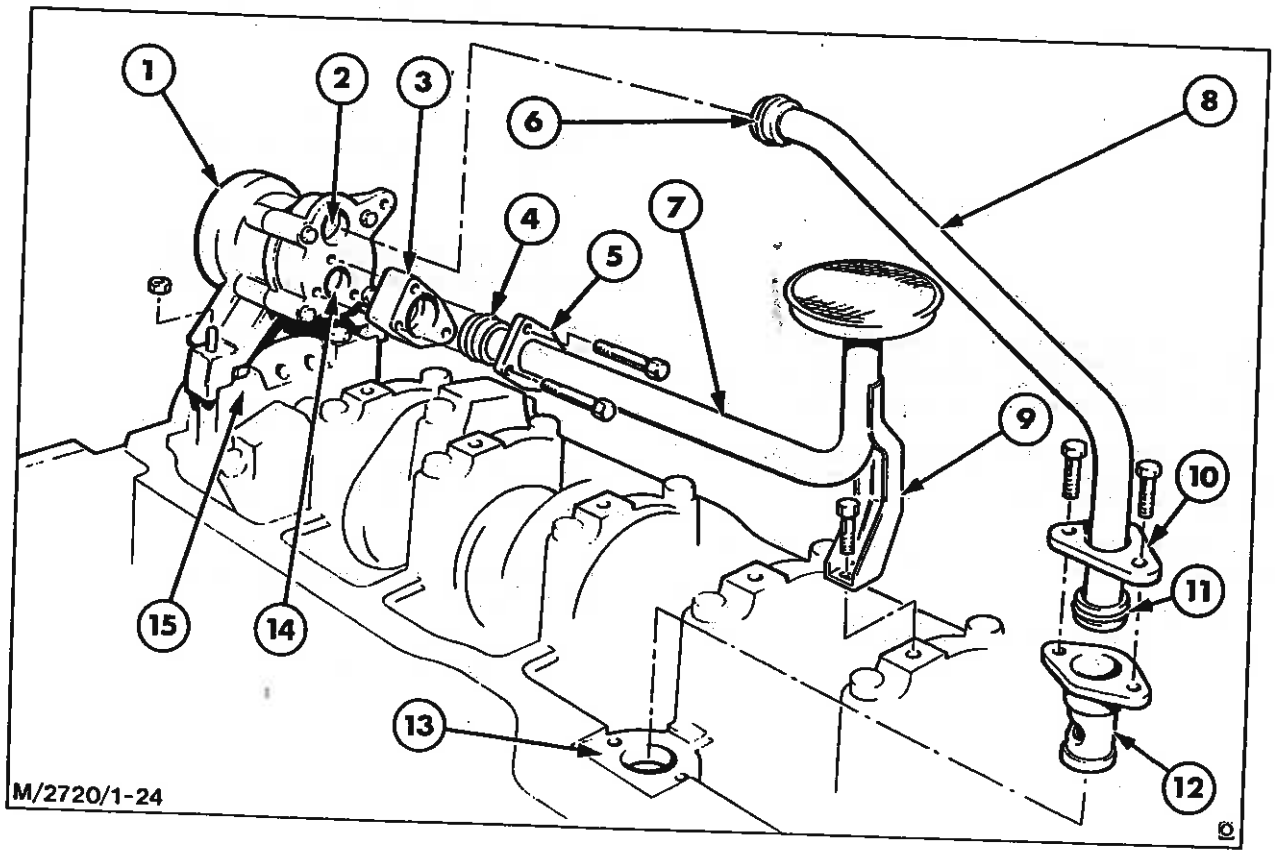


Fig. 24- Oil Pump Removal/Replacement - 2728T Engines

1. Oil Pump
2. Pump Outlet
3. Spacer
4. 'O' Ring
5. Loose Flange
6. 'O' Ring
7. Pick-Up Pipe
8. Delivery Pipe
9. Support Bracket
10. Loose Flange
11. 'O' Ring
12. Flanged Adaptor
13. Cylinder Block Lower Flange
14. Pump Inlet
15. Front Main Bearing Cap

2722, 2723, 2725 and 2726T engines fitted with high inclination oil pans - see Fig. 25.

39. Remove all bolts and lockwashers retaining the pump and pipes then remove the pump from the spigot location in the block.

40. Remove the gauze screens by turning through 90° to release.

41. Bend back the locking plate tabs and unscrew the pipe unions and remove the pipes.

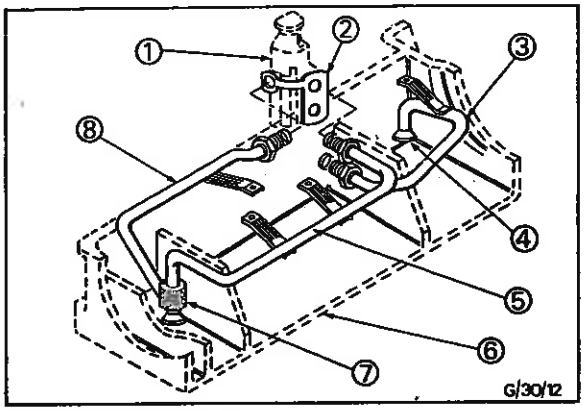


Fig. 25 - Oil Pump and Piping for High Inclination Oil Pans

1. Scavenge Pump
2. Lock Plate
3. Scavenge Pipe
4. Gauze Screen
5. Delivery Pipe
6. Oil Pan
7. Diffuse Box
8. Oil Reservoir Feed Pipe

REMOVING TIMING GEARS AND HOUSING

IMPORTANT: On 2728T intercooled engines, the oil pan must be removed first before attempting to remove the timing gear housing. On all other 2720 range engines, the timing gear housing can be removed first if required.

42. Slacken the bolts securing the timing gear housing cover and, noting the positions of the various different length bolts, remove the bolts and cover.

43. Support the cover and drift out the oil seal. Retain the spacer(s) for reassembly.

44. Lock the camshaft gear to stop it turning and remove gear retaining bolt – see Fig. 26A. Using a suitable puller remove the camshaft gear. Remove the thrust washer.

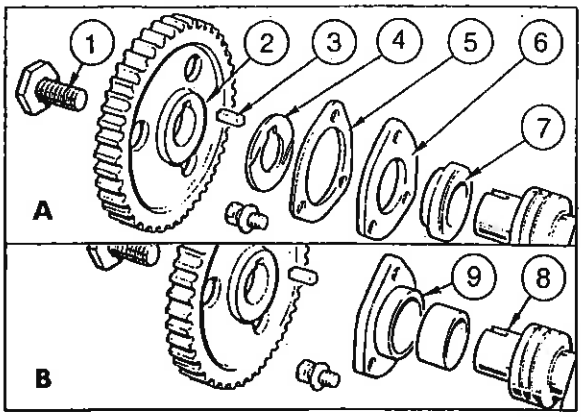


Fig. 26 – Camshaft Gear Assembly

1. Gear Retaining Bolt
2. Camshaft Gear
3. Key
4. Thrust Washer
5. Retaining Plate
6. Thrust Plate
7. Thrust Collar
8. Bushing
9. Thrust plate

45. Remove the three bolts securing the camshaft gear lockplate and thrust plate to the front of the engine, remove the two plates and the camshaft thrust collar. (Fig. 26A).

NOTE: On later engines, the thrust washer and retaining plate are omitted and the camshaft is retained by a modified thrust plate; the thrust collar is replaced by a bushing – see Fig. 26B.

46. Remove the timing gear housing retaining bolts and carefully separate the housing from the block. Retain the locating ring if this also falls free with the housing.

47. Remove the crankshaft gear, if necessary, using a suitable puller.

REMOVING CAMSHAFT, CRANKSHAFT AND PISTONS

48. Ensure that the cam followers are all clear of the cam lobes and carefully withdraw the camshaft from the front of the engine.

CAUTION: Take great care to ensure that the camshaft lobes do not damage the camshaft bearing liners as the shaft is withdrawn.

49. Lift out the cam followers and retain in numerical sequence for reassembly in the same positions.

50. Taking each piston and connecting rod assembly in turn remove the big end bearing cap bolts or nuts and remove the bearing cap. Disengage the big end from the crank pin and using a suitable soft drift (wooden hammer shaft) tap the piston and rod assembly out through the top of the cylinder bore. It may be necessary to scrape away the carbon from the top of the cylinder bore to ease removal. Ensure that the piston, connecting rod and cap are suitably identified for reassembly in the same positions and facing the correct way round relative to one another and to the engine block.

51. Remove the main bearing cap bolts, lift off the bearing caps and bearing liners (shells) and, using a suitable sling and hoist, lift the crankshaft from the crankcase.

52. Remove the upper bearing liners and thrust washers.

53. Ensure all bearing caps and liners are suitably identified for reassembly in their original positions.

COMPONENT TESTING AND RENEWAL

GENERAL

Thoroughly clean and dry all parts.

Ensure all old gaskets and sealing materials are cleaned off mating faces and that all threaded holes are sound and free from debris and swarf. Damaged threads may be restored using Helicoil inserts and following the manufacturers instructions. Check to ensure all studs are secure and undamaged.

Any loose or damaged studs must be refitted or renewed using the specified sealant and tightened to the specified torque value.

If the lubricating oil system is suspect in any way (i.e. bearing failure) or the block is being rebored and/or new cylinder liners fitted, the oil gallery plugs must be removed to enable all oil passageways to be thoroughly cleaned out.

If the original pistons are being refitted, remove all carbon deposits from the piston crown.

OIL PAN

Check to ensure the oil pan mating faces are clean and free from burrs or damage and that the oil pan itself is free from cracks. Check to ensure that the drain plug thread insert is secure and that the filler/tube adaptor is not loose or leaking.

A new drain plug insert or an oversize filler/tube adaptor may be installed, if necessary - refer to 'Lubrication System', Section 2.

CYLINDER BLOCK

Check the cylinder bores visually for scoring caused by broken rings and for uneven wear pattern. On turbocharged engines, cylinder liners showing signs of scuffing, glazing or uneven wear patterns must be renewed.

Check all the main bearing housings and side cheeks and the rear main bearing oil return groove for damage caused by badly worn centre main thrust washers allowing excessive end float of the crankshaft, or siezed bearing liners rotating and blocking off the oil supply.

On 2728T intercooled engines, ensure the piston cooling nozzles are clean and undamaged (Fig. 27). If the engine is being re-sleeved the piston cooling nozzles should be removed to avoid damage or blockage. Push the nozzles out by hand towards the bearing housing.

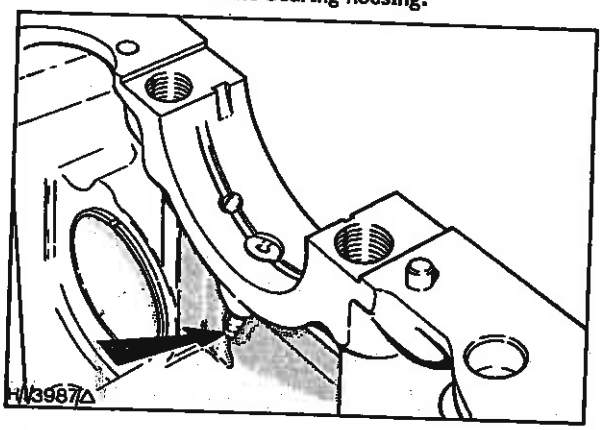


Fig. 27 - Piston Cooling Nozzle (Front Main Bearing Housing Illustrated)

Inspect the cam follower bores for scoring or scuffing which could cause seizure of the cam followers.

Check the camshaft bearings for scoring or excessive wear.

If any one bearing requires renewal all the other bearings should also be renewed otherwise camshaft alignment may be affected.

If the camshaft bearing bores are damaged oversize bearings are available. As the bearing bores will require to be accurately machined to specified oversize diameter (see Specifications) this particular operation can only be carried out where line boring facilities are available.

To install new bearings see 'Camshaft Bearing Renewal'.

Using an internal micrometer, measure and record the diameter of each cylinder bore at the following three points, both in line with, and at 90° to, the crankshaft axis - see Fig. 28.

1. Immediately below the highest point reached by the piston top ring.

2. 80 mm (3,15 in) from the top of the cylinder block face.

3. 200 mm (7,90 in) from the top of the cylinder block face.

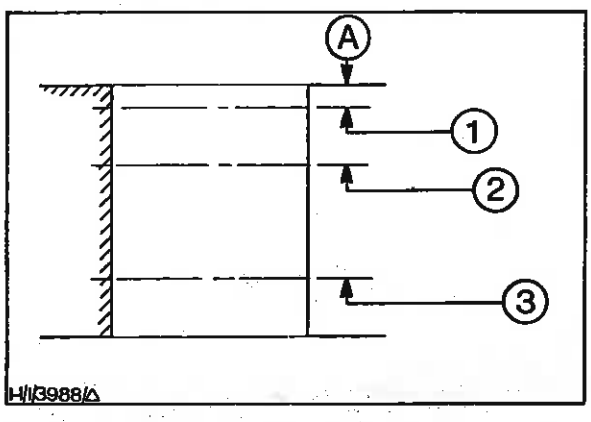


Fig. 28 - Cylinder Bore Wear Measuring Locations (See Text)
A. Cylinder Block Face

Calculate the average of the six diameters measured. This gives the mean bore diameter which should be used in conjunction with the Specification to establish piston skirt to bore clearance figures.

On new cylinder blocks the measurement is taken as at 2 only.

PISTONS AND CONNECTING RODS

Remove the piston rings, identifying them so that each ring can be refitted later (if serviceable) in the same groove in the piston from which it came.

Remove all carbon deposits from the ring grooves.

Remove the piston pin circlips and warm the piston in hot water. Push out the piston pin and separate the piston from the connecting rod - see Fig. 29. Keep each piston with its respective connecting rod.

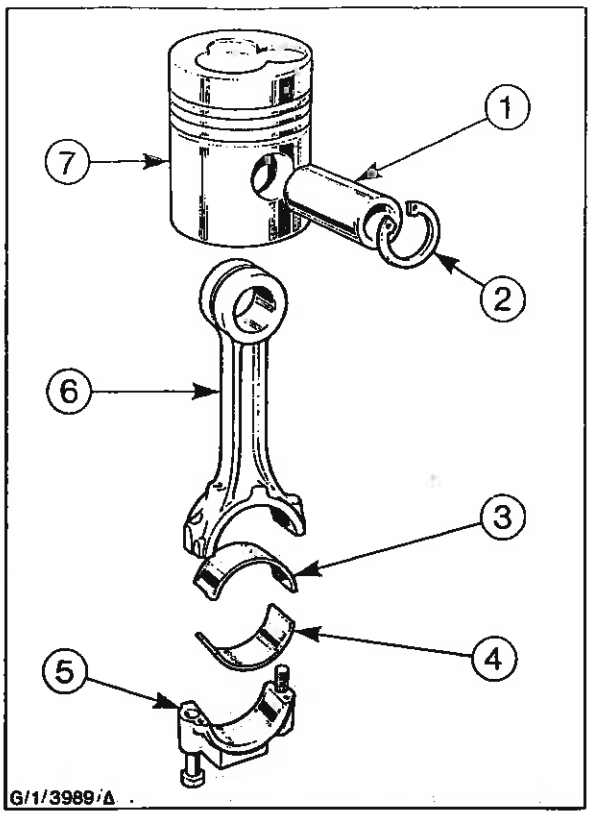


Fig. 29 - Piston and Connecting Rod Assembly
1. Piston Pin
2. Circlip
3. Upper Bearing Liner
4. Lower Bearing Liner
5. Bearing Cap
6. Connecting Rod
7. Piston

The piston must be free from scuffing or scoring and the piston ring lands sound and undamaged around the full circumference of the piston.

Measure the diameter of the piston at 90° to the piston pin at the piston grade point - see Fig. 30 and refer to 'Specifications'.

Calculate the piston clearance by subtracting this measurement from the mean diameter of the cylinder bore.

If the specified clearances cannot be achieved the pistons must be renewed, or if the cylinder bores are worn or damaged they may be rebored to fit oversize pistons (see specifications).

Measure the width of the piston rings and ensure they are within the specified limits.

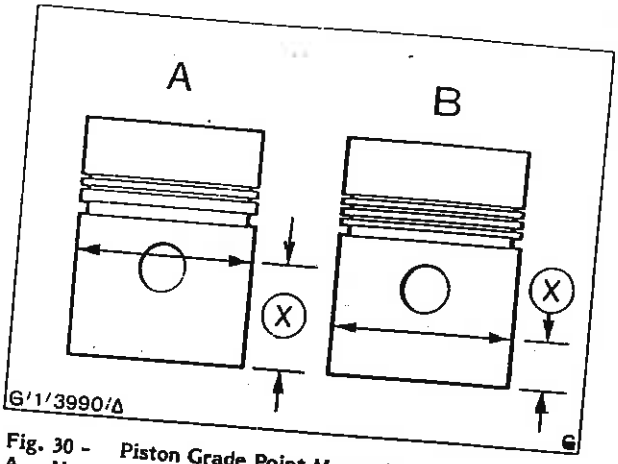


Fig. 30 - Piston Grade Point Measuring Locations
A. Naturally Aspirated Engines
B. Turbocharged Engines
X. See Specifications

Locate each ring in turn in its respective cylinder bore and ensure the ring gap is within the specified limits - see Fig. 31.

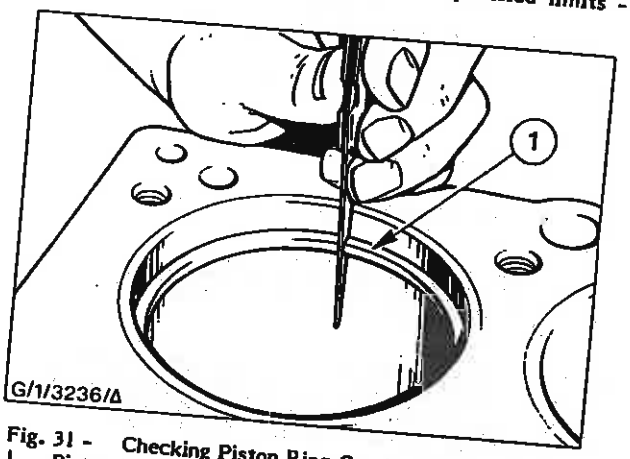


Fig. 31 - Checking Piston Ring Gap in Cylinder Bore
1. Piston Ring

Install the rings in their respective grooves in the piston with the TOP mark uppermost and measure the ring clearances as follows:

Top Compression Ring (Tapered Section) on Turbocharged Engines.

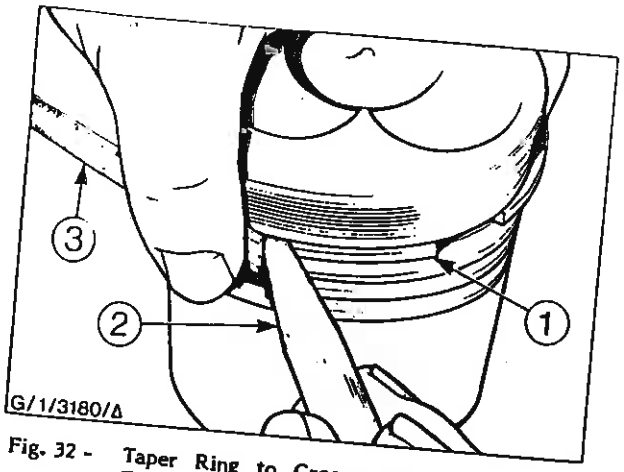


Fig. 32 - Taper Ring to Groove Clearance Check - Turbocharged Engines
1. Top Compression Ring
2. Feeler Gauge
3. Steel Rule

Hold the piston in one hand with a small steel rule held by the thumb so that it bridges the top ring groove - see Fig. 32.

With the index finger press the top ring from the opposite side of the piston, against the steel rule.

Measure the ring to groove clearance by inserting a feeler gauge as near as possible to the point where the ring touches the steel rule. The feeler gauge must be inserted to the full depth of the groove.

All Other Rings (Including Oil Control)

Hold the ring in the approximate installed position and measure the clearance between the ring and the groove at three equi-distant points around the piston - see Fig. 33.

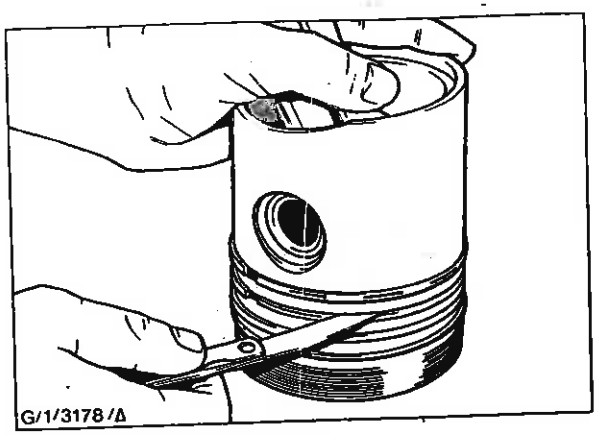


Fig. 33 - Checking Piston Ring to Groove Clearance

Measure the piston pin bore at two points in both sides at approximately 45° to the vertical plane using a suitable dial gauge - see Fig. 34.

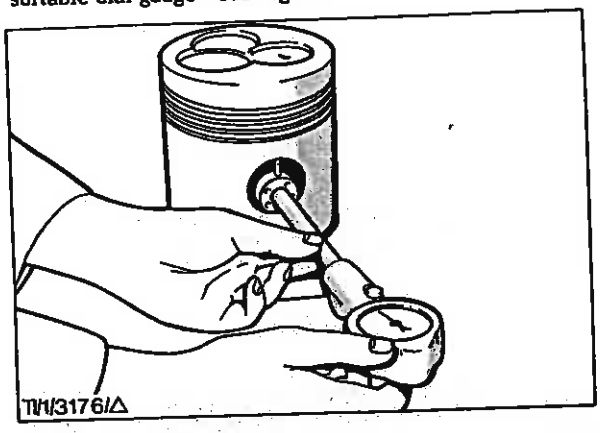


Fig. 34 - Measuring Piston Pin Bore

If the specified clearances cannot be achieved with the original components, or by fitting new rings and/or piston pins, the pistons must be renewed.

Check to ensure the big end bearing housing is undamaged and that the side cheeks are not damaged or scored. If the engine has suffered a major failure the rods must be checked for twist or bend.

Measure the small end bush bore (piston pin bore) using a suitable dial gauge - see Fig. 35. If the bore is not within the specified limits a new connecting rod must be fitted.

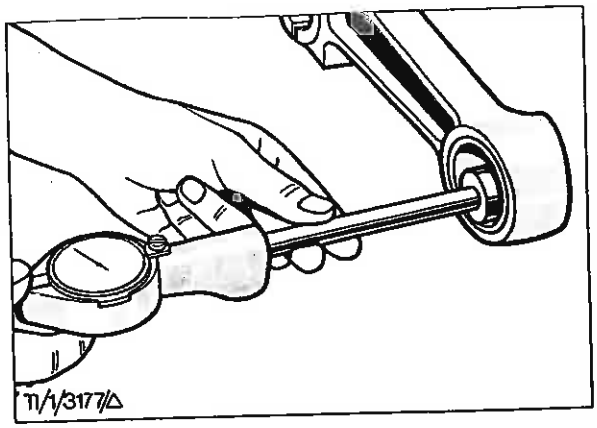


Fig. 35 - Measuring Connecting Rod Bush Diameter

NOTE: The combustion space is closely controlled by means of length graded connecting rods. The connecting rods can be identified by a grade stamp. When repairing or rebuilding these engines it is essential that all connecting rods are the same grade as those originally fitted. If a new or a reground crankshaft is to be fitted then a complete set of connecting rods may be required to maintain the 'bump height' clearance. To establish the connecting rod grade for each cylinder the procedure detailed in 'Assembling the Engine' must be carried out.

CRANKSHAFT AND BEARINGS

The crankshaft journals must be free from scoring or excessive wear.

Measure the diameter of each journal in at least four places and ensure that it is within the specified limits of wear, taper and ovality.

Measure the length of the centre main journal against the specified dimensions in order to ensure that the crankshaft end float can be maintained within the specified limits (using oversize thrust washers, if necessary).

Check to ensure all oil supply holes are clear and that the rear main oil seal wiping surface is free from damage which may render the oil seal ineffective.

On 6 cylinder engines, if the crankshaft is to be renewed or reground, unscrew and remove the front adaptor plug.

Check to ensure that the flywheel mounting flange bolt hole threads are sound, and that the flange itself is free from burrs or damage which may cause misalignment of the flywheel.

If the crankshaft is considered serviceable, check the main and big end bearing liners for scoring, pitting or excessive wear. A properly fitted bearing will appear dull grey after a reasonable period of service, indicating it has been running on an oil film. Bright spots indicate a metal to metal condition of contact and black spots indicate excessive clearance, and these bearings must be renewed as must those which are chipped, flaked or scored.

If the bearing surfaces appear serviceable, measure the thickness of each liner to ensure they are within the specified limits.

NOTE: Original assembly bearing liners are 'graded', see Specifications.

CAMSHAFT BEARING RENEWAL

NOTE: Service camshaft bearings are 'pre-sized' and do not require machining after being installed.

1. Remove the timing gear housing locating ring (if not already removed) - see Fig. 36.

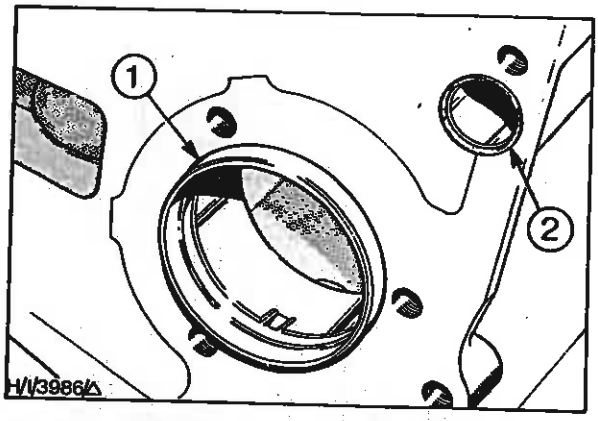


Fig. 36 - Cylinder Block Front Face
1. Timing Gear Housing Locating Ring
2. Oil Gallery Seal 'O' Ring

2. Drive out the expansion plug in the rear of the camshaft bearing housing.

3. Remove the camshaft bearing bushes using Special Tool No. (21-022) and Adaptor Kit (21-022-51A and 21-022-53). Select the stepped cylindrical adaptor whose small end will spigot into the bearing bush (see illustration Fig. 38).

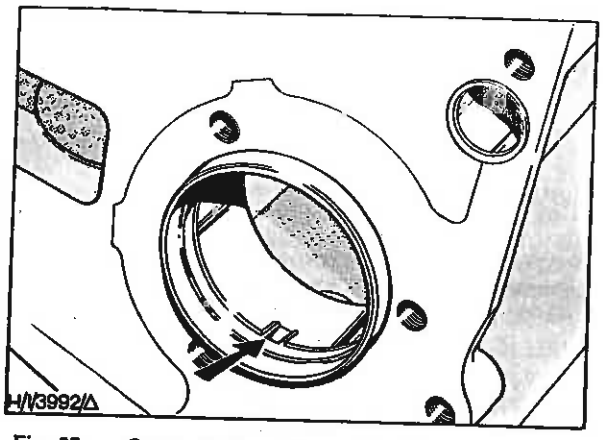


Fig. 37 - Camshaft Front Bearing Tang

4. Bend up the tang on the camshaft front bearing (Fig. 37).

5. With the open end of the tool against the outer face of the front or rear camshaft bearing boss and the screwed centre bar passing through the intermediate bearing boss(es), position the adaptor with its small end spigoted into the bearing to be removed.

6. Fit the 'C' plate in the groove in the centre bar behind the adaptor and by rotating the main handle withdraw the bearing from its boss.

7. Repeat the operation for each bearing.

NOTES:
(i) The front bearing has a copper/lead bearing surface while the rest have white metal, and it is essential to ensure that the front bearing is of the correct type.

(ii) In order that the lubrication holes line up correctly, the new bearings must be installed with the split to the right side of the engine and the notch to the rear. The notch must be positioned vertically and toward the oil pan face of the engine.

8. Install the new bearings using the Special Tool No. (21-022) and Adaptor Kit (21-022-51A and 21-022-53). Select the stepped adaptor used previously together with the two guides which must be used to ensure the bushes are pulled squarely into position (see illustration). Assemble the guide and bush onto the screwed rod, with the spigoted end of the adaptor fitted into the bearing being installed.

9. Fit the 'C' plate onto the centre bar behind the adaptor and rotate the main handle to draw the bearing into the housing until is is flush with the face.

10. Repeat the operation for each of the bearings.

11. After fitting the front bearing, bend the tang into the locating hole in the cylinder block - see Fig. 37.

12. Fit a new expansion plug into the rear face of the cylinder block. Apply a thin film of specified sealer to the outer periphery of the plug and around the plug bore before pressing into position. The sealer must be kept clear of the camshaft bearing.

13. Lubricate the bearings with clean engine oil and install the camshaft carefully to avoid damaging the bearings. Check to ensure it rotates freely.

NOTE: If a new camshaft is being installed the phosphate coating on the journals must be burnished off in a continuous rotating movement, in the normal direction of rotation.

CYLINDER LINER RENEWAL - 2726T AND 2728T ENGINES ONLY

This operation is described using an EPCO Flexiforce Cylinder Liner Press (FF 138). Alternative equipment may be used providing a suitable replacer plate is available to give the specified protrusion of the new liner when assembled into the block.

1. Assemble the four support legs into the cylinder pressure plate and the main pressure plate onto the opposite end of the legs - see Fig. 39.

2. Locate the assembly over the liner to be removed and retain with a locating bolt into one of the cylinder head stud holes.

3. Insert the long pull rod through the cylinder bore and assemble the remover plate, washer and nut to the lower end.

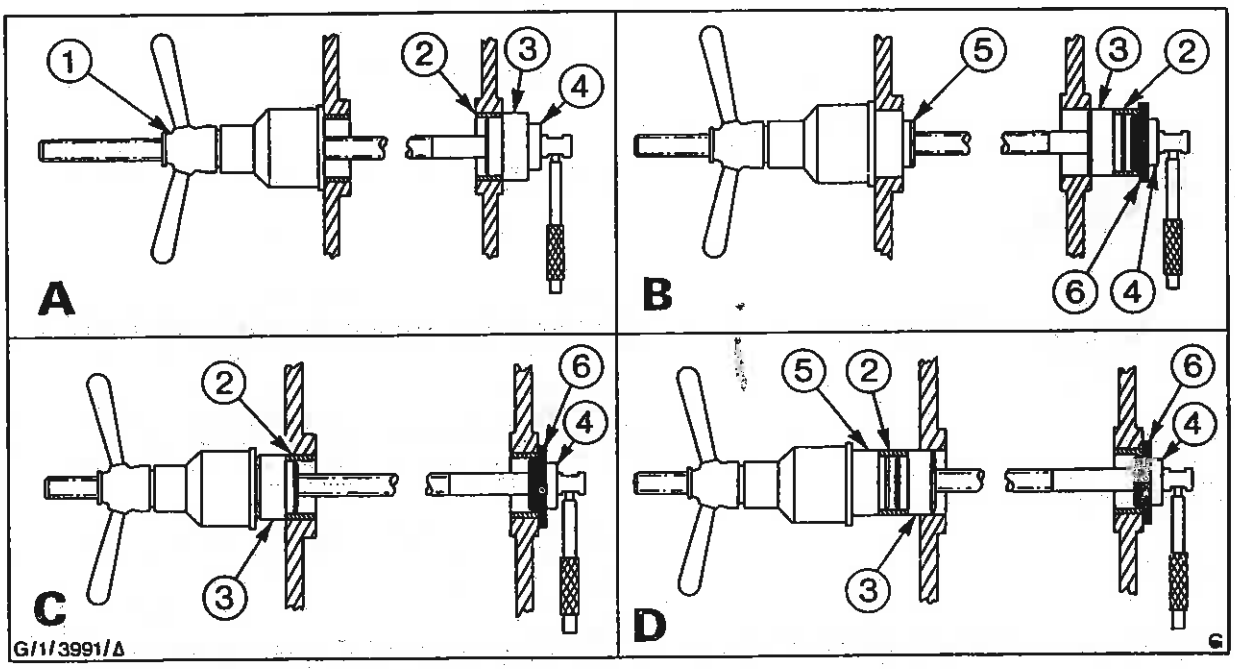


Fig. 38 - Camshaft Bearing Renewal
A. Removing an Intermediate Bearing
B. Installing an Intermediate Bearing
C. Removing a Front or Rear Bearing
D. Installing a Front or Rear Bearing
1. Main Tool Remover/Installer No. 21-022
2. Bearing
3. Long Adaptor/Locator
4. Parts of Tool No. 21-022-51A
5. Short Adaptor/Locator
6. Shouldered Locator/Installer

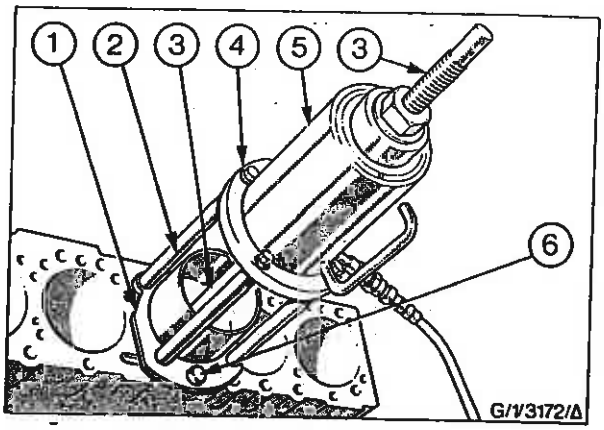


Fig. 39 - Cylinder Liner Removal
1. Cylinder Pressure Plate
2. Support Legs
3. Pull-Rod
4. Ram Pressure Plate
5. Ram Assembly
6. Retaining Bolt

4. Position the ram assembly over the pull rod and locate the ram base into the ram pressure plate. Pass the pull rod through the ram and retain the washer and nut.

5. Ensure the remover plate is correctly located in the lower end of the liner and tighten the upper nut to nip the assembly together.

6. Connect the hydraulic pump to the ram, close the pressure release valve and operate the pump to withdraw the liner.

7. When the ram reaches the end of its stroke release the pressure and allow the ram to return to the free position. Adjust the length of the pull rod by tightening the upper nut, close the pressure release valve and operate the pump to further withdraw the liner.

8. Repeat the operation until the liner is fully withdrawn.

9. Thoroughly clean and degrease the cylinder block bore and the new cylinder liner.

10. Coat the outside surface of the new cylinder liner with Locquic Primer T (FORD Specification SM4G-4647-A) and allow to dry.

11. Apply a 75 mm (3 in) wide band of Loctite Sealer (FORD Specification EM4G-64) to the top of the cylinder block bore.

12. Enter the liner into the block, internal chamfer uppermost, using a hide mallet. Check that the liner is perfectly square with the cylinder block using a square against the cylinder block face in at least four places.

13. Assemble the two long pull rods together using the pull rod coupler, and assemble the cross beam with a nut and washer to the lower end. Pass the assembly through the cylinder bore and liner, locating the cross beam across the bottom face of the crankcase - see Fig. 40.

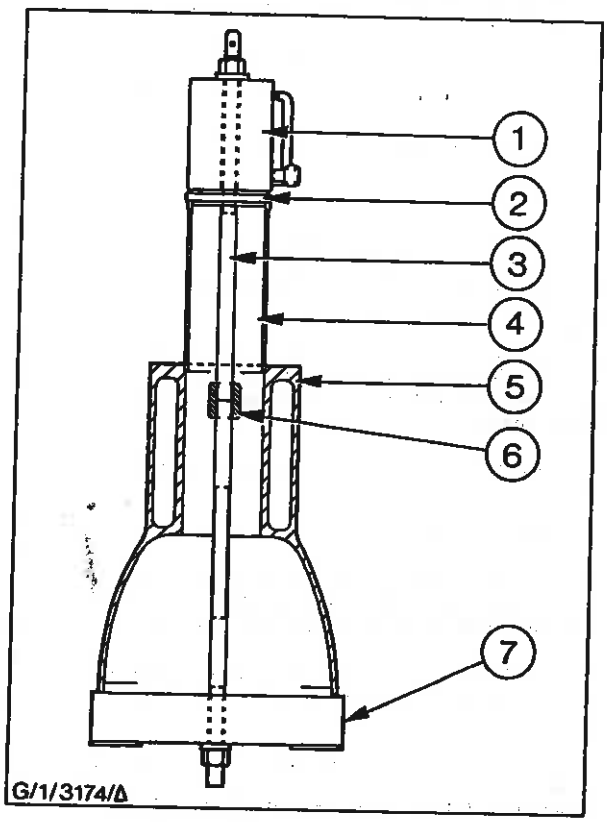


Fig. 40 - Fitting Cylinder Liner
1. Ram
2. Replacer Plate
3. Pull-Rod
4. Liner
5. Cylinder Block
6. Coupler
7. Crossbeam

14. Slide the replacer plate over the top of the pull rod and locate the groove on to the top of the liner.

15. Place the ram assembly over the pull rod and against the replacer plate. Fit the nut and flat washer and tighten to nip the assembly together.

Adjust the length of the pull rod by tightening the upper nut, close the pressure release valve and operate the pump to further press the liner into the block.

16. Connect the hydraulic pump to the ram, close the pressure release valve and operate the pump two or three strokes to pressurise the system and take up any free play. Check to ensure that the cross beam is central under the bore and that the liner is still perfectly square with the block and operate the pump to press the liner into the block. Check to ensure the liner is entering the block squarely.

17. When the ram reaches the end of its stroke, release the pressure and allow the ram to return to the free position.

18. Repeat the operation until the liner is fully home and the replacer plate is flush against the cylinder block face. (The groove in the replacer plate should give the correct liner protrusion).

NOTE: Maintain the operations in an as continuous a sequence as possible. Do not allow the pressing operation to stop any longer than is absolutely necessary to adjust the pull rod nut.

19. Remove the press and check the liner protrusion.

CYLINDER HEAD OVERHAUL

The following dismantling instructions exclude the rocker shaft assembly, push rods and injectors which would have been removed when dismantling the engine.

1. Remove the valve stem caps in sequence so that each cap can be replaced on the same valve during assembly.

2. Using the Valve Spring Compressor and Adaptors (21-024, 21-024-02, and 21-516) depress each valve spring in turn and remove the collets, retainers, springs, seats, seals and valves. Retain each assembly in a numbered sequence for reassembly to the same position in the head.

CLEANING AND INSPECTION

Thoroughly clean the cylinder head in a kerosene bath, using a soft metal scraper to clean away carbon deposits. Ensure all water and oil passages are flushed clean. Clean gasket faces with a blunt scraper. Dry the head with compressed air. Scrape carbon from the valves and clean them on a buffing wheel.

Examine the head visually for obvious damage; cracks, scored flange faces, bent studs, damaged threads or loose valve guides. Tap the valve seat inserts lightly to detect any looseness. Mark any seats which are loose, worn, burnt or otherwise require renewal.

Where required, check the cylinder head for cracks using dye penetrant or magnetic detection methods. Reject a cracked head.

Check the cylinder head-to-block face for longitudinal and transverse bowing. If outside the specified limits the head may be skimmed to restore flatness.

NOTE: Skimming will require valve seat renewal to enable counterbore recutting. This is essential to maintain valve seat to head face relationship.

Measure the valve guide bores for wear and ovality with a small bore gauge. Where a gauge is not available, use a new valve to estimate any wear. Mark worn guides for renewal.

RESURFACING

An end mill (carbide tool tip cutter) of 250 mm (10 in) minimum diameter must be used for resurfacing the head. Under no circumstances is grinding permitted.

A tool tip speed of 1,22 m/s (240 ft/min), a tool feed speed of 0,076 mm (0,003 in) per rev/min per tool tip and a tool cutting angle of 0,10 to 0,25 mm (0,004 to 0,010 in) positive must be adopted to achieve the required surface finish of 2032 to 3048 nanometres (80 to 120 micro inches).

When clamping the head to the machine table, the 'bowed' condition must be maintained to ensure that it will be removed by the machining process.

After resurfacing, renew the valve seats as described elsewhere in this section.

VALVE GUIDE RENEWAL

Using Valve Guide Installer/Remover Tool (21-500) or a suitable press, remove the valve guide(s). Check the cylinder head bore for scoring or tearing. Carefully stone out any damage, removing only the burred material.

Using the special tool or a bench press, insert the new guide (internally chamfered end facing outwards) to the specified protrusion - see Fig. 41.

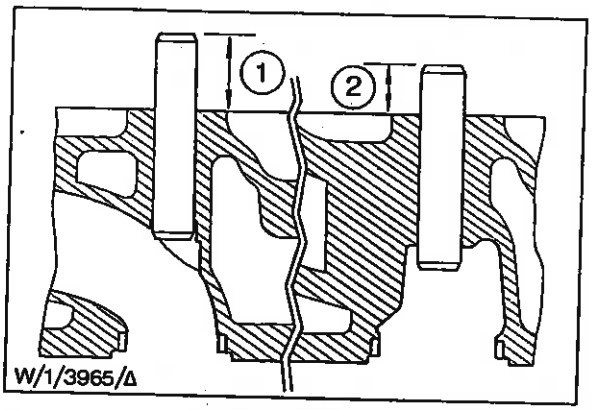


Fig. 41 - Valve Guide Protrusion
1. Exhaust
2. Inlet

Check the valve guide/seat concentricity by carrying out a 'blueing' check and recut or relap the seats as required.

VALVE SEAT INSERT RENEWAL

This operation requires special equipment beyond the scope of this manual, however, the following points should be observed:

Remove the inserts by machining. Any other method may cause irreparable damage to the cylinder head.

Remove only the minimum amount of material (if any) to clean up the insert recess. If the cylinder head face has been skimmed, recut the recess by an amount equal to the skimming cut. Where oversize inserts are to be fitted, recut in depth and diameter to accommodate the larger insert.

Maintain concentricity with the existing counterbore and use the cylinder head upper face as the datum for measurements.

Shrink the new seats in liquid nitrogen for a minimum period of 5 minutes before fitting.

After fitment, cut the seats to the smallest possible specified width and check for 100% circumferential contact. Lap in lightly as required.

NOTE: Due to the design difference of valve seat and valve face angle, it is not necessary to attempt to gain full seat width contact.

Label the valves as per their lapped position.

VALVES AND VALVE CAPS

Examine the valves and reject any which are burnt, pitted, cracked, bent or worn beyond specified limits. Discard any valve cap which is grooved or valve collets which are worn. Although it is preferable to renew all valves during overhaul, otherwise serviceable valves may be refaced and refitted provided that the specified valve protrusion is maintained.

Remove only the minimum amount of metal to correct any fault then lap the valves to the seats with grinding paste. Check the seating with engineers blueing compound, checking for a 100% minimum, but narrow band of contact.

NOTE: Label the valves after lapping to ensure they will be fitted to their respective seats.

Thoroughly clean all traces of lapping compound from the valves and seat inserts.

VALVE SPRINGS

Except where the springs are to be renewed, examine for broken or distorted coils. Measure the spring load against the specified length and renew springs which do not come within the limits.

PUSH RODS

Examine the rods generally, check for bend and for worn ball and socket ends. Where required, determine serviceability by blue checking against a new cam follower and rocker arm adjusting screw.

ROCKER SHAFT ASSEMBLY - SEE FIG. 42

Dismantle the assembly by removing the shaft locking bolts and sliding all components from the shaft(s). Remove each component in sequence so that it can be replaced in the same position when assembling. Remove and discard the shaft cup plugs. Clean all components in kerosene and ensure all oilways are clear.

Measure the rocker shaft diameter in the rocker arm areas. Discard if grooved or worn beyond limit.

Examine the rocker arms for cracks, worn or grooved valve pads and worn bushes. Check the condition of the adjusting screw ball end and the self locking property (torque required to turn) of the screw against the specified limits. Discard any arm assembly which does not meet specifications.

Examine the shaft supports for cracks.

Examine the springs for general conditions and check the 'load to compress to specified length'. Renew any which do not conform to the limits.

Using a suitable tool, press new cup plugs in the shaft(s). For 6 cylinder engines, note that only the outermost end of each shaft is recessed for the plug. The inner end must be left open for the passage of oil.

Lubricate the shaft(s) and assemble the components into the order shown. Fit new lock washers, then correctly locate and tighten the intermediate support bolts to the specified torque.

NOTE: On 6 cylinder engines, the inner end of each 'half shaft' is a sliding fit in the central support, the actual positions being determined during installation to the engine.

Use string, locking wire or large, old 'O' rings to 'tie' the assembly together until it is required for installation.

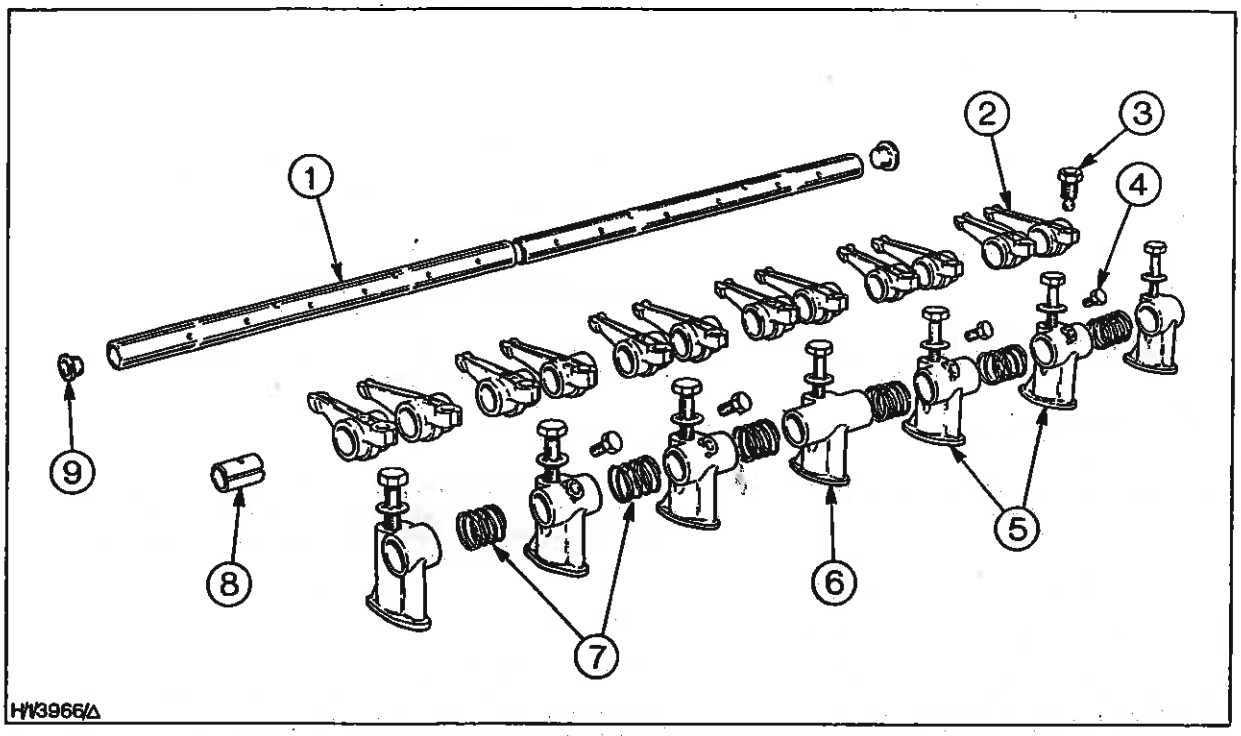


Fig. 42 - Rocker Shaft Assembly Exploded - 6 Cylinder Engines

1. Rocker Shafts
2. Rocker
3. Adjusting Screw
4. Shaft Locking Bolt
5. Support Pillars
6. Support Pillar with Oil Feed
7. Spacer Springs
8. Bush
9. Cup Plug

FITTING THE VALVES

Lightly lubricate the valve guides and insert the valves in their respective positions. Use a piece of wood to hold the valves onto their seats while the cylinder head is face down.

Position the valve spring seating washers and fit new seals to all valve stems as follows:

Inlet Valves of Naturally Aspirated engines: Fit spring loaded type seals only to these valves. Install the seals with the Seal Installer (21-537) - see Fig. 43.

CAUTION: FAILURE TO INSTALL THE SEALS CORRECTLY CAN CAUSE HIGH OIL CONSUMPTION AND SEVERE CARBONING OF THE INLET PORTS.

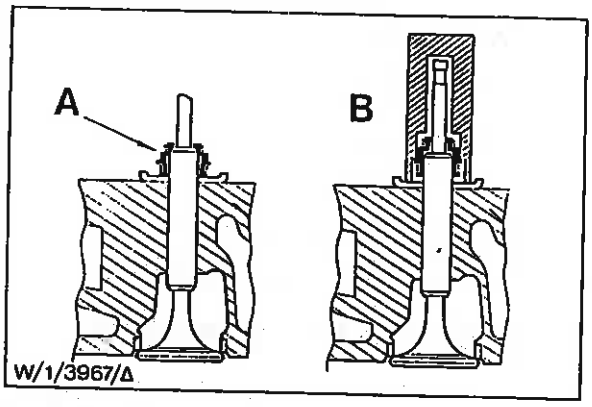


Fig. 43 - Fitting Inlet Valve Stem Seals on Naturally Aspirated Engines
A. Incorrectly installed causing enlarged sealing edge
B. Correctly installed using Tool No. 21-537

All other valves: Fit plastic umbrella type seals.

Position the valve springs and retainers, compress the springs with the special tool (21-024, 21-024-02, and 21-506) and fit the collets.

NOTE: Exhaust valve springs are longer than inlet springs before fitting and are identified by a painted yellow line. Both inlet and exhaust valve springs may be fitted either way up.

Lightly lubricate and install the valve stem caps.

CAUTION: IF AN INLET VALVE SEAL OF A NATURALLY ASPIRATED ENGINE IS REMOVED FOR ANY REASON - TEMPORARY OR OTHERWISE, IT LOSES ITS OIL CONTROLLING CAPABILITY. ALWAYS FIT A NEW SEAL AND DESTROY THE OLD.

CLUTCH PILOT BEARING

Extract the bearing using Remover, Tool No. 21-036. Drive the new bearing into position, using a hardwood block and a mallet.

NOTE: Bush type bearings must be driven home until the underside of the flange is in contact with the flywheel face. Ball type bearings must be installed so that the outer end is flush with the housing.

FLYWHEEL RING GEAR RENEWAL

1. Remove the six countersunk screws retaining the ring gear to the flywheel.

2. If an oven with heat control is available, heat the flywheel and ring gear to 190°C (375°F) and remove the ring gear using a hammer and a blunt nosed chisel.

3. If an oven with heat control is not available support the flywheel in a sturdy vice taking great care not to damage the flywheel face, and cut through the ring gear between two of the teeth and in line with one of the retaining screw holes using a sharp hacksaw. Cut into the ring gear as far as possible taking care not to cut into the flywheel.

4. Take a sharp chisel and a heavy hammer and drive the chisel into the cut from the outer (toothed) edge again taking care not to damage the ring gear register. The ring gear should snap across the line of the cut and will spring apart.

5. Clean the flywheel. Lightly stone off any burrs but do not clean the ring gear register with emery cloth or similar materials as this could upset the interference fit of the ring gear.

6. Screw locating studs into two diametrically opposite retaining bolt holes in the flywheel.

7. If an oven with heat control is available, heat the ring gear to 190°C (375°F).

8. If an oven with heat control is not available, support the ring gear on a flat heat resistant surface (e.g. fire brick) and heat the ring gear evenly using a suitable heating torch (NOT a cutting torch) to 190°C (375°F). To ensure the ring gear is not overheated use a 190°C (375°F) Tempilstick crayon or equivalent. Stroke the ring gear several times with crayon whilst applying heat. The crayon will leave a chalk mark until the temperature is reached when a liquid smear will appear.

CAUTION: OVERHEATING WILL SOFTEN THE RING GEAR.

9. Locate the ring gear over the two locating studs and tap it firmly and evenly into place while still hot.

10. Remove the locating studs.

11. Apply specified sealer to the retaining screw threads and tighten to the specified torque.

ASSEMBLING THE ENGINE

GENERAL

Lubricate all moving parts and threads with clean engine oil as assembly proceeds unless otherwise instructed.

Use only the specified sealers where indicated.

BASIC ENGINE ASSEMBLY

1. Mount the engine on the Stand (200B) using Mounting Bracket (21-535).

2. Check, renew, or refit as necessary all blanking plugs, expansion plugs, union adaptors and studs removed during overhaul and cleaning.

3. On the threaded main oil gallery plugs (front, side and rear) apply specified sealer to the leading threads before fitting. Tighten to the specified torque.

4. On the oil gallery core plug (rear), the tachometer drive blanking plug and the cylinder block rear water jacket core plug (4 cylinder engines only) apply specified sealer around the plug bore and drive the plug firmly home - see Fig. 44.

CAUTION: DO NOT ALLOW THE SEALER TO CONTACT THE CAMSHAFT REAR BEARING.

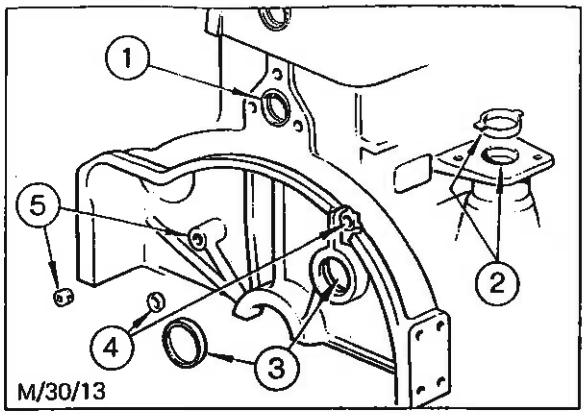


Fig. 44 - Cylinder Block Blanking Plugs
1. Rear Water Jacket Core Plug (4 cylinder only)
2. Tachometer Drive Blanking Plug
3. Camshaft Bore Rear Cup Plug
4. Oil Gallery Core Plug
5. Main Oil Gallery Threaded Plug (also front, and side when not fitted with Turbocharger)

5. On the camshaft bore rear cup plug, apply specified sealer to the outer periphery of the plug and around the plug bore and drive the plug firmly home. DO NOT allow the sealer to contact the camshaft rear bearing.

6. On the water pump studs, apply specified sealer to the leading threads before fitting. Tighten to the specified torque.

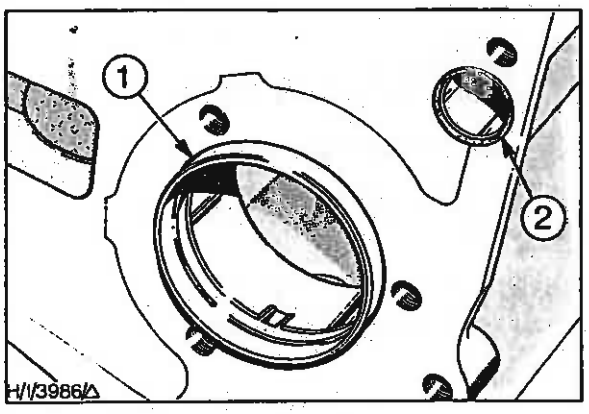


Fig. 45 - Cylinder Block Front Face
1. Timing Gear Housing Locating Ring
2. Oil Gallery Seal 'O' Ring

7. Place the timing gear housing locating ring into the counterbore in the camshaft front bearing housing, and tap it firmly against the stop using a soft faced mallet (Fig. 45.).

8. Invert the engine to bring the crankcase oil pan face uppermost.

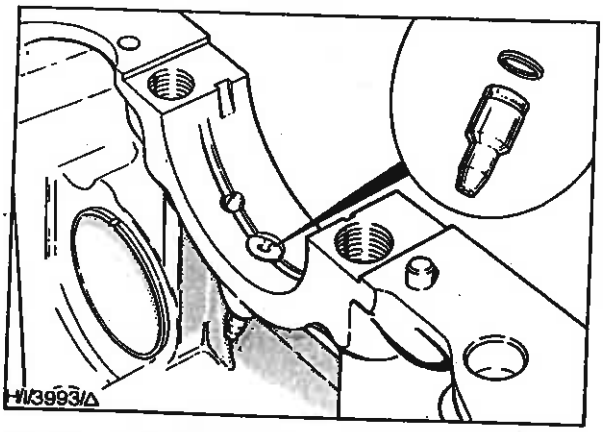


Fig. 46 - Piston Cooling Nozzle

9. On 2728T intercooled engines, if the piston cooling nozzles have been removed, fit new 'O' rings to the nozzles and fit the nozzles into the main bearing housings (Fig. 46). Lightly lubricate the 'O' rings to aid assembly. Ensure the nozzles do not protrude into the bearing housings.

NOTE: The centre main bearing housing is not fitted with a piston cooling nozzle.

10. Ensure the front main bearing cap locating dowels are in position and driven firmly home.

CAMSHAFT INSTALLATION

11. Locate the camfollowers into their respective bores in the block.

12. Enter the camshaft into the block taking great care not to score or damage the bearing liners on the cam lobes.

NOTE: When fitting a new camshaft to a heavy duty PTO engine, only the specified heavy duty camshaft must be used.

CRANKSHAFT INSTALLATION

13. Install the graphited fibre rope type seal into the groove in the rear main bearing cap and the cylinder block. DO NOT use any sealer or adhesive. Tap the seal fully home into the respective grooves using Seal Installer 21-506 as shown in Fig. 47.

With each half seal held with the installer, trim the ends of the seal with a sharp knife or scalpel to leave 0,635 to 0,762 mm (0,025 to 0,030 in) proud of the face. Trim off any frayed threads.

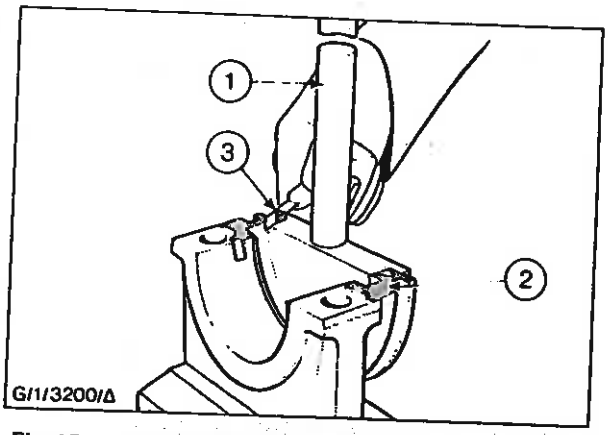


Fig. 47 - Fitting Crankshaft Rear Oil Seal - (Main Bearing Cap Shown)
1. Installer (21-506)
2. Seal
3. Trim Seal

14. Ensure the main bearing housings and caps are perfectly clean and dry and fit the main bearing liners into their respective positions, with the locating tongues engaged in the slots.

NOTE: The liners with oil holes and a continuous oil groove fit into the block, those without oil holes fit into the caps. The centre and rear main bearing cap liners only, have a continuous oil groove.

15. Fit the centre main bearing upper thrust washers into position ensuring that the tongues are located in the anchor slots - see Fig. 48.

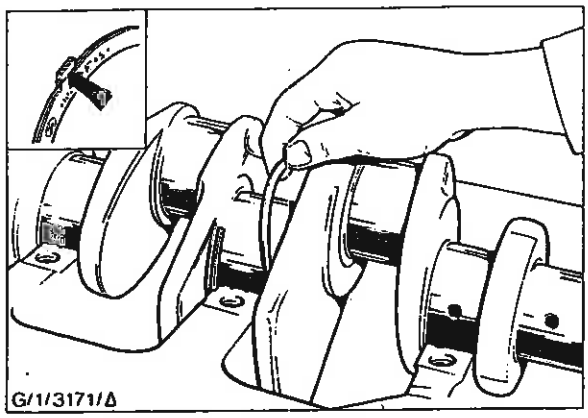


Fig. 48 - Installing Centre Main Bearing Upper Thrust Washers

16. Thoroughly lubricate the bearing liners and crankshaft main journals. Apply a smear of grease (FORD Specification SGM-1C-9001A) to the running surface of each half of the rear main oil seal.

17. Carefully lower the crankshaft into the block taking care not to disturb or damage the centre main bearing thrust washers.

The 2720 range of engines originally used one of two alternative crankshaft thrust washers. If the tag on the lower thrust washer, shown in the inset of Fig. 48, has a groove, this can cause loss of strength and possible breakage of the tag.

With effect from 24th February, 1983, only lower thrust washers without grooved tags have been fitted in production.

If the tags on the lower thrust washers are grooved, discard the thrust washers and replace with the later type - see following Part Nos.

Parts Required

Description	Part No.	Finis Code	Qty
Kit-Crankshaft main thrust washer			
Standard	826F-6A355-AIA	6106285	2
+0,0025 in oversize	826F-6A355-BIA	6106287	2
+0,005 in oversize	826F-6A355-CIA	6106289	2
+0,0075 in oversize	826F-6A355-DIA	6106291	2
+0,010 in oversize	826F-6A355-EIA	6106293	2
+0,015 in oversize	826F-6A355-FIA	6106295	2
+0,020 in oversize	826F-6A355-GIA	6106297	2

18. Locate the centre main lower thrust washers into the centre main bearing cap and fit it to the block. Tighten the bolts finger tight. Fit the intermediate and front main bearing caps and liners into their respective positions and tighten the bolts finger tight.

19. Lever the crankshaft backwards and forwards axially to ensure the centre main bearing cap is centralised and tighten the bolts to the specified first stage torque. Check crankshaft rotation.

20. Ensure that the rear main bearing cap and block mating faces are clean and dry, and apply specified sealer to the cylinder block at the areas shown in Fig. 49.

CAUTION: (i) THIS SEALER HARDENS ON CONTACT WITH METAL AND THE JOINT MUST NOT THEREFORE BE LEFT IN A DISMANTLED CONDITION ANY LONGER THAN IS ABSOLUTELY NECESSARY.

(ii) IT IS ESSENTIAL THAT THE SEALER IS APPLIED WITH A FINE TIPPED NOZZLE TO THE AREAS SHOWN.

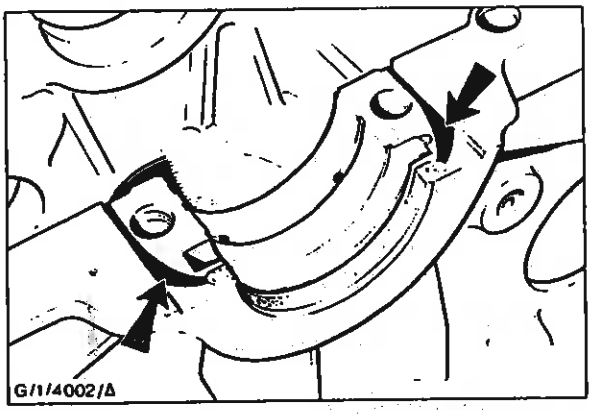


Fig. 49 - Crankshaft Rear Main Bearing Housing (Apply Sealer in areas shown)

21. Fit the rear main bearing cap and tighten the bolts to the specified first stage torque.

22. Tighten the remaining main bearing cap bolts in turn to the specified first stage torque, checking the crankshaft rotation after tightening each cap.

23. Check the crankshaft end float. Lever the crankshaft forward to take up end float in one direction, and insert feeler blades between the crankshaft thrust washer and the crankshaft to check that the end float is within the specified limits - see Fig. 50.

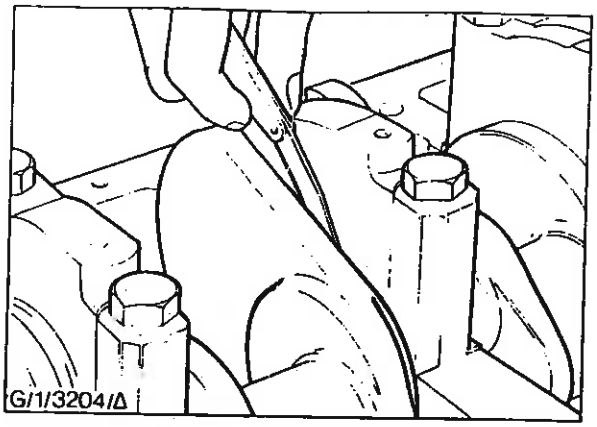


Fig. 50 - Measuring Crankshaft End-Float

24. Fit oversize thrust washers if the end float is excessive and recheck as before.

25. Tighten the main bearing cap bolts in turn to the specified second stage torque again checking the crankshaft rotation after tightening each cap.

CRANKSHAFT GEAR INSTALLATION'

26. Fit the crankshaft gear key into the crankshaft, stepped end toward the front end of the crankshaft.

27. Heat the crankshaft gear to 82°C (185°F) in a suitable hotplate, oven or oil bath, and fit it over the crankshaft, shouldered face outermost, aligning the keyway with the key in the crankshaft. Push or drive it fully home against the shoulder.

TIMING GEAR HOUSING INSTALLATION

28. Locate a new 'O' seal ring into the counterbore at the end of the oil gallery on the front face of the block and position the timing gear housing (using a new gasket) over the locating ring - see Fig. 51.

29. Fit the camshaft thrust collar, shouldered face outermost, the thrust plate (well lubricated), and the lockplate. Fit the bolts but do not tighten – see Fig. 52A.

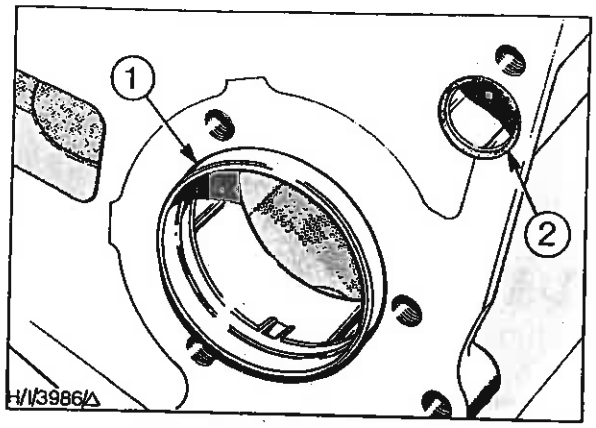


Fig. 51 - Cylinder Block Front Face
1. Timing Gear Housing Locating Ring
2. Oil Gallery Seal 'O' Ring

NOTE: On later engines, fit the camshaft bushing, slotted face outwards, and the thrust plate (well lubricated) – see Fig. 52B. Fit the retaining bolts and washers but do not tighten at this stage.

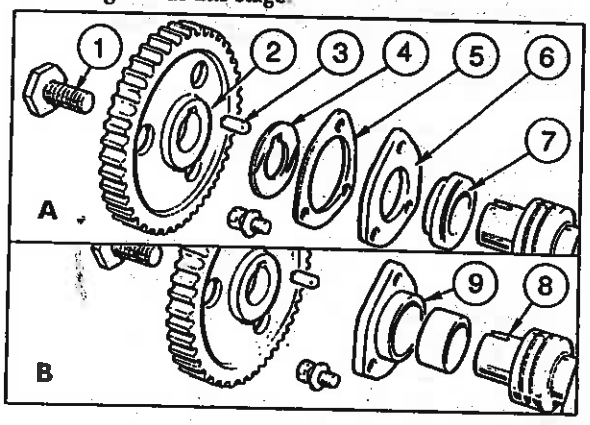


Fig. 52 – Camshaft Gear Assembly
1. Gear Retaining Bolt
2. Camshaft Gear
3. Key
4. Thrust Washer
5. Retaining Plate
6. Thrust Plate
7. Thrust Collar
8. Bushing
9. Thrust plate

30. On 2728T Intercooled engines, check the alignment of the lower face of the timing gear housing in relation to the lower face of the crankcase. Looking from the front of the engine in the inverted position, the faces on the left side must be flush, with the right side as near flush as possible or to within a maximum of 0,18 mm (0,007 in) misalignment either above or below the face - refer to Figs. 53 and 54.

Check that the three studs are secure - see Fig. 53. If new studs are fitted apply the specified sealant to the threads when screwing them into position.

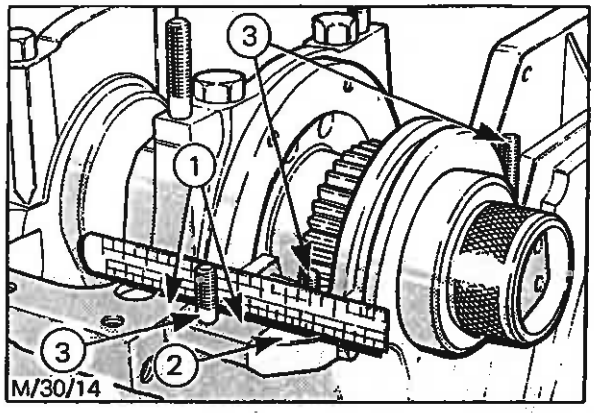


Fig. 53 - Timing Gear Housing and Cover Alignment (Left Hand Side on 2728T Engines)
1. Housing Flush with Block Face
2. Cover Parallel to Housing and Block
3. Oil Pan Studs

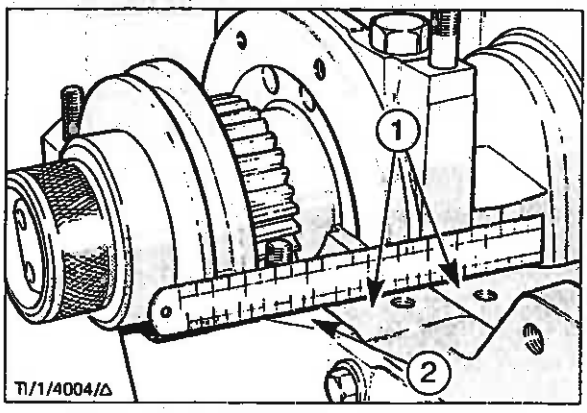


Fig. 54 - Timing Gear Housing and Cover Alignment (Right Hand Side) on 2728T Engines)
1. Housing Flush to within a maximum of 0,18 mm (0,007 in) Misalignment
2. Cover Parallel to Block

31. Nip the camshaft thrust plate bolts to secure the housing in position then tighten all the bolts in the sequence shown to the specified torque - refer to Fig. 55 or 56.

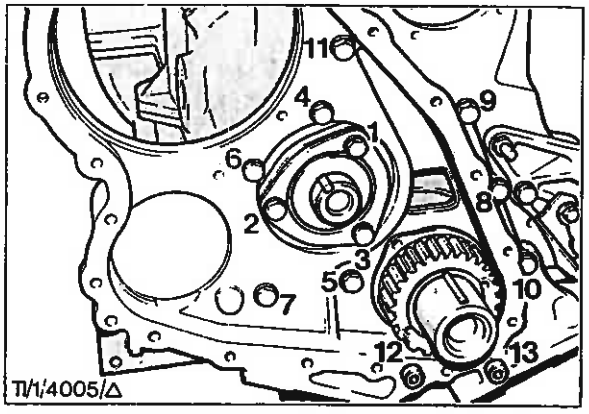


Fig. 55 - Timing Gear Housing Bolt Tightening Sequence - 4 Cylinder Engines

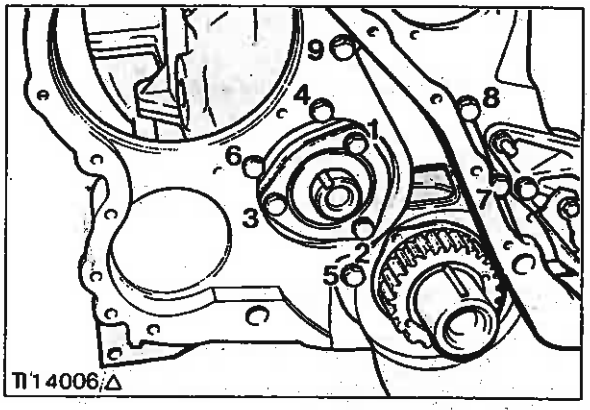


Fig. 56 - Timing Gear Housing Bolt Tightening Sequence - 2728T Engines

32. Fit the thrust washer, grooved face innermost, and the camshaft key to the camshaft.

CAMSHAFT GEAR INSTALLATION

33. Rotate the crankshaft and camshaft to bring both shafts in correct relationship to one another so that the timing marks on both gears will line up with one another when the camshaft gear is fitted. Fit the camshaft gear on to the camshaft ensuring that the keyway and the timing marks are correctly aligned - see Fig. 57. DO NOT hammer the gear on to the shaft. If the gear is too tight to fit easily, heat the gear to 82°C (180°F) before fitting it onto the shaft.

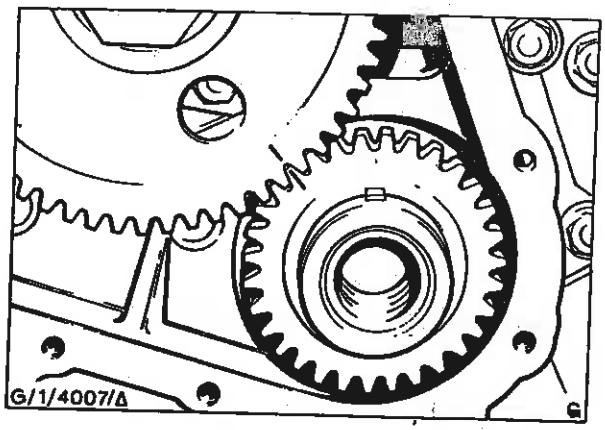


Fig. 57 - Camshaft and Crankshaft Gear Timing Marks in Alignment

34. Tighten the camshaft gear retaining bolt to the specified torque.

NOTE: IF A HEAVY DUTY PTO CAMSHAFT IS FITTED, THE SPECIAL LONG GEAR RETAINING BOLT MUST BE USED. THE LONG BOLT MUST NOT BE USED WITH STANDARD DUTY CAMSHAFTS - PROBE THE DEPTH OF THE HOLE WITH A PIECE OF STIFF WIRE TO ESTABLISH THE TYPE OF CAMSHAFT FITTED.

35. Check the camshaft end float using a dial gauge and magnetic base. If the end float is excessive the thrust collar and thrust washer must be renewed.

36. On 6 cylinder engines, if the crankshaft has been renewed, fit the crankshaft pulley adaptor insert. Apply four drops of specified sealer to the leading threads before assembly and tighten to the specified torque.

FRONT COVER INSTALLATION

37. Position a new gasket onto the front face of the timing gear housing.

38. Place the front cover onto the housing using the Housing Aligner/Seal Installer (21-536) to position the cover assembly over the crankshaft.

39. Fit the bolts and flat steel washers ensuring that the correct length bolts and socket headed bolts, when used, are installed in the correct locations.

40. On all except 2728T engines, tighten the bolts gradually and evenly to the specified torque.

41. On 2728T engines check to ensure that the lower face of the cover is parallel and flush to within 0,152 mm (0,006 in) with the crankcase lower face. Tighten the bolts evenly and gradually to the specified torque.

42. Remove the Housing Aligner/Seal Installer Tool.

CRANKSHAFT PULLEY SEAL INSTALLATION

43. After the timing housing cover has been installed and the Aligner Tool No. 21-536 removed, check the crankshaft pulley hub outer diameter at the point where it runs in the front oil seal. If the seal is in contact with a highly polished ring, remove one or both spacers (one spacer only on the 2722 engine) before installing the oil seal - see Fig. 58. This will enable the seal to run on an unpolished part of the pulley hub. Failure to do this could result in an overheated seal and subsequent oil leakage.

44. Locate the oil seal, lipped edge inwards as shown in the inset of Fig. 58 and push it fully home using tool No. 21-536. DO NOT use any sealant for this operation.

45. Invert the engine to bring the top face of the block uppermost.

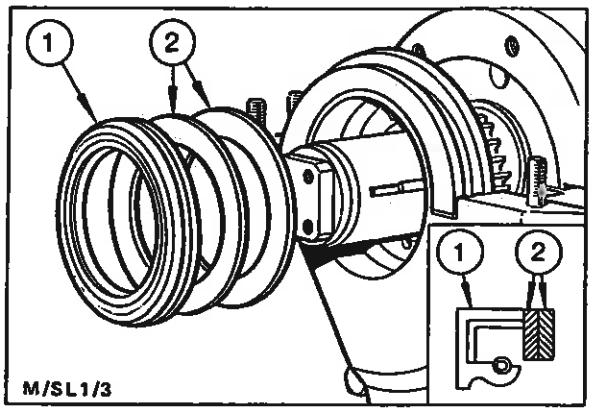


Fig. 58 - Assembling Crankshaft Pulley Oil Seal into Timing Gear Housing Cover
1. Oil Seal
2. Spacers

PISTON AND CONNECTING ROD ASSEMBLY AND INSTALLATION

If the original crankshaft is being used, then the original connecting rods, if serviceable, or new rods of the same grade length can be used in reassembly. If a new or reground crankshaft is being used it may be necessary to fit different grade rods in order to maintain the piston protrusion (bump height) within the specified limits - see under 'Checking Bump Height'.

46. Assemble each piston to its respective connecting rod. Heat the piston in hot water, locate the small end of the connecting rod into the piston ensuring that the arrow or notch on the piston crown and 'F' or 'Front' mark on the connecting rod are facing the same way (Fig. 59) and insert the piston pin into the piston and through the connecting rod. Fit the two retaining circlips.

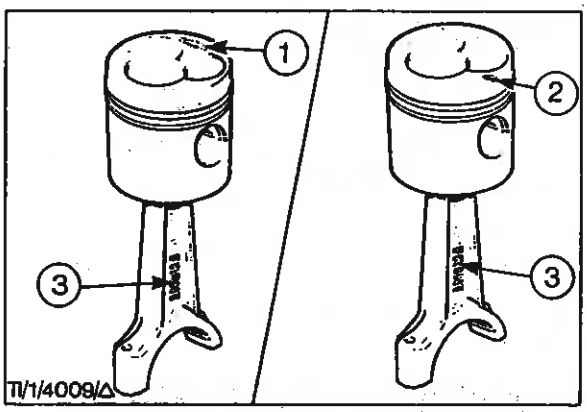


Fig. 59 Piston and Connecting Rod 'Fitting' Marks (Towards Front of Engine)
1. Arrow on Piston Crown Pointing towards front of Engine
2. Cut Out in Piston Crown
3. 'FRONT' on Connecting Rod Web

47. Assemble the piston rings into their respective grooves on the piston ensuring that the 'TOP' marked face is uppermost.

NOTE: (i) Turbocharged engines have one tapered upper compression ring, two lower chamfered compression rings and one oil control ring - see Fig. 60 (A).

(ii) All naturally aspirated engines have one plain upper compression ring, one lower chamfered compression ring and one oil control ring - see Fig. 60 (B).

(iii) It is particularly important that the lower compression rings on all engines are assembled the correct way up as the effect of the slight chamfer on the face of the ring if inverted will be to induce lubricating oil into the combustion space giving rise to smoke and excessive oil consumption.

48. Rotate the crankshaft to bring the respective journal to its lowest point.

49. Position the ring gaps at 90° to one another (turbocharged engines) or 120° (naturally aspirated engines) and using a suitable piston ring clamp, locate the piston and rod assembly into its bore ensuring that the 'FRONT' marks face the front of the engine.

50. Use a soft wooden drift and tap the assembly into the bore, taking care that the lower end of the connecting rod does not foul the crankshaft - see Fig. 61.

51. Working from the bottom of the engine, place the upper half of the big end bearing liner into the connecting rod, and draw the rod into place over the big end journal. Thoroughly lubricate the journal with new engine oil.

NOTE: On turbocharged engines, the upper bearing liner must be fitted so that the oil hole aligns with the hole in the connecting rod.

From November 1987, revised upper bearing liners with slots were introduced. These later type liners which improve piston lubrication, can be fitted to earlier engines.

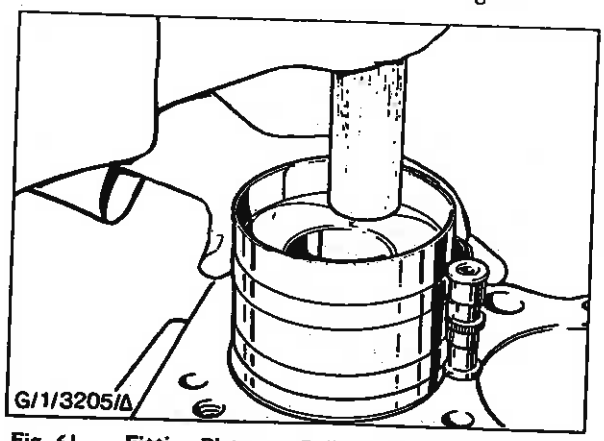


Fig. 61 - Fitting Piston to Cylinder Block

52. Locate the lower half of the big end bearing liner into the connecting rod cap and fit the cap over the journal onto the connecting rod. Tighten the nuts or bolts evenly to the specified first stage torque.

53. Check that the crankshaft can be turned in its normal direction of rotation without using excessive effort, then tighten the nuts or bolts to the specified second stage torque.

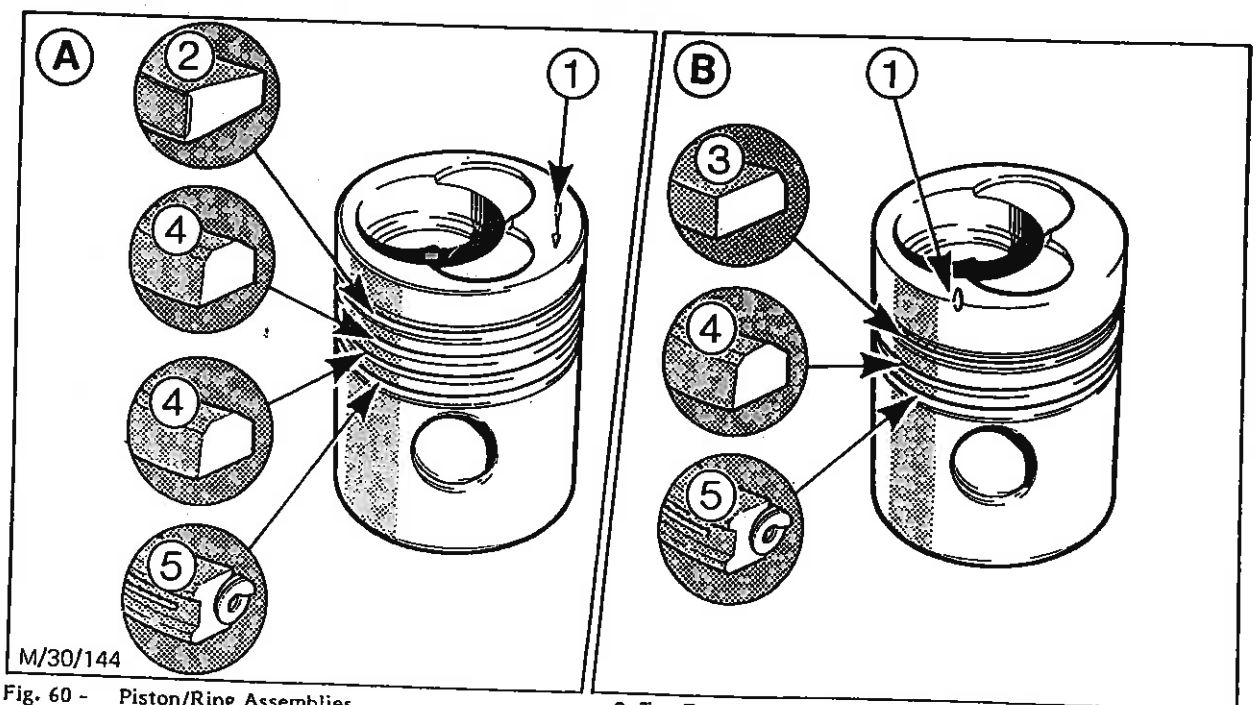


Fig. 60 - Piston/Ring Assemblies
A. Turbocharged Engines
B. Naturally Aspirated Engines
1. 'FRONT' Mark on Piston
2. Top Taper Compression Ring
3. Top Plain Compression Ring
4. Lower Compression Ring(s)
5. Oil Control Ring

CHECKING 'BUMP' HEIGHT

54. Rotate the crankshaft to bring the piston to Top Dead Centre (TDC). Use a dial gauge and magnetic base to ensure piston is at maximum height while applying a load to the top of the piston - see Fig. 62.

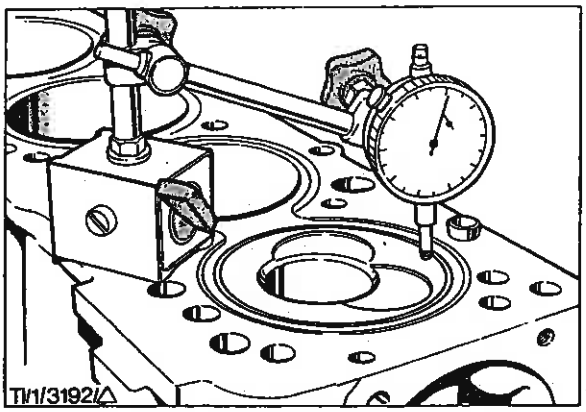


Fig. 62 - Measuring Piston 'Bump Height'

55. Measure and record the protrusion of the piston above the face of the block in at least three places and note the maximum and minimum protrusion (Fig. 63). Calculate the average of the three readings. If the figure is within the specified limits for piston protrusion (bump height) the existing connecting rod length is satisfactory. If, however, the piston protrusion is outside the limits with the grade of rod fitted, it will be necessary to remove the piston and rod assembly and fit a longer or shorter grade of rod as required. Refer to specifications, for rod grades.

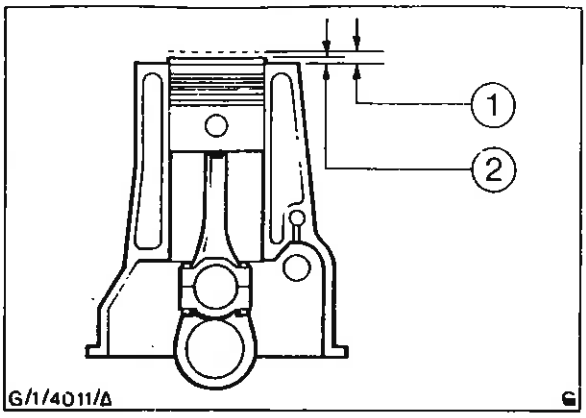


Fig. 63 - Piston Protrusion
1. Maximum Protrusion
2. Minimum Protrusion

56. Check crankshaft rotation after fitting each piston and rod assembly. Investigate and rectify cause if excessive effort is required to rotate crankshaft. When all pistons have been checked for bump height and finally installed, check to ensure rotational effort is within the specified limits.

OIL PUMP INSTALLATION

2722, 2723, 2725, 2726T engines not fitted with high inclination oil pans.

57. Check to ensure that the oil pump is well lubricated and the shaft rotates freely. Lubricate the drive gear with Hypoid 90 oil (FORD Specification EM-2C-29).

58. Locate the pump assembly into the cylinder block and tighten the retaining bolts to the specified torque - see Fig. 64.

59. Fit a new union nut lock tab washer to the pick-up pipe orifice, if not already fitted.

60. Locate the pick up pipe into the pump and the support bracket to main bearing cap. Tighten the union nut to the specified torque. Check to ensure the union nut has fully secured the pipe. Tighten the support bracket bolt to the specified torque. Peen over the union nut lock tab to secure.

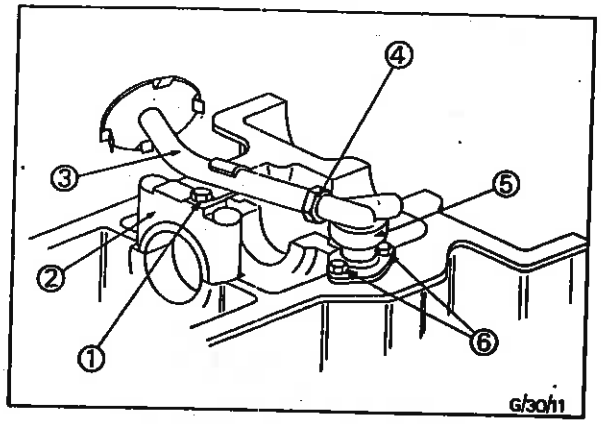


Fig. 64 - Oil Pump Removal/Replacement - 2722, 2723, 2725 and 2726T Engines Not Fitted with High Inclination Oil Pans

1. Support Bracket Bolt
2. Main Bearing Cap
3. Pick-Up Pipe
4. Pick-Up Pipe Union
5. Oil Pump
6. Oil Pump Securing Bolt

2728T Intercooled Engines - Refer to Fig. 66

61. Check that the pump mounting studs in the front main bearing cap are secure and undamaged. Studs should be renewed or refitted as necessary, applying the specified sealer to the leading threads and tightening to the specified torque.

62. Check to ensure that the pump is well lubricated and idler gear rotates freely.

63. Ensure that the main bearing cap shoulders and the pump mounting faces are perfectly clean and dry and mount the pump over the two studs. Engage the idler and crankshaft gear teeth. Ensure that the pump is square and flush to the main bearing cap and tighten the nuts to the specified torque.

64. Fit a new 'O' ring to the oil pick-up pipe, then install the pipe with spacer and new gasket onto the oil pump. Secure pipe flange and bracket with the four bolts tightened to the specified torque.

65. Locate the flanged adaptor into the oil delivery hole in the block. Fit new 'O' rings to both ends of the delivery pipe and assemble it, first into the oil pump, then into the adaptor in the cylinder block. Align the bolt holes in the loose flange and the adaptor with the block; fit and tighten the bolts to the specified torque.

2722, 2723, 2725 and 2726T engines fitted with high inclination oil pans.

1. Locate a new union locking plate on the pump and insert the pipes into their correct locations but do not tighten or lock the unions until the pump is secured to the engine and the pipes correctly aligned - see Fig. 65.

2. Secure the pipe brackets to the block, tighten the pipe unions and bend the locking plate to lock the unions.

3. Fit the gauze screens.

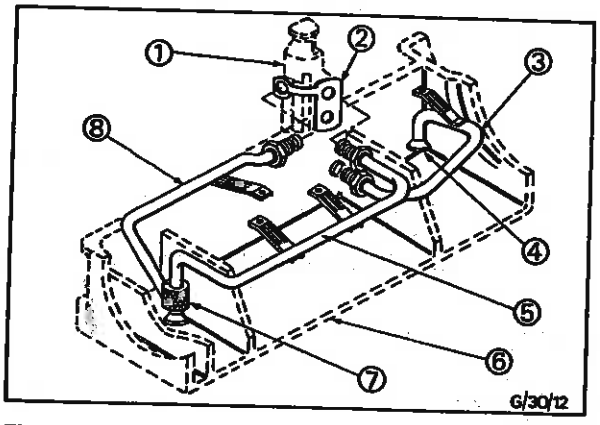


Fig. 65 - Oil Pump and Piping for High Inclination Oil Pans

1. Scavenge Pump
2. Lock Plate
3. Scavenge Pipe
4. Gauze Screen
5. Delivery Pipe
6. Oil Pan
7. Diffuse Box
8. Oil Reservoir Feed Pipe

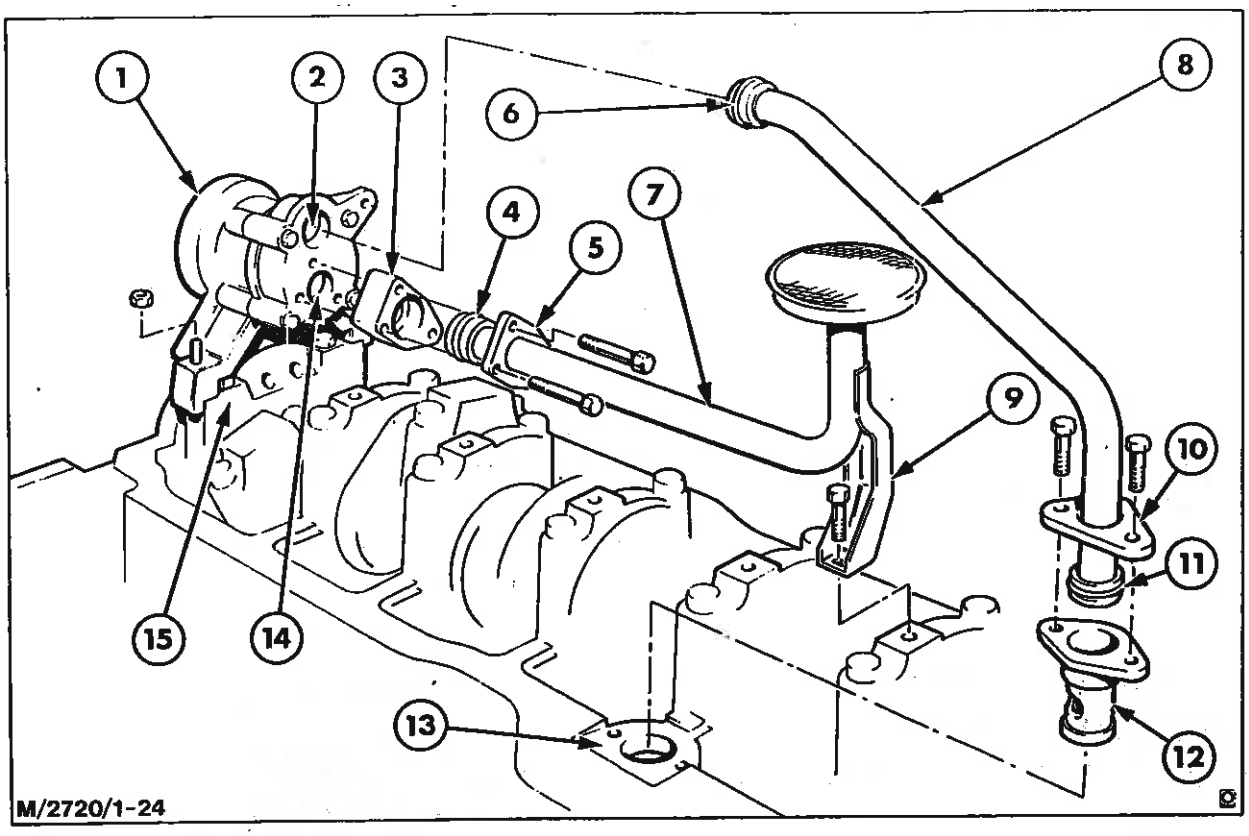


Fig. 66 – Oil Pump Removal/Replacement – 2728T Engines

1. Oil Pump
2. Pump Outlet
3. Spacer
4. 'O' Ring
5. Loose Flange
6. 'O' Ring
7. Pick-Up Pipe
8. Delivery Pipe
9. Support Bracket
10. Loose Flange
11. 'O' Ring
12. Flanged Adaptor
13. Cylinder Block Lower Flange
14. Pump Inlet
15. Front Main Bearing Cap

OIL PAN INSTALLATION

NOTE: Before commencing to fit the oil pan, ensure that the four studs (all except 2728T engine) or the five studs (2728T engine) are in position - see Figs. 53 and 67.

CAUTION: THE SPECIFIED SEALER DRIES RELATIVELY QUICKLY AND SHOULD NOT BE ALLOWED TO FORM A SKIN DURING AN ASSEMBLY SEQUENCE. ONCE STARTED, THE PROCEDURE SHOULD BE PROGRESSED THROUGH TO TORQUE TIGHTENING WITHOUT ANY IDLE PERIOD.

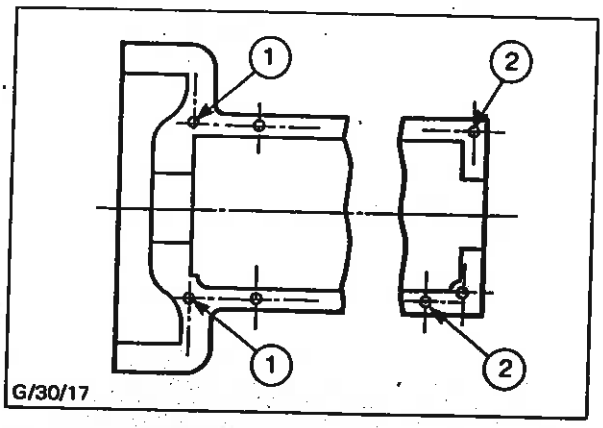


Fig. 67 - Oil Pan Studs
1. Studs for all engines
2. Studs for all engines except 2728T

NOTE: The three studs for 2728T engines not shown here are located in the timing gear housing and cover - see Fig. 53.

All Engines Except 2728T

66. Position the rear seal, dry, onto the rear main bearing cap then apply a small spot of specified sealer into and from each foot as shown in Fig. 68.

67. Position the side gaskets to the block, ensuring that the rear ends fit over the rear seal feet.

NOTE: A small amount of sealer may be used along the block flange to retain the gaskets in position, if necessary.

68. Fit the front seal in position with the feet over the gaskets, then apply a spot of sealer to the joints where the front and rear seals adjoin the gaskets - see Fig. 68.

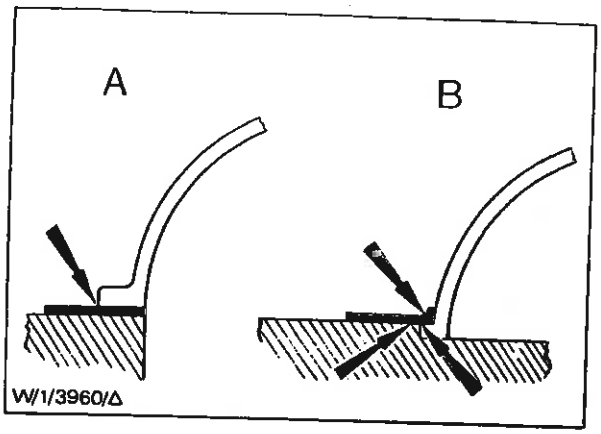


Fig. 68 - Oil Pan Gaskets and Seals Installation for All Engines Except 2728T
A. Front
B. Rear
Apply Sealer to Areas as Shown

69. Check to ensure that the rear face of the oil pan is flush to within 0,15 mm (0,006 in) max below the rear (clutch housing mating) face of the cylinder block. The oil pan must not stand proud of the cylinder block.

70. Fit the oil pan carefully over the four studs without dislodging the seals or gaskets and enter all bolts and nuts finger tight only.

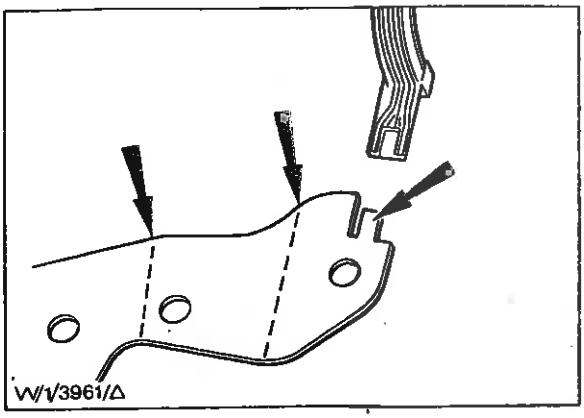


Fig. 69 - Oil Pan Front Seal and Gasket Installation - 2728T Engine
Apply Sealer to Block/Housing/Cover Joint Lines and Gasket/Seal Interlocked Joint where shown

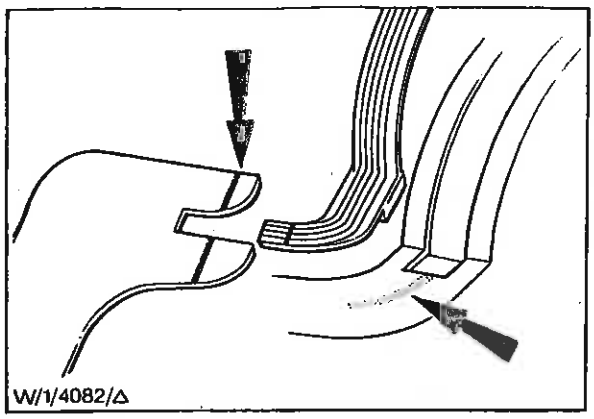


Fig. 70 - Oil Pan Rear Seal and Gasket Installation - 2728T Engines
Apply Sealer to Joint and Oil Pan Rail Areas indicated.

2728T Engines

71. Check that the two locating dowels are in position - see Fig. 71.

72. Apply a small bead of specified sealer to the flange joint lines of the front housing and to the rear of the block oil pan rail as shown in Fig. 69 and 70.

73. Position the front and rear seals and gaskets to the block flange, ensuring correct interlocking of cut-outs and tongues - see Figs. 69 and 70.

NOTE: A small amount of sealer may be used along the block flange to retain the gaskets in position, if necessary.

74. Apply a spot of sealer to each interlocked joint and fit the oil pan over the five studs carefully without dislodging the seals or gaskets. Fit all bolts and nuts finger tight only. Check to ensure that the rear face of the oil pan is flush to within 0,15 mm (0,006 in) max below the rear (clutch housing mating) face of the cylinder block. The oil pan must not stand proud of the cylinder block.

All Engines:

75. Starting at the fourth pair of bolts from the rear and working forwards, tighten all bolts, nuts and washers in pairs (left to right), to the specified torque. Return to the starting position and continue rearwards, again working in pairs. Fit drain plug(s).

New Oil Pan Installation - 2728T Engines Only - Refer to Fig. 71

76. Before fitting any seals or gaskets, drift out the two dowels and place the oil pan onto the crankcase. Loosely insert at least four bolts (two each side) and check that the rear face of the oil pan is radially aligned and flush to within 0,15 mm (0,006 in) max below the rear (clutch housing mating) face of the cylinder block. The oil pan must not stand proud of the cylinder block.

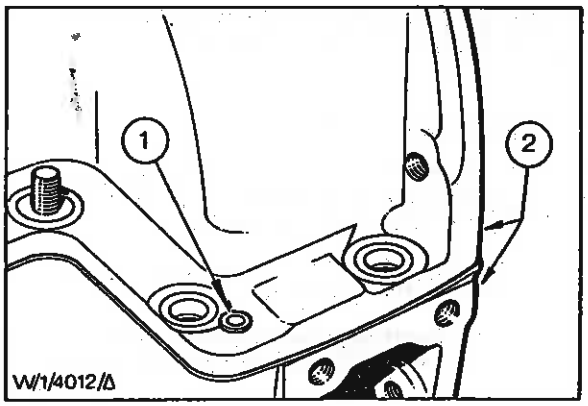


Fig. 71 - Oil Pan Rear Alignment - 2728T Engines
1. Locating Dowel
2. These Faces Flush - see text

77. Tighten the four bolts to secure the oil pan. Using the two dowel holes in the block as guides, ream the oil pan dowel holes to 9,5 to 9,7 mm (0,375 to 0,383 in) diameter.

78. Refit the dowels and check that the alignment has not been disturbed.

79. Remove the oil pan and clean off all swarf from the oil pan and block.

80. Fit the oil pan as described under 'Oil Pan Installation.

FLYWHEEL INSTALLATION

81. Fit, or check that the flywheel locating dowel is fitted, to the crankshaft flange.

82. Locate the flywheel over the dowel and on to the flange, fit and progressively and evenly tighten the retaining bolts to the specified torque.

83. Using a dial gauge and magnetic base check that the flywheel run out is within the specified limits when measured at 140 mm (5,50 in) radius - see Fig. 72.

84. If the run out is excessive, remove the flywheel and check the flange and flywheel mating faces for burrs or swarf. Lightly stone off any burrs and thoroughly clean off any dirt and/or swarf. Reassemble and recheck the run out as before.

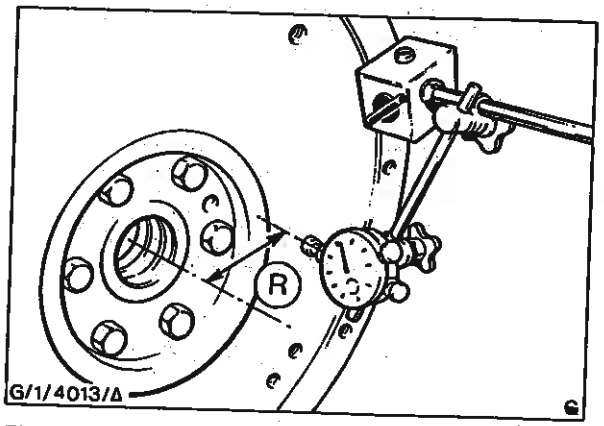


Fig. 72 - Checking Flywheel Run-Out
R = 140 mm (5,50 in)

CRANKSHAFT PULLEY INSTALLATION

86. Wipe a smear of grease around the inner periphery of the timing cover oil seal.

All Engines Except 2728T:

87. Locate the crankshaft pulley on to the crankshaft ensuring the key and keyway are aligned and push fully home. Fit the retaining bolt and tighten to the specified torque.

2728T Engines:

88. Fit new 'O' rings to the grooves in the crankshaft adaptor and the locking sleeve. Use a small quantity of engine oil to aid assembly.

89. Locate the crankshaft pulley onto the crankshaft ensuring the key and keyway are aligned and push fully home.

90. Insert the spacer and the two locking rings in the order shown in Fig. 73, with the gaps opposite to one another. Fit the locking sleeve and the four bolts ensuring the locking rings are pushed fully and squarely into position.

91. Tighten the bolts evenly to the specified torque.

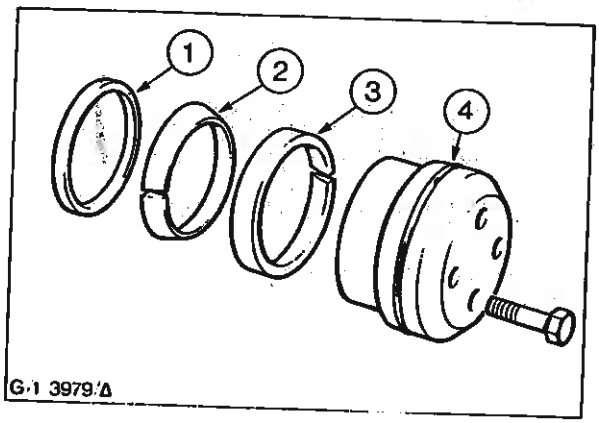


Fig. 73 - Crankshaft Pulley Retaining Components - 6 Cylinder Engines (Ringfeder Locking Mechanism)
1. Spacer Ring
2. Internal Locking Ring
3. External Locking Ring
4. Locking Sleeve

CYLINDER HEAD INSTALLATION

92. Rotate the engine on the stand to bring the block face uppermost.

93. Ensure the block and head faces are clean and dry.

94. Check to ensure the locating dowels are fitted into the counterbores of the two head bolt threads and the water circulating passage at the positions shown in Fig. 74.

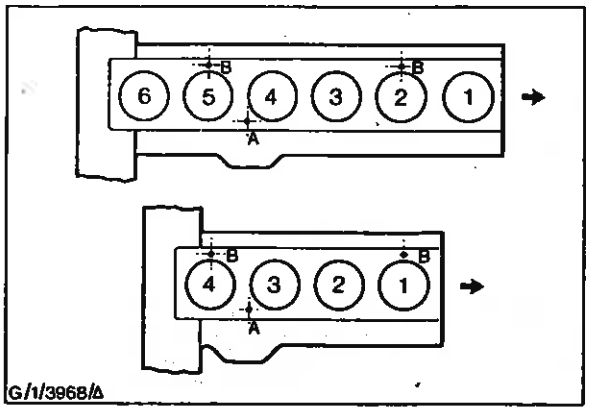


Fig. 74 - Cylinder Head/Gasket Locating Dowels
A. Dowel in Water Gallery
B. Dowels in Head Bolt Holes

95. Positon a new gasket over the locating dowels on to the block.

96. Using the built-in lifting brackets and a suitable sling and hoist locate the cylinder head carefully onto the block ensuring that the gasket is not disturbed.

97. Insert and hand tighten all the cylinder head bolts and remove the sling and hoist.

98. Tighten the cylinder head bolts by increments, in the sequence shown in Fig. 75 to the specified torque.

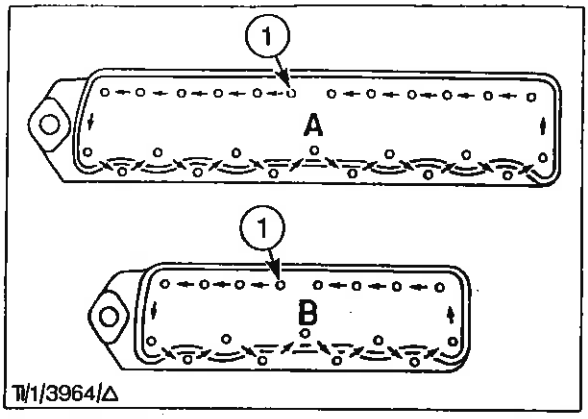


Fig. 75 - Cylinder Head Bolts Tightening Sequence
A. 6 Cylinder Engines
B. 4 Cylinder Engines
1. Start here when tightening

99. When all bolts have been tightened, further tighten each bolt in the same sequence, by exactly 90°.

CAUTION: MARK EACH BOLT HEAD AS TIGHTENING PROCEEDS TO ENSURE NO BOLT IS EITHER MISSED OR DUPLICATED.

INSTALLING INJECTORS AND VALVE GEAR

100. Ensure that the cylinder head injector apertures are thoroughly clean, then fit new sealing washers - see Fig. 76.

101. Fit a new 'O' ring seal to each injector assembly.

102. Insert the injectors into the cylinder head and fit but do not tighten the securing bolts - see Fig. 77.

103. Place the leak-off pipe in position and fit but only hand tighten the leak-off pipe banjo bolts. Tighten the gland nut securing the leak-off pipe to the cylinder head connection.

104. Tighten the injector securing bolts evenly to the specified torque, then tighten the leak-off pipe banjo bolts to the specified torque.

105. Install the pushrods and valve caps into the same positions as when removed, position the rocker shaft assembly, locating the adjuster ball ends into the push rod cups, and gradually and evenly tighten the retaining bolts to the specified torque - see Fig. 78.

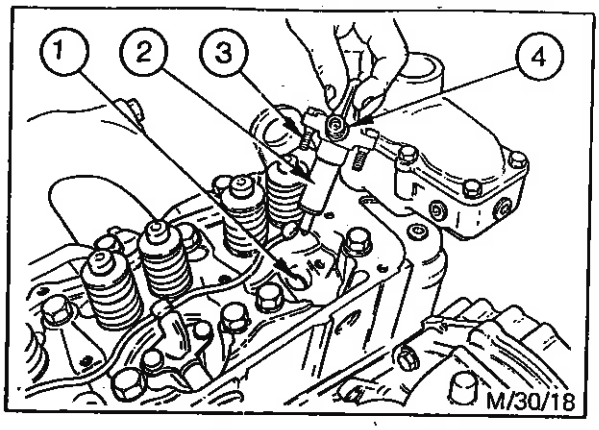


Fig. 76 - Replacing Injectors
1. Recess or Copper Sealing Washer
2. Injector
3. Injector Retaining Bolt
4. 'O' Ring

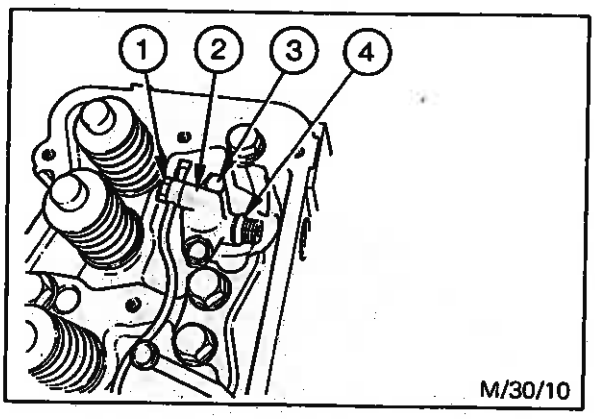


Fig. 77 - Replacing Injectors
1. Leak-Off Pipe Banjo Bolt
2. Injector
3. Injector Retaining Bolt
4. 'O' Ring

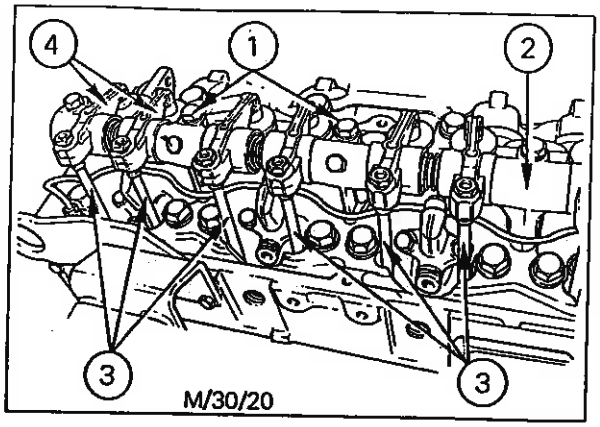


Fig. 78 - Installing Valve Gear
1. Rocker Shaft Pedestal Retaining Bolts
2. Rocker Shaft Assembly
3. Push Rods
4. Rocker Arms

SETTING VALVE CLEARANCES

106. Following the sequence shown below, rotate the crankshaft in the direction of rotation and adjust the valves to the specified clearances.

4 cylinder engines

Valves Open	Adjust Valves
1 and 6	3 and 8
2 and 4	5 and 7
3 and 8	1 and 6
5 and 7	2 and 4

6 cylinder engines

Valves Open	Adjust Valves
1 and 4	9 and 12
8 and 10	3 and 5
2 and 6	7 and 11
9 and 12	1 and 4
3 and 5	8 and 10
7 and 11	2 and 6

To adjust the valve clearance, insert the correct thickness feeler gauge between the rocker pad and the valve cap. Turn the adjusting screw with a ring spanner or socket until the correct clearance is obtained. This is when the feeler gauge is just gripped between the rocker pad and the valve cap but can be moved with a slight pull - see Fig. 79.

NOTE: The adjusting screw is designed to be self locking. If it does not feel tight enough, unscrew it until a positive clearance is obtained (not less than 0,25 mm (0,010 in) and then check the torque required to turn the screw. If less than specified, renew the rocker arm assembly.

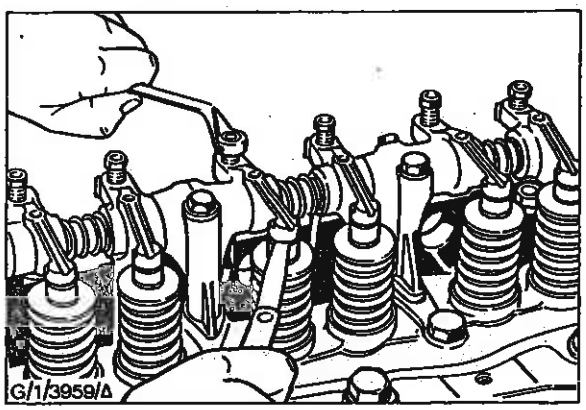


Fig. 79 - Adjusting Valve Clearance

ASSEMBLING ENGINE ANCILLARIES

THERMOSTATS

107. Test the thermostat(s) if necessary, as described in Section 3 then fit housing, thermostat(s) and cover, as appropriate, with new gaskets. If removed, replace or fit a new temperature sensitive switch.

WATER PUMP

All Engines Except 2728T

108. Position pump on cylinder block, using a new gasket, and secure with the bolts/nuts tightened to the correct torque value. Where applicable, fit hose between water pump and thermostat housing and tighten clips.

109. Fit the extension tube to the cylinder block and locate the connecting hose between pump and tube. Ensure that the engine mounting bracket or spacers (as appropriate) are in position when inserting the securing bolts. Tighten bolts to the correct torque value and tighten hose clips.

2728T Engine Only

110. Locate a new gasket over the studs and assemble the back plate to the cylinder block. Fit the set bolt in the centre of the back plate and tighten to the specified torque - see Fig. 80.

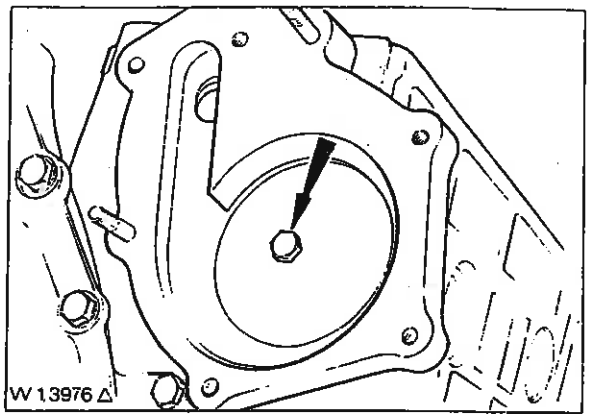


Fig. 80 - Water Pump Backplate Showing Retaining Set Bolt Behind Pump on 2728T Engine

111. Locate the pump, using a new gasket, over the studs and on to the back plate. Tighten the nuts first then the bolts to the specified torque - see Fig. 81.

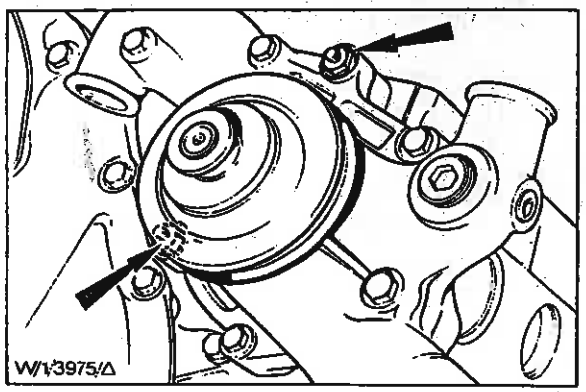


Fig. 81 - Water Pump Mounting Nuts and Bolts on 2728T Engine

Arrowed Studs Pass Through Backplate into Block - Tighten These First

112. Replace the complete split flow water tube assembly connecting the water pump to the rear of the cylinder block. Tighten all clips and support bracket bolts.

Raw Water Pump - Marine Engines

113. Fit the raw water pump to the PTO drive at the rear of the timing gear housing.

Alternator

114. Assemble the alternator on to its mounting bracket but do not fully tighten bolts at this stage.

'Low Loss' Type Water Pumps

115. Place the bearing retainer outer plate, centre boss outwards, on the fan pulley hub. Position the fan on the bearing retainer boss and secure with the four bolts.

Standard Water Pump - All Engines Except 2728T

116. Place the fan on the water pump hub and secure with the 4 or 6 bolts. On single belt drive pumps, assemble the pulley onto the pump hub before installing the fan.

DRIVE BELTS

117. Fit the drive belt(s) and adjust the alternator position to achieve the correct belt tension - see Fig. 82 or 83.

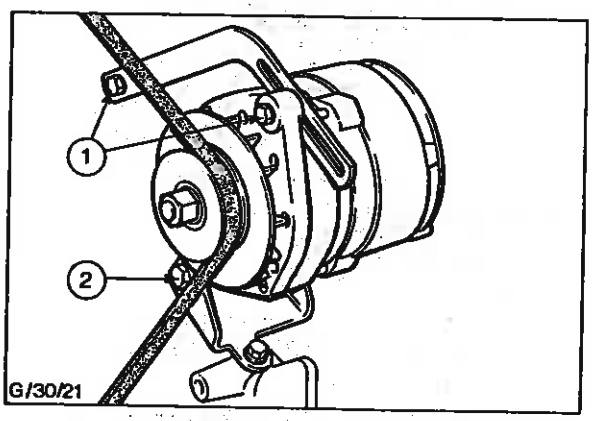


Fig. 82 - Alternator Drive Belt Adjustment
1. Adjusting Bolts
2. Mounting Bolts

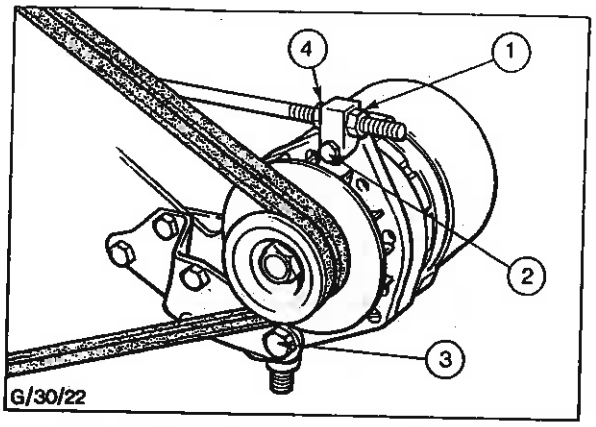


Fig. 83 - Alternator Drive Belt Adjustment
1. Locking Nut
2. Adjusting Bolts
3. Mounting Bolts
4. Adjusting Nut

On 'Low Loss' drive systems, the fan belts must be adjusted separately by means of the idler pulley positioning - see Fig. 84.

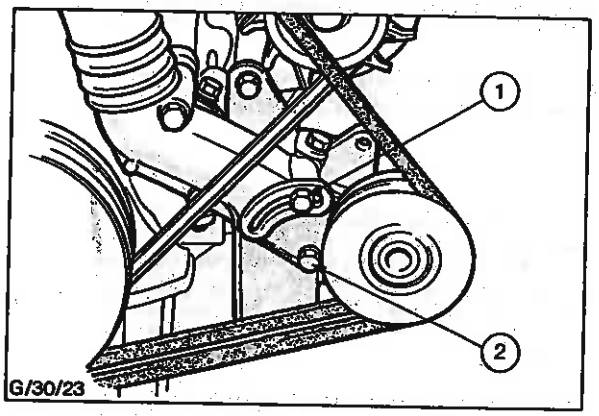


Fig. 84 - Drive Belt Adjustment - 'Low-Loss' Fan Drive Water Pump
1. Adjusting Bolt
2. Mounting Bolt

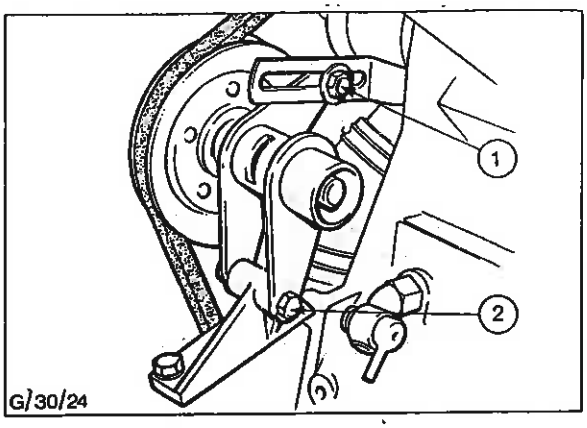


Fig. 85 - Drive Belt Adjustment - No Alternator Fitted
1. Adjusting Bolt
2. Mounting Bolt

Where no alternator is fitted, a special idler pulley is installed instead; this must be positioned to give the correct belt tension - see Fig. 85.

The high level fan fitted to some 4 cylinder engines, is positioned by the two adjusting bolts located at the top of the fan pulley bearing bracket - see Fig. 86. The two securing bolts must be slackened when carrying out belt adjustments.

After drive belt(s) have been correctly tensioned, tighten fan securing bolts while gripping drive belt(s).

INJECTION PUMP

118. Remove the timing aperture cover from the flywheel housing and turn the engine in the normal direction of rotation until the specified number of degrees before TDC on No. 1 cylinder is indicated against the timing mark on the edge of the timing aperture (Fig. 87). No. 1 cylinder must be on the compression stroke.

NOTE: If the correct piston stroke is in doubt, check that both pushrods of No. 1 cylinder are free to rotate. If they are not, rotate the crankshaft through 360° and check the flywheel marking again.

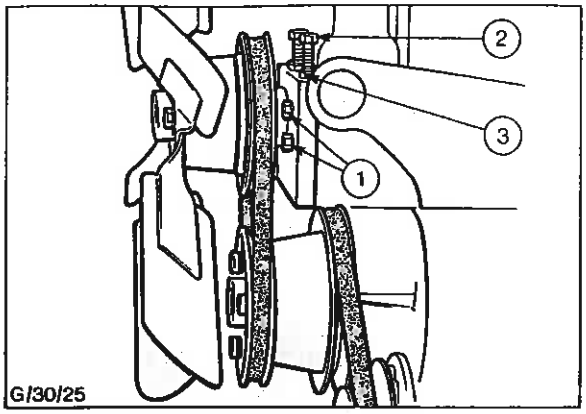


Fig. 86 - Drive Belt Adjustment - High Level Fan
1. Fan Bearing Housing Securing Bolts
2. Adjusting Bolts
3. Locknuts

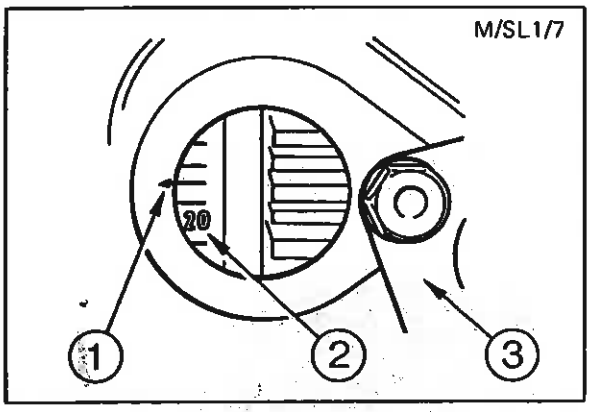


Fig. 87 - Engine Timing
1. Timing Mark on Housing
2. Timing Scale on Flywheel
3. Timing Aperture Cover

AUTOMOTIVE AND G.P. GOVERNED INJECTION PUMPS - Carry out operations 119 to 124 inclusive then continue with operation 128.

119. New pumps only. Fit the ring gear and plate into position, but do not fully tighten the screws (Fig. 88). Drain any oil from the fuel gallery of the new pump.

120. Remove the blanking plug from the timing bush on the injection pump mounting flange (Fig. 89).

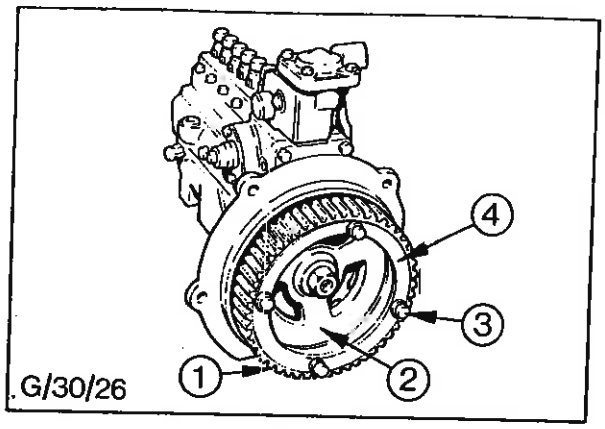


Fig. 88 - Injection Pump Drive Gear
1. Ring Gear
2. Drive Hub
3. Clamping Screws
4. Clamping Plate

121. Rotate the pump drive hub until the timing hole is centred in the bush aperture, then screw the timing tool (23-507) into position. Rotate drive gear slightly as necessary to engage the plunger in the drive gear hub hole.

122. Remove the adjustment cover plate on the front of the timing cover (Fig. 90).

123. Fit a new 'O' ring to the pump mounting flange and install the pump carefully, tightening the bolts to the specified torque.

NOTE: If the pump flange holes cannot be aligned with the holes in the engine timing gear case, slacken the four drive gear clamping screws to enable the pump to be rotated slightly, relative to the gear.

124. Tighten the drive gear clamping screws to the specified torque and check that the correct flywheel marking is still indicated. Replace the timing cover adjustment plate and the flywheel timing aperture cover and tighten the securing screws. Remove the timing tool (23-507) and replace the timing bush cap.

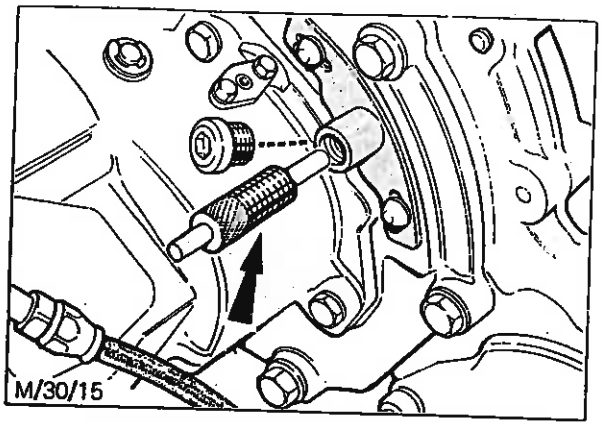


Fig. 89 - Injection Pump Timing - Automotive and G.P. Governed Pumps
1. Timing Bush Blanking Plug
2. Timing Tool 23-507

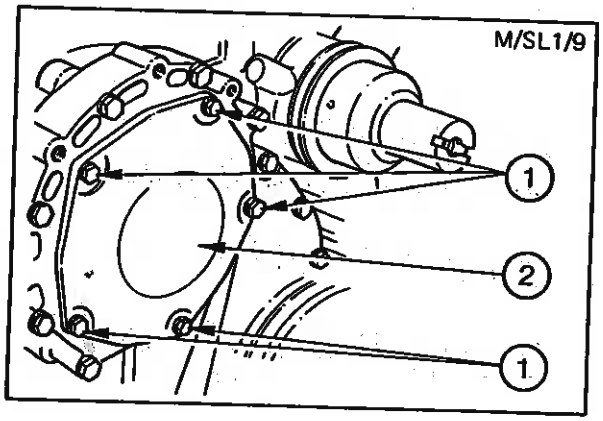


Fig. 90 - Removing Injection Pump Timing Aperture Cover Plate
1. Securing Bolts
2. Cover Plate

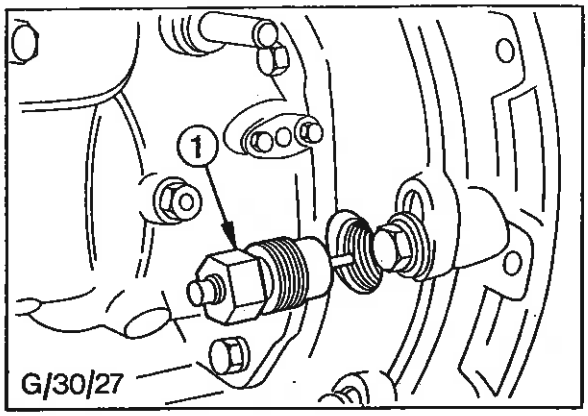


Fig. 91 - Injection Pump Timing - Class 'A' and Combine Harvester Governed Pumps
1. Timing Tool 23-504

CLASS 'A' AND COMBINE HARVESTER GOVERNED INJECTION PUMPS - Carry out operations 125 to 127 inclusive then continue with operation 128.

125. Remove blanking plug from injection pump mounting flange - see Fig. 91. Rotate the pump drive gear until the hole in the gear is centred in the hole in the flange, then screw the timing tool (23-504) into position - see Fig. 91. Rotate the drive gear slightly, as necessary, to engage the timing tool plunger in the hole.

126. Fit a new 'O' ring to the pump mounting flange and install the pump carefully; tighten the bolts and nut to the specified torque.

127. Check that the correct flywheel marking is still indicated, then replace the flywheel timing aperture cover and the injection pump timing aperture sealing plug.

128. Where applicable, replace the lead connecting the automatic excess fuel solenoid to the temperature sensitive switch on the thermostat housing.

129. Secure oil filter head to cylinder block using a new gasket. Tighten bolts to specified torque value. Where applicable, fit the oil feed pipe between oil filter head and injection pump. On turbocharged engines replace pipe connecting injection pump boost control to inlet manifold.

130. Remove all blanking plugs/caps from high pressure pipes, injectors and injection pump.

131. Connect the high pressure fuel pipes to the injection pump but do not fully tighten gland nuts at this stage.

132. Unscrew large oil seal nut fully - see Fig. 92.

133. Connect high pressure feed pipe and tighten gland nut to the specified torque value.

134. Tighten large oil seal nut.

135. Repeat operations 132, 133 and 134 for remaining injectors.

136. Tighten high pressure fuel pipe gland nuts at the injection pump to the specified torque value.

137. Replace any high pressure pipe clamps - see Fig. 93.

138. Carry out the leak-off pipe pressure test described in Section 4.

139. Replace rocker cover, using a new gasket.

With effect from 1st February, 1983, a revised design rocker cover retaining screw and captive washer assembly was introduced in production. Any engine build prior to that date that exhibited oil leaks from the rocker cover-to-cylinder head gasket joint before dismantling, should have these later type screws, Part No. E404828-S100 (Finis Code 6172279) fitted in place of the original screws. The tightening torque is unchanged.

140. Replace the fuel filters complete with mounting bracket.

141. Replace fuel lift pump and (where fitted) the pre-filter unit.

142. Replace the low pressure fuel pipes connecting fuel lift pump, fuel filters and injection pump.

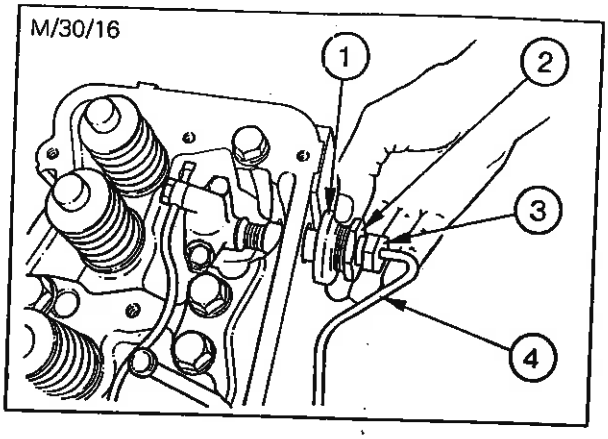


Fig. 92 - Replacing High Pressure Fuel Pipes
1. Oil Seal
2. Oil Seal Nut
3. High Pressure Pipe Gland Nut
4. High Pressure Pipe

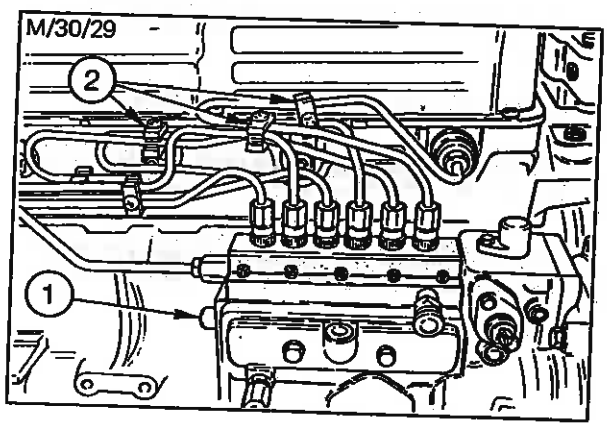


Fig. 93 - Replacing Injection Pump
1. Idling Damper Adjustment Cover
2. High Pressure Fuel Pipe Clamps

143. If a new injection pump with automotive or G.P. governing has been fitted, remove the oil filler plug and insert the specified quantity of clean engine oil. Refit and tighten the plug.

144. Where an injection pump with Class 'A' or combine harvester governing has been installed, remove the level and filler plugs and top up with clean engine oil as required - see Fig. 94.

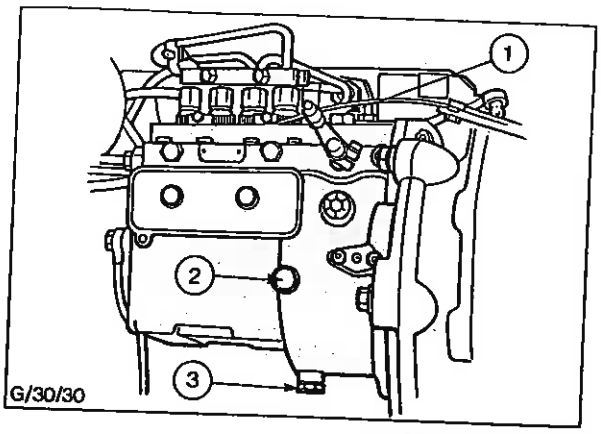


Fig. 94 - Injection Pump Oil Plugs (Class 'A' and Combine Harvester Governing only)
1. Filler Plug
2. Level Plug
3. Drain Plug

145. Where applicable, replace the dipstick tube in the oil pan.

146. Replace the dipstick and, if removed, the oil pressure sender unit.

147. Prime the new oil filter with clean engine oil and screw it into position; tighten by hand only - do NOT use a strap wrench or similar device.

148. Using a suitable hoist attached to the cylinder head lifting brackets, take the weight of the engine and detach the mounting bracket from the stand (200B). Remove the mounting bracket from the engine.

149. Replace the starter motor and tighten bolts to the specified torque value. If removed, replace the cylinder block coolant drain plug or tap.

150. Check that the manifold mounting studs are secure in the cylinder head.

NOTE: It is imperative that the special shouldered studs, in the positions shown are fully tightened or they may prevent the manifolds fitting flush to the cylinder head - see Fig. 95.

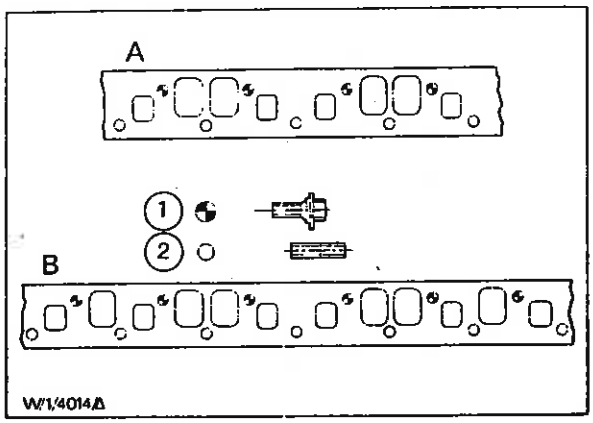


Fig. 95 - Manifold Stud Positions
A. 4 Cylinder Engines
B. 6 Cylinder Engines
1. Special Studs with Integral Washer in Position
2. Plain Studs in Positions Marked

151. Assemble the manifold gasket over the studs.

NOTE: On turbocharged engines the gasket has eyelets and is 'handed'. The full flange of the eyelet must be against the cylinder head.

If the exhaust manifold has been dismantled, stagger the gaps of the piston type sealing rings in the exhaust manifold joints when assembling.

152. Assemble the manifolds to the cylinder head and retain with flat washers and the special nuts (copper colour). Tighten the nuts evenly to the specified torque.

153. Where applicable, replace the inter-cooler complete with mounting bracket.

154. Where applicable, assemble the turbocharger to the exhaust manifold using a new gasket. Secure with the four nuts tightened to the correct torque value. Fit the support plate and bracket to turbocharger and cylinder block, placing a new gasket between support plate and turbocharger. DO NOT tighten the nuts securing the turbocharger to the bracket as a new gasket will be required when fitting the exhaust pipe after the engine is installed.

155. Install the hose connecting the turbocharger and inlet manifold adaptor or intercooler and tighten clips. On industrial engines, replace the air inlet pipe and connecting hose to turbocharger; tighten securing bolts and hose clips.

156. Replace the turbocharger oil feed and return pipes.

INSTALLING THE ENGINE

Because of the various vehicles/installations in which the engine can be fitted, it is not possible to give detailed instructions. However, after the engine has been installed and BEFORE it is started, the following points should be noted.

1. The cooling system must be filled with coolant to the correct level.

2. The oil pan must be filled with the correct grade and quantity of new lubricating oil meeting Ford Specification SM-2C-1017A. In the case of turbocharged engines, the turbocharger must be primed with engine oil and the recommended start-up procedure followed - refer to Section 4.

3. Injection pumps must contain the specified amount of engine oil - refer to Specifications, Section 4.

4. The fuel system must contain sufficient fuel of the correct type and be bled to remove all air - refer to Section 4.

5. The battery must contain the correct amount of electrolyte and be adequately charged - refer to Volume 2, Section 2.

SPECIFICATIONS

General

Type		OHV Direct Injection Diesel				
		Naturally Aspirated			Turbocharged	
		2722	2723	2725	2726T	2728T
Number of Cylinders		4	6	6	6	
Bore	mm (in)	107,21 (4,221)	104,80 (4,126)	107,21 (4,221)	104,80 (4,126)	
Stroke	mm (in)	114,80 (4,524)	114,80 (4,524)	114,80 (4,524)	114,80 (4,524)	
Capacity	cm^3 (in^3)	4149,5 (253,2)	5946,7 (362,9)	6224,3 (379,8)	5946,7 (362,9)	
Compression Ratio		15,9:1	15,9:1	15,9:1	15,45:1	14,7:1
Firing Order		1,2,4,3	1,5,3,6,2,4	1,5,3,6,2,4,	1,5,3,6,2,4	
Number 1 Cylinder		Front of Engine				

POWER RATINGS

	Power Measuring Standard	2722 Standard Power GP I	2722 High Power GP II	2723 Standard Power GP I	2725 Standard Power GP I	2725 High Power GP II
Intermmittent Power Output	BS 5514 (ISO 3046)	54,5 kW @ 2500 rpm	58,5 kW @ 2600 rpm	76,2 kW @ 2500 rpm	84,6 kW @ 2500 rpm	90,0 kW @ 2600 rpm
	BS 649	58,9 kW @ 2500 rpm	63,4 kW @ 2600 rpm	80,5 kW @ 2500 rpm	88,7 kW @ 2500 rpm	94,7 kW @ 2600 rpm
	DIN 6270	54,3 kW @ 2500 rpm	58,3 kW @ 2600 rpm	76,0 kW @ 2500 rpm	84,3 kW @ 2500 rpm	89,8 kW @ 2600 rpm
Intermittent Torque Output	BS 5514 (ISO 3046)	232 Nm @ 1500 rpm	261 Nm @ 1600 rpm	325 Nm @ 1500 rpm	354 Nm @ 1500 rpm	380 Nm @ 1600 rpm
	BS 649	241 Nm @ 1500 rpm	269 Nm @ 1600 rpm	333 Nm @ 1500 rpm	362 Nm @ 1500 rpm	387 Nm @ 1600 rpm
	DIN 6270	231 Nm @ 1500 rpm	260 Nm @ 1600 rpm	324 Nm @ 1500 rpm	353 Nm @ 1500 rpm	378 Nm @ 1600 rpm

	Power Measuring Standard	2726T	2726T Marine	2728T
Intermittent Power Output	BS 5514	107,5 kW @ 2400 rpm	111,9 kW @ 2400 rpm	-
	BS 649	111,9 kW @ 2400 rpm	-	-
	BS AU 141a 1971	118 kW @ 2400 rpm	114,0 kW @ 2400 rpm	149 kW @ 2450 rpm
	DIN 6270	107,6 kW @ 2400 rpm	-	-
Intermittent Torque Output	BS 5514	461 Nm @ 1700 rpm	457 Nm @ 2000 rpm	-
	BS 649	473 Nm @ 1700 rpm	-	-
	BS AU 141a 1971	498 Nm @ 1700 rpm	491 Nm @ 1700 rpm	600 Nm @ 1800 rpm
	DIN 6270	462 Nm @ 1700 rpm	-	-

CYLINDER BLOCK

NOTE: Standard size cylinder bore diameters are graded at a point 80 mm (3,15 in) from the top of the bores across the cylinder block (the 'Grade Point'). Bores which fall between grades are categorized in the lower grade.

Bore Diameter - Standard

2723 engine	Grade 1	104,770 to 104,795 mm (4,1248 to 4,1258 in)
	Grade 2	104,795 to 104,820 mm (4,1258 to 4,1268 in)
2726T and 2728T engines	Grade 1	104,770 to 104,795 mm (4,1248 to 4,1258 in)
	Grade 2	104,795 to 104,820 mm (4,1258 to 4,1268 in)
2722 and 2725 engines	Grade 1	107,188 to 107,213 mm (4,2200 to 4,2210 in)
	Grade 2	107,213 to 107,238 mm (4,2210 to 4,2220 in)
Cylinder Bore Taper - Maximum		0,0013 mm (0,0005 in) small at the top of the bore, Bores must NOT be small at the bottom of the bore.

Cylinder Liners - 2726T and 2728T engines only

Bore Diameter in the Cylinder Block for the Cylinder Liner	Grade 1	108,966 to 108,991 mm (4,290 to 4,291 in)
	Grade 2	108,991 to 109,016 mm (4,291 to 4,292 in)
Cylinder Liner Outside Diameter	Grade 1	108,953 to 108,979 mm (4,289 to 4,290 in)
	Grade 2	108,979 to 109,004 mm (4,290 to 4,291 in)
Cylinder Liner Protrusion above or below the Top Face of the Cylinder Block		0,0254 mm (0,001 in) max below face to 0,127 mm (0,005 in) max above face

Bore Diameter for Main Bearing Liners

Standard Size	80,429 to 80,459 mm (3,1665 to 3,1676 in)
Oversize 0,381 mm (0,015 in) - Service Only	80,810 to 80,843 mm (3,1815 to 3,1826 in)

Bore Diameter for Camshaft Bearing Bush

Standard Size	58,750 to 58,775 mm (2,313 to 2,314 in)
Oversize 0,508 mm (0,02 in) - Service Only	59,260 to 59,285 mm (2,333 to 2,334 in)

PISTON, PISTON RINGS AND PISTON PIN

Piston

NOTE: Standard Size pistons are graded by skirt diameter measured at 90° to the piston pin bore at a graded height (X) from lower edge of piston.

2722, 2723 and 2725 engines	X = 56,3 mm (2,217 in)
2726T and 2728T engines	X = 25,6 mm (1,01 in)

Skirt Diameter - Standard Size

2723 engine	Grade 1	104,658 to 104,682 mm (4,1204 to 4,1213 in)
	Grade 2	104,683 to 104,707 mm (4,1314 to 4,1223 in)
2722 and 2725 engines	Grade 1	107,076 to 107,100 mm (4,2156 to 4,2165 in)
	Grade 2	107,101 to 107,125 mm (4,2166 to 4,2175 in)
NOTE: For 2722, 2723 and 2725 engines	Graded Pistons are not supplied in service	
2726T engine	Grade 1	104,592 to 104,618 mm (4,1178 to 4,1188 in)
	Grade 2	104,618 to 104,693 mm (4,1188 to 4,1198 in)
2728T engine	Grade 1	104,579 to 104,605 mm (4,1173 to 4,1183 in)
	Grade 2	104,605 to 104,630 mm (4,1183 to 4,1193 in)

NOTE: Only Grade 2 pistons are available for service use

Skirt Diameter - Oversize (Measured at the Grade Point)

2723 engine		
- Oversize	0,381 mm (0,015 in)	105,089 to 105,113 mm (4,137 to 4,138 in)
	0,889 mm (0,035 in)	105,597 to 105,621 mm (4,157 to 4,158 in)
	1,397 mm (0,055 in)	106,105 to 106,129 mm (4,177 to 4,178 in)
2722 and 2725 engines		
- Oversize	0,381 mm (0,015 in)	107,507 to 107,531 mm (4,2326 to 4,2335 in)
	0,889 mm (0,035 in)	108,015 to 108,039 mm (4,2526 to 4,2535 in)
	1,397 mm (0,055 in)	108,523 to 108,547 mm (4,2726 to 4,2735 in)

Piston Skirt Clearance in the Cylinder Bore - at the grade point	
2722, 2723 and 2725 engines	0,088 to 0,137 mm (0,0035 to 0,0054 in)
2726T engine	0,152 to 0,203 mm (0,006 to 0,008 in)
2728T engine	0,165 to 0,216 mm (0,0065 to 0,0085 in)
Piston Crown Protrusion (Bump Height)	
Height above the Cylinder Block Top Face at T.D.C. (See Connecting Rod Length)	0,152 to 0,381 mm (0,006 to 0,015 in)
Piston Ring Grooves	
Number of Ring Grooves	
2722, 2723, 2725 engines	3
2726T and 2728T engines	4
Width of Ring Grooves for - Top Compression Ring	
2726T and 2728T engines	Tapered Ring
2722, 2723 and 2725 engines	2,465 to 2,485 mm (0,097 to 0,098 in)
Second Compression Ring	2,445 to 2,465 mm (0,096 to 0,097 in)
Third Compression Ring - (2726T and 2728T engines only)	2,444 to 2,469 mm (0,096 to 0,097 in)
Oil Control Ring	
2726T and 2728T engines	4,800 to 4,826 mm (0,189 to 0,190 in)
2722, 2723 and 2725 engines	4,767 to 4,787 mm (0,188 to 0,189 in)
Piston Pin Bore Diameter	
2722, 2723 and 2725 engines	36,508 to 36,516 mm (1,4373 to 1,4376 in)
2726T and 2728T engines	40,991 to 41,001 mm (1,6138 to 1,6142 in)
Piston Rings	
Piston Ring Gap	
2722, 2723 and 2725 engines	
Compression Rings - All	0,33 to 0,58 mm (0,013 to 0,023 in)
Oil Control Ring	0,33 to 0,71 mm (0,013 to 0,028 in)
2726T and 2728T engines	
Compression Rings - Top	0,43 to 0,64 mm (0,017 to 0,025 in)
Second and third	0,33 to 0,58 mm (0,013 to 0,023 in)
Oil Control Ring	0,33 to 0,58 mm (0,013 to 0,023 in)
Colour Code - Standard Rings	
2726T and 2728T engines - Violet	
2723 engines - Green	
2722 and 2725 engines - Orange	
Piston Ring Width	
2722, 2723 and 2725 engines	
Compression Rings - Top	2,362 to 2,375 mm (0,0930 to 0,0935 in)
- Second	2,351 to 2,375 mm (0,0926 to 0,0935 in)
Oil Control Ring	4,717 to 4,737 mm (0,1857 to 0,1865 in)
2726T and 2728T engines	
Compression Rings - Top	Tapered
- Second and Third	2,351 to 2,375 mm (0,0926 to 0,0935 in)
Oil Control Ring	4,717 to 4,737 mm (0,1857 to 0,1865 in)
Piston Ring to Piston Groove Clearance	
2722, 2723 and 2725 engines	
Compression Rings - Top	0,090 to 0,123 mm (0,0035 to 0,0048 in)
- Second	0,070 to 0,114 in (0,0028 to 0,0045 in)
Oil Control Ring	0,030 to 0,070 mm (0,0012 to 0,0028 in)
2726T and 2728T engines	
Compression Rings - Top	0,000 to 0,127 mm (0,0000 to 0,0050 in)
- Second and Third	0,069 to 0,118 mm (0,0027 to 0,0047 in)
Oil Control Ring	0,064 to 0,109 mm (0,0025 to 0,0043 in)

Piston Pin

Outside Diameter	
2722, 2723 and 2725 engines	36,502 to 36,510 mm (1,4371 to 1,4374 in)
2726T and 2728T engines	40,985 to 40,993 mm (1,6136 to 1,6139 in)

Clearance in Piston Bosses at 20°C (68°F)
NOTE: Piston pins are fitted selectively to pistons to obtain the specified clearance. These components should be retained as matched sets if re-assembling to an engine.

Selective Fit	0,002 to 0,010 mm (0,00008 to 0,00040 in)
Length	
2722, 2723 and 2725 engines	85,80 to 86,20 mm (3,378 to 3,394 in)
2726T and 2728T engines	86,74 to 87,12 mm (3,415 to 3,430 in)

CONNECTING RODS

Length - Centre of Big End to Centre of Small End

NOTE: Grade letter is centre letter of the three identifying letters on big end thrust face. Graded rods are used to control 'Bump Height' (See Piston specifications).

Grade A	203,175 to 203,251 mm (7,999 to 8,002 in)
Grade B (Plus 0,076 mm (0,003 in))	203,251 to 203,327 mm (8,002 to 8,005 in)
Grade C (Plus 0,152 mm (0,006 in))	203,327 to 203,403 mm (8,005 to 8,008 in)
Grade D (Plus 0,228 mm (0,009 in))	203,403 to 203,479 mm (8,008 to 8,011 in)

Big End Bore Diameter (Steel)

2723 engine	67,208 to 67,223 mm (2,6460 to 2,6466 in)
All other engines	70,879 to 70,894 mm (2,7905 to 2,7911 in)

Small End Bore Diameter (Steel)

2722, 2723 and 2725 engines	39,67 to 39,72 mm (1,562 to 1,564 in)
2726T and 2728T engines	44,08 to 44,13 mm (1,7354 to 1,7374 in)

Small End Bush Bore Diameter

2722, 2723 and 2725 engines	36,523 to 36,541 mm (1,4379 to 1,4386 in)
2726T and 2728T engines	41,006 to 41,024 mm (1,6144 to 1,6151 in)

Small End Bush to Piston Pin Clearance	0,013 to 0,039 mm (0,0005 to 0,0015 in)
End Float on Crankpin	0,076 to 0,279 mm (0,003 to 0,011 in)

CRANKSHAFT, CRANKSHAFT BEARINGS AND OIL SEAL

Main Bearing Journals

Diameter - Standard Size

2722, 2723 and 2725 engines	
Standard Size 1	76,200 to 76,230 mm (3,0000 to 3,0012 in)
Standard Size 2	75,946 to 75,976 mm (2,9900 to 2,9912 in)
2726T and 2728T engines	76,205 to 76,225 mm (3,0002 to 3,0010 in)

Diameter - Service Regrind

2722, 2723, 2725, 2726T and 2728T engines	
Standard Size 1	
Undersize - 0,254 mm (0,010 in)	75,958 to 75,971 mm (2,9905 to 2,9910 in)
- 0,508 mm (0,020 in)	75,704 to 75,717 mm (2,9805 to 2,9810 in)
- 0,762 mm (0,030 in)	75,450 to 75,463 mm (2,9705 to 2,9710 in)
- 1,016 mm (0,040 in)	75,196 to 75,209 mm (2,9605 to 2,9610 in)
2722, 2723 and 2725 engines - Standard Size 2	
Undersize - 0,254 mm (0,010 in)	75,704 to 75,717 mm (2,9805 to 2,9810 in)
- 0,508 mm (0,020 in)	75,450 to 75,463 mm (2,9705 to 2,9710 in)
- 0,762 mm (0,030 in)	75,196 to 75,209 mm (2,9605 to 2,9610 in)

Length		
Front		32,89 to 33,15 mm (1,295 to 1,305 in)
Centre		45,695 to 45,745 mm (1,799 to 1,801 in)
Rear		46,51 to 46,76 mm (1,831 to 1,841 in)
Intermediate		35,43 to 35,69 mm (1,395 to 1,405 in)
Runout		
Runout of Intermediate and Centre Bearings Journals with Crankshaft Mounted on Front and Rear Journals	4 Cyl.	0,064 mm (0,025 in) T.I.R. Maximum
	6 Cyl.	0,051 mm (0,002 in) T.I.R. Maximum
Thrust Faces		
Taper on Each Face		0,051 mm (0,002 in) Maximum
Runout at Outside Edge		0,013 mm (0,0005 in) T.I.R. Maximum
Crankpin Bearing Journals		
Diameter - Standard Size		
2723 engine (up to November 1985) Standard Size 1		63,492 to 63,512 mm (2,4997 to 2,5005 in)
Standard Size 2		63,213 to 63,258 mm (2,4887 to 2,4905 in)
2722 and 2725 engines and 2723 engines from November 1985 Standard Size 1		66,654 to 66,675 mm (2,6242 to 2,6250 in)
Standard Size 2		66,400 to 66,421 mm (2,6142 to 2,6150 in)
2726T and 2728T engines		66,654 to 66,675 mm (2,6242 to 2,6250 in)
Diameter - Service Regrind		
2723 engine - Standard Size 1		
Undersize - 0,254 mm (0,010 in)		63,246 to 63,258 mm (2,4900 to 2,4905 in)
- 0,508 mm (0,020 in)		62,992 to 63,004 mm (2,4800 to 2,4805 in)
- 0,762 mm (0,030 in)		62,738 to 62,750 mm (2,4700 to 2,4705 in)
- 1,016 mm (0,040 in)		62,484 to 62,496 mm (2,4600 to 2,4605 in)
2723 engine - Standard Size 2		
Undersize - 0,254 mm (0,010 in)		62,992 to 63,004 mm (2,4800 to 2,4805 in)
- 0,508 mm (0,020 in)		62,738 to 62,750 mm (2,4700 to 2,4705 in)
- 0,762 mm (0,030 in)		62,484 to 62,496 mm (2,4600 to 2,4605 in)
2722 and 2725 engines - Standard Size 1		
Undersize - 0,254 mm (0,010 in)		66,408 to 66,421 mm (2,6145 to 2,6150 in)
- 0,508 mm (0,020 in)		66,154 to 66,167 mm (2,6045 to 2,6050 in)
- 0,762 mm (0,030 in)		65,900 to 65,913 mm (2,5945 to 2,5950 in)
- 1,016 mm (0,040 in)		65,646 to 65,659 mm (2,5845 to 2,5850 in)
2722 and 2725 engines - Standard Size 2		
Undersize - 0,254 mm (0,010 in)		66,154 to 66,167 mm (2,6045 to 2,6050 in)
- 0,508 mm (0,020 in)		65,900 to 65,913 mm (2,5945 to 2,5950 in)
- 0,762 mm (0,030 in)		65,646 to 65,659 mm (2,5845 to 2,5850 in)
2726T and 2728T engines - Standard Size 1		
Undersize - 0,254 mm (0,010 in)		66,408 to 66,421 mm (2,6145 to 2,6150 in)
- 0,508 mm (0,020 in)		66,154 to 66,167 mm (2,6045 to 2,6050 in)
- 0,762 mm (0,030 in)		65,900 to 65,913 mm (2,5945 to 2,5950 in)
- 1,016 mm (0,040 in)		65,646 to 65,659 mm (2,5845 to 2,5850 in)
Length		42,160 to 42,266 mm (1,660 to 1,664 in)

Main and Crankpin Bearing Journals

Fillet Radii	4,32 to 4,83 mm (0,17 to 0,19 in)
Ovality - Maximum Permitted	
- Crankpin	0,006 mm (0,00025 in)
- Main	0,010 mm (0,00040 in)
Taper - Maximum Permitted	0,013 mm (0,0005 in)

Main Bearing Liners

Thickness - Standard

Standard Size 1	2,071 to 2,080 mm (0,08250 to 0,08215 in)
Standard Size 2	2,198 to 2,207 mm (0,08750 to 0,08715 in)

Thickness - Service Regrind

Standard Size 1		
Undersize	- 0,254 mm (0,010 in)	2,198 to 2,207 mm (0,08655 to 0,08690 in)
	- 0,508 mm (0,020 in)	2,325 to 2,334 mm (0,09155 to 0,09190 in)
	- 0,762 mm (0,030 in)	2,452 to 2,461 mm (0,09655 to 0,09690 in)
	- 1,016 mm (0,040 in)	2,579 to 2,588 mm (0,10155 to 0,10190 in)
Standard Size 2		
Undersize	- 0,254 mm (0,010 in)	2,325 to 2,334 mm (0,09155 to 0,09190 in)
	- 0,508 mm (0,020 in)	2,452 to 2,461 mm (0,09655 to 0,09690 in)
	- 0,762 mm (0,030 in)	2,579 to 2,588 mm (0,10155 to 0,10190 in)

NOTE: For 0,381 mm (0,015 in) oversize bearing housings, liners are 0,191 mm (0,0075 in) thicker than dimensions specified above.

Length	- Front and Intermediate	26,29 to 26,67 mm (1,035 to 1,050 in)
	- Centre and Rear	35,81 to 36,19 mm (1,410 to 1,425 in)
Clearance - Main Bearing Liner to Journal		0,038 to 0,086 mm (0,0015 to 0,0034 in)

Thrust Washer

Thickness

Standard		2,311 to 2,362 mm (0,091 to 0,093 in)
Oversize	- 0,063 mm (0,0025 in)	2,375 to 2,426 mm (0,0935 to 0,0955 in)
	- 0,127 mm (0,0050 in)	2,438 to 2,489 mm (0,0960 to 0,0980 in)
	- 0,190 mm (0,0075 in)	2,502 to 2,553 mm (0,0985 to 0,1005 in)
	- 0,254 mm (0,010 in)	2,565 to 2,616 mm (0,101 to 0,103 in)
	- 0,381 mm (0,015 in)	2,692 to 2,743 mm (0,106 to 0,108 in)
	- 0,508 mm (0,020 in)	2,819 to 2,870 mm (0,111 to 0,113 in)
Clearance (Crankshaft End Float)		0,050 to 0,254 mm (0,002 to 0,010 in)

Crankpin Bearing Liners (Big End)

Thickness - Standard

2723 engine	
Standard Size 1	1,821 to 1,830 mm (0,07170 to 0,07205 in)
Standard Size 2	1,948 to 1,957 mm (0,07670 to 0,07705 in)
2722, 2725, 2726T and 2728T engines	
Standard Size 1	2,075 to 2,084 mm (0,08170 to 0,08205 in)
Standard Size 2	2,202 to 2,211 mm (0,08670 to 0,08705 in)

Thickness - Service Regrind	
2723 engine - Standard Size 1	
Undersize - 0,254 mm (0,010 in)	1,948 to 1,957 mm (0,07670 to 0,07705 in)
- 0,508 mm (0,020 in)	2,075 to 2,084 mm (0,08170 to 0,08205 in)
- 0,762 mm (0,030 in)	2,202 to 2,211 mm (0,08670 to 0,08705 in)
- 1,016 mm (0,040 in)	2,329 to 2,338 mm (0,0917 to 0,09205 in)
2723 engine - Standard Size 2	
Undersize - 0,254 mm (0,010 in)	2,075 to 2,084 mm (0,08170 to 0,08205 in)
- 0,508 mm (0,020 in)	2,202 to 2,211 mm (0,08670 to 0,08705 in)
- 0,762 mm (0,030 in)	2,329 to 2,338 mm (0,09170 to 0,09205 in)
2722, 2725T, 2726T and 2728T engines - Standard Size 1	
Undersize - 0,254 mm (0,010 in)	2,202 to 2,211 mm (0,08670 to 0,08705 in)
- 0,508 mm (0,020 in)	2,329 to 2,338 mm (0,09170 to 0,09205 in)
- 0,762 mm (0,030 in)	2,456 to 2,465 mm (0,09670 to 0,09705 in)
- 1,016 mm (0,040 in)	2,583 to 2,592 mm (0,10170 to 0,10205 in)
2722, 2725, 2726T and 2728T engines - Standard Size 2	
Undersize - 0,254 mm (0,010 in)	2,329 to 2,338 mm (0,09170 to 0,09205 in)
- 0,508 mm (0,020 in)	2,456 to 2,465 mm (0,09670 to 0,09705 in)
- 0,762 mm (0,030 in)	2,583 to 2,592 mm (0,10170 to 0,10205 in)
Width	33,655 to 34,036 mm (1,325 to 1,340 in)
Clearance - Crankpin Bearing Liner to Journal	
Standard	0,036 to 0,086 mm (0,0014 to 0,0034 in)
Service Regrind	0,036 to 0,079 mm (0,0014 to 0,0031 in)
End Float	0,076 to 0,279 mm (0,003 to 0,011 in)

NOTE: If crankshaft bearings are re-used they should always be fitted to their original housings.

Crankshaft Oil Seal	
Seal Protrusion Above Cylinder Block/Rear Main Bearing Cap Face	
- Both Sides, Both Faces	0,635 to 0,762 mm (0,025 to 0,030 in)

Crankshaft Turning Torque			
Crankshaft Only in Block	Nm	Kgm	lbft
2722 engine	8 to 16	0,8 to 1,7	6 to 12
2723, 2725, 2726T and 2728T engines	11 to 20	1,1 to 2,0	8 to 15
Complete Engine less Injectors and Driven Equipment			
2722 engine	34 to 61	3,5 to 6,2	25 to 45
2723 and 2725 engine	47 to 75	4,8 to 7,6	35 to 55
2726T and 2728T engines	41 to 68	4,1 to 6,9	30 to 50

CAMSHAFT AND CAMFOLLOWERS (Tappets)	
Camshaft	
Cam Lift - Maximum	7,87 mm (0,310 in)
Bearing Journal Diameter	55,48 to 55,50 mm (2,1842 to 2,1850 in)
Bearing Journal Clearance	
Front	0,038 to 0,076 mm (0,0015 to 0,0030 in)
Intermediate and Rear	0,025 to 0,064 mm (0,0010 to 0,0025 in)
End Float	0,050 to 0,533 mm (0,002 to 0,021 in)
Camfollowers (Tappets)	
Stem Diameter	17,475 to 17,488 mm (0,6880 to 0,6885 in)
Length - Cup to Face	56,75 to 57,25 mm (2,2343 to 2,2539 in)
Clearance - Camfollower to Cylinder Block	0,012 to 0,063 mm (0,0005 to 0,0025 in)

TIMING GEARS

Number of Teeth	
Crankshaft Gear	35
Camshaft Gear	70
Fitting	
Camshaft Gear to Camshaft	0,042 mm (0,0016 in) to 0,002 mm (0,0008 in) Interference
Crankshaft Gear to Crankshaft	0,0000 mm (0,00 in) to 0,50 mm (0,002 in) Interference
Temperature - Crankshaft and Camshaft Gears	82°C (180°F)
Backlash	
Crankshaft Gear to Camshaft Gear	0,025 to 0,279 mm (0,001 to 0,011 in)
Camshaft Gear to Injection Pump gear	0,025 to 0,279 mm (0,001 to 0,011 in)

NOTE: Crankshaft and Camshaft Gears are graded for mesh and identified by a coloured paintspot. Gears should be matched Red/Red, Yellow/Yellow, Blue/Blue, but should matching colours be unavailable in service alternative pairing of gears MAY give the specified backlash.

CAUTION: BACKLASH MUST BE WITHIN THE SPECIFIED LIMITS OR DAMAGE MAY OCCUR FROM INCORRECT MESHING OF THE GEARS.

Basic Engine Timing - Refer to Section 4.

FLYWHEEL AND STARTER RING GEAR

Runout of Flywheel Face at a radius of 140 mm (5,5 in)	0,178 mm (0,007 in) T.I.R. Maximum
Number of Teeth on Ring Gear	128
Fitting Temperature of Ring Gear	190°C (375°F)

CYLINDER HEAD, VALVE GUIDES AND VALVE SEAT INSERTS

Cylinder Head	
Datum Face	Rocker Cover Face
Height - (new)	92,68 to 92,81 mm (3,649 to 3,654 in)
- minimum after re-surfacing	92,17 to 92,30 mm (3,629 to 3,634 in)
Bow/twist within	0,254 mm (0,010 in) Max. Overall
Valve Guide	
Length	76,2 mm (3,0 in)
Diameter - Internal	9,528 to 9,558 mm (0,3751 to 0,3763 in)
- External - Standard	15,893 to 15,905 mm (0,6257 to 0,6262 in)
Protrusion Above the Top Face	
- Inlet	18,29 mm (0,72 in)
- Exhaust	26,67 mm (1,05 in)
Valve Seat Insert Recess - Standard Size	
Diameter - Inlet	46,876 to 46,901 mm (1,8455 to 1,8465 in)
- Exhaust	39,764 to 39,789 mm (1,5655 to 1,5665 in)
Depth - Inlet and Exhaust	6,553 to 6,832 mm (0,258 to 0,269 in)
Valve Seat Insert Recess - Oversize	0,254 mm (0,010 in)
Diameter - Inlet	47,130 to 47,155 mm (1,8555 to 1,8565 in)
- Exhaust	40,018 to 40,043 mm (1,5755 to 1,5765 in)
Depth - Inlet and Exhaust	6,807 to 7,085 mm (0,268 to 0,279 in)

Valve Seat Insert - Standard Size		
Outside Diameter	- Inlet	46,977 to 46,990 mm (1,8495 to 1,8500 in)
	- Exhaust	39,865 to 39,878 mm (1,5695 to 1,5700 in)
Thickness	- Inlet and Exhaust	6,794 to 6,845 mm (0,2675 to 0,2695 in)
Valve Seat Insert - Oversize 0,254 mm (0,010 in)		
Outside Diameter	- Inlet	47,231 to 47,244 mm (1,8595 to 1,8600 in)
	- Exhaust	40,119 to 40,132 mm (1,5795 to 1,5800 in)
Thickness	- Inlet and Exhaust	7,048 to 7,099 mm (0,2775 to 0,2795 in)
Valve Seat Face Width		1,60 to 2,38 mm (0,063 to 0,094 in)
Valve Seat Angle		30° 00' to 30° 30'

VALVES

Head Diameter	- Inlet	45,47 to 45,72 mm (1,790 to 1,800 in)
	- Exhaust	38,15 to 38,40 mm (1,502 to 1,512 in)
Stem Diameter	- Inlet	9,474 to 9,500 mm (0,373 to 0,374 in)
	- Exhaust	9,456 to 9,482 mm (0,3723 to 0,3733 in)
Stem to Guide Clearance	- Inlet	0,028 to 0,084 mm (0,0011 to 0,0033 in)
	- Exhaust	0,045 to 0,102 mm (0,0018 to 0,0004 in)
Angle of Valve Seat		29° 00 to 29° 30'
Valve Head Protrusion compared to Head Face		
- Inlet		+ 0,254 to - 0,508 mm (+ 0,010 to - 0,020 in)
- Exhaust		+ 0,431 to + 1,016 mm (+ 0,017 to + 0,040 in)

VALVE SPRINGS

Inlet

Number of Coils		7,5 Total
Free Length of Spring		58,7 mm (2,31 in)
Spring Load at a length of		
	- 40 mm (1,56 in)	71,21 to 76,66 kg (157 to 169 lb)
	- 50 mm (1,97 in)	28,12 to 30,84 kg (62 to 68 lb)
Identification		Blue Paint Line

Exhaust

Number of Coils		7,98 Total
Free Length of Spring		69,93 mm (2,753 in)
Spring Load at a length of		
	- 40 mm (1,56 in)	70,31 to 77,56 kg (155 to 171 lb)
	- 50 mm (1,97 in)	46,11 to 50,96 kg (102 to 112 lb)
Identification		Yellow Paint Line

ROCKER SHAFT, ROCKERS AND PUSH RODS

Rocker Shaft

Diameter	18,872 to 18,898 mm (0,743 to 0,744 in)
Number of Springs	
- 4 Cylinder Engines	4
- 6 Cylinder Engines	6
Load of Rocker Shaft Spring	1,81 to 2,27 kg at 26,92 mm (4 to 5 lb at 1,06 in)
Rocker - Bore Diameter	18,923 to 18,949 mm (0,7450 to 0,746 in)
Push Rod - Length (Cup to Ball)	301,88 to 302,64 mm (11,89 to 11,91 mm)

VALVE CLEARANCE, TIMING AND LIFT

Clearance (Hot and Cold - All Valves)	
2722, 2723 and 2725 engines	0,38 mm (0,015 in)
2726T and 2728T engines	0,46 mm (0,018 in)
Timing	Camshaft and Crankshaft Gear Timing Marks
Lift (Maximum)	11,02 mm (0,43 in)

FAN BELT

Tension (Total Deflection)	13,0 mm (0,50 in) Measured Mid-way between Alternator and Water Pump Pulleys

Compression Pressures at Cranking Speed

Minimum for Each Cylinder	20,7 bar (300 lb/in^2)
Maximum Variation between Cylinders	5,5 bar (80 lb/in^2)

ENGINE LUBRICATION - Refer to Section 2

SEALERS AND ADHESIVES

	FORD Specification
Cylinder Block	
Taper Plug Sealer	SJM-4G-9102-A
Core Plug Retaining Sealer	SM-4G-4645-AA
Camshaft Plug and Blanking Plug Sealer	EM-4G-44-A
Lift Pump Studs to Block Sealer	SJM-4G-9102-A
Water Pump Studs to Block Sealer	SPM-4G-9102-A
Fuel Injection Pump and Compressor Studs	SDM-4G-9107-A
Cylinder Liner	
Primer	SM-4G-4647-A
Sealing Compound	EM-4G-64
Main Bearing Cap to Cylinder Block	SDM-4G-9105-A
Sump Gasket Sealer	SPM-2G-9121-A
Ring Gear Retaining Screw Sealer	EM-4G-52
Oil Pump	
Mounting Studs to Main Bearing Cap Sealer - 2728T Engines Only	SPM-2G-9102-A
2728T Engine	
Front Housing Cup Plug Sealer	SM-4G-4645-A
Front Housing Studs Sealer	SPM-4G-9120-A
Front Timing Cover Studs Sealer	SPM-4G-9120-A
Crankshaft Insert Sealer	SDM-4G-9102-A
Thermostat Housing Connectors Sealer	SJM-4G-9102-A
Exhaust System	
Anti Seize Compound	SAM-1C-9107-A

TIGHTENING TORQUES

		Nm	Kgm	lbft
Cylinder Block				
Main oil gallery plugs (front and rear)		27 to 34	2,8 to 3,5	20 to 25
Main oil gallery cross drilling plug		27 to 34	2,8 to 3,5	20 to 25
Connector - turbocharger oil feed		34 to 40	3,5 to 4,1	25 to 30
Fuel lift pump mounting studs		19 to 24	1,9 to 2,5	14 to 18
Oil pan locating studs		31 to 39	3,2 to 4,0	23 to 29
Water pump mounting stud		19 to 24	1,9 to 2,5	14 to 18
Oil pressure sender unit		19 to 22	1,9 to 2,2	14 to 16
Drain cock/plug		20 to 27	2,0 to 2,8	15 to 20
Crankshaft mainbearing cap bolts,				
	1st stage	149 to 156	15,2 to 15,9	110 to 115
	final stage	156 to 163	15,9 to 16,6	115 to 120
Connecting rod cap nuts (early 2723 engine only)				
	1st stage	60 to 75	6,1 to 7,6	45 to 55
	final stage	75 to 82	7,6 to 8,3	55 to 60
Connecting rod cap bolts (all engines except 2723)				
	1st stage	108 to 115	11 to 11,7	80 to 85
	final stage	115 to 122	11,7 to 12,4	85 to 90
Crankshaft pulley (all engines except 2728T)				
Centre bolt		313 to 340	31,8 to 34,6	230 to 250
Crankshaft pulley (2728T only)				
Locking sleeve bolts		25 to 30	2,5 to 3,0	18 to 22
Insert to crankshaft		80 to 110	8,2 to 11,2	59 to 81
Flywheel retaining bolts		102 to 122	10,4 to 12,4	75 to 90
Oil filter head to cylinder block bolts		50 to 62	5,1 to 6,3	37 to 46
Timing Gears				
Timing gear housing to cylinder block bolts		34 to 40	3,5 to 4,1	25 to 30
Camshaft thrust plate bolts		34 to 40	3,5 to 4,1	25 to 30
Camshaft gear retaining bolt		203 to 210	20,7 to 21,4	150 to 155
Timing gear housing cover				
5/16 UNC bolts		19 to 22	1,9 to 2,2	14 to 16
3/8 UNC bolts		30 to 34	3,0 to 3,5	22 to 25
Timing gear housing cover inspection plate bolts (Automotive and G.P. governed pumps only)		8 to 11	0,8 to 1,1	6 to 8
Timing gear housing studs - oil pan location (2728T engine only)		31 to 39	3,2 to 4,0	23 to 29
Cylinder Head				
Inlet and exhaust manifold studs		37 to 40	3,8 to 4,0	27 to 30
Cylinder head retaining bolts				
1st stage		60 to 75	6,1 to 7,6	45 to 55
2nd stage		122	12,4	90
3rd stage		Tighten through a further 90°		
Rocker shaft pedestal bolts		23 to 30	2,3 to 3,0	17 to 22
Valve clearance adjusting screw (inherent torque)		12 to 35	1,2 to 3,5	9 to 26
Rocker cover retaining screws		4 to 5,5	0,4 to 0,6	3 to 4
Fuel filter mounting bracket retaining bolts		31 to 39	3,1 to 4,0	23 to 29
Injectors				
Injector retaining bolts		17 to 22	1,8 to 2,2	12 to 16
High pressure fuel pipes				
gland nuts		17 to 20	1,8 to 2,0	12 to 15
oil seal nuts		22 to 27	2,2 to 2,8	16 to 20
Injector leak-off pipe banjo bolt		16 to 20	1,6 to 2,0	12 to 15
Injection Pump				
Drive gear hub nut	Automotive & G.P.	60 to 65	6,1 to 6,6	44 to 48
Drive ring gear locking bolts	governed pump only	20 to 25	2,0 to 2,5	15 to 18
Pump mounting bolts		22 to 27	2,2 to 2,7	16 to 20
Filler, level and drain plugs		4 to 6,8	0,4 to 0,7	3 to 5
Bleed screws		4 to 6,8	0,4 to 0,7	3 to 5
Fuel Lift Pump				
Adaptor to cylinder block nuts		19 to 24	1,9 to 2,5	14 to 18
Pump retaining nuts - std. low pressure pump		20 to 25	2,0 to 2,5	15 to 18
Pre-filter banjo bolt		30 to 40	3,0 to 4,1	22 to 29
Pump retaining bolts - high pressure pump		9 to 11	0,9 to 1,1	7 to 8
Low Pressure Fuel Pipe Unions		11 to 16	1,1 to 1,7	8 to 12

TIGHTENING TORQUES

	Nm	Kgm	lbft
Fuel Filters			
Filter element retaining bolt	6,8 to 9,5	0,7 to 1,0	5 to 7
Bleed screws	6,8 to 9,5	0,7 to 1,0	5 to 7
Oil Pump - 2728T Engine Only			
Pump mounting studs in crankshaft main bearing cap	10 to 15	1,0 to 1,5	7 to 11
Pump securing nuts	40 to 50	4,1 to 5,1	29 to 37
Pick-up pipe to pump bolts	20 to 25	2,0 to 2,5	15 to 18
Delivery pipe flange to cylinder block bolts	18 to 22	1,8 to 2,2	13 to 16
Delivery pipe support bracket bolt	18 to 22	1,8 to 2,2	13 to 16
Oil Pump - Engines (Except 2728T) with Front Well, Rear Well or Shallow Oil Pans			
Pump securing bolts	18 to 22	1,8 to 2,2	13 to 16
Pick-up pipe to pump union nut	75 to 88	7,6 to 9,0	55 to 65
Pick-up pipe support bracket bolt	18 to 22	1,8 to 2,2	13 to 16
Oil Pump - Engines (Except 2728T) with High Inclination Oil Pans			
Pump securing bolts	18 to 22	1,8 to 2,2	13 to 16
Pick-up pipes to pump gland nuts	75 to 88	7,6 to 9,0	55 to 65
Pick-up pipes support bracket bolts	18 to 22	1,8 to 2,2	13 to 16
Oil Pan			
Securing bolts/nuts	30 to 33	3,0 to 3,3	22 to 24
Drain plug(s)	47 to 54	4,8 to 5,5	35 to 40
Water Pump			
Pump back plate securing bolt (2728T Engine only)	18 to 22	1,8 to 2,2	13 to 16
Pump securing bolts/nuts	18 to 22	1,8 to 2,2	13 to 16
Water pump extension tube bolts	43 to 50	4,4 to 5,1	32 to 37
Split flow water tube to cylinder block bolts (2728T engine only)	31 to 39	3,1 to 4,0	23 to 29
Thermostats			
Housing to cylinder head securing bolts (twin thermostats only)	18 to 22	1,8 to 2,2	13 to 16
Water outlet connection to housing or cylinder head nut/bolts	20 to 25	2,0 to 2,5	15 to 18
Electrical			
Starter motor securing bolts - CAV	33 to 39	3,4 to 4,0	24 to 29
- Lucas	50 to 55	5,1 to 5,6	37 to 40
Alternator mounting and adjusting bolts	16 to 20	1,7 to 2,0	12 to 15
Fans and Drive Belt Tensioning			
Fan securing bolts (including 'Low Loss' fan)	16 to 20	1,6 to 2,0	12 to 15
Idler pulley mounting and adjusting bolts	16 to 20	1,6 to 2,0	12 to 15
Turbochargers			
Turbocharger mounting studs - exhaust manifold	20 to 25	2,0 to 2,5	15 to 18
Exhaust pipe/elbow mounting studs - turbocharger	15 to 20	1,5 to 2,0	11 to 15
Turbocharger to exhaust manifold nuts	41 to 51	4,2 to 5,2	30 to 38
Turbocharger to support plate nuts	20 to 25	2,0 to 2,5	15 to 18
Support plate to support bracket bolts	41 to 51	4,2 to 5,2	30 to 38
Support bracket to cylinder block bolts			
5/16 UNC bolts	18 to 22	1,8 to 2,2	13 to 16
7/16 UNC bolts	50 to 62	5,1 to 6,3	37 to 46
Oil feed pipe flange bolts	20 to 25	2,0 to 2,5	15 to 18
Oil feed pipe cylinder block connection	34 to 40	3,5 to 4,1	25 to 30
Oil drain pipe flange bolts	20 to 25	2,0 to 2,5	15 to 18
Oil drain pipe adaptor to oil pan	54 to 61	5,5 to 6,2	40 to 45
Intercooler			
Intercooler to inlet manifold duct screws (both ends)	20 to 25	2,0 to 2,5	15 to 18
Intercooler to support bracket bolts	20 to 25	2,0 to 2,5	15 to 18
Support bracket to cylinder block bolts	50 to 62	5,1 to 6,3	37 to 46

CONTENTS

General Description

All 2720 range engines are equipped with high output bi-rotor oil pumps incorporating a pressure relief valve.

The pumps used on engines fitted with front well, rear well or shallow oil pans, incorporate a reservoir which retains oil within the rotor assembly; this feature ensures rapid priming and prevents air locks from occurring.

Engines fitted with high inclination oil pans employ a slightly different oil pump and an alternative oil pick-up pipe layout with two gauze filters.

The 2728T engine has its oil pump mounted on the crankshaft front main bearing cap; it is driven from a gear on the crankshaft via an idler gear. All other engines have the oil pump mounted on the base of the cylinder block, the drive being taken from a skew gear on the camshaft.

As illustrated in Fig. 1, the oil pump draws oil through a coarse gauze filter(s) and pumps it through the full flow, spin-on canister type oil filter into the main oil gallery. The filtered oil is then directed at full pressure to the following:

i) Crankshaft main and big-end journals.

ii) Camshaft bearing bushes.

iii) Where fitted, compressor crankshaft bearing bushes.

iv) Turbocharger bearings (where fitted) via an external pipe.

v) Fuel injection pump, via a pipe from the oil filter mounting block (automotive and G.P. governed pumps only).

vi) Piston cooling jets, on 2728T engines only, which are tapped into the main bearing support webs and direct a continuous flow of oil to the underside of each piston crown.

Offset drillings in one of the camshaft journals direct a metered oil feed to the centre pedestal of the valve rocker shaft support, to lubricate the shaft and the valve gear. A spiral groove in the camshaft front bearing journals provides an oil feed to the gears in the timing cover. Oil is returned to the holes and drillings in the cylinder head and block castings.

The filter head on 2728T engines has built-in connections for the mandatory oil cooler and incorporates a pressure relief valve which operates when the engine is cold to allow the oil to by-pass the cooler and so warm up more quickly. The by-pass also acts as a protection against excessive pressure which might damage the cooler.

On 2722, 2723, 2725 and 2726T engines, an oil filter adaptor is available to enable an oil cooler to be connected if required. This adaptor is fitted between the filter head and cylinder block and contains a pressure relief valve.

The full flow filter assembly is fitted with a by-pass facility which acts if the filter element becomes blocked.

The engine may be refilled with oil via the rocker cover mounted filler cap or (except for 2728T engines) through the low level filler, mounted on the oil pan.

Various types of oil pan can be fitted to all engines except the 2728T model. In all cases, the oil pan incorporates the lower half of the flywheel housing.

The oil pan is sealed to the lower face of the crankcase by rubber asbestos composition gaskets and, at the front and rear by synthetic rubber seals.

On turbocharged engines, the oil return pipe from the turbocharger is connected directly into the top of the oil pan. A magnetic drain plug is fitted into a threaded insert in a boss in the bottom of the well. Two drain plugs are fitted to high inclination oil pans.

On 2722, 2723 and 2725 engines, a low level dipstick is fitted. On 2726T and 2728T engines, a longer dipstick tube is fitted to enable a high level dipstick to be employed.

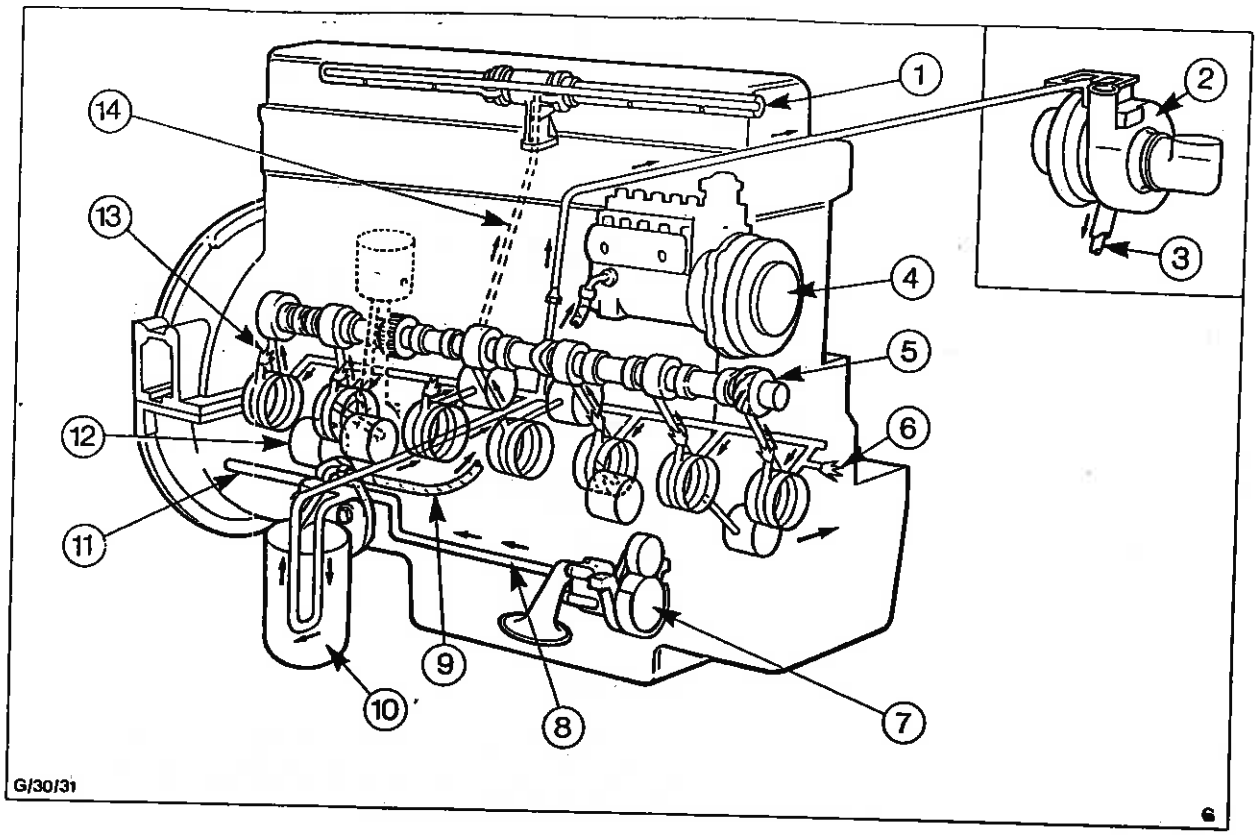


Fig. 1 - Engine Oil Lubricating Circuit (Schematic) - 2728T Engine Illustrated

1. Rocker Shaft
2. Turbocharger
3. Oil Drain to Oil Pan
4. Fuel Injection Pump
5. Camshaft Bearings
6. Spray to Timing Gear
7. Oil Feed Pipe to Main Oil Gallery
8. Feed Pipe to Main Oil Gallery
9. Feed Pipe to Fuel Injection Pump
10. Oil Filter
11. Main Oil Gallery
12. Big End Bearings
13. Main Bearing and Piston Cooling Nozzle
14. Metered Oil Feed to Rocker Shaft

OIL PAN REPAIRS

If a drain plug insert has become dislodged a new 3/4 in - 24NS2 insert (service part) must be fitted using a 'Helicoil' inserting tool of the prewind type (Fig. 2) in the following manner:

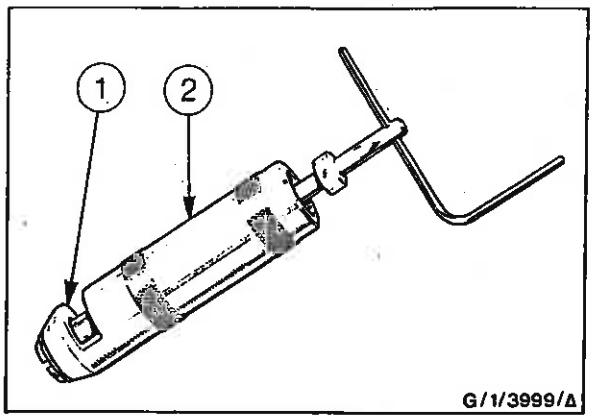


Fig. 2 - Helicoil Inserting Tool
1. Chamber
2. Tool Body

1. Withdraw the handle from the tool body until the mandrel is clear of the chamber.

2. Locate the insert in the chamber with the tang towards the nozzle.

3. Push the handle into the tool body to engage the slot in the mandrel with the tang.

4. Rotate the handle clockwise gently pushing the handle until the insert engages with the nozzle. Continue rotating the handle until the insert starts to appear from the end of the nozzle.

5. Place the tool squarely over the drain plug hole and without applying any end pressure, wind the insert into the oil pan until the insert is 1,6 to 2,4 mm (0,063 to 0,095 in) below the face of the boss - see Fig. 3.

6. Break the tang off using a pull and push action with a pair of long nosed pliers.

7. Stake the oil pan thread at the start of the insert to prevent the insert unwinding.

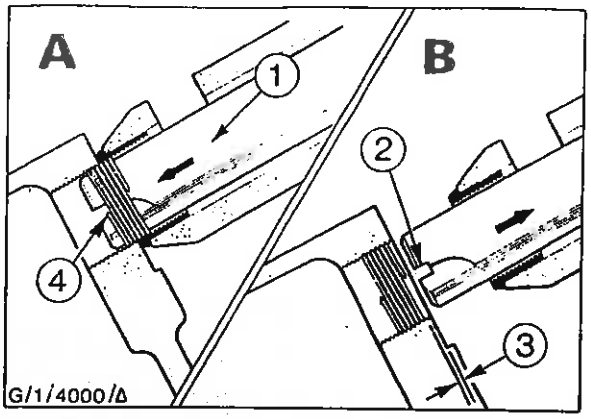


Fig. 3 - Installing Oil Pan Insert
A. Winding In Insert
B. Insert Installed
1. Mandrel
2. Slot
3. Install Insert below Face
4. Tang

OIL PUMP SERVICING

When installing a service cylinder assembly supplied without an oil pump, the existing oil pump must be either renewed or overhauled as detailed in the following text - see appropriate heading.

OIL PUMP OVERHAUL - 2722, 2723, 2725 and 2726T ENGINES NOT FITTED WITH HIGH INCLINATION OIL PANS

Remove the oil pan and pump from the engine as described under 'Dismantling the Basic Engine' in Section 1 (Operations 35, 36 and 37).

Either one of the two types of pump may be fitted, 'Holborn Eaton' or 'Motofides'. Complete pumps are interchangeable, individual components other than the skew drive gear are not. When obtaining spares the pumps may be identified from the assembly part number cast into the main body of the pump.

Dismantling - Refer to Fig. 4

1. Support the pump in a soft jawed vice, drive gear end downward.

2. Slacken and carefully remove the pressure relief valve cap and remove the spring and plunger.

3. Remove the bolts securing the cover plate and the pick up pipe union lock tab.

4. Carefully remove the cover plate from the pump body, if necessary, by tapping with a soft faced mallet.

CAUTION: DO NOT USE LEVERS OR SCREWDRIVERS TO PRISE OFF THE COVER PLATE, AS IRREPARABLE DAMAGE COULD BE DONE TO THE MATING FACES. HOLBORN EATON PUMPS HAVE TWO HOLLOW DOWELS LOCATING THE COVER PLATE TO THE PUMP BODY.

5. Mark the outer rotor to ensure reassembly the same way round and remove it from the pump body.

6. Clean and dry the rotors, the cover plate and the pump body interior and check for scoring or excessive wear. If the pump body and cover plate are scored, the pump should be renewed. If the rotors are only scored or worn these can be renewed separately as a matched pair.

7. Place a straight edge across the pump face and measure the clearance to the face of the inner rotor (rotor end float) - see Fig. 5. Refit the outer rotor and measure the clearance between the outer rotor and the pump body, and between the rotor lobes - see Fig. 6. If the clearances are not within the specified limits the rotors should be renewed.

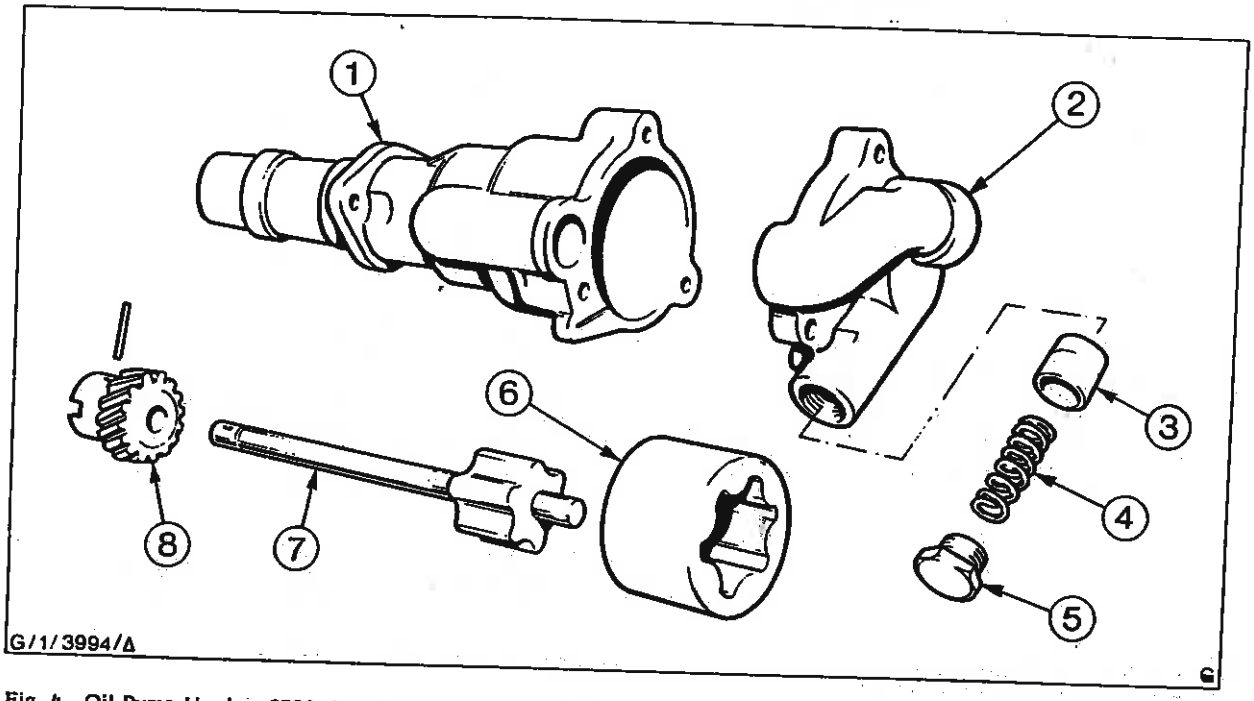


Fig. 4 - Oil Pump Used on 2722, 2723, 2725 and 2726T Engines Not Fitted with High Inclination Oil Pans
1. Pump Body
2. Cover
3. Pressure Relief Valve Plunger
4. Pressure Relief Valve Spring
5. Valve Cap
6. Outer Rotor
7. Inner Rotor and Shaft
8. Skew Drive Gear

8. Remove the outer rotor and, using a 4 mm pin punch, drift out the pin retaining the skew gear to the shaft. Remove the gear and withdraw the inner rotor and shaft assembly.

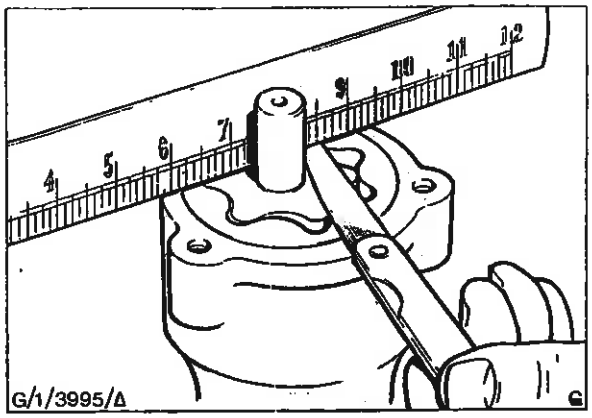


Fig. 5 - Measuring Pump Rotor End Float

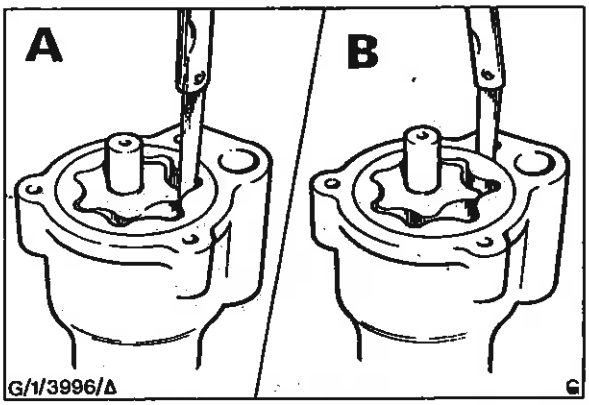


Fig. 6 - Measuring Rotor Lobe/Body Clearance
A. Checking Inner to Outer Rotor Clearance
B. Checking Outer Rotor to Pump Body Clearance

Cleaning and Inspection

Thoroughly clean and dry all parts.

Check the shaft and the bearings in the pump body and the cover plate for scoring or excessive wear.

NOTE: Bearings are not available separately for in service renewal.

If the bearings and pump body are considered satisfactory, but the condition of the rotors is suspect, temporarily install new inner and outer rotors and check the inner rotor end float, the rotor lobe clearance and outer rotor to body clearance as described previously. If the clearances are still not within the specified limits the pump assembly must be renewed.

Check the skew gear for scoring or excessive wear. If a new camshaft or a service cylinder assembly is being installed a new gear must be fitted.

The pressure relief valve plunger and seat should be examined to ensure good face to face contact, and the spring should stand upright when placed on end onto a flat surface. It should also be free from localised 'bright' marks on the outsides of the coils indicating a 'waisting' and possible weakening of the spring.

Reassembly - Refer to Fig. 7

1. Fit the inner rotor and shaft assembly into the pump body.

2. Press the skew gear onto the shaft until a clearance of 0,13 to 0,38 mm (0,005 to 0,015 in) is obtained between the gear and the pump body, with the rotor flush with the end plate face (Fig. 7).

NOTE: If the existing rotor is being used the gear must be turned to bring the pin hole at 90° to the original.

3. Drill and ream a hole 4,94 to 4,98 mm (0,194 to 0,196 in) through the shaft and gear, drive in the retaining pin and peen both ends to secure.

4. Fit the outer rotor, ensuring that it is the correct way round.

5. On Motofides pumps (no locating dowels) apply a very light smear of Loctite 510 (FORD Specification SLM-4G-9111-A) to the pump body to cover plate mating face. DO NOT allow the sealer to contact the pump rotor either when being applied or when the cover bolts are tightened.

6. Fit the cover plate and bolts, fit a new union nut lock plate to the bolt adjacent to the inlet orifice and tighten the bolts to the specified torque.

7. Fit the pressure relief valve plunger and spring, apply one spot of the specified thread lock sealant to the valve cap threads and tighten to the specified torque.

8. Ensure the pump rotates freely.

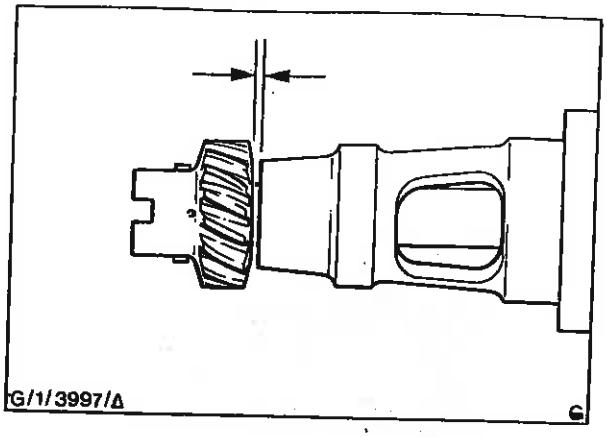


Fig. 7 - Skew Gear to Pump Body Clearance

9. Replace the pump and oil pan as described under 'Oil Pump Installation' (operations 58, 59 and 60) and 'Oil Pan Installation' (operations 66 to 70 inclusive and 75) in Section 1.

OIL PUMP OVERHAUL - 2722, 2723, 2725 and 2726T ENGINES FITTED WITH HIGH INCLINATION OIL PANS

Remove the oil pan and pump from the engine as described under 'Dismantling the Basic Engine' in Section 1 (operations 35, 36 and 38a, 38b and 38c).

Dismantling and Checking - Refer to Figs. 8 and 9

1. Remove the four retaining bolts and remove the end plate.

2. Check the oil pump for wear. Place a straight edge across the face of the pump housing and check the clearance between the straight edge and both parts of rotor. If this exceeds the clearance specified, the pump housing can be lapped to bring the clearance within tolerance.

3. Inner to outer rotor clearance and outer rotor to pump housing clearance should be measured with a feeler gauge, see Fig. 9; if these exceed the clearances specified, the inner and outer rotor should be renewed.

4. Remove the inner and outer scavenge rotors, and remove the woodruff key from the shaft.

5. Remove the lower pump body and the oil pressure relief plunger and spring.

6. The same checks for wear should be carried out on the delivery rotors as on the scavenge rotors. See operation 3. Should the clearance exceed the specified tolerance fit a new shaft and inner and outer rotors.

7. If it is necessary to renew the delivery rotors and shaft or skew gear, remove the outer rotor. Drive out the retaining pin securing the skew gear to the drive shaft and pull off the gear. The inner rotor and shaft can now be removed from the upper housing.

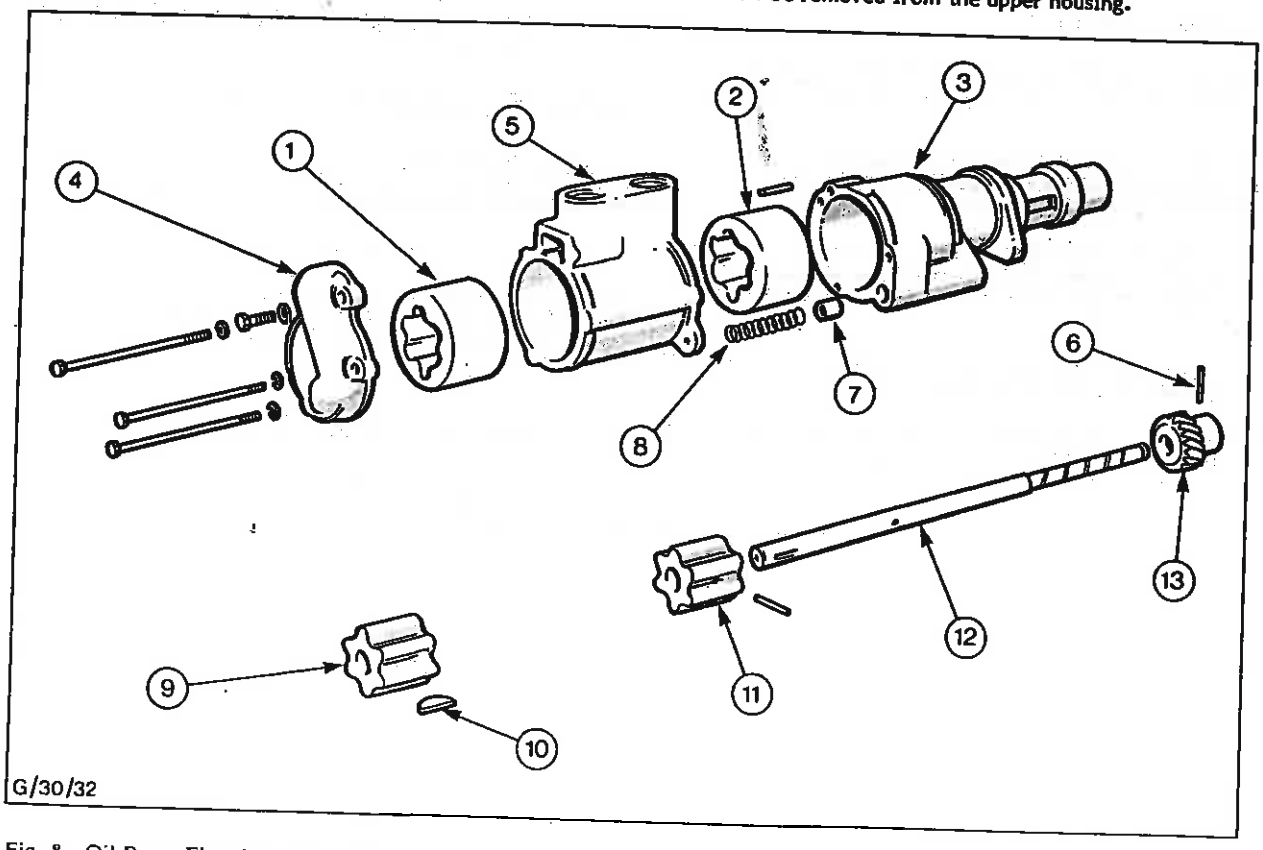


Fig. 8 - Oil Pump Fitted to 2722, 2723, 2725 and 2726T Engines with High Inclination Oil Pan
1 and 9 Scavenge Rotor Assembly
2, 11 and 12 Shaft and Rotor Assembly
3. Upper Pump Housing
4. End Plate
5. Lower Pump Housing
6. Pin
7. Pressure Relief Plunger
8. Pressure Relief Spring
10. Woodruff Key
13. Skew Gear

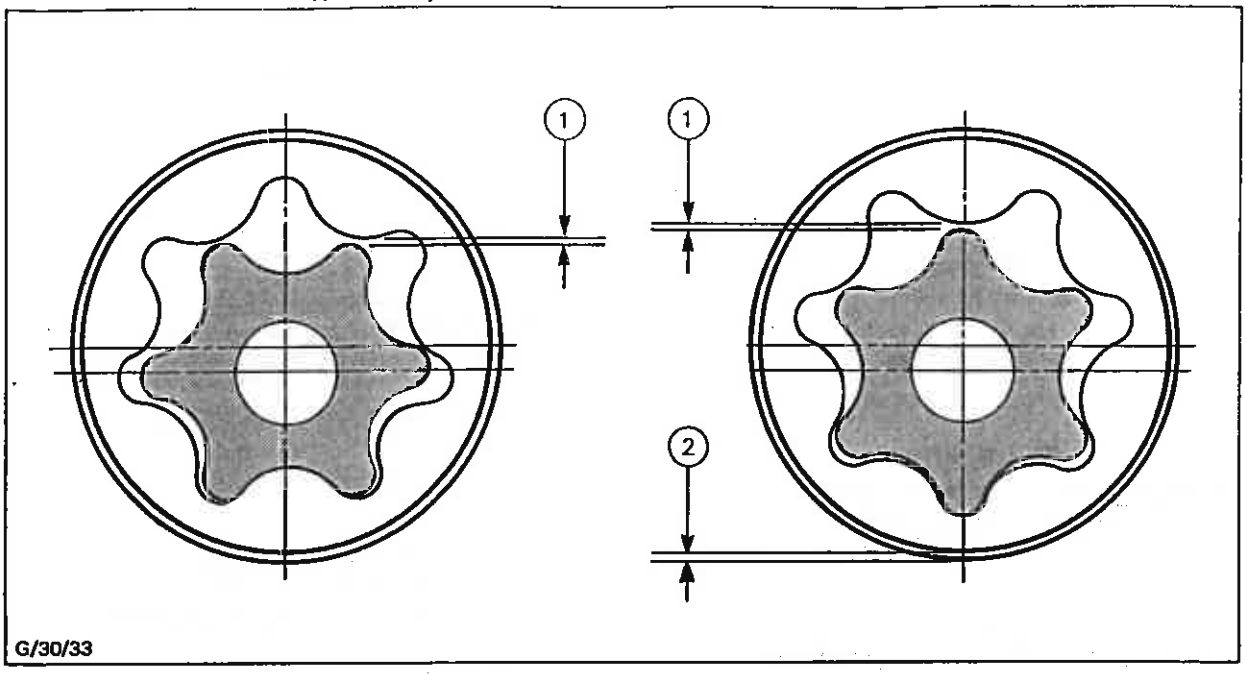


Fig. 9 - Measuring Rotor Clearance - 2722, 2723, 2725 and 2726T Engines Fitted with High Inclination Oil Pans
1. Inner to Outer Rotor 2. Outer Rotor to Pump Housing

Assembly - Refer to Fig. 7

1. If the pump has been completely dismantled, slide the new drive shaft and main inner rotor into the upper housing.

2. Press the skew gear onto the drive shaft end until there is a clearance of 0,178 to 0,305 mm (0,007 to 0,012 in) between the gear and pump housing.

3. Supporting the shaft at the rotor end, drill and ream 3,175 mm (0,125 in) diameter hole diametrically through the gear hub and shaft 13,72 mm (0,540 in) from the slotted end.

4. Fit the gear retaining pin and peen the ends over securely to prevent it becoming loose in service.

5. Replace the outer rotor, chamfered end first, and insert the oil pressure relief plunger and spring in the upper pump housing.

6. Slide the lower pump housing onto the shaft and fit the woodruff key in the shaft.

7. Replace inner rotor and outer rotor, chamfered end first, into the lower pump housing.

8. Fit the end plate and secure with the four bolts and lockwashers, ensuring that each is in its correct location, and then tighten to the specified torque value.

9. Ensure that the pump rotor revolves freely.

10. Replace pump and oil pan as described under 'Oil Pump Installation' (operations 1, 2 and 3) and 'Oil Pan Installation' (operations 66 to 70 inclusive and 75) in Section 1.

OIL PUMP OVERHAUL - 2728T ENGINE ONLY

Remove oil pan and pump as described under 'Dismantling the Basic Engine' (Operations 35, 36, 38a, 38b and 38c) in Section 1.

Either one of two types of pump may be fitted, 'Holborn Eaton or Motofides'. Complete pumps are interchangeable, individual components except for the idler and drive gears are not. Idler and drive gears will not normally be available for in service renewal. If these are badly worn then the pump assembly complete should be renewed. The pumps may be identified from the assembly part number cast into the pump body mounting. For service identification Holborn Eaton pumps have a cast iron rear cover plate, Motofides a cast aluminium cover plate with a steel thrust plate between this cover and the pump main body.

Dismantling - Refer to Fig. 10 or 11

1. Support the pump in a soft jawed vice, drive gear downwards.

2. Slacken and carefully remove the pressure relief valve cap and remove the spring and plunger.

3. Remove the bolts securing the cover plate, and the thrust plate, when fitted. Do not prise off the cover with levers or screwdrivers as damage could be caused to the mating faces.

4. Mark the outer rotor to ensure reassembly the same way round and remove it from the pump body.

5. Clean and dry the rotors, the cover plate and the pump body interior and check for scoring or excessive wear. If the pump body and cover plate, or thrust plate when fitted, are scored, the pump should be renewed. If the rotors are scored or worn these can be renewed separately as a matched pair.

6. As shown in Fig. 12, place a straight edge across the pump face and measure the clearance to the face of the inner rotor (rotor end float). Refit the outer rotor and measure the clearance between the outer rotor and the pump body, and between the rotor lobes (Fig. 13). If the clearances are not within the specified limits the rotors should be renewed.

7. Remove the outer rotor and support the pump on a press allowing room under the pump body for the inner rotor to be pressed out.

CAUTION: THE ROTOR MUST BE PRESSED, NOT DRIFTED, OUT OF THE PUMP BODY.

8. Using a mandrel of suitable shape or diameter to clear the drive gear retaining roll pin press the shaft and rotor assembly out of the gear. Restrain the rotor to prevent damage. Remove the roll pin.

Cleaning and Inspection

Thoroughly clean and dry all parts.

Check the shaft and the bearings in the pump body and the cover plate for scoring or excessive wear.

NOTE: Bearings are not available separately for in service renewal.

If the bearings and pump body are considered satisfactory, but the condition of the rotors is suspect, temporarily install new inner and outer rotors and check the inner rotor end float, the rotor lobe clearance and outer rotor to body clearance as described previously. If the clearances are still not within the specified limits the pump assembly must be renewed.

The pressure relief valve plunger and seat should be examined to ensure good face to face contact, and the spring should stand upright when placed on end onto a flat surface. It should also be free from localised 'bright' marks on the outsides of the coils indicating a 'waisting' and possible weakening of the spring.

Reassembly

1. Fit the inner rotor and shaft assembly into the pump. Support the pump on a press, locate the drive gear onto the rotor shaft and, while ensuring that the drive gear teeth align with the idler gear, press the gear onto the shaft until the specified clearance is obtained between the gear and the pump body.

2. Support the pump, restrain the gears to prevent them rotating, and drill a hole 1/8 in diameter and 11,9 mm (0,47 in) deep at the mating periphery of the gear and shaft. Ensure that the drill does not contact the bearing. Clean off all swarf.

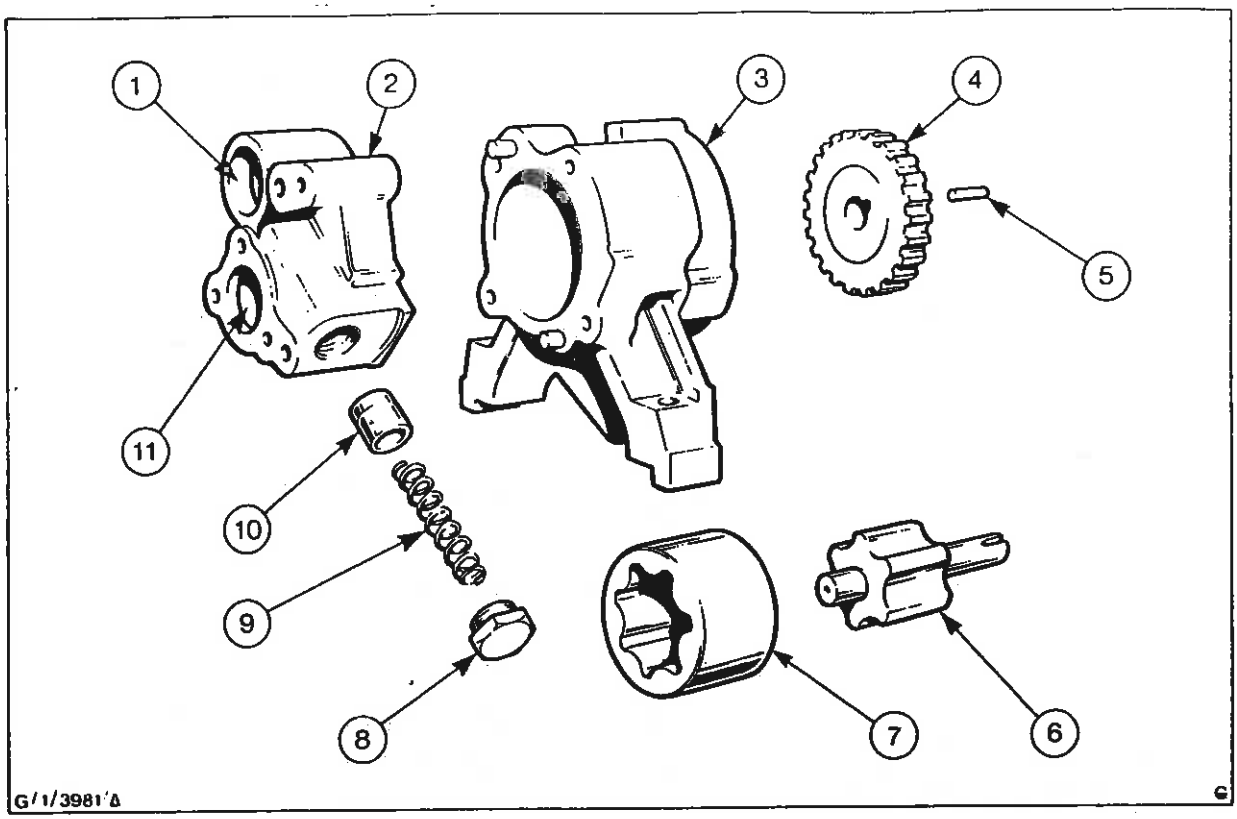


Fig. 10 - Exploded View of Holborn Eaton Type Oil pump

1. Pump Outlet
2. End Cover (Cast Iron)
3. Pump Body
4. Drive Gear
5. Roll Pin
6. Inner Rotor and Shaft
7. Outer Rotor
8. Valve Cap
9. Pressure Relief Valve Spring
10. Plunger
11. Pump Inlet

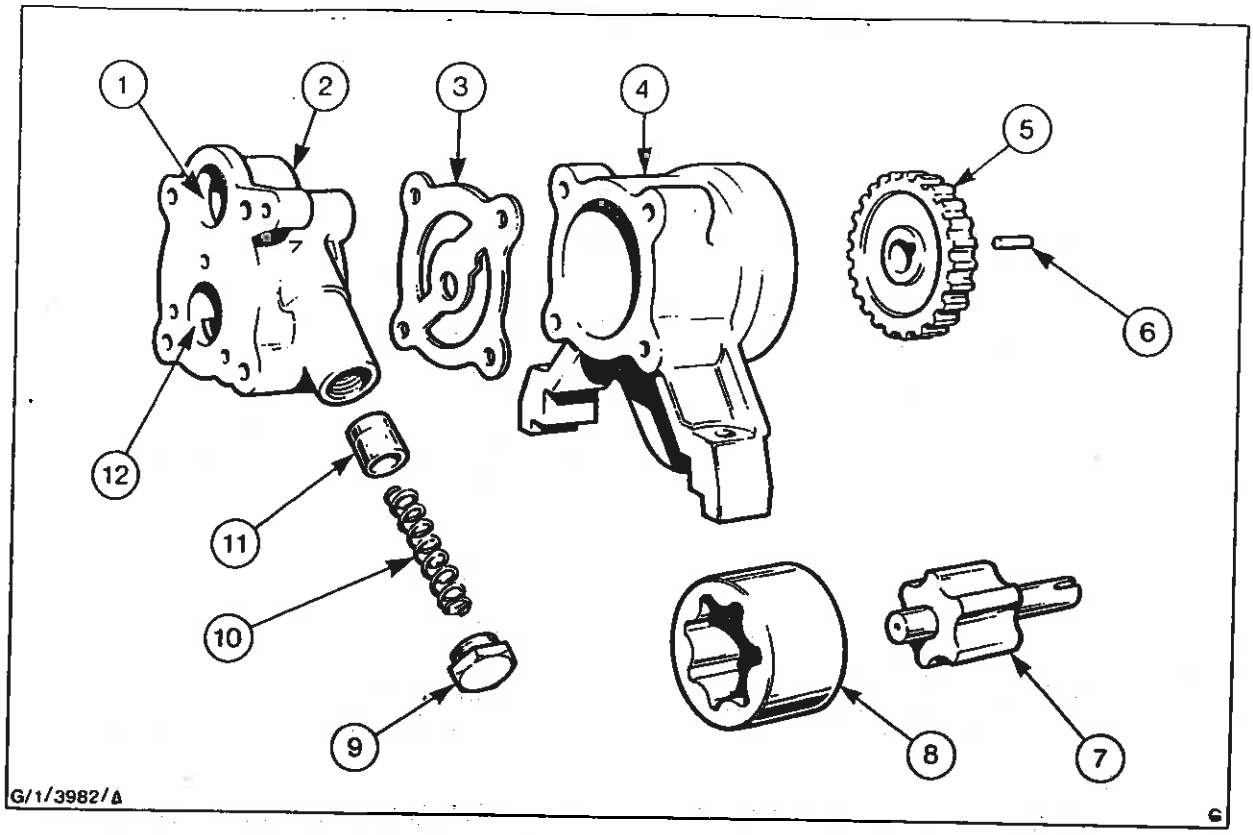


Fig. 11 - Exploded View of Motofides Type Oil pump

1. Pump Outlet
2. End Cover (Die Cast)
3. Thrust Plate
4. Pump Body
5. Drive Gear
6. Roll Pin
7. Inner Rotor and Shaft
8. Outer Rotor
9. Valve Cap
10. Pressure Relief Valve Spring
11. Plunger
12. Pump Inlet

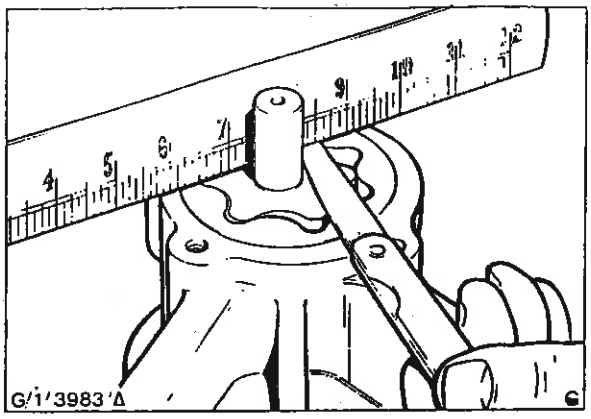


Fig. 12 - Measure Pump Rotor End Float

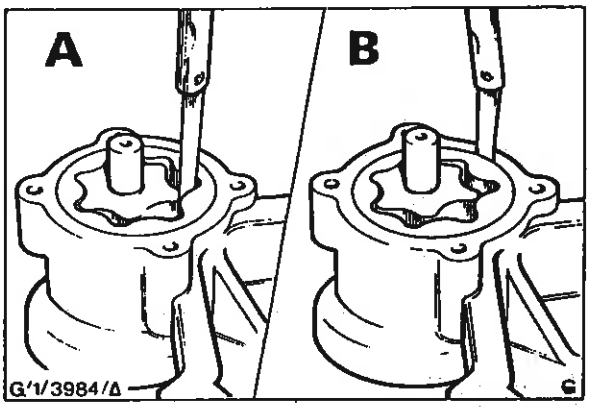


Fig. 13 - Measuring Rotor Lobe/Body Clearance
A. Checking Inner to Outer Rotor Clearance
B. Checking Outer Rotor to Pump Body Clearance

3. Apply Loctite 290 (FORD Specification GE SM46 4500A) to the roll pin and carefully press it into the hole taking care not to disturb the gear end float. Check that the pump rotates freely.

4. Fit the outer rotor, ensuring it is the correct way round.

5. Fit the cover plate, and the thrust plate when fitted, and tighten the bolts to the specified torque.

6. Fit the pressure relief valve and spring, apply one spot of the specified thread lock sealant to the valve cap threads and tighten to the specified torque.

7. Ensure the pump rotates freely.

8. Replace pump and oil pan as described under 'Oil Pump Installation' (operations 61 to 65 inclusive) and 'Oil Pan Installation' (operations 71 to 75 inclusive) in Section 1.

OIL FILTER ELEMENT RENEWAL

1. Unscrew the oil filter element and allow the oil to drain into a suitable container. Discard the element.

2. Fill a new filter element with clean engine oil of the specified grade, then screw the element onto the filter head until it contacts the 'O' ring seal. Turn the element a further 1/6 to a 1/4 turn BY HAND ONLY.

3. On turbocharged engines, prime the turbocharger as described in Section 4.

4. Check the engine oil level and top up as necessary with engine oil to specification.

5. Start the engine and check for oil leakage. Rectify as necessary.

SPECIFICATIONS

Engine		2722	2723	2725	2726T	2728T
Oil Temperature (max)			116°C (241°F)			110° (230°F)
Oil pressure (min)	1600 min	2,8 bar		2,1 bar		2.65 bar
	2000 rpm	3,2 bar		2,9 bar		3,1 bar
Service oil fill capacity (including filter)						
Engine with Front Well Oil Pan		9,1 litre (16 pt)		13,6 litre (24 pt)		-
Engine with Rear Well Oil Pan		9,1 litre (16 pt)		13,6 litre (24 pt)		-
Engine with Shallow Oil Pan		9,1 litre (16 pt)		17,2 litre (30 pt)		19 litre (33 pt)
Engine with High Inclination Oil Pan		11,7 litre (20,6 pt)		21,2 litre (37,3 pt)		-
Oil filter capacity				1 litre (1,76 pt)		
Oil Type				To meet Ford Specification SM-2C-1017A (API SF/CD)		
Oil Grade (viscosity)						
	From below −30°C to +30°C			SAE 5W/30		
	From −20°C to +30°C			SAE 10W/30		
	From −20°C to above +40°C			SAE 10W/40 or 10W/50		
	From −15°C to above +40°C			SAE 15W/40 or 15W/50		
	From −10°C to above +40°C			SAE 20W/40 or 20W/50		
Oil Pump						
Type				Bi-rotor		
Delivery in litres (gallons)/min						
Engine with Front Well Oil Pan						
Engine with Rear Well Oil Pan				36,37 (8,0) at 2000 rpm		88,65 (19,5) at 2600 rpm
Engine with Shallow Oil Pan						
Engine with High Inclination Oil pan		27,9 (6,13) at 1000 rpm		36,37 (8,0) at 1000 rpm		-
Idler gear end float				-		0 to 0,35 mm (0 to 0,014 in)
Rotor End Float				0,127 mm (0,005 in) max		
Clearance - drive gear to pump housing				0,13 to 0,38 mm (0,005 to 0,015 in)		Front faces of drive and idle gears to be flush
Clearance - inner to outer rotor lobes				0,229 mm (0,009 in) max		
Clearance - outer rotor to pump housing				0,304 mm (0,012 in) max		

SEALERS

Oil Pump	
Drive Gear Retaining Roll Pin Sealer	GE-SM4G-4500-A
Pressure Relief Valve Cap Sealer	FPM-2G-9120-A
End Cover Sealer - Motofides only	SLM-4G-9111-A

TIGHTENING TORQUES

	Nm	Kgm	lbf ft
Oil Pump - 2728T Engine Only			
End cover plate retaining bolts	16 to 20	1,6 to 2,0	12 to 15
Pressure relief valve cap	25 to 28	2,5 to 2,8	18 to 21
Oil Pump - Engines(Except 2728T) Fitted with Front Well, Rear Well or Shallow Oil Pans			
End cover plate retaining bolts			
Holborn Eaton pumps	19 to 22	1,9 to 2,2	14 to 16
Motofides pumps	16 to 20	1,6 to 2,0	12 to 15
Oil Pump - Engines (Except 2728T) Fitted with High Inclination Oil Pans			
End cover plate retaining bolts	16 to 20	1,6 to 2,0	12 to 15

CONTENTS

GENERAL DESCRIPTION

Cooling of all 2720 range engines is by means of a pump assisted thermo-syphon system in which coolant is circulated around the cylinders and through the cylinder head.

For industrial applications, a conventional radiator is employed in conjunction with an engine driven fan. The actual size and type of radiator used (open or sealed) will be determined by the requirements of the installation. Various sizes of fan can be employed; both water pump mounted and high level mounted types are employed. Rapid warming-up is achieved by the use of a thermostat(s) mounted in the cylinder head water outlet position.

For marine applications, the engines are fitted with fresh water cooled exhaust manifolds; the turbocharger housing is also water cooled from the exhaust manifold. The inter-cooler fitted to the 2728T engine is connected into the 'raw' water circuit. The raw water system components are fitted by the mariniser and include a heat exchanger, oil cooler and a raw water pump driven from the PTO position on the rear of the timing gear housing. Figs. 1 and 2 show the water cooling circuits for the 2726T and 2728T marine engines respectively.

The fresh water circuit can be an open or sealed type and a thermostat is fitted between the water cooled exhaust manifold and the fresh water pump.

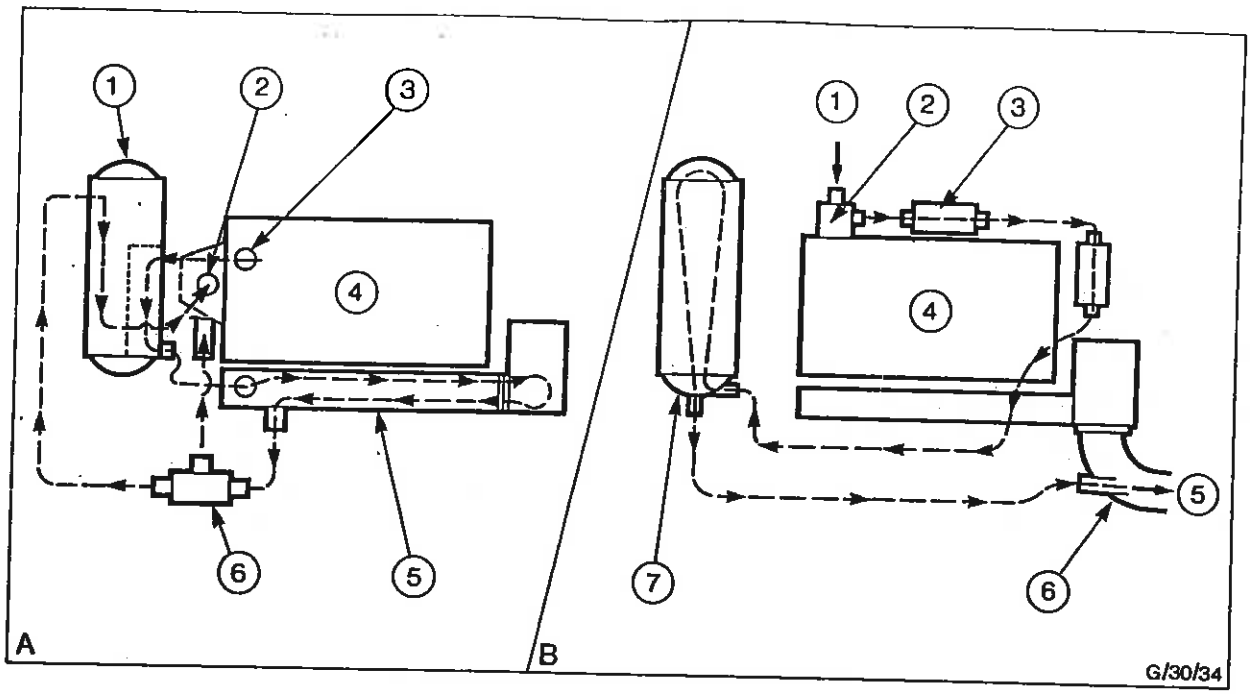


Fig. 1 - Cooling Circuit for 2726T Marine Engine

A. Fresh Water Circuit
1. Heat Exchanger Circuit
2. 2 O'Clock Water Pump Inlet
3. Cylinder Head Outlet
4. Engine
5. Water Cooled Exhaust Manifold and Turbocharger
6. Full Flow By-Pass Thermostat (to 5 o'clock inlet)

B. Raw Water Circuit
1. Water Inlet
2. Raw Water Pump
3. Engine Oil Cooler
4. Engine
5. Water Outlet
6. Exhaust Elbow
7. Heat Exchanger

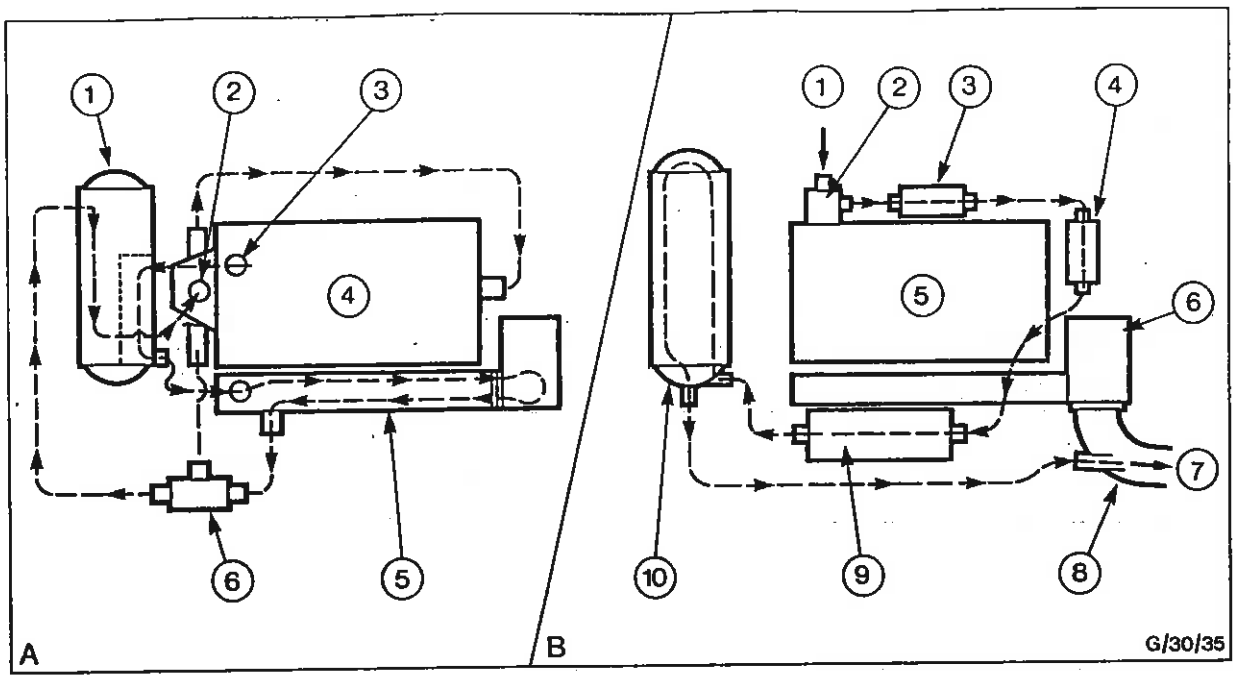


Fig. 2 - Cooling Circuit for 2728T Marine Engine

A. Fresh Water Circuit
1. Heat Exchanger
2. 2 O'Clock Water Pump Inlet
3. Cylinder Head Outlet
4. Engine
5. Water Cooled Exhaust Manifold and Turbocharger
6. Full Flow By-Pass Thermostat (to 5 o'clock inlet)

B. Raw Water Circuit
1. Water Inlet
2. Raw Water Pump
3. Engine Oil Cooler
4. Transmission Oil Cooler
5. Engine
6. Exhaust Manifold and Turbocharger
7. Water Outlet
8. Exhaust Elbow
9. Charge air cooler
10. Heat exchanger

WATER PUMPS

General Information - Naturally Aspirated and Turbocharged Industrial Engines

The same standard pump can be fitted to 4 and 6 cylinder engines. It is designed for industrial applications and has a 25,4 mm (1,0 in) diameter shaft, heavy duty bearings and a 'cassette' type of seal. It can be fitted with a single or twin sheave drive pulley - refer to Fig. 3.

In place of the standard water pump a 'low loss' fan drive system can be fitted. This is basically the standard water pump fitted with a single sheave drive pulley having an extended hub. On this extended hub, an additional fan pulley assembly is fitted with its own bearings - see Fig. 4. This arrangement enables the fan to be driven at a lower speed than the water pump.

General Information - Turbocharged Marine and Combine Harvester Engines

These engines are fitted with the automotive type of water pump which has an additional water outlet connected to the rear of the cylinder block. This arrangement ensures more efficient water circulation. This type of pump is not designed to carry a fan - see Fig. 5.

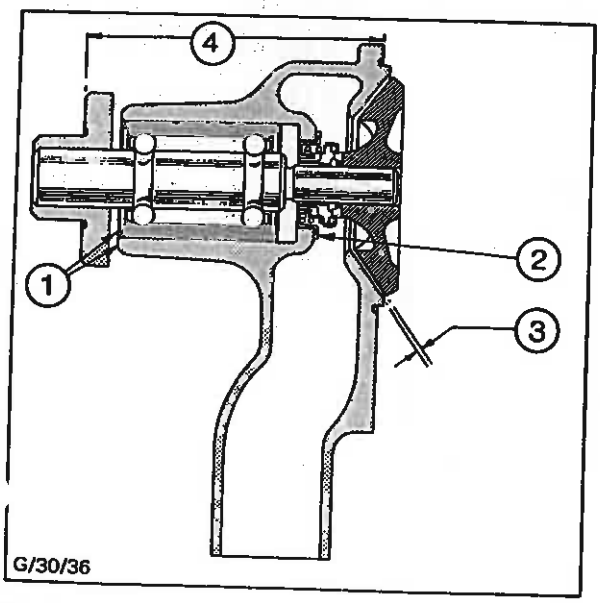


Fig. 3 - Water Pump Assembly for All Engines Except 2728T
1. Bearing Outer Race Flush with Housing
2. Spring Cage of Seal Correctly Seated
3. Impeller to Housing Clearance
4. Correct Pulley Hub Position: 127 mm (5,0 in)

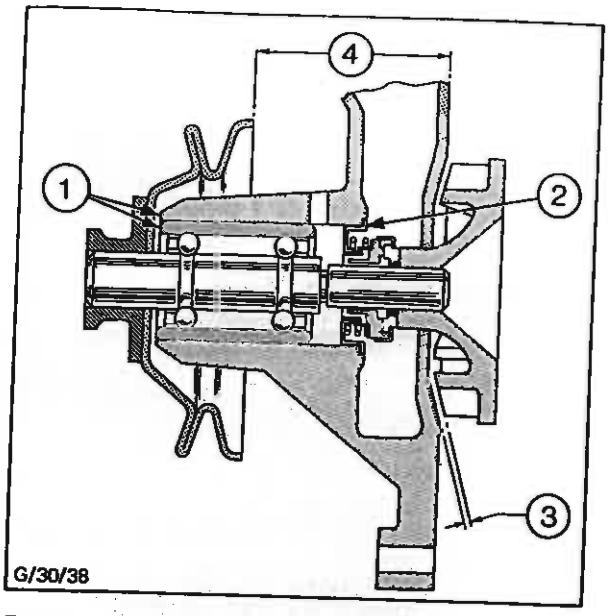


Fig. 5 - Water Pump Assembly for 2728T Engines
1. Bearing Outer Race Flush with Housing
2. Spring Cage of Seal Correctly Seated
3. Impeller to Housing Clearance
4. Correct Pulley Position

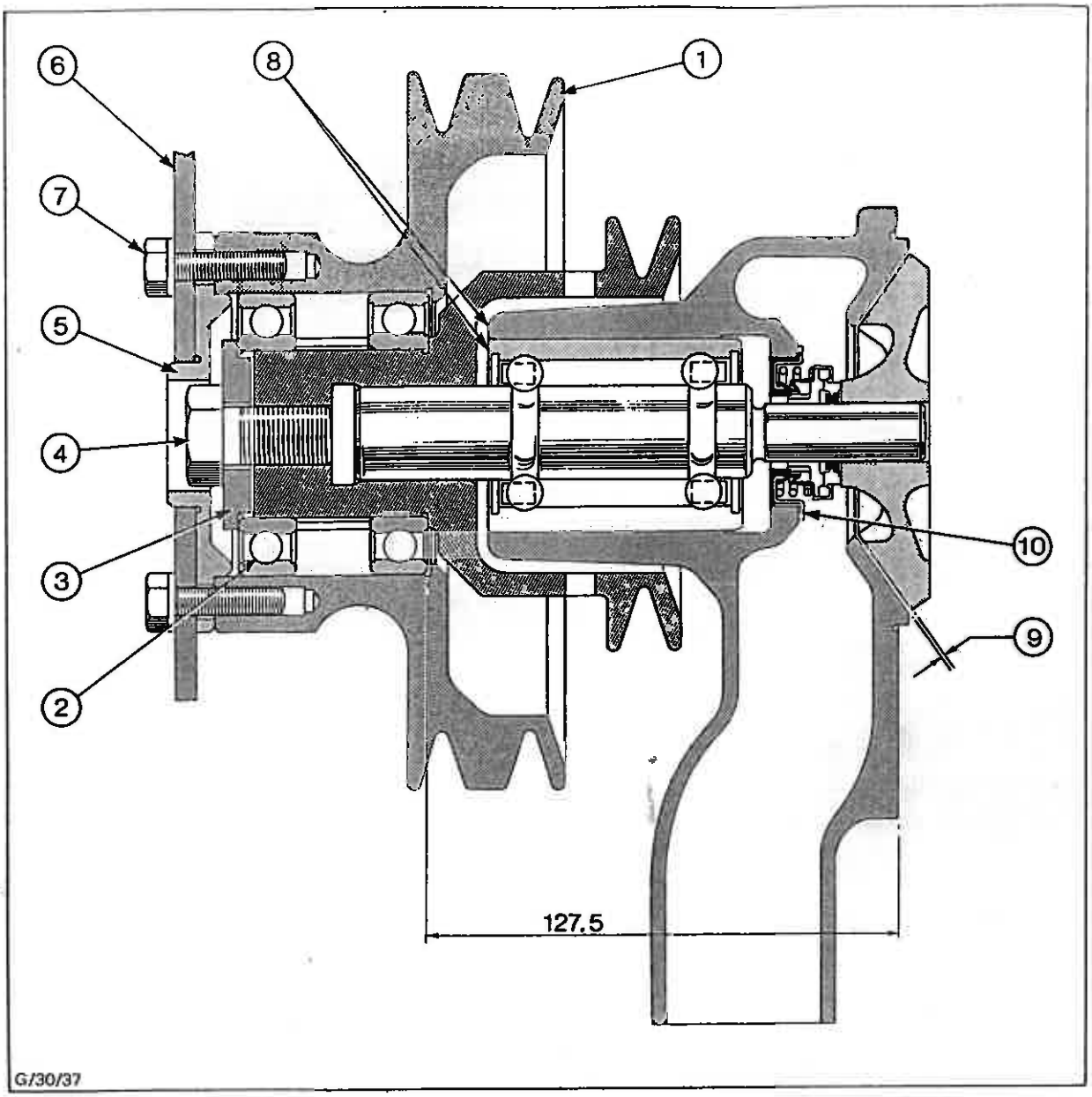


Fig. 4 - Water Pump Assembly for 'Low Loss' Fan Drive System

1. Fan Pulley
2. Fan Hub Bearing
3. Bearing Retainer Inner Plate
4. Fan Hub Retaining Bolt
5. Bearing Retainer Outer Plate
6. Fan
7. Fan Retaining Bolt
8. Bearing Outer Race Flush with Housing
9. Impeller to Housing Clearance
10. Spring Cage of Seal Correctly Positioned

WATER PUMP OVERHAUL

1. Remove radiator/header tank filler cap(s).

2. Place a suitable clean receptacle under each drain cock.

NOTE: One drain cock is located in the cylinder block below the alternator, the other is situated at the bottom of the radiator (industrial applications) or in the water cooled exhaust manifold (marine engines).

3. Open drain cocks and allow coolant to drain from system. Retain coolant if it is to be used again - refer to text under the heading 'Coolant' for method used to determine the antifreeze concentration present and/or the use of corrosion inhibitor.

Removal - 'Low Loss' Fan Drive System

1. Slacken and remove fan securing bolts while gripping fan pulley drive belt.

2. Detach fan and bearing retainer outer plate - refer to Fig. 4.

3. Slacken fan hub retaining bolt while gripping pump pulley drive belt.

4. Remove drive belts and detach water hose(s).

5. Remove pump securing bolts/nuts and detach pump from engine. Discard gasket.

Removal - Turbocharged Marine and Combine Harvester Engines

1. Remove drive belts and detach water hoses.

2. Remove pump securing bolts/nuts and detach pump from engine. Discard gasket.

Removal - Naturally Aspirated and Turbocharged Industrial Engines

1. Slacken and remove fan securing bolts while gripping drive belt(s).

2. Detach fan.

NOTE: On single belt drives, the pulley can be removed at the same time.

3. Slacken and remove pulley retaining bolts while gripping drive belt(s).

4. Remove drive belt(s) and pulley.

5. Detach water hose(s).

6. Remove pump securing bolts/nuts and detach pump from engine. Discard gasket.

Dismantling

On 'Low Loss' fan drive systems, remove the fan hub retaining bolt and bearing retainer inner plate and detach the fan hub.

1. As shown in Fig. 6, support the pump housing on the bed of a suitable press with sufficient clearance to allow the impeller to be pressed out. Push the bearing, shaft and impeller out by pressing on the shaft.

CAUTION: DO NOT ATTEMPT TO REMOVE THE PULLEY WITH A CLAW TYPE OF EXTRACTOR AS THIS MAY EASILY RESULT IN THE PULLEY BEING DISTORTED.

2. Support the front face of the impeller on a padded surface and press out and discard the bearing and shaft assembly and the seal assembly.

Cleaning/Inspection

Clean the pump housing, pulley and impeller in a general cleaning solvent. Examine the components for obvious damage, pulley distortion and impeller erosion. Check the dimensions of the impeller bore, the pulley bore and the bearing outer race bore in the pump housing. Components exceeding the specified maximum value will not provide the necessary interference fit and should be renewed.

Assembly

1. Place the pump housing on the bed of a suitable press, with the pulley end upwards. Press a new bearing and shaft assembly into the housing as follows:

a) Small diameter end of shaft innermost - see Fig. 3, 4 or 5 as applicable.

b) Outer edge of outer bearing race to be flush with front edge of pump housing - see Fig. 3, 4 or 5 as applicable.

CAUTION: APPLY FORCE ONLY TO THE OUTER RACE - NOT TO THE SHAFT.

2. Ensure the shaft is clean and free of oil or grease, then hold the seal assembly by the red retainer and slide the assembly (large diameter inwards) onto the shaft. Push it firmly into position using the special tool shown in Fig. 7 to ensure that pressure is exerted on both parts of the assembly simultaneously. The tool should be made locally to the dimensions shown.

CAUTION:
1. DO NOT SEAT THE SPRING CAGE BY PRESSING ON THE STEEL END OF THE ASSEMBLY.

2. DO NOT DISMANTLE THE SEAL ASSEMBLY IN ANY WAY, EITHER BEFORE OR AFTER INSTALLATION. THE RED COLOURED RETAINER WILL AUTOMATICALLY DISSOLVE DURING INITIAL OPERATION ON THE ENGINE.

3. Stand the assembly on the pulley end of the shaft and press the impeller onto the shaft until the specifed impeller to housing clearance is obtained - see Fig. 3, 4 or 5.

NOTE: A screw press is recommended for this operation.

4. Place the pulley nose down on the bed of the press and align/insert the shaft squarely over the pulley/hub. Apply force onto the impeller end of the shaft (NOT the impeller) until the pulley/hub is set to the specified position - see Fig. 3, 4 or 5.

5. Check that the rotating components turn freely.

On 'Low Loss' fan drive system only:

Slide fan pulley assembly onto the water pump pulley hub and secure with the bearing retainer inner plate and bolt - see Fig. 4.

Replacing Pump on Engine

1. Remove all traces of old gasket from pump mating face on cylinder block.

2. Position pump on cylinder block, using new gasket and secure with the bolts/nuts tightened to the specified torque value.

3. Replace water hose(s) and tighten clips.

4. On turbocharged marine and combine harvester engines replace drive belt(s) and adjust to give the correct tension.

5. On naturally aspirated and turbocharged industrial engines, replace the drive pulley and fan and fit the drive belt. Grip the drive belt while tightening the fan/pulley retaining bolts to the specified torque value.

6. On 'Low Loss' fan drive systems, fit the pump drive belt and grip it while tightening the fan pulley retaining bolt to the specified torque value. Fit the bearing retainer outer plate and fan and secure with the six bolts - see Fig. 4. Fit fan drive belt and grip it while tightening fan securing bolts to specified torque value.

7. Adjust all drive belts to the correct tension and close drain cocks.

8. Fill system with the correct coolant and check for leaks. Under no circumstances may the engine be started without liquid in the cooling system.

On engines with water cooled manifolds, run engine slowly for 30 minutes with the coolant filler cap removed to allow any trapped air to disperse.

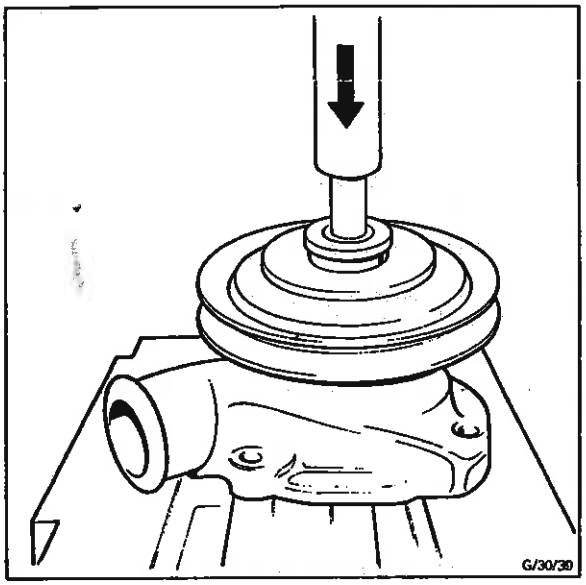


Fig. 6 - Extracting Shaft and Bearing

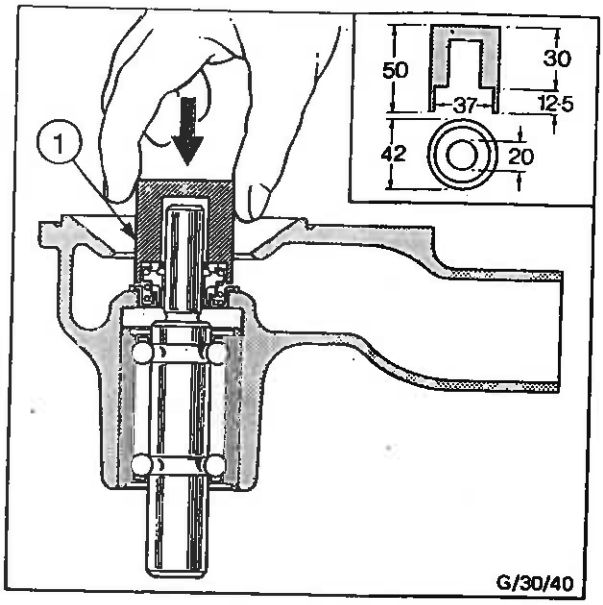


Fig. 7 - Fitting the Seal Assembly
1. Locally made fitting tool. All dimensions are in millimetres.

THERMOSTATS

General Information

The 2722 engine uses a single thermostat which opens at the coolant temperature specified. It is located in the cylinder head and is retained by the bolted-on water outlet connection used for industrial applications. The same thermostat is used for marine applications but the engine is supplied without the water outlet connection to enable the special marine equipment to be fitted; the thermostat is situated in the external pipework.

The industrial versions of the 2723, 2725 and 2726T engines are equipped with twin thermostats which operate at different coolant temperatures and incorporate a full flow radiator by-pass facility. Both thermostats are located in a special housing which is bolted to the cylinder head in place of the water outlet connection. The housing is ribbed internally to ensure that each thermostat can only be fitted in it's correct position. A specially designed water outlet connection bolts to the top of the housing and retains the thermostats. The primary thermostat has an extended centre shaft which carries an additional valve to close off the by-pass port - Fig. 8 illustrates the complete operating sequence.

Marine versions of 2723, 2725 and 2726T engines and the 2728T intercooled engine use a single thermostat situated in the external pipework. The twin thermostat housing is not fitted so allowing the special marine equipment to be connected to the cylinder head water outlet port.

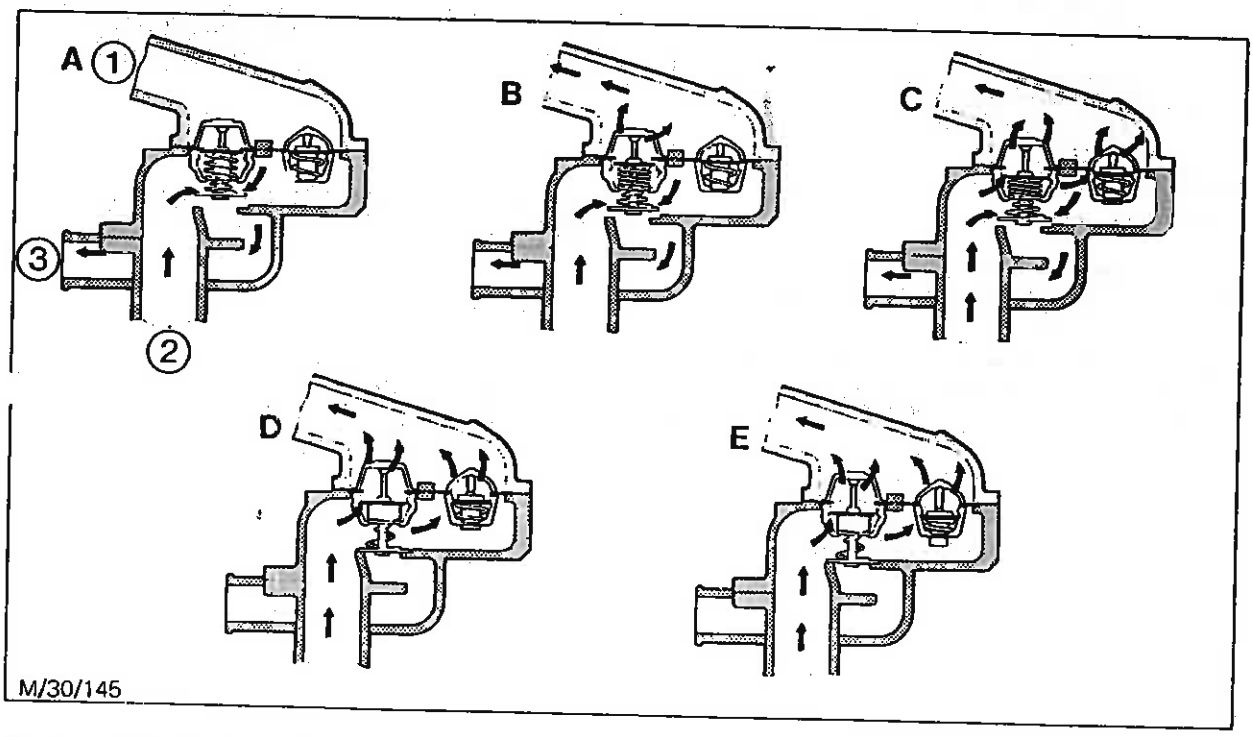


Fig. 8 - Twin Thermostat Operation
A. Primary and Secondary Thermostats Closed. By-Pass Valve Open
B. Primary Opening, By-Pass Closing, Secondary Closed
C. Primary Opening, By-Pass Closing, Secondary Opening
D. Primary Fully Open, Secondary Opening, By-Pass Closed
E. Primary and Secondary Fully Open, by-Pass Valve Closed

1. Coolant Flow to Radiator
2. Coolant Flow from Engine
3. Coolant Flow to By-Pass

Checking/Renewing Thermostats - Industrial Engines

1. Drain coolant - see under 'Water Pump Overhaul'.

NOTE: It is not necessary to drain off all the coolant.

2. Where applicable, disconnect the wire from the temperature sensitive switch situated in the top of the thermostat housing.

3. Slacken hose clip and detach hose from water outlet connection.

4. Remove screws and lift off the water outlet connection.

5. Discard gasket and clean mating faces of water outlet connection and housing.

6. Clear away any remaining gasket debris, then lift out the thermostat(s).

7. Suspend the thermostat to be tested in a water filled metal container so that it is submerged but not touching the container - see Fig. 9.

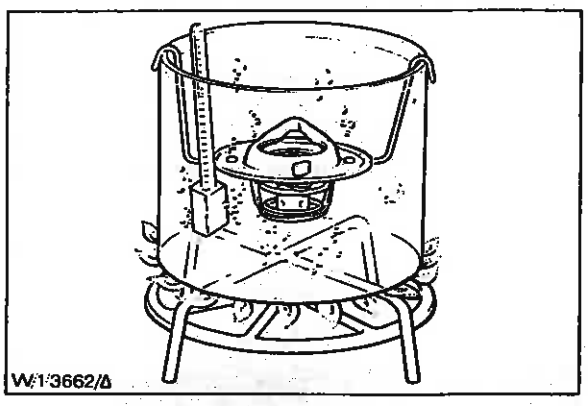


Fig. 9 - Testing the Thermostat

8. Gradually heat the water while checking the water temperature with an accurate thermometer. DO NOT let the thermometer touch the container.

9. Observe the temperatures at which the thermostat starts to open and when it is fully open. Compare results with the specified figures. If outside the stated limits, the thermostat must be rejected.

When checking or renewing a thermostat in service it is essential that only genuine Ford parts are used to ensure optimum cooling system performance. Ford Thermostats can be identified by the trade name 'WAXSTAT' stamped on the top plate.

Conventional Thermostat (No By-pass Valve)
The temperature setting is 82°, which is stamped on the underside of the copper operating capsule; it is used for the following applications:

2722 industrial and marine engines
2723,2725,2726T and 2728T marine engines
2723,2725 and 2726T industrial engines as the secondary thermostat.

By-pass Thermostat
The temperature setting is 77°, which is stamped on the underside of the bottom plate; it is used as the primary thermostat on 2723, 2725 and 2726T industrial engines.

10. Carefully clean the recessed seat(s) in the housing, then install the thermostat(s) making sure that it is fully seated in its recess.

NOTE: On twin thermostat applications ensure that the correct pair of thermostats are installed (one has two valves).

11. Fit the water outlet connection, using a new gasket and tighten the screws to the specified torque figure.

12. Re-fit the hose and tighten the clip. Where applicable, re-connect the wire to the temperature sensitive switch. Close drain cocks.

13. Re-fill the system slowly with the original coolant or with new coolant of the correct type and mixture - see under 'Coolant'.

14. Check for leaks, run the engine and top-up as necessary. On engines with water cooled manifolds, run engine slowly with coolant filler cap removed to allow any trapped air to disperse.

COOLANT

The coolant used may contain either anti-freeze or corrosion inhibitor depending on the circumstances under which the engine operates.

Anti-Freeze Solutions

WARNING: Antifreeze contains Monoethylene Glycol and other constituents which are toxic if taken internally and can be absorbed in toxic amounts on repeated or prolonged skin contact. Persons using antifreeze are recommended to adhere to the following precautions:

1. Antifreeze must never be taken internally. If antifreeze is swallowed accidentally, medical advice should be sought immediately.

2. Precautions should be taken to avoid skin contact with antifreeze. In the event of accidental spillage onto the skin, antifreeze should be washed off as soon as practicable. If clothing is splashed with antifreeze, it should be removed and washed before being worn again, to avoid prolonged skin contact.

3. For regular and frequent handling of antifreeze, protective clothing (plastic or rubber gloves, boots and impervious overalls or aprons) must be used to minimise skin contact.

It is preferable always to use a mixture of 50% 'Motorcraft Antifreeze Super-Plus' to 50% water. The Coolant Concentrate should comply with Ford Specification M97B-18C. This will give protection against freezing down to -36°C (-34°F) and will also greatly reduce corrosion in the engine cooling system.

Motorcraft Antifreeze products are fully compatible, and Super-Plus can be safely used for topping-up engines previously filled with Motorcraft Antifreeze Plus. The improved performance characteristics of Super-Plus will be reduced, however. It should be noted that mixing the pink Super-Plus Antifreeze with blue/green Motorcraft Antifreeze will result in a brown coloured fluid, which is unrelated to performance.

Motorcraft Antifreeze Super-Plus can be used to top-up engines previously filled with a proprietory antifreeze. No serious deficiency should occur provided that the total antifreeze concentration in the cooling system is maintained at recommended levels.

The table (Fig. 25) shows the protection provided when weaker solutions are used.

NOTE: When these concentrations (less than 50%) are used, the coolant should be drained and the system flushed after every winter season.

IF AN ANTIFREEZE MIXTURE IS NOT BEING USED IN FROSTY WEATHER, IT IS ESSENTIAL THAT THE COOLING SYSTEM IS DRAINED PRIOR TO THE ENGINE STANDING IDLE AND REFILLED IMMEDIATELY BEFORE THE ENGINE IS USED AGAIN.

NOTES: When refilling the cooling system on engines fitted with water cooled manifolds, the engine should be run slowly for half an hour with the pressure cap removed to allow any air locks in the cooling system to disperse.

Disconnecting the hose from the manifold outlet connection will also assist in expelling any trapped air.

Volume of 'Motorcraft Antifreeze Super-Plus' in water	Protection Down to
10%	-8°C(17°F)
15%	-13°C(9°F)
20%	-19°C(-2°F)
25%	-29°C(-20°F)
50%	-36°C(-33°F)

G/30/41

Fig. 10 - Antifreeze Solutions

Corrosion Inhibitor Solutions

A corrosion inhibitor is available as an alternative to antifreeze or where the antifreeze concentration is below the specified limit.

The inhibitor will protect water pumps, core plugs, thermostat housings and radiators against corrosion when used at the correct concentration.

THE INHIBITOR IS NOT AN ANTIFREEZE.

a) Plain water in cooling system:

Add the corrosion inhibitor concentrate to the vehicle coolant in the ratio of 2½% by volume, i.e. 1 part inhibitor to 39 parts of water. This proportion has the anti-corrosion properties of a 50% concentration of 'Motorcraft Antifreeze-Plus' but will not provide any frost protection.

NOTE: Where a vehicle cooling system has previously been neglected with regard to frost protection, the cooling system should be flushed out before adding the inhibitor.

b) Weak antifreeze solution in cooling system

The inhibitor may be added to the vehicle coolant to supplement the antifreeze corrosion resisting properties as follows:

Test the antifreeze concentration using a suitable hydrometer.

A reading of 1080 represents a 50% antifreeze concentration.

A reading of 1040 represents a 25% antifreeze concentration.

A reading of 1000 represents plain water.

If the hydrometer reading is 1080 or above, no inhibitor need be added. If the hydrometer reading is 1040 add half the quantity required for plain water. If a reading in the region of 1000 is obtained, add inhibitor as described for plain water - see (a).

The addition of the inhibitor will not increase the frost protecting properties of the coolant.

NOTE: Adding the inhibitor will not alter the hydrometer reading, therefore, a note should be made on the vehicle records and a label attached to the cooling system filler cap recording the date and amount of inhibitor added. The cooling system should be topped up with water/inhibitor mixture consisting of 1 part inhibitor to 39 parts of water.

The effective life of the inhibitor is similar to that of 'Motorcraft Antifreeze-Plus' (2 years), therefore the cooling system should be drained and refilled with a plain water/inhibitor mixture after this period of time.

Draining and Flushing the Cooling System

Drain the cooling system as described under 'Water Pump Overhaul'. If the flow ceases, probe the cocks carefully to dislodge any sediment that may be causing a temporary blockage.

Flush the system through with a hose until clean water emerges; allow all water to drain out, then close the drain cocks before refilling the system.

NOTES: When refilling the cooling system on engines fitted with water cooled manifolds, the engine should be run slowly for half an hour with the pressure cap removed to allow any air locks in the cooling system to disperse.

Disconnecting the hose from the manifold outlet connection will also assist in expelling any trapped air.

SPECIFICATIONS

Type of System	Pump Assisted Thermo-Syphon	
Thermostats	Starts to Open	Fully Open
2722 engine - industrial or marine	80-84°C (176-183°F)	94°C (201°F)
2723, 2725, 2726T and 2728T marine engines	80-84°C (176-183°F)	96°C (205°F)
2723, 2725 and 2726T industrial engines		
Primary	75-79°C (167-174°F)	91°C (196°F)
Secondary	80-84°C (176-183°F)	96°C (205°F)
Minimum Travel of Valve	9,1 mm (0,360 in)	
Antifreeze	FORD Specification SSM 97B 9103A	
Corrosion Inhibitor	FORD Specification SSM 97B 9100	

SPECIFICATION - Water Pumps

Type of Engine	Turbocharged Marine and Combine Harvester	Naturally Aspirated and Turbocharged Industrial	'Low Loss' Fan Drive System
Bearing Outer Race dia.	38,087 to 38,10 mm (1,499 to 1,500 in)	51,987 to 52,000 mm (2,0467 to 2,0472 in)	51,987 to 52,000 mm (2,0467 to 2,0472 in)
Bearing Outer Race-Bore In Pump Housing	38,06 to 38,08 mm (1,498 to 1,499 in)	51,940 to 51,97 mm (2,0449 to 2,0461 in)	51,940 to 51,97 mm (2,0449 to 2,0461 in)
Impeller Shaft Dia.	15,905 to 15,918 mm (0,6262 to 0,6267 in)	15,905 to 15,918 mm (0,6262 to 0,6267 in)	15,905 to 15,918 mm (0,6262 to 0,6267 in)
Impeller Bore	15,85 to 15,875 mm (0,624 to 0,625 in)	15,850 to 15,875 mm (0,6240 to 0,6250 in)	15,850 to 15,875 mm (0,6240 to 0,6250 in)
Pulley/Pulley Hub Shaft Dia.	18,948 to 18,961 mm (0,745 to 0,746 in)	25,008 to 25,017 mm (0,9846 to 0,9849 in)	25,008 to 25,017 mm (0,9846 to 0,9849 in)
Pulley/Pulley Hub Bore	18,893 to 18,918 mm (0,744 to 0,745 in)	24,948 to 24,965 mm (0,9822 to 0,9828 in)	24,967 to 24,988 mm (0,9830 to 0,9838 in)
Impeller Clearance between Front of Vanes and Housing	0,508 mm (0,020 in)	0,508 (0,020 in)	0,508 mm (0,020 in)

TIGHTENING TORQUES

	Nm	Kgm	lbf ft
Water Pumps			
Pump securing bolts/nuts (all versions)	18 to 22	1,8 to 2,2	13 to 16
Fan securing bolts (including 'Low Loss Fan' System)	16 to 20	1,6 to 2,0	12 to 15
'Low Loss Fan' pulley retaining bolt	100	10,2	74
Thermostats			
Water outlet connection securing bolts/nuts	20 to 25	2,0 to 2,5	15 to 18

CONTENTS

CONTENTS (Continued)

GENERAL DESCRIPTION

The principle working components of the fuel system are the lift pump, injection pump and injectors. Together with the tank and filters these items make up the basic system which provides direct injection of fuel into the engine cylinders.

The fuel lift pump is mounted on the right hand, rear end of the cylinder block and is operated by an eccentric on the engine camshaft. Its function is to draw fuel from the tank and provide a constant supply to the injection pump.

The injection pump is an integrated assembly of pumping and governing units mounted on the rear of the timing gear housing and driven by the timing gears.

In the pumping section of the injection pump, spring loaded, fuel fed pumping plungers are operated by an internal camshaft. Each plunger delivers fuel to its respective injector at high pressure and in the correct engine firing order. To vary the quantity of fuel delivered in accordance with specific throttle demand or condition, the plungers are collectively linked to the governing section via a 'control rod'.

The governing section receives a signal of engine speed from the camshaft mounted flyweights. This 'signal' combines with other signal inputs of starting, stopping and power demand (throttle setting) to position the plunger control rod. The flyweight type governor provides automatic idle speed control and restricts maximum engine speed to a pre-set limit.

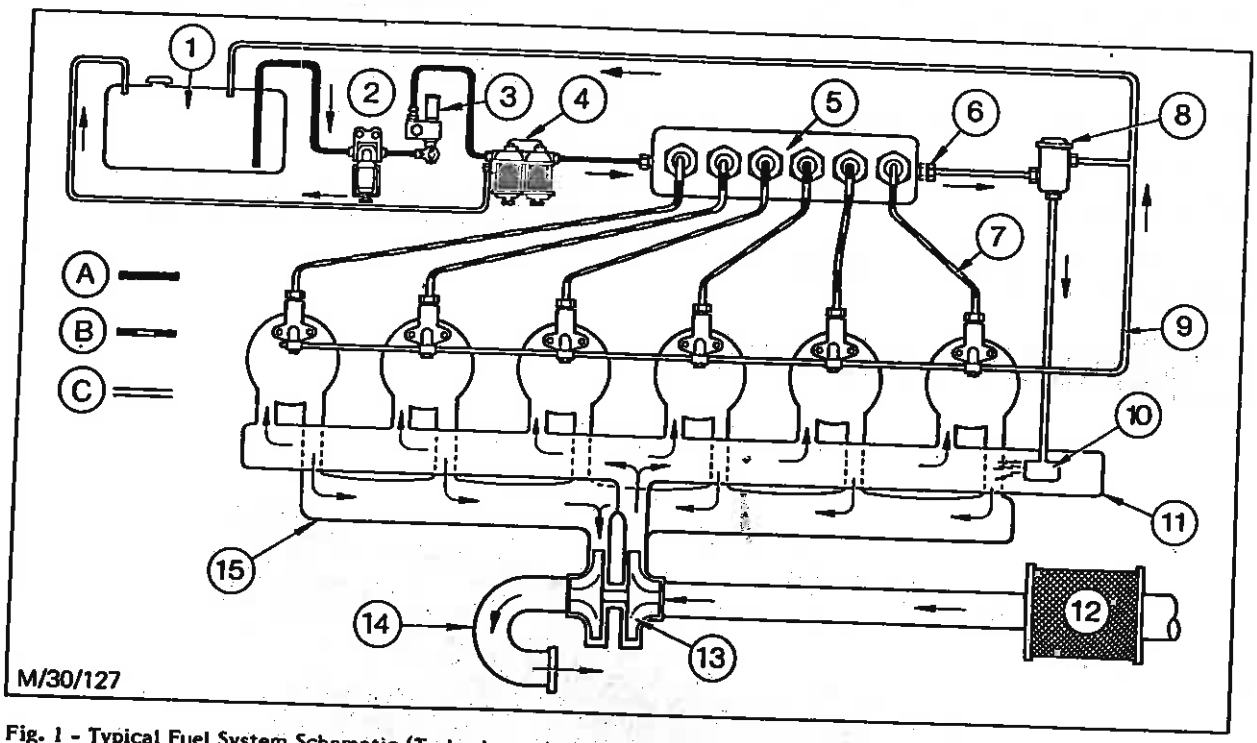


Fig. 1 - Typical Fuel System Schematic (Turbocharged engine shown)
A. Low Pressure Fuel Path
B. High Pressure Fuel Path
C. Leak-off Fuel Return to Tank and Thermostart Feed Paths

1. Tank
2. Water Separator Filter (when fitted)
3. Lift Pump and (when fitted) Pre-Filter Unit
4. Engine Mounted Filters and Pressure Relief Valve Assembly
5. Injection Pump
6. Fuel Gallery Air Bleed
7. High Pressure Delivery Pipes to Injectors
8. Thermostart Reservoir
9. Leak-Off Pipe to Tank
10. Thermostart Element(s)
11. Intake Manifold
12. Air Cleaner
13. Turbocharger
14. Exhaust Elbow/Exhaust Pipe
15. Exhaust Manifold

On turbocharged engines the boosted intake manifold pressure results in higher volumetric efficiency and increased engine power output. A 'boost control' on the injection pump of these engines is fitted to prevent excessive overfuelling during acceleration.

The fuel injectors act as spring loaded on/off valves, providing a high degree of atomisation while open. A calculated, self lubricating internal leakage is allowed to return to the tank via a 'leak-off' pipe.

Stopping the engine is achieved principally by moving the pump plungers into a 'non-delivery' condition. This is achieved by means of a stop lever which moves the plunger control rod to the required position.

To enhance engine starting performance, the injection pump is capable of operating briefly in an overfuelling condition. This device places the pump plungers in an 'excess fuel' position.

Automotive and G.P. governed injection pumps have an integral automatic excess fuel facility which is temperature sensitive. All other injection pumps have a manually operated excess fuel device but an automatic device is available as an option.

For extreme cold weather conditions a thermostart system may be fitted as an option (mandatory on turbocharged engines).

This system pre-heats the air to the combustion chambers by igniting a small flow of low pressure fuel in the air intake manifold.

FUEL LIFT PUMP

Operation of Standard Pump - Refer to Fig. 2

The eccentric on the camshaft operates the fuel pump rocker arm and link and pulls the diaphragm inwards against the pressure of the return spring. This creates a partial vacuum in the pump chamber, causing the inlet valve to open and draw fuel into the diaphragm chamber.

Further movement of the camshaft eccentric allows the rocker arm to return and the diaphragm is pushed outwards by the return spring, causing the inlet valve to close and the outlet valve to open. The fuel is then forced through the replaceable element filter to the injection pump. The pulsator diaphragm works in sympathy with the pump diaphragm and reduces fuel delivery surge.

When the injection pump is full of fuel, pressure created in the diaphragm chamber holds the diaphragm in against the action of the return spring until fuel is delivered by the injection pump.

During the time the diaphragm is held in by the fuel pressure, the rocker arm idles on the camshaft eccentric without operating the link.

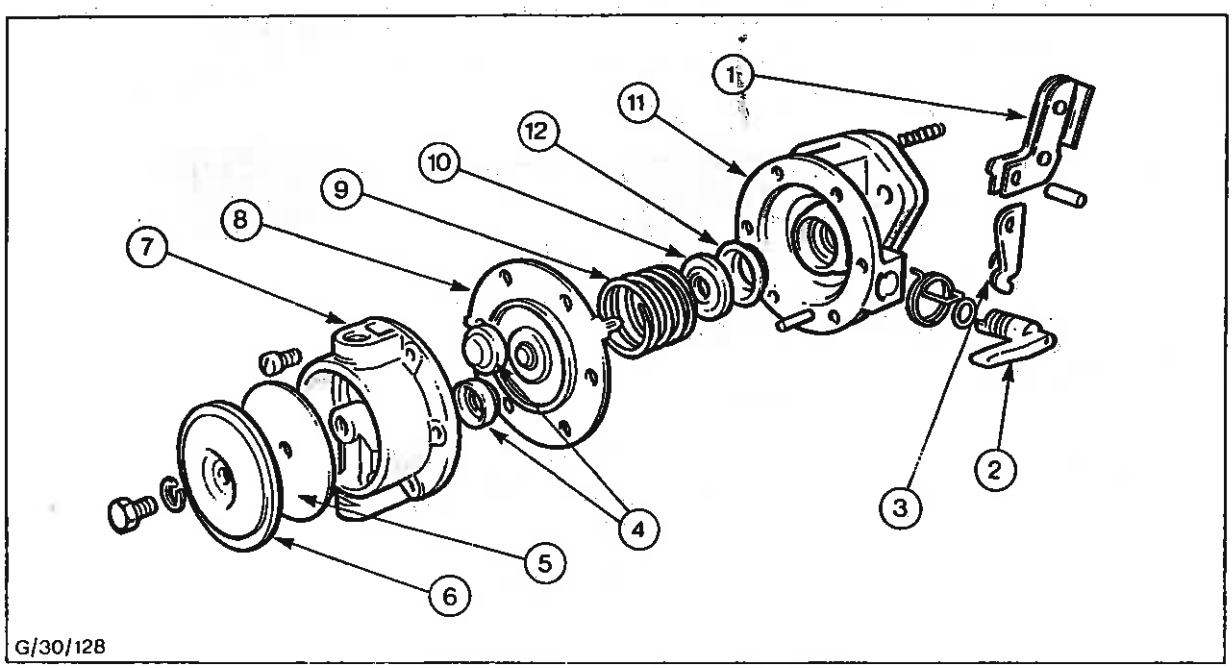


Fig. 2 - Exploded View of Standard Pump

1. Rocker Arm
2. Priming Lever
3. Rocker Arm Link
4. Valves
5. Pulsator Diaphragm
6. Cover
7. Outer Body
8. Pump Diaphragm
9. Return Spring
10. Oil Seal Retainer
11. Inner body
12. Oil Seal

Operation of High Pressure Pump - Refer to Figs. 3 and 4

The fuel lift pump is mounted to an adaptor at the rear of the engine block.

A plunger rod housed in the adaptor contacts the eccentric on the camshaft at one end and the fuel lift pump plunger rod at the other end.

On rotation of the engine, the eccentric cam forces the plunger rods and plunger in the direction of the pump suction chamber; fuel is thereby forced out of the suction chamber through the balancing channel into the compression chamber. At the same time the plunger spring is compressed.

The fuel is then forced out of the compression chamber, through the balancing channel to the fuel filter and the injection pump.

As the eccentric cam goes beyond the highest point, the plunger is forced back by the plunger spring.

At the same time, the receding plunger creates a vacuum in the suction chamber, the suction valve opens and fuel is again drawn from the fuel tank.

If more fuel than necessary is pumped, the pressure in the compression chamber rises. This pressure acts through the balancing channel on the plunger against the force of the plunger spring. If the force exerted by the plunger is exceeded by the force exerted by the pressure in the compression chamber, the plunger no longer moves as far towards the cam, and so the amount of fuel pumped is reduced.

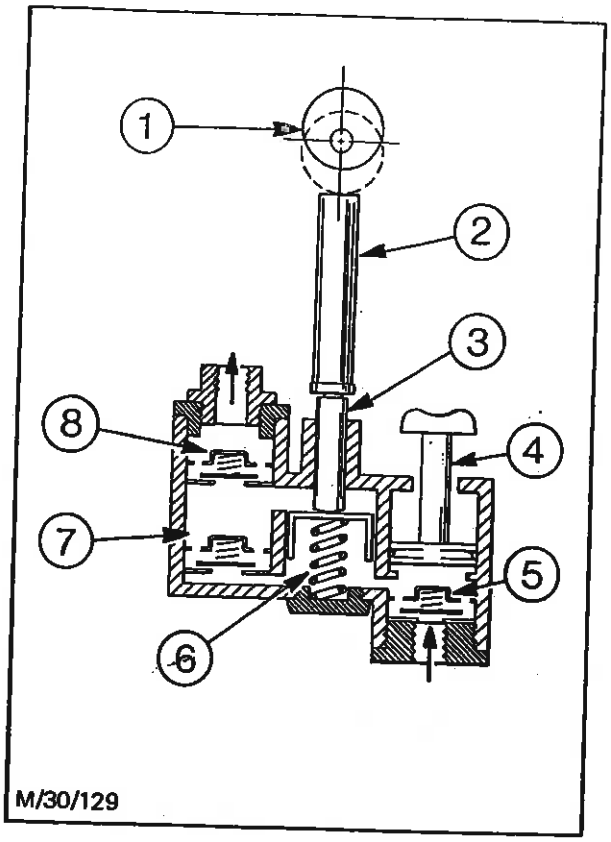


Fig. 3 - High Pressure Pump Shown in Diagramatic Form
1. Camshaft Eccentric
2. Adaptor Rod
3. Plunger Rod
4. Priming Pump
5. Inlet Valve
6. Plunger Return Spring
7. Transfer Valve
8. Outlet Valve (AC Delco Pumps Only)

TESTING THE FUEL LIFT PUMP

Providing there are no air leaks or obstruction in the fuel system, a quick check on the pump efficiency can be made as follows:

1. Remove the air bleed screw from the inlet side of the fuel filter.

2. Operate the hand priming lever in the normal manner when there should be a well defined surge of fuel for each working stroke of the pump. If no resistance of the diaphragm spring can be felt, it is likely that the diaphragm is held down, due to the operating lever being on the high point of the camshaft eccentric, and it will be necessary to rotate the engine approximately one turn.

If the pump does not operate correctly, check the inlet depression and delivery pressure by Diagnosis Test Set, Gang Gauge Set No. 500-X or suitable vacuum and pressure gauges.

FUEL PUMP INLET DEPRESSION TEST

1. Operate the lift pump hand primer to fill the injection pump fuel gallery.

2. Disconnect the fuel inlet pipe from the pump and connect the vacuum gauge to the pump inlet union.

3. Start the engine and allow to run at idling speed. The vacuum readings should be at least 21,59 cm (8,5 in) of mercury.

4. Stop the engine and check the leak-down time for the specific pumps as follows:

Standard Pump - 0,0172 bar (0,0176 kgf/cm^2 or 0,25 lbf/in^2) in 25 minutes

High Pressure Pump - 0,207 bar (0,21 kgf/cm^2) or 3 lbf/in^2) in 25 minutes

Should the reading drop quicker than this, it indicates an air leak or faulty outlet valve.

5. Bleed the fuel system as described in the appropriate section.

NOTE: This test can be carried out at any connection between the lift pump and fuel tank to check for air leaks in the fuel system as a whole. By starting the tests at the fuel tank and working towards the fuel lift pump, it will be possible to determine the faulty component.

FUEL PUMP DELIVERY PRESSURE TEST

1. Operate the lift pump hand primer to fill the injection pump gallery.

2. Disconnect the fuel outlet pipe from the pump and connect the pressure gauge to the pump outlet.

3. Start the engine and observe the pressure at idling speed. Increase the speed and check throughout the speed range that the pressure is between:

0,34 to 0,55 bar (0,35 to 0,56 kgf/cm^2 or 5 to 8 lbf/in^2) standard pump
1,03 to 1,24 bar (1,05 to 1,27 kgf/cm^2 or 15 to 18 lbf/in^2) high pressure pump

NOTE: Low fuel pump pressure may affect engine performance due to lack of fuel.

4. Bleed the fuel system.

Servicing the Standard Fuel Lift Pump - see Fig. 2

1. Disconnect the fuel inlet and outlet pipes from the lift pump. Where applicable, remove banjo bolt and detach pre-filter unit.

2. Remove the two securing nuts and detach the lift pump from the cylinder block. Discard gasket.

3. Unscrew the bolt securing the pump cover plate and remove the cover plate and pulsator diaphragm.

4. Mark the positions of the two halves of the pump adjacent to the small tab on the pump diaphragm. Remove the six securing screws and separate the two halves of the pump.

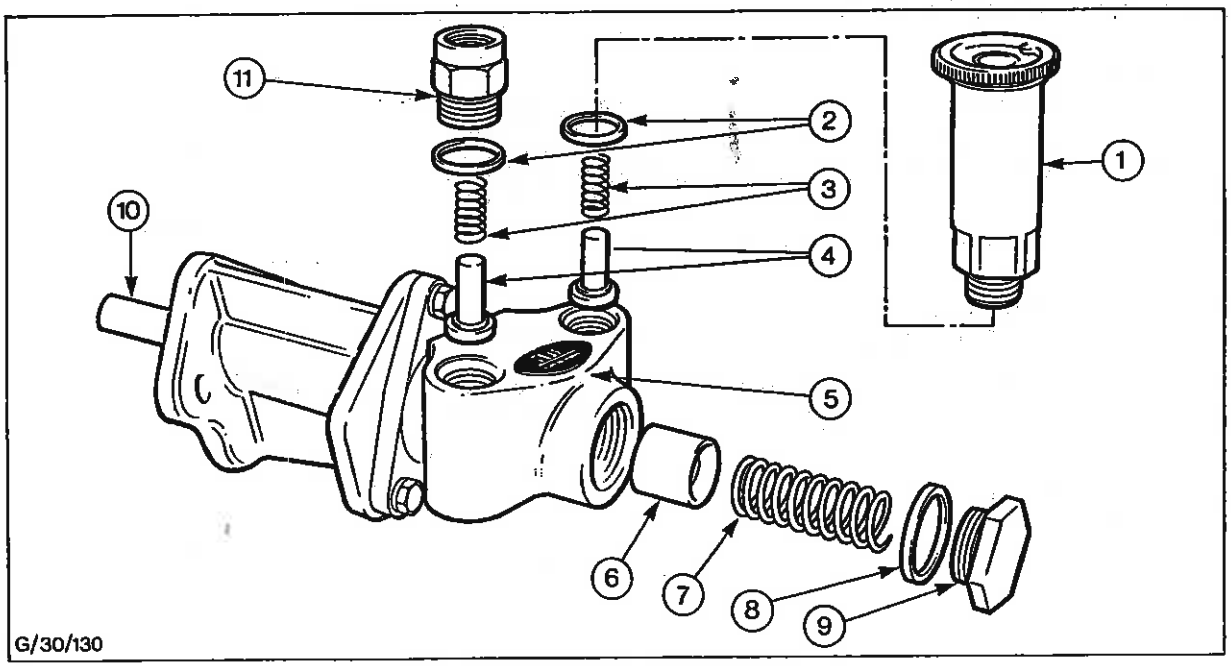


Fig. 4 - Exploded View of High Pressure Pump
1. Primer Plunger Assembly
2. Seal
3. Spring
4. Valve
5. Body
6. Plunger Sleeve
7. Spring
8. Seal
9. Plug
10. Plunger Rod
11. Connector

5. If necessary, punch back the staking and remove the two valves from the outer body.

6. Drive out the pin securing the priming lever and withdraw the lever and spring. The priming lever shaft has a flat at its end which locates behind a lug on the diaphragm spring seat.

7. Push the pump diaphragm down against the return spring pressure and disengage the pull rod from the operating link.

8. If necessary, carefully punch back the staking locating the rocker arm pivot pin, tap out the pin and remove the rocker arm and link. Take care not to lose the small spring fitted between the rocker arm and the housing.

9. Thoroughly clean all parts with kerosene or test oil.

10. Insert the inlet and outlet valves, ensuring that they are in their correct positions. The inlet valve is the lower one and is assembled to the outer body with the spring nearest to the pump diaphragm. The outlet valve fits the other way round. Secure each valve by staking the body at four points.

11. Assemble the rocker arm, link and pin to the inner body, locating the return spring between the rocker arm and the housing. Stake the housing at either end of the pivot pin to ensure that it is securely retained.

12. Locate the return spring on the pump diaphragm spring seat and assemble the diaphragm to the inner body with the lug on the spring seat adjacent to the priming lever bore and the small tab next to the mark on the body. Engage the link with the pull rod.

13. Compress the pump diaphragm and return spring and insert the priming lever shaft, with the 'O' sealing ring in the outer groove, into the inner body so that the flat is located behind the spring seat lug. Locate the priming lever return spring in the small hole. Replace the priming lever retaining pin, which locates in a groove in the shaft and drive home.

14. Locate the two halves of the pump body together in the marked positions, insert the six screws until fingertight. Operate the rocker arm a few times to centralise the diaphragm and tighten the screws, holding the rocker lever fully down.

15. Replace the pump cover plate and pulsator diaphragm and secure with a screw and lock-washer. Tighten to the specified torque value.

16. Locate a new gasket on the cylinder block mounting studs, place the lift pump in position and secure with the two nuts and washers. Tighten nuts to the specified torque value.

17. Where applicable, secure the pre-filter unit to the pump with the banjo bolt and washers and tighten bolt to the specified torque value.

18. Connect the fuel inlet and outlet pipes and bleed the system - see under 'Bleeding the Fuel System'.

Servicing the Bosch High Pressure Fuel Lift Pump

The following operations 1 to 15 relate to the pump illustrated in Fig. 4.

If, after dismantling and examination, it proves necessary to renew the pump, then the later type fuel lift pump can be fitted – see under 'The AC Delco High Pressure Fuel Lift Pump' on page 8.

1. Disconnect the fuel inlet and outlet pipes from the lift pump. Where applicable, remove banjo bolt and detach the pre-filter unit.

2. Remove the three securing bolts and detach the lift pump from the adaptor. Discard gasket.

3. Unscrew and remove the fuel inlet and outlet adaptors with their washers.

4. Unscrew the priming plunger assembly.

5. Withdraw the valve springs and valves.

6. Unscrew the plug, remove the sealing washer and withdraw the spring, plunger sleeve and rod.

7. Thoroughly clean the pump body and all parts with kerosene or test oil.

8. Examine the valves and ensure correct seating in the housing. If satisfactory, refit valves together with springs.

9. Screw in the priming plunger assembly, using new sealing washers.

10. Replace inlet and outlet adaptors using new sealing washers.

11. Examine plunger rod and plunger sleeve for damage or excessive wear, then, if serviceable, insert them into pump body and check that they move easily. Replace spring and secure with plug fitted with new sealing washer.

12. Ensure that the pump mounting face is clean, fit a new gasket and secure the pump to the adaptor housing with the three bolts and washers. Tighten bolts to the specified torque value.

13. Where applicable, secure pre-filter unit to the pump with banjo bolt and washers. Tighten bolt to specified torque value.

14. Connect fuel inlet and outlet pipes.

15. Bleed the system as detailed under 'Bleeding the Fuel System'.

The AC Delco High Pressure Fuel Lift Pump

With effect from July 1st, 1985, a new type of AC Delco high pressure fuel lift pump was introduced. The new pump is non-serviceable but is fully interchangeable with the previous type providing that:

(a) The fuel supply pipe used on the installation is flexible enough to cater for the variation in the pump inlet location.

(b) A new pump-to-filter fuel pipe is fitted to suit the new pump installation – see Fig. 4A.

(c) On intercooled turbocharged marine applications a new water feed pipe to the rear of the block is fitted to suit the new pump installation – see Fig. 4A.

Should it be necessary to fit a new type pump in place of the earlier version, the following procedure should be adopted.

1. Disconnect the fuel supply pipe.

2. Disconnect pump-to-filter fuel pipe and discard it.

3. On marine turbocharged and intercooled engines, remove and discard the rear water supply pipe to rear of cylinder block. Retain hardware.

4. Remove lift pump and mounting adaptor assembly by unscrewing the two retaining nuts. Retain hardware. Remove inlet connection and, where fitted, the prefilter and retain for refitting. Discard the remainder of pump and adaptor assembly.

5. After cleaning the cylinder block pump mounting face, fit the new pump using a new gasket and the retained mounting hardware.

6. After cleaning, refit pump prefilter (where applicable) and/or the inlet connection using new sealing washer(s).

NOTE: If a prefilter is fitted it should be turned about its mounting banjo bolt to a position best suited to the fuel supply pipe run. The prefilter can be fitted either way round.

7. On marine turbocharged and intercooled engines, fit the new water supply pipe.

8. Fit the new lift pump-to-filter fuel pipe.

9. Bleed the system as detailed under 'Bleeding the Fuel System'.

NOTE: The AC Delco pump uses inlet/outlet adaptors made from soft aluminium. Extra care must be taken when removing and replacing these; always hold them with a spanner when loosening or tightening fuel pipe gland nuts.

FUEL FILTERS

Pre-Filter Unit

This filter is attached to the lift pump by a banjo-bolt and receives fuel directly from the tank. The element comprises a fine mesh cage enclosed in a transparent glass bowl and retained by a thumb screw tensioned 'stirrup' – see Fig. 5.

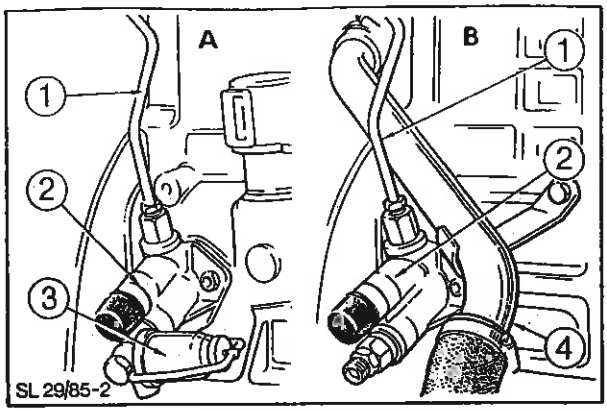


Fig. 4A – AC Delco High Pressure Fuel Lift Pump Assembly
A. 4 cylinder engine with pre-filter fitted
B. 6 cylinder turbocharged intercooled engine
1. Lift pump-to-filter pipe
2. Lift pump
3. Pre-filter unit
4. Water pipe

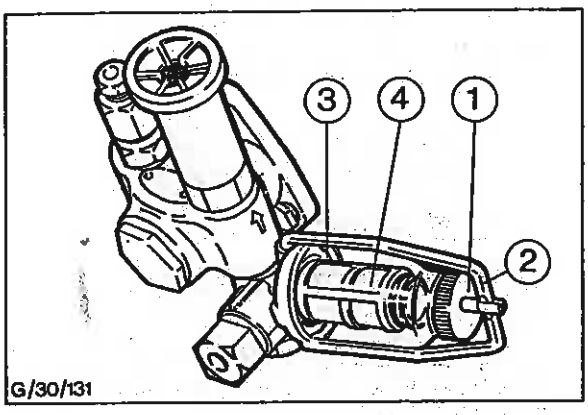


Fig. 5 - Pre-Filter Unit
1. Knurled Clamping Knob
2. 'Stirrup'
3. Glass Bowl
4. Filter Element

To clean the pre-filter unit proceed as follows:

1. Fully slacken off the knurled clamping knob and swing the 'stirrup' to one side.

2. Remove glass bowl and detach filter element.

3. Wash filter element and bowl thoroughly in clean test oil and dry bowl with non-fluffy rag.

4. Place filter element in glass bowl, spring first, then assemble bowl to housing, ensuring that the element spigot enters the recess in the housing.

5. Swing 'stirrup' into position and tighten clamp knob sufficiently to ensure a good seal. Do not overtighten.

6. Bleed the fuel system - see under 'Bleeding the Fuel System'.

7. Run the engine and check for fuel leaks.

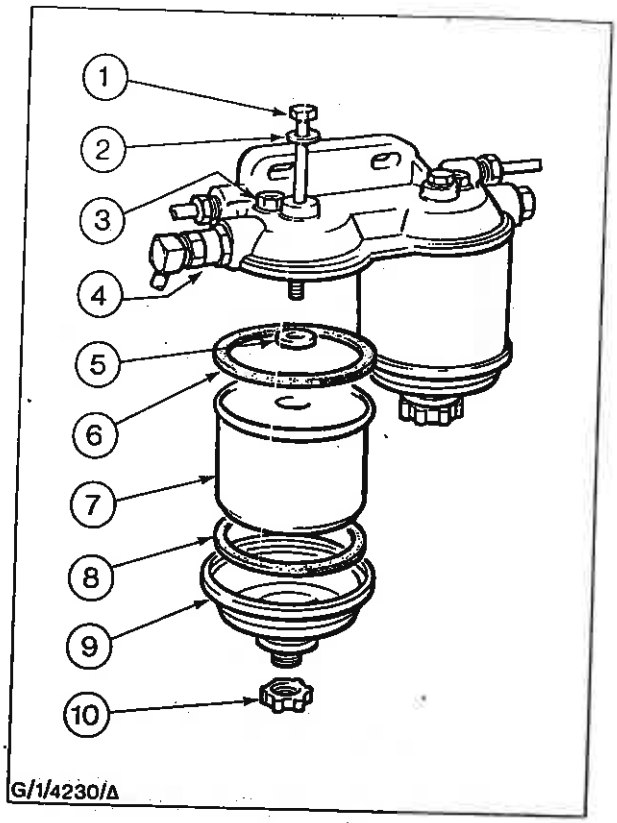


Fig. 6 - Engine Mounted Fuel Filter Unit
1. Centre Bolt
2. Sealing Washer
3. Bleed Screw
4. Lift Pump Relief Valve
5. Seal - Inner
6. Seal - Outer
7. Filter Element
8. Seal - Outer
9. Bowl
10. Drain Cap

Engine Mounted Filters - See Fig. 6

The filter assembly protects the high pressure components in the injection pump and injectors against damage from dirt. Each paper element is in the form of a renewable canister, secured between the filter head and base plate by a central bolt. A drain cap on each base plate allows water checks to be accomplished. Bleed screws on the filter head permit air to be bled from the system where necessary.

Renew fuel filter elements as follows:

1. Turn off the fuel supply tap.

2. Unscrew the drain caps and allow the filter contents to drain into a suitable container.

3. Remove the filter element centre bolts to detach the elements and base plates. Discard the elements and all sealing rings.

4. Clean the base plates with clean test oil or kerosene and hand tighten the drain caps.

5. Fit one new large and one new small sealing ring onto the underside of each filter head. Assemble the base plates with new elements and sealing rings and secure centrally to the filter heads with the centre bolts and new sealing rings. Tighten the bolts to the specified torque.

6. Dry off any spilt fuel, turn on the fuel supply tap, then operate the priming pump to check for leaks. Rectify as necessary.

BLEEDING THE FUEL SYSTEM

Although the system is of a self purging nature, the following procedure will hasten the clearance of air from the system following any large component fitment, i.e. filter or injection pump.

1. After a filter change, remove the bleed screws from the engine mounted filters. Operate the priming pump until air free fuel flows, then refit the bleed screws.

2. After an injection pump fitment, disconnect the pipe from the fuel gallery non-return valve (NRV). Operate the priming pump until air free fuel flows from the valve, then reconnect the pipe.

3. If a thermostart reservoir has been emptied, disconnect its overflow pipe and operate the priming pump until the bowl is full. Reconnect the pipe.

4. After any of the above operations, dry off any spilt fuel, operate the priming pump and check that all reconnections are dry.

AIR CLEANERS

Clean the Air Cleaner Element - Engine Mounted Oil Bath Type

1. Slacken clips securing air cleaner hose and remove hose.

2. Remove wing bolt (Fig. 7) and detach complete air cleaner assembly from engine.

3. Detach cover and lift out filter element. Wash element in gasoline and allow to dry.

4. Dip element in new engine oil and leave to drain.

5. Wash out air cleaner body with gasoline, stand body on level surface and fill with new engine oil to the level mark.

6. Fit filter element in body and replace cover.

7. Fit air cleaner assembly on the engine and secure with the wing bolt.

8. Replace hose and tighten clips.

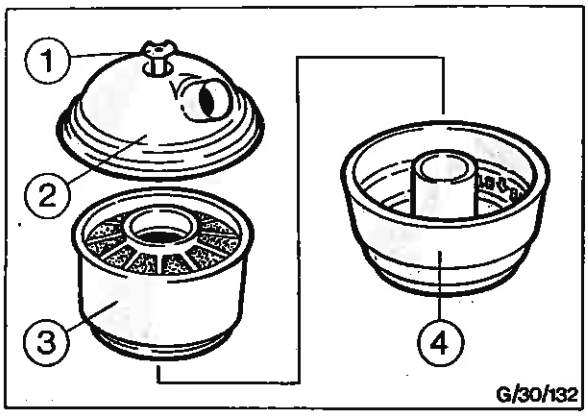


Fig. 7 - Oil Bath Air Cleaner
1. Wing Bolt
2. Cover
3. Filter Element
4. Air Cleaner Body

Empty the Air Cleaner Dust Cap and/or Renew Paper Element

1. Slacken off the clamp screw and remove the clamp and dust cup - see Fig. 8.

NOTE: On some air cleaners, the dust cup is retained by a moulded plastic knob which must be unscrewed.

2. Empty all dust from the cup.

3. Remove the wing nut and washer and extract the element from the air cleaner body.

4. Clean the element by directing the compressed air nozzle up and down the pleats on the inside of the element. Maintain a reasonable distance between the nozzle and element.

5. Check the condition of the element by placing a bright light inside. The slightest hole in the element will render it unfit for further use. Replace by a new element if necessary.

6. Insert the element in the air cleaner body, replace the washer and screw on and tighten the wing nut.

7. Replace the dust cup and clamp.

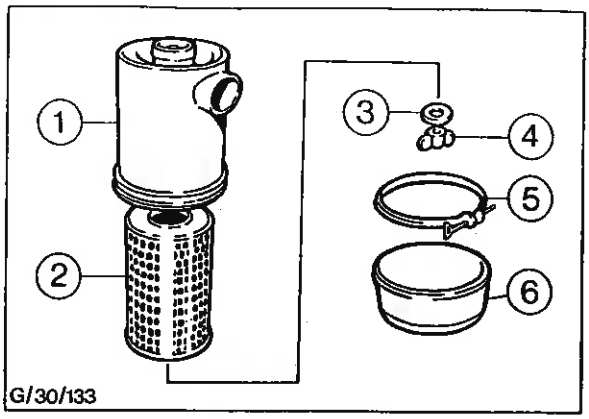


Fig. 8 - Paper Element Air Cleaner
1. Body
2. Element
3. Washer
4. Wing Nut
5. Clamp
6. Dust Cup

NOTE: The level of dust in the cup should not be allowed to build up excessively; empty more frequently than specified if necessary.
If a restriction indicator is fitted (Fig. 9) the air cleaner should be serviced when the red signal shows.

A type now in common use has a red signal that automatically locks in the fully exposed position, indicating the need for air cleaner service. After the element is cleaned or replaced, the indicator is reset by pressing the rubber button at the base of the body.

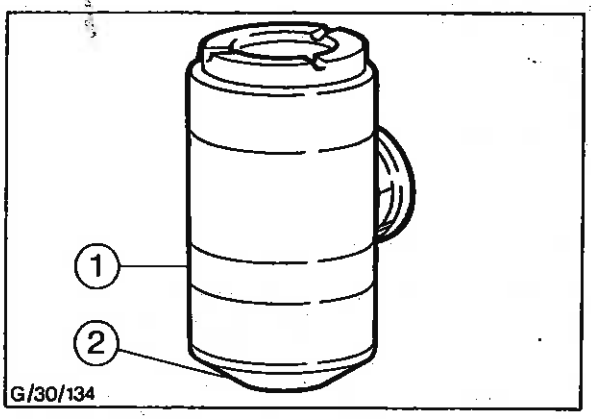


Fig. 9 - Air Cleaner Restriction Indicator
1. Red Signal
2. Reset Button

THERMOSTART SYSTEM

Description - See Fig. 10

When selected, this system assists engine starting in cold weather conditions by pre-heating the air in the intake manifold. The system consists of a reservoir which supplies fuel to thermostart element(s) fitted in the air intake ducting. A pre-heater selection button on the instrument panel controls the operation.

The reservoir is connected by pipe line to the injection pump fuel gallery so that it is constantly supplied during engine running. The removable lid of the reservoir incorporates a plate valve controlled and gauze protected vent. The valve closes when the reservoir is full, surplus fuel flowing out through an overflow and back to the tank via the leak-off pipe. An outlet at the base of the reservoir feeds fuel to the element(s).

The element consists of a thermally controlled ball valve and a combined heating and igniter coil contained within a body and shield assembly. The element is fitted into a boss on the air intake manifold.

Operation

In the non-energised state, the ball valve is held closed by a rod in the tubular valve casing.

With the ignition switch in the running position, depression of the pre-heater button energises the element coil. As the coil heats up, the valve casing expands axially to move the rod away from the ball valve. Fuel then flows by gravity from the reservoir to be warmed and vapourised by the heater and ignited by the igniter portion of the coil. Cranking the engine draws air through dilution holes in the element shield to mix freely with the burning fuel in the intake manifold.

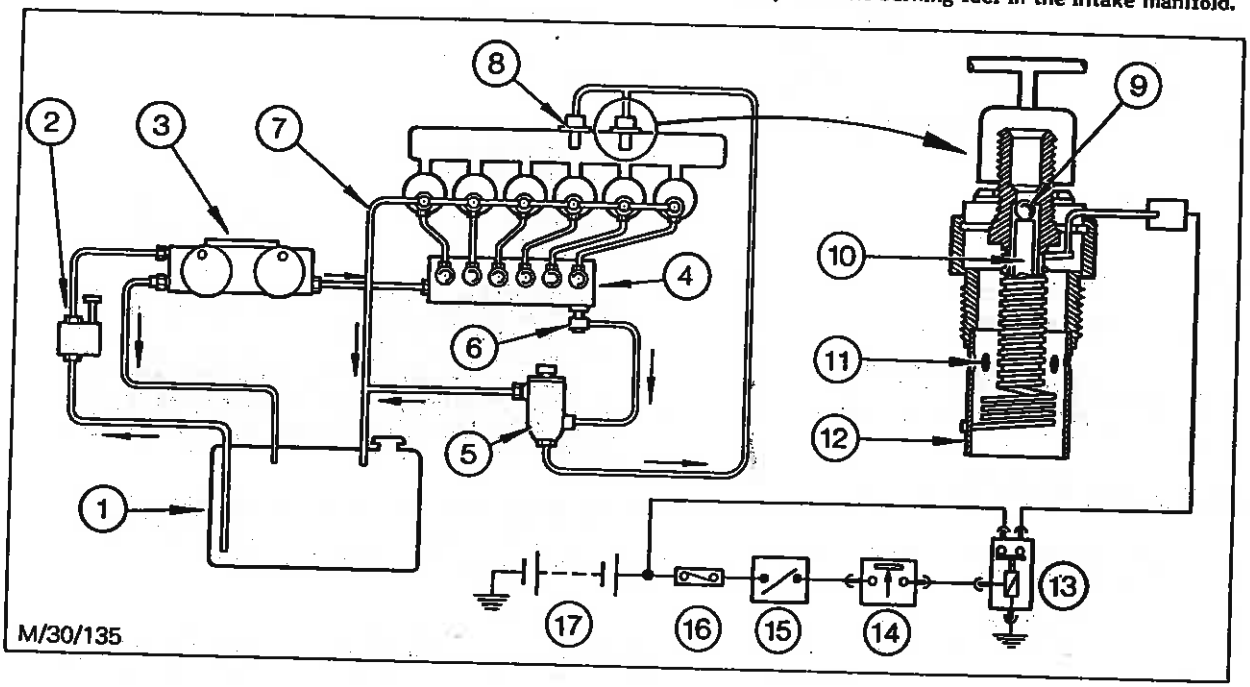


Fig. 10 - Thermostart System Schematic

1. Fuel Tank
2. Fuel Lift Pump
3. Fuel Filters
4. Injection Pump
5. Reservoir
6. Injection Pump Gallery Outlet
7. Leak-Off Pipe
8. Thermostart Element(s)
9. Ball
10. Rod
11. Dilution Holes
12. Shield
13. Thermostart Relay
14. Pre-Heater Button
15. Ignition Switch
16. Fusebox
17. Battery

Servicing

1. Disconnect the battery.

2. Disconnect the electrical connector and fuel pipe from the thermostart element. Allow the fuel to drain into a container.

3. Unscrew the element from the intake manifold and fit a protective cap to the element and the manifold (Fig. 11).

4. Disconnect the pipes from the reservoir and remove the reservoir.

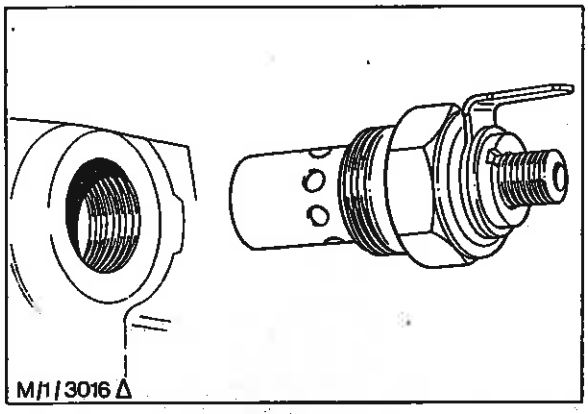


Fig. 11 - Removing/Replacing Thermostart Element

5. Remove the reservoir cover and clean the bowl and cover with kerosene or test oil. Dry the vent filter with low pressure compressed air and re-assemble the unit with a new gasket.

6. Clean the element by brushing lightly with a soft bristled brush.

7. Install the reservoir and reconnect all the fuel pipes except the overflow pipe.

8. Prime the system by operating the lift pump priming plunger until fuel flows from the reservoir. Reconnect the pipe.

9. Install the thermostart element into the manifold and connect the fuel pipe and the electrical connector.

10. Reconnect the battery and operate the thermostart pre-heater button. Check that the inlet manifold radiates warmth in the vicinity of the element. If not, investigate the fuel supply and/or electrical continuity to the element. Rectify and/or renew the element as required.

HIGH PRESSURE FUEL PIPES

Fuel is supplied from the injection pump to the injectors through high pressure steel pipes. Each pipe has an individual shape and cannot therefore be fitted in any position other than to its own cylinder. The pipe ends are suitably formed to connect without using separate olives and the pipes are clamped to each other to reduce vibration.

INJECTORS

Description - Refer to Fig. 12

The following description embraces both CAV and Bosch injectors. Although slightly different in appearance, the two makes are interchangeable providing that injectors for NA engines are not mixed with those for TC engines.

Fitted into machined recesses in the cylinder head, each injector is retained by two bolts. The recesses are angled towards the centre of each piston's combustion bowl.

Each injector is basically a spring loaded needle valve acting as an on-off valve in a 4 hole nozzle. The nozzle, valve and an adaptor plate are retained to the nozzle holder of the injector by a cap nut. Dowel pins in the adaptor plate ensure that the fuel drilling is correctly aligned.

The upper, larger diameter of the needle valve is an accurately ground and lapped fit in the nozzle. These two component parts are classed as a pair for replacement purposes. The annular area formed between the two diameters of the valve spindle is the area on which the valve lifting force is subjected. The lower end of the valve spindle is ground and lapped to form a fuel tight fit on the nozzle seat.

The four spray holes in the nozzle are provided in differently angled pairs. This arrangement accommodates the injector installation angle to result in even distribution into the piston bowl.

A calibrated, self lubricating fuel leakage is permitted between the close fitting diameters of the needle valve and the nozzle. This flow returns to the tank via a 'leak-off' pipe connection at the top of the injector.

Operation - Refer to Fig. 12

As the injection pump delivery valve opens, pressure is felt on the annular face of the needle valves' larger diameter. When fuel pressure overcomes spring pressure, the valve will open. Flow through the spray holes creates a pressure drop which allows the valve to close until pressure rises again. This very rapid, repetitive action causes a 'chattering' or 'buzzing' noise which is audible during bench testing. The very high fuel pressure and minute spray holes combine to create a high degree of atomisation.

Adjustment to the valve operating pressure can only be made by dismantling and reshimming the spring - see under 'Servicing'.

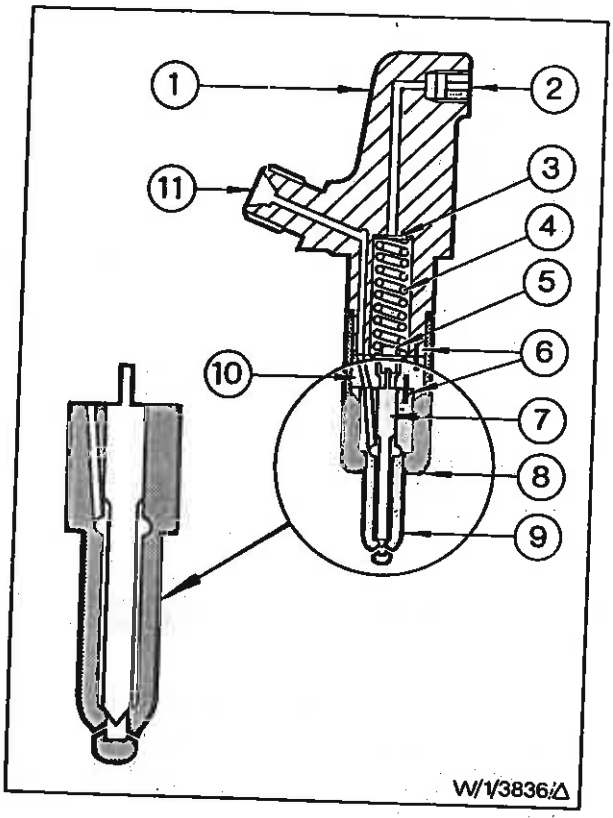


Fig. 12 - Injector
1. Nozzle Holder
2. Leak-Off Connector
3. Shim
4. Spring
5. Spring Seat
6. Dowel Pins
7. Needle Valve
8. Cap Nut
9. Nozzle
10. Adaptor Plate Assembly
11. Inlet Connection

Servicing

The complete procedure for dismantling, overhauling, assembling and testing injectors is given in the separate publication '2720 Range Fuel Injection Equipment'. Consequently, the information following will only cover removing, testing and replacing injectors.

Removing

1. Disconnect the engine breather pipe from the rocker cover.

2. Remove the rocker cover and discard the gasket.

NOTE: If only one injector is to be removed, proceed directly to operation 6. If several injectors are to be removed, it will be found easier to remove the rocker shaft assembly as detailed in operations 3, 4 and 5 following.

3. Slacken each rocker shaft pedestal retaining bolt approximately one turn at a time until all are loose, then remove them - see Fig. 13.

4. Tie the two end rockers in position to keep the complete assembly together, then lift off rocker shaft assembly complete.

5. Remove push rods in sequence and mark them to ensure that they are replaced in their original positions when assembling them later. Do not dislodge the valve stem caps.

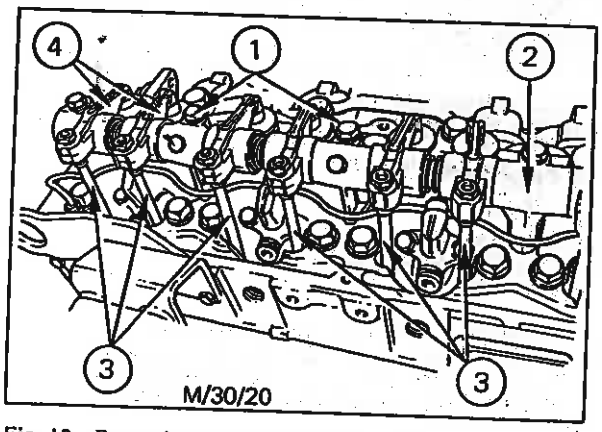


Fig. 13 - Removing Rocker Shaft Assembly
1. Rocker Shaft Pedestal Retaining Bolts
2. Rocker Shaft Assembly
3. Push Rods
4. Rocker Arms

6. Slacken the large oil seal nut (Fig. 14). Where necessary, remove high pressure pipe clamps to gain access.

7. Unscrew the gland nut securing the high pressure delivery pipe to the injector.

CAUTION: DO NOT BEND THE DELIVERY PIPE(S). IF NECESSARY, UNCLAMP AND DISCONNECT BOTH ENDS OF THE PIPE(S).

8. Unscrew and remove the banjo bolt from leak-off pipe.

9. Unscrew securing bolts and withdraw injector. Discard 'O' ring.

10. Remove seating washer from recess in cylinder head and discard it.

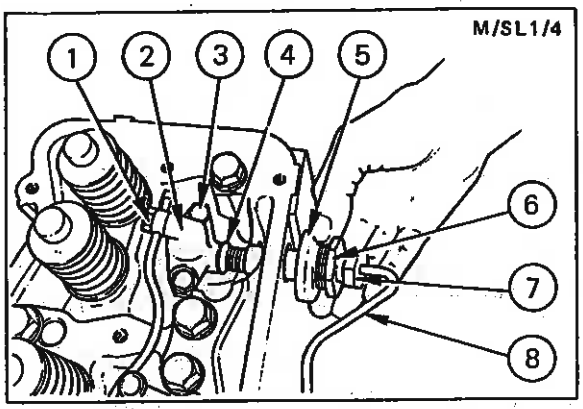


Fig. 14 - Removing Injector
1. Leak-Off Pipe Banjo Bolt
2. Injector
3. Injector Retaining Bolt
4. 'O' Ring
5. Oil Seal
6. Oil Seal Nut
7. High Pressure Pipe Gland Nut
8. High Pressure Pipe

11. Repeat operations 6 to 10 inclusive for all other injectors to be removed. If new or reconditioned injectors are not being fitted immediately, fit blanking plugs or caps to the cylinder head apertures and all open pipe connections.

Testing

! WARNING: When testing injectors, great care should be taken to ensure that the atomised spray from the nozzle does not come into contact with the hands or any other part of the body. The high pressures involved with the atomisation of the test oil may cause it to penetrate the skin and cause possible blood poisoning. Goggles, gloves and suitable protective clothing should be worn during testing.

1. Fit a protective cap to the inlet union and thoroughly clean the injector with kerosene or test oil.

2. Remove the protective cap and connect the injector to the tester - see Fig. 15. Carefully wipe the nozzle completely dry.

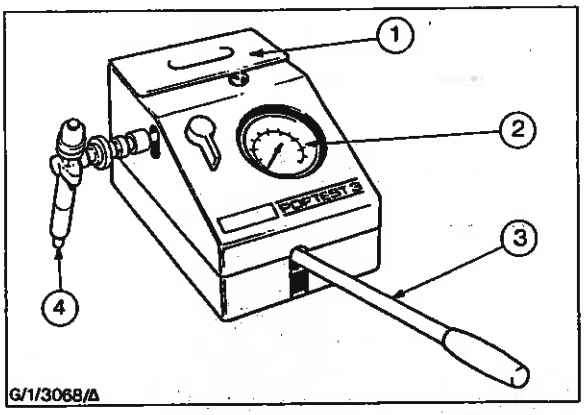


Fig. 15 - Typical Injector Tester
1. Oil Supply Tank
2. Pressure Gauge
3. Pump Handle
4. Injector

3. With the pressure gauge valve closed, operate the hand pump several times to expel air from the unit, then open the valve.

4. Pump sufficiently to raise the pressure until the gauge flickers. This indicates the pressure required to lift the needle from its nozzle seat. Recheck, note the pressure and allow it to reduce. Compare the result with the specified 'setting' or 'working' pressure, as appropriate.

NOTE: A correctly operating injector will emit a 'chattering' sound while spraying.

5. Increase the pressure to the upper specified back leak test pressure. Start a stop watch and note the time for the pressure to fall naturally through 50 bars, i.e. to the lower specified test pressure. Compare the time taken with the specified time/oil temperature.

6. Check that the nozzle tip is perfectly dry, then increase the pressure to approximately 10 bars (145 lb/in^2) below the pressure required to lift the needle. While maintaining this pressure constant, check that droplets of fuel do not collect or drip from the nozzle face for at least 6 seconds. (A slight dampness is acceptable).

7. Close the tester valve and operate the hand pump at approximately 1 1/2 strokes per second. A correct spray pattern will be formed with fuel emitting from all holes in the nozzle and free from irregular streaks.

CAUTION: AT CERTAIN OPERATING PRESSURES A PARTIALLY BLOCKED NOZZLE HOLE MAY PRODUCE A GOOD SPRAY PATTERN. BECAUSE OF THIS FACT, ALL INJECTORS REMOVED FROM ENGINES WITH POWER LOSS OR SMOKING COMPLAINTS SHOULD BE OVERHAULED BEFORE TESTING.

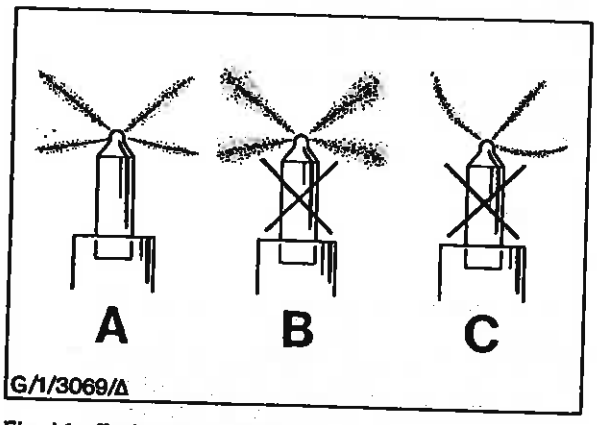


Fig. 16 - Typical Spray Patterns
A. Good
B. Reject - Poor Atomisation
C. Reject - Blocked Spray Hole

Replacing

1. Ensure that the cylinder head injector aperture is thoroughly clean, then fit new sealing washer - see Fig. 17.

2. Fit a new 'O' ring seal to the injector.

3. Insert the injector into the cylinder head and fit but do not tighten the securing bolts - see Fig. 17.

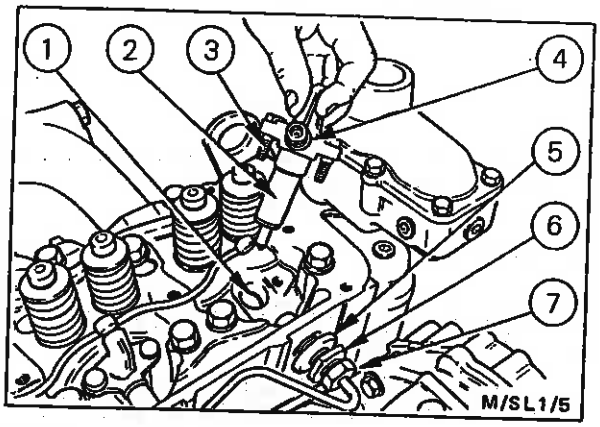


Fig. 17 - Replacing Injector
1. Recess for Copper Sealing Washer
2. Injector
3. Injector Retaining Bolt
4. 'O' Ring
5. Oil Seal
6. Oil Seal Nut
7. High Pressure Pipe Gland Nut

4. Insert the leak-off pipe banjo bolt (Fig. 14) and tighten it by hand only.

5. Connect the high pressure pipe to the injector and hand tighten the gland nut.

6. Repeat operations 1 to 5 inclusive for each other injector being installed.

7. Tighten all injector securing bolts evenly to the specified torque, then tighten the delivery pipe unions and the leak-off pipe banjo bolts to the specified torque.

8. Tighten the oil seal nuts to the specified torque and reclamp any slackened delivery pipes.

NOTE: Before replacing the rocker shaft and/or cover, carry out the 'Injector Leak-Off Rail Pressure Test'.

9. Install the pushrods into the same positions as when removed. Position the rocker shaft assembly, locating the adjuster ball ends into the push rod cups, and gradually and evenly tighten the retaining bolts to the specified torque.

10. Adjust the valve clearances as detailed in Section 1.

11. Replace the rocker cover with a new gasket and tighten screws to the specified torque value.

12. Replace the engine breather pipe.

INJECTOR LEAK-OFF RAIL - PRESSURE TEST

The injector leak-off rail should be pressure tested whenever it is refitted to the engine or if dilution of the engine lubrication oil by fuel oil is suspected.

1. Disconnect the battery.

2. Remove the external leak-off pipe banjo connection at the rear of the cylinder head and fit a single outlet banjo connection securely in its place - see Fig. 18.

3. Connect a cooling system pressure tester to the banjo connection and pressurise the leak-off rail to 0,7 bar (10 lb/in^2).

If the pressure remains constant for 10 seconds or longer, the system is satisfactory - proceed to operation No. 8.

If the pressure cannot be maintained or begins to drop in less than 10 seconds, a leak is indicated - continue with operation No. 4.

4. Check and eliminate the external connections and the pressure tester as the source of leak.

5. Recheck and, if the leak persists, remove the rocker cover for access to the leak-off rail and the injectors.

6. Inspect the leak-off rail and connections for damage and security. If the rail is cracked or split, fit a new rail. If the leak is from a banjo connection to an injector, remove the banjo bolt, check the bolt and banjo faces for scoring or damage and renew or rectify as required.

NOTE: The leak-off rail banjo's are made from a soft material designed to eliminate the need for sealing washers between the faces and the banjo bolts. This material is easily scored and leakages can result.

7. Recheck and when the test pressure can be maintained satisfactorily, refit the rocker cover, using a new gasket.

8. Remove the pressure test equipment and the banjo connection. Refit the external leak-off pipe and tighten the banjo bolt securely.

9. Reconnect the battery.

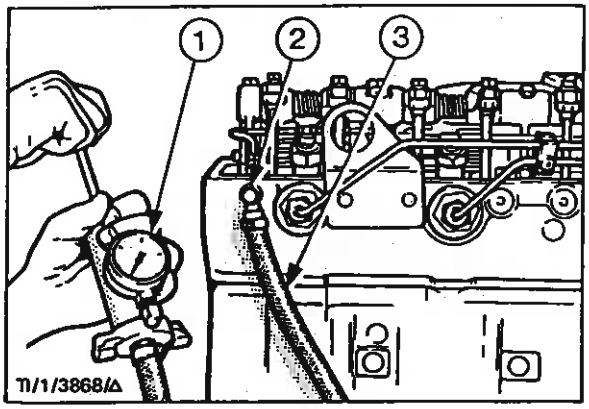


Fig. 18 - Pressure Testing the Leak-Off Rail
1. Cooling System Pressure Tester
2. Suitable Banjo Connector
3. Connecting Hose

FUEL INJECTION PUMP

Introduction

Two types of fuel injection pumps are used with the 2720 range of engines. Those with automotive or G.P. (general purpose) governing are lubricated by a pressure fed system, the oil feed being taken direct from the engine oil filter head; the oil return to the engine is via a drilling in the pump mounting flange which communicates with the engine timing gear case. The drive gear on these pumps has slotted holes to provide fine timing adjustment.

Injection pumps with Class 'A' or combine harvester governing do not have an external oil feed, lubrication being by means of an oil filled cambox. The drive gear on these pumps is not adjustable with respect to the hub, fine timing adjustment being obtained by means of slotted holes in the pump mounting flange which enable the complete pump to be rotated slightly.

Apart from the differences outlined, the two types of injection pump are very similar in construction. The following descriptive text, although written specifically for the automotive governed pump, covers both types; where any significant differences occur, they will be dealt with in the text.

Description

General

The fuel injection pump delivers precisely equal quantities of high pressure fuel to each injector in the correct firing order. Control of fuel flow to vary engine power is by means of the 'speed control lever' on the pump. A control to provide a rich fuel condition for easy engine starting in cold weather is incorporated and also a means of stopping the fuel flow.

The injection pump is mounted on the rear face of the engine timing gear housing and is comprised of two main components, namely the pump housing and the pump body. The light alloy housing encloses and supports a multi-lobed camshaft and associated tappets which operate spring loaded pumping plungers called 'elements'. The elements, one for each engine cylinder, are contained in the steel pump body mounted on the housing. The governor control mechanism is housed in the forward section of the pump housing.

Pumping Section

Camshaft and Drive Gear:

The camshaft is supported in two tapered roller bearings. Forward of the front (No. 1 cylinder) cam, the shaft is flanged to attach the governor weight carrier.

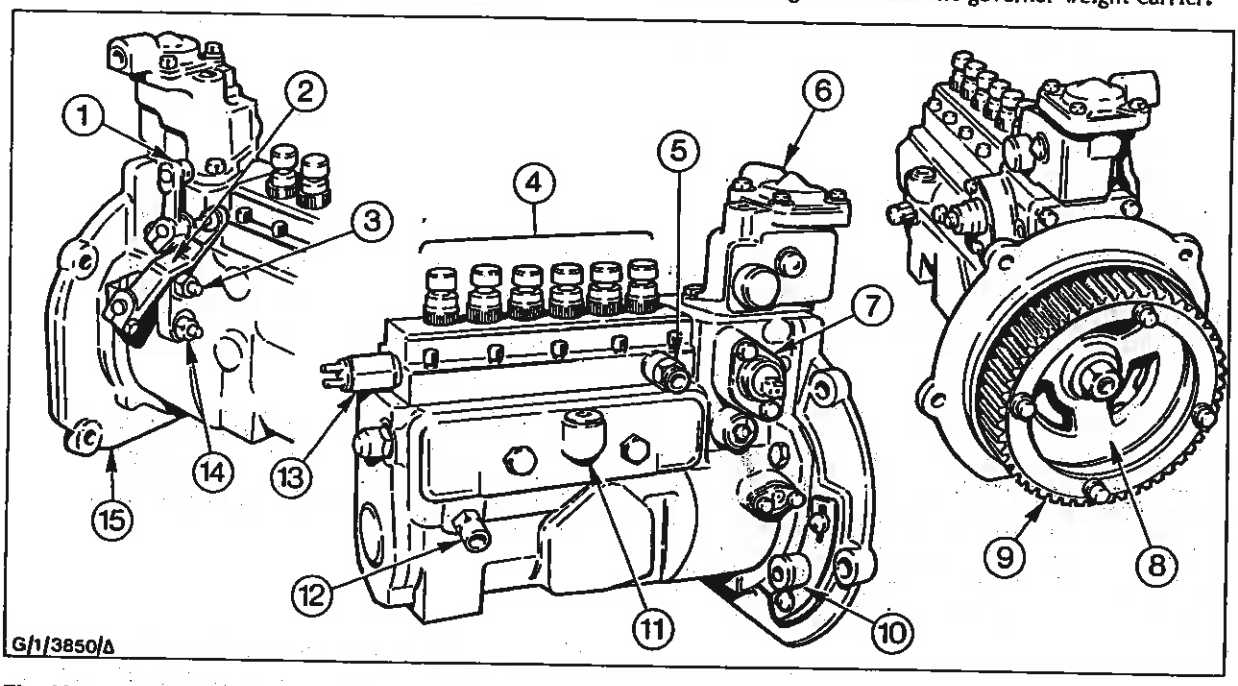


Fig. 19 - CAV Fuel Injection Pump (Automotive and G.P. Governed Type Shown)

1. Stop Control Lever
2. Speed Control Lever
3. Idle Speed Stop
4. Delivery Valves
5. Fuel Gallery Airbleed
6. Boost Control Unit
7. Excess Fuel Solenoid
8. Drive Hub
9. Drive Gear Ring
10. Timing Tool Adaptor
11. Oil Fill Plug (Initial Fitment Only)
12. Pressure Oil Feed Connection
13. Fuel Inlet
14. Maximum Speed Stop
15. Mounting Flange

The forward end of the shaft is tapered, keyed and threaded to mount and secure a drive hub. On automotive and G.P. Governed pumps, a ring gear is bolted to the hub via elongated holes which permits gear adjustment during pump timing.

On Class 'A' and combine harvester governed pumps, the drive hub and gear are in one piece.

A timing tool adaptor is installed on the outer face of the pump mounting flange; a threaded plug normally closing the aperture. During pump fitment a special tool is fitted with a plunger which locates in a hole in the drive hub. When so aligned, the No. 1 plunger inlet port has 'just closed', indicating the injection timing position.

Tappets:

Hardened steel tappets operate in plain bores in the pump housing. Each tappet embodies a hardened steel roller fitted on a floating steel bush and pin. A flat is machined on the upper outer diameter of each tappet body to allow the tappets to be radially positioned with an 'E' shaped locating plate ('T' shaped on Class 'A' and combine harvester governed pumps). This arrangement allows the tappets to reciprocate while maintaining the roller in correct alignment with the cam lobes.

Each tappet body is fitted with a circlip retained 'phasing spacer'. The spacers are available in varying thicknesses to provide a means (during pump calibration only) of adjusting the plunger 'phase angles' i.e. the angle of camshaft rotation between successive injections.

Lubrication - Automotive and G.P. Governed Pumps

The camshaft, bearings, tappets and governor flyweights are lubricated by engine oil from a tapping on the engine oil filter/cooler assembly. The oil enters the pump via a metering adaptor fitted on the side of the pump housing. A knife edge type oil seal is fitted on the governor front cover to prevent oil draining through the front bearing. This creates an oil bath in the housing up to an overflow drain hole in the front cover through which the oil returns to the engine system.

Lubrication - Class 'A' and Combine Harvester Governed Pumps

The cambox and governor housing are kept filled with lubricating oil to the correct level by means of the filler and level plugs. Fuel oil leakage past the pumping plungers mixes with the lubricating oil, necessitating regular oil changing. A drain plug is provided for this purpose.

Pump Elements - See Figs. 20 and 21

Each pump element includes a pump plunger, its cylinder barrel and a delivery valve. The elements are contained in the steel pump body fitted on the upper section of the pump housing.

The plungers and barrels are produced as very accurately machined and graded 'pairs' to produce a close sliding and leak free fit. The upper side of each barrel is drilled at different levels with an (upper) 'inlet' port and a (lower) 'spill' port. A master serration locates the barrels radially to ensure correct relationship with a helical groove in the plungers.

The area surrounding the barrel ports is formed into a 'fuel gallery' which interlinks all the barrels and is fed with fuel from the engine mounted filter(s). To provide a self clearing air bleed, an outlet to the tank is permitted via a restrictor and a disc valve. The restriction ensures that an adequate supply of fuel is always maintained in the gallery and the valve prevents fuel syphoning back to the tank during non-running periods.

A circular diaphragm type of pulsation damper is fitted on the side of the pump body of naturally aspirated engines where automotive or G.P. governing is employed. The damper is connected to the fuel gallery to assist smoothing out fuel pressure fluctuations caused by the interval between successive injections.

Plungers:

Each plunger is an accurately machined and ground rod with an arm fitted to its lower end to affect partial rotation. A deep annular groove on the mid length of the plunger connects with a shallow spiral on the upper length surface. Any leakage between the plunger and barrel is 'collected' in the annular groove and passed back to the fuel gallery via the spiral. Coil springs between the pump body and a spring seat on the plunger stem maintain the plungers in contact with the tappets.

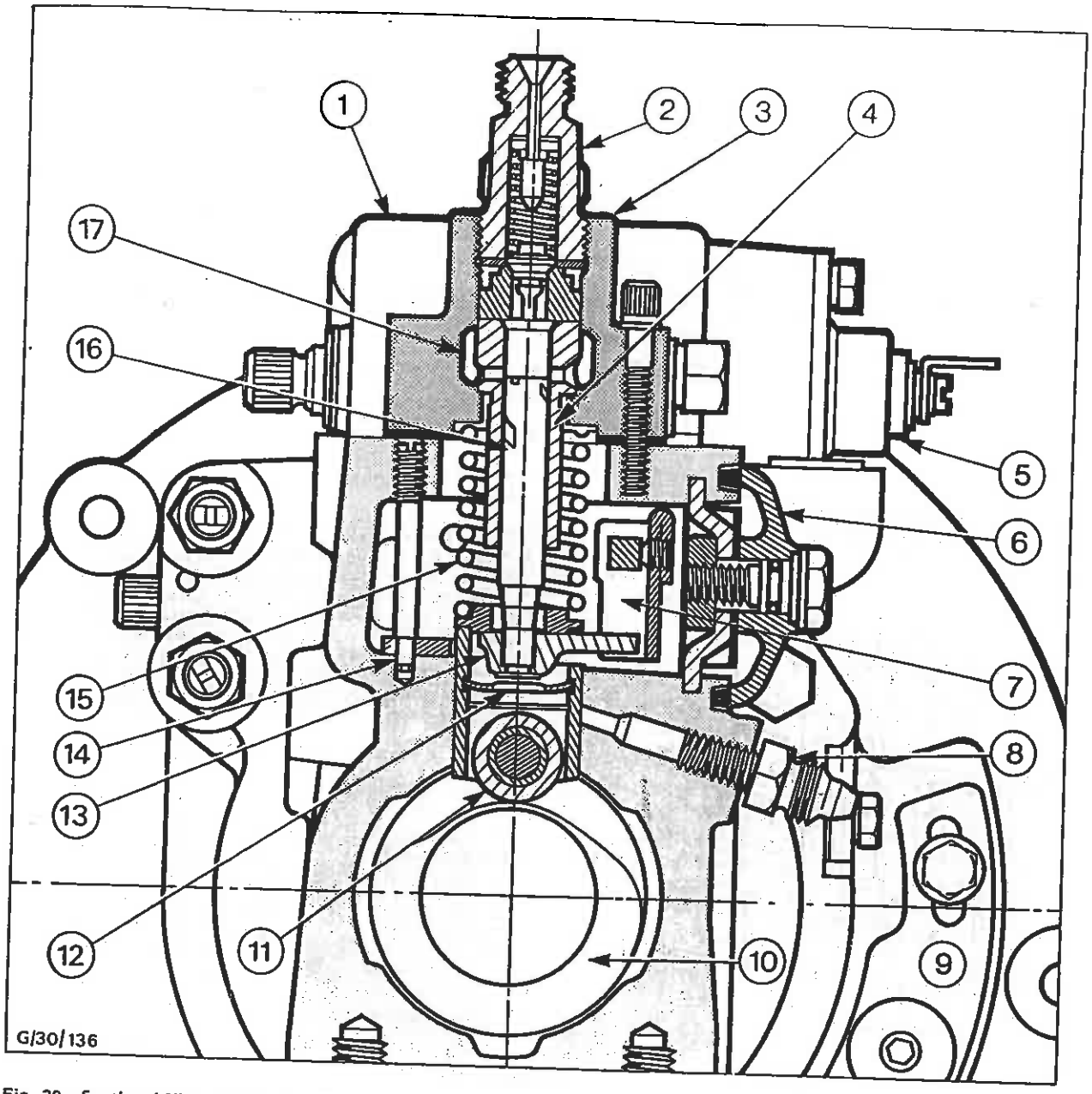


Fig. 20 - Sectional View of Injection Pump

1. Pump Housing
2. Delivery Valve Holder
3. Pump Body
4. Barrel
5. Excess Fuel Solenoid (automotive and G.P. governed pumps only)
6. Side Cover
7. Control Fork
8. Oil Metering Adaptor (automotive and G.P. governed pumps only)
9. Timing Tool Adaptor Plate (automotive and G.P. Governed pumps only)
10. Camshaft
11. Tappet Roller
12. Phasing Spacer
13. Plunger Control Arm
14. Tappet Locating Plate/Screw (automotive and GP governed pumps only)
15. Plunger Spring
16. Plunger
17. Fuel Gallery

A helically shaped groove is machined in the upper side of the plungers and connected by a drilled hole to a central drilling in the crown. As the plunger(s) move upward during their delivery stroke, fuel will be pressurised until the helical groove contacts the spill groove. The radial positioning of the groove in relation to the port thus determines the effective stroke of the plungers.

Radial movement is affected by the arm attached to the lower end of each plunger. The outer end of the arms locate in 'forks' which are locked onto a control rod. The open sided, box type forks permit the plunger arms to reciprocate during pumping. Any backward or forward movement of the control rod (through action of the governor mechanism) is therefore transmitted simultaneously to all plungers. The movement ranges from fuel cut-off through maximum to an 'excess fuel' position.

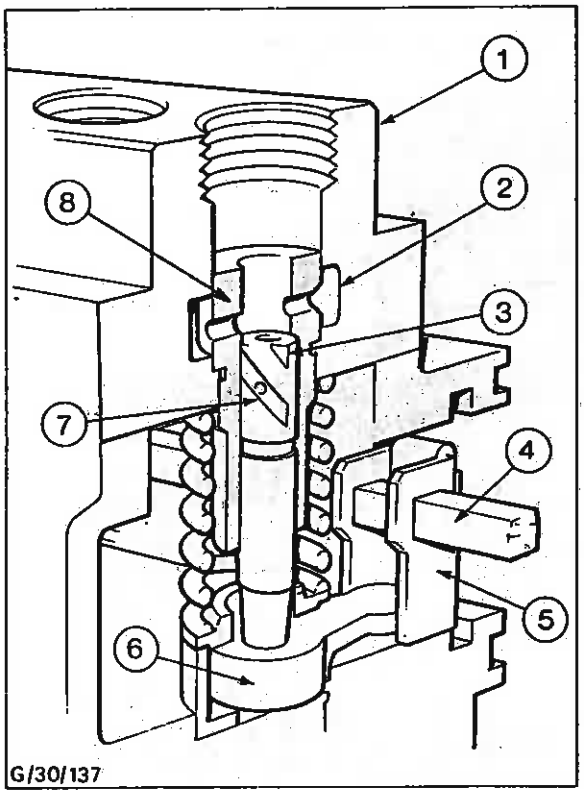


Fig. 21 - Pump Element Arrangement
1. Pump Body
2. Fuel Gallery
3. Starting Groove
4. Control Rod
5. Control Fork
6. Plunger Arm
7. Fuel Metering Groove
8. Barrel

The edge of each plunger crown incorporates a 'starting groove'. The groove is operative only when the plungers are in the excess fuel position and functions by delaying the point at which the inlet port closes. This retards the point (in terms of piston position) at which fuel pressure is sufficient to cause injection. As the engine accelerates to idle speed the governor/control rod mechanism repositions the plungers to nullify the starting groove and excess fuel position.

Delivery Valves - See Fig. 22

These valves are contained in the 'delivery valve holders' which form the outlet of each element. The valves fulfil three functions, viz:

a) Prevent delivery line draining during the plungers intake stroke.

b) Assist pressure build up during injection stroke.

c) Cause rapid pressure reduction in injection line at end of delivery.

Each valve is basically a poppet valve with a fluted stem sliding in a guide. A small piston land formed between the valve face and guide flutes is an accurate fit in the guide. As the plunger opens the barrel port at the end of the delivery stroke, the valve piston first 'plugs' the guide bore. Further downward movement increases the volume above the piston by an amount equal to the pistons movement. This action allows the delivery pipe pressure to fall very rapidly (much quicker than by conical valve only) to effect 'dribble free' closing of the injector.

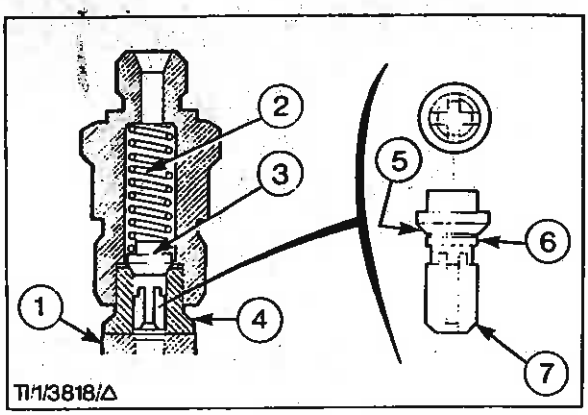


Fig. 22 - Delivery Valve Detail
1. Barrel
2. Spring
3. Delivery Valve
4. Valve Guide
5. Conical Seat
6. Piston
7. Flutes

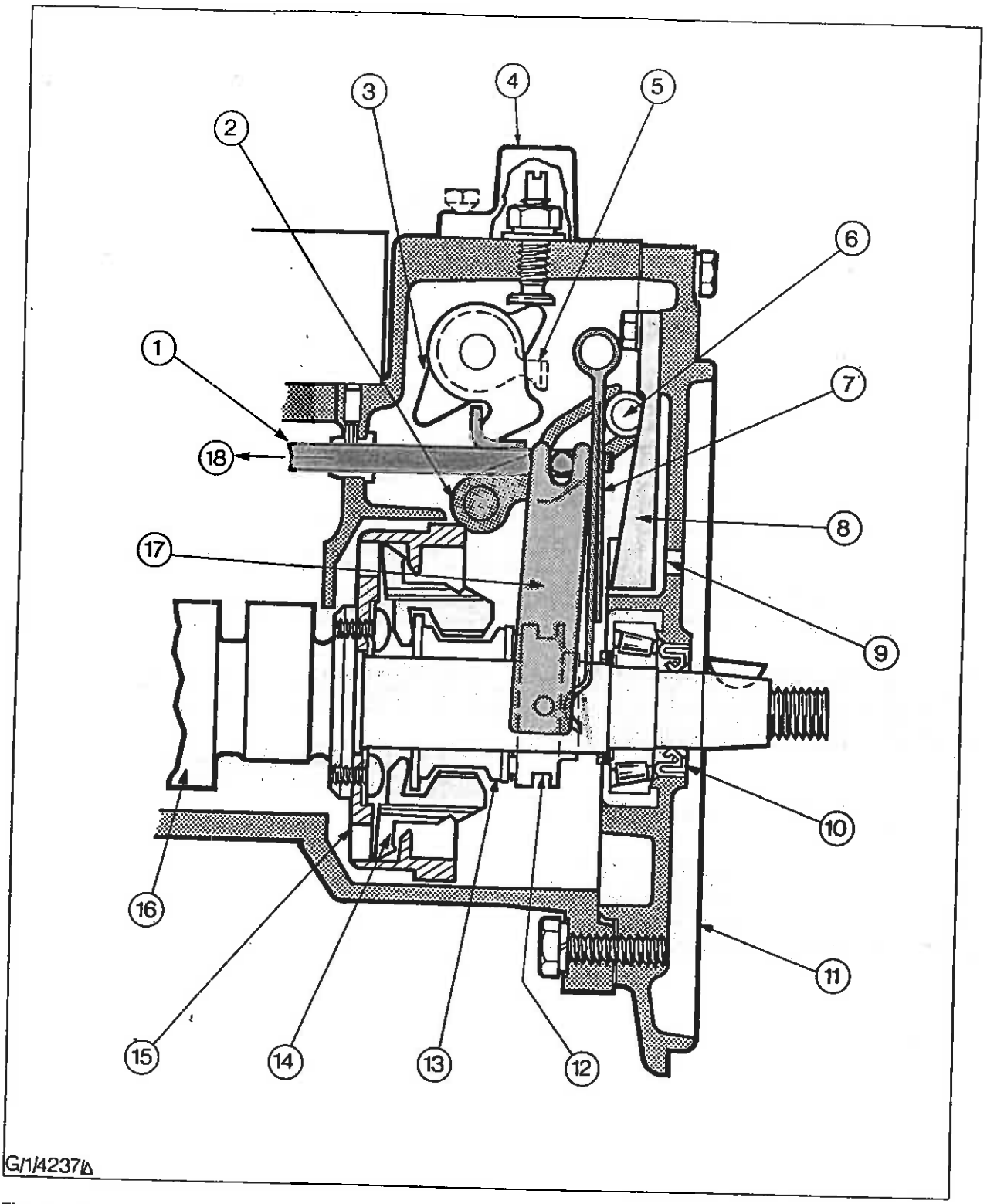


Fig. 23 - Governor Assembly Schematic

1. Control Rod
2. Roller Control Lever moved by Speed Control Lever
3. Maximum Stop Lever
4. Maximum Fuel Stop (NA Engines)
5. Stop Control Lever
6. Roller
7. Governor Spring
8. Ramp
9. Oil Level Hole
10. Oil Seal
11. Cover (Mounting Flange)
12. Thrust Pad
13. Sleeve
14. Flyweights
15. Carrier
16. Camshaft
17. Rocking Lever
18. Direction for Minimum Fuel

Governor Section - See Fig. 23

The governor assembly maintains accurate and sensitive control of the engine speed for any given throttle setting and co-ordinates demands for starting and stopping the engine. The assembly is located at the front end of the injection pump housing and enclosed by the pump mounting flange.

The governor consists of a flyweight mechanism operating in opposition to a throttle lever tensioned spring. A carrier for the flyweights is secured onto a flange of the pump camshaft with four screws.

Six steel flyweights (four on Class 'A' and two on combine harvester governed pumps) are positioned in the carrier, with their inner arms located behind a thrust washer and spool shaped sleeve. Forward of the sleeve a grooved thrust pad is separated from the sleeve by a needle roller race and a thrust washer. The legs of an inverted 'U' shaped governor leaf spring press against the thrust pad. The spring is pivoted on a spindle at the top of the casing and is positioned vertically in close relationship to a ramp on the governor casing front cover.

The throttle control shaft passes through both sides of the governor housing with the speed control lever clamped to one end. Internally, the shaft mounts a forked lever which passes through the legs of the governor leaf spring and carries a dumb bell shaped roller. Movement of the control shaft causes the roller to move up or down the inclined ramp. The movement changes the governor spring force in relation to the position of the thrust pad.

A rocking lever translates the position of the thrust pad into pump plunger control rod position. The lever is pivoted to the side of the governor housing, a pin in the lower end fitting into a groove of the thrust pad. The upper end is attached to the control rod by a sliding fork and pin.

Control Rod and Associated Equipment - See Figs 23 and 24

The control rod to which the pumping plunger control forks are attached is supported in two bushes. The forward bush is mounted in the governor to pump housing dividing wall and the rear bush in an end cover in the pump housing rear wall. On some engines, the bush is incorporated in an idling speed damper, fitted in place of the end cover.

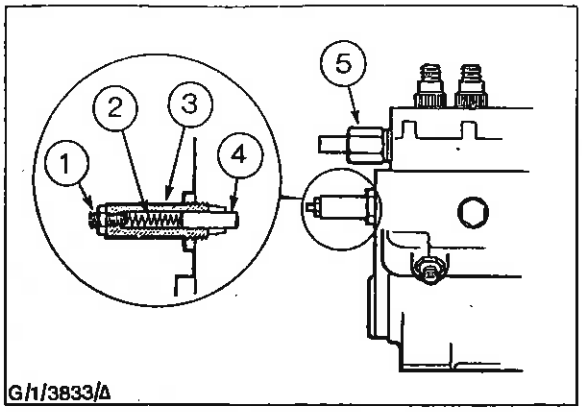


Fig. 24 - Control Rod Idling Damper
1. Adjustment Screw
2. Spring
3. Bush Retainer
4. Control Rod and Bush
5. Fuel Inlet Connection

The idling speed damper comprises an adjustable spring 'buffer' for the control rod. This prevents the rod moving past the idling position into a no-delivery position during a rapid deceleration.

A bracket is riveted to the control rod where it operates in the governor section of the pump. The bracket has two functions:

1) To relate the position of the control rod to the camlike maximum (fuel) stop lever. (This 'lever' is mounted on a cross shaft in the upper section of the casing).

2) To provide the point of leverage through which the stop control lever can move the control rod rearward into a 'no-delivery' position.

Engine Stop Control:

A stop control lever is fitted on the engine facing side of the pump and operated by a cable or other form of linkage.

The lever controls an internally spring loaded shaft on which a camlike stop control lever is fitted. When operated, the lever pushes on the control rod bracket to rotate the pump plungers into a 'no-delivery' condition. As the control is relaxed, an externally mounted spring returns the lever to the run position and the governor spring returns the control rod to the selected fuel position.

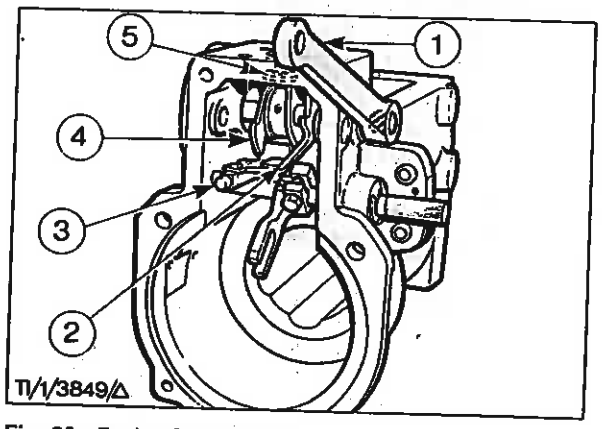


Fig. 25 - Engine Stop Control
1. External Stop Control Lever (in Stop position)
2. Stop Control Lever in Pump
3. Control Rod
4. Maximum Stop Lever
5. Maximum Fuel Stop

Excess Fuel Device:

This device is a means of overriding the maximum fuel stop so that the control rod can be moved into an 'excess' fuel condition.

On Class 'A' and combine harvester governed pumps, the device takes the form of a push button situated on the outside of the governor housing. To select excess fuel, the button is depressed while moving the speed control lever to the maximum speed position. When the speed control lever is returned towards the idling speed position, the excess fuel button is released automatically, thus returning the control rod to a normal fuel condition. An additional unit enables the excess fuel device to be operated from a remote position automatically.

On automotive and G.P. governed pumps, the device consists of a solenoid which, when operated, pulls the maximum (fuel) stop lever clear of the control rod bracket. Operation during starting depends on whether or not the 'excess fuel temperature switch' contacts are closed. (See Fig. 26). The switch is fitted on the engine thermostat housing to sense the metal temperature (not the coolant temperature). At or below 0 to 8°C (32 to 46°F) the closed contacts will complete a circuit to the solenoid when the starter relay is energised. Depressing the accelerator pedal will then cause the control rod to move into the excess fuel position.

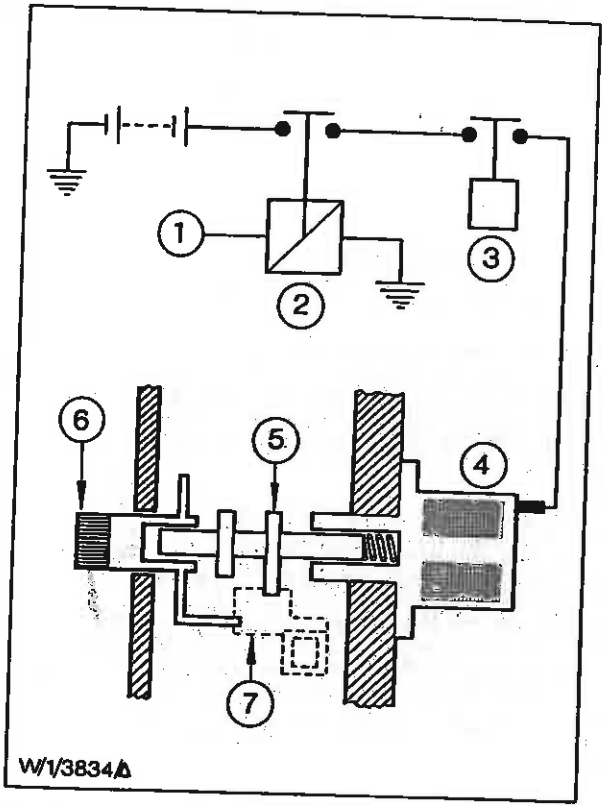


Fig. 26 - Excess Fuel Device Schematic
1. Ignition Switch Contacts
2. Starter Relay
3. Excess Fuel Temperature Switch
4. Excess Fuel Solenoid
5. Maximum Stop Lever
6. Engine Stop Lever Shaft
7. Control Rod Bracket

Boost Control Unit - Turbocharged Engines Only

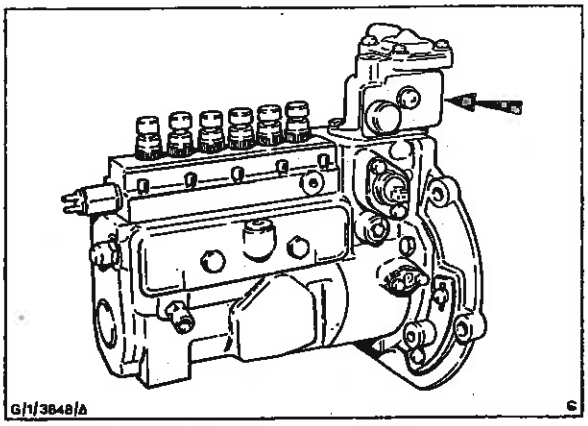


Fig. 27 - Boost Control Unit

This unit prevents overfuelling during acceleration in the low turbocharger speed range by controlling fuel flow in relation to manifold air pressure.

Bolted to the top of the pump governor (Fig. 27), the unit functions as a variable position maximum fuel stop. The casing is divided into two chambers, the upper containing a spring loaded piston type diaphragm assembly. A cover plate encloses the diaphragm and is connected by sensing pipeline to the intake manifold.

As illustrated in Fig. 28, a central rod is connected to the diaphragm and passes through a guide bush in the casing into the lower chamber. The fork end of a camplate is pivoted to the lower end of the rod. The opposite end of the camplate is enclosed in a 'C' shaped shoe and pivoted into the slotted block of the maximum fuel adjuster. This second pivot is so positioned to create a small lever between the pivot and the centre line of the block. A maximum fuel stop rod is fitted in the casing as shown. The rod is a free floating relay between the 'C' shaped shoe and the maximum fuel stop lever in the governor casing.

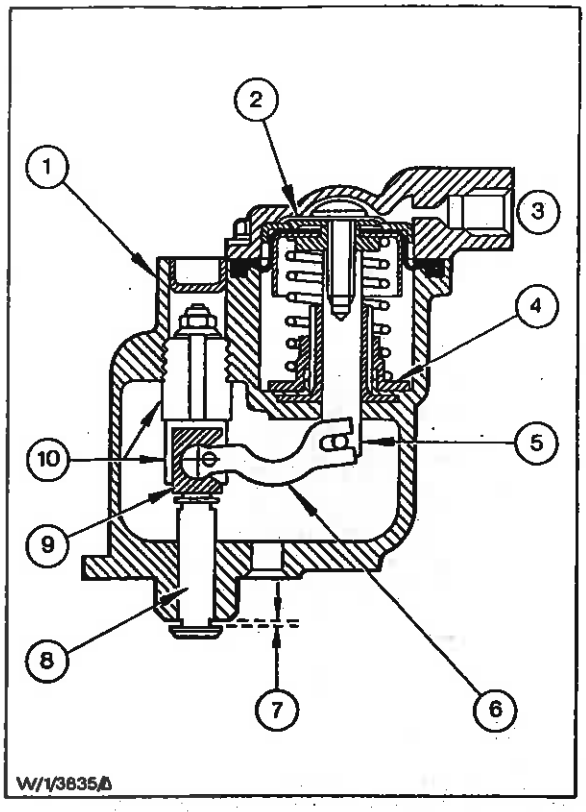


Fig. 28 - Boost Control Unit Semi-Schematic
1. Casing
2. Diaphragm and Piston Assembly
3. Air Connection
4. Spring Seat (Adjuster)
5. Rod
6. Camplate
7. Effective Movement of Rod
8. Fuel Stop Rod
9. Shoe
10. Maximum Fuel Adjuster and Slotted Block

The illustration shows the unit in the 'zero-boost' condition. The fully relaxed diaphragm rod position creates maximum camplate leverage in a downward (fuel restricting) direction. This position is relayed to the maximum fuel stop lever in the governor to determine the 'maximum fuel stop' for the current (turbocharger output) condition. As turbocharger output increases with speed, the higher manifold air pressure overcomes the diaphragm spring to reset the stop.

Adjustments on the vehicle are not permitted. Three points of adjustment are provided for use during calibration on a test rig:

a) Maximum Fuel Adjusting Screw. This hollow 'screw' is threaded into the casing to provide an adjustable mounting point for the slotted block. Turning the screw will reset the maximum fuel stop by raising or lowering the camplate pivot.

b) Diaphragm Spring Load. The lower spring seat is threaded onto the diaphragm rod guide bush. The edge of the seat is serrated to mate with a leaf spring and form a 'click' type of adjustment.

c) Zero boost. This adjustment (not shown) sets the zero boost position of the diaphragm by setting the maximum upward position of the rod pivot pin.

The adjuster is in the form of a thumb operated wheel nut which acts as a pivot stop.

Access to all adjustments is through a side cover plate which is secured by a tamperproof bolt.

OPERATION

Low Pressure System

Fuel is drawn through the water separator filter (if fitted) and/or the lift pump filter by action of the lift pump. The pressure forces fuel through the engine mounted filters and pressurises the injection pump fuel gallery. Pressure in the gallery is maintained by the self-idling action of the lift pump and limited by the relief valve on the engine mounted filter.

During engine running a small constant bleed occurs from the gallery through the restrictor/NRV assembly. The bleed, which ensures the clearance of any air in the system is normally connected to the leak-off line from the injectors. On engines with thermostart systems, the gallery bleed supplies the thermostart reservoir. Overflow from the reservoir rejoins the leak-off line to return to the tank.

High Pressure Generation - See Fig. 29

Given that the injection pump shut off lever is in the normal running position, high pressure is developed by the pump elements immediately camshaft rotation occurs. The sequence of events during the cycle of a pumping element is described and illustrated as follows.

At position 'A' the plunger is at the bottom of its stroke and fuel under lift pump pressure fills the pumping element via the two ports in the barrel.

As the camshaft rotates, the plunger rises until position 'B' is reached where fuel can no longer enter the element.

NOTE: During starting, when the plungers are in their starting fuel position, the barrel port closure is delayed by the starting groove. This function 'retards' the point (in terms of crankshaft degrees) at which pressure is sufficiently developed to cause injection. Further upward movement of the plunger compresses the fuel and begins to lift the delivery valve off its seat.

When the fuel pressure is sufficient to lift the delivery valve completely off its seat and the piston is clear of its guide (position 'C'), fuel passes along the pipe line to the injector.

The fuel pressure developed by the plunger lifts the injector needle valve off its seating and allows fuel in a highly atomised state to be sprayed into the cylinder. Fuel continues to be injected until the plunger reaches position 'D' where the helical groove contacts the spill port. At this position the fuel in the pumping chamber dissipates to low pressure via the central drilling and helical groove in the plunger. The reduction in pressure in the element causes the delivery valve to close rapidly.

The sudden reduction in pressure as the delivery valve closes is sufficient to allow the injector needle valve to snap shut under the force of its spring. This prevents fuel dribbling from the injector which would result in carbon build up on the injector tip.

Although the plunger continues to rise to the top of the stroke, the helical groove in the plunger prevents pressure being developed. The cam holds the plunger at the top of its stroke until that particular engine cylinder is on compression stroke again. This prevents the engine running in the reverse direction in the event of a backfire.

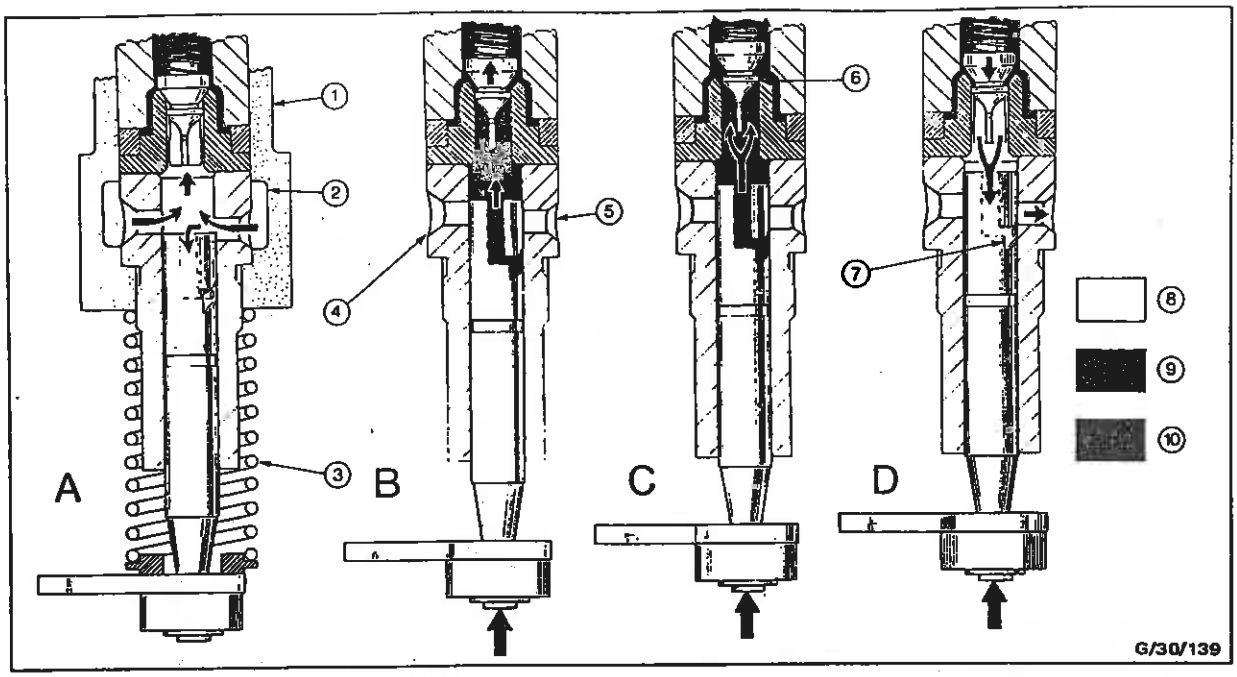


Fig. 29 - Pumping Element Action

1. Pump Body
2. Fuel Gallery
3. Plunger Spring
4. Inlet Port
5. Spill Port
6. Delivery Valve Piston
7. Helical Groove
8. Lift Pump Pressure
9. Injection Pressure
10. Delivery Line Residual Pressure

A. Element Filling
B. Inlet Port Shut
C. Injection
D. Spill Port Open

Fuel Control

The mount of fuel injected into the engine cylinders is entirely dependent upon the effective stroke of the pump plungers, i.e. inlet port closed to spill port open. This can be changed by turning the plungers to a new rotary position in their barrels, thereby altering the helical groove position in relation to the spill port.

The plungers are rotated in their barrels by means of arms attached to the base of each plunger, which in turn engage into forks on the control rod. Causing the control rod to move forward increases the effective stroke, whilst moving it rearwards decreases the stroke. The control rod is connected to the governor by a rocking lever, so that movement of the flyweights alters the volume of fuel delivered and thus controls the engine speed.

Since the governor flyweight force is opposed by the governor spring force, fuel delivery (and therefore engine speed) will be constant when the two forces are equal.

Static to Idling Speed - See Fig. 30

Before starting the engine and without any depression of the accelerator pedal, the governor flyweights will be fully closed and the plunger control rod will be in the maximum fuel position.

In cold weather conditions where the engine temperature is at or below 0 to 8°C (32 to 46°F) the excess fuel device should be operated. Where an automatic excess fuel device is fitted, the temperature switch will energise the excess fuel solenoid when the starter motor engages. In the pump this moves the maximum stop lever clear of the control rod bracket. Depression of the accelerator pedal will then cause the rod to move into the excess fuel position. This device is assisted by the starting groove on the plungers which together function to deliver a high volume supply at a retarded piston position.

As the engine starts and accelerates, governor flyweight centrifugal force increases. (At this point, the accelerator pedal should be released to idle, or acceleration will continue to maximum speed).

With the speed control lever in the idling position, the 'dumb-bell' shaped roller is at the top of the ramp and the governor spring load is small. Under these conditions the flyweights are thrown outward and the rocking lever pushes the control rod rearwards. This movement reduces the effective stroke of the element plungers to reduce the fuel quantity. Acceleration now reduces until centrifugal force falls enough to equal spring force. This balanced condition holds the control rod in a position suitable to result in the specified idling speed.

As the control rod resets towards the idle position, excess fuel and starting groove functions are automatically cancelled. The excess fuel solenoid de-energises as soon as the starter key is released. The excess fuel temperature switch will monitor the engine temperature during operation to determine and control the excess fuel requirement during any further engine starting.

If speed increases or decreases without changing the acclerator pedal setting, the flyweight force or the spring force (whichever is the greater) will reset the control rod to maintain the selected speed. When the accelerator pedal is depressed, the pump responds as described in the following text for maximum speed.

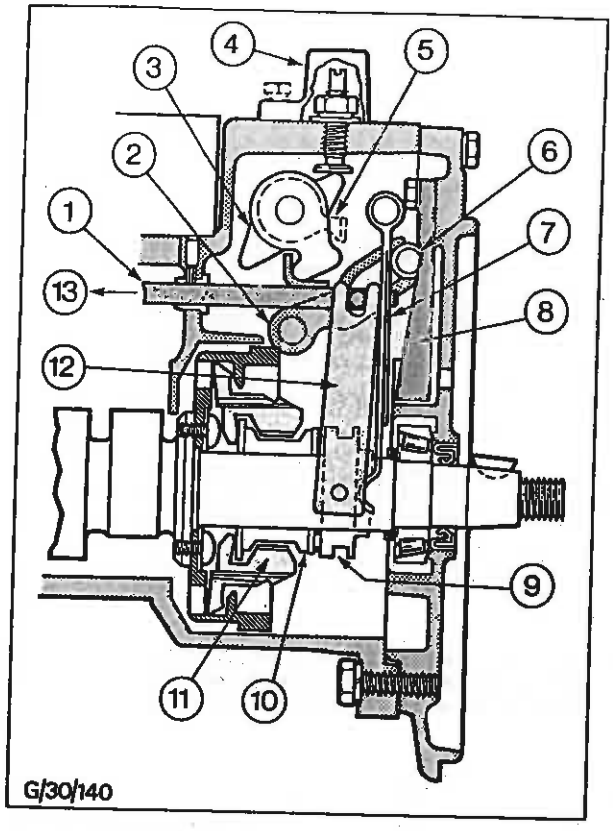


Fig. 30 - Governor Assembly
1. Control Rod
2. Roller Control Lever - moved by Speed Control Lever
3. Maximum stop lever
4. Maximum Fuel Stop (NA Engines)
5. Stop Control Lever
6. Roller
7. Governor Spring
8. Ramp
9. Thrust Pad
10. Sleeve
11. Flyweights
12. Rocking Lever
13. Direction for Minimum Fuel

Maximum Speed

Moving the speed control lever to the maximum position causes the roller to move down the ramp to increase governor spring load. The spring load is then sufficient to overcome the centrifugal force of the governor weights and move the sleeve and thrust pad along the camshaft.

This motion is transmitted to the control rod by the rocking lever which pulls the rod forwards, increasing the volume of fuel injected with subsequent rise in engine speed. The maximum fuel position is reached when the control rod bracket contacts the maximum fuel stop camlike lever which in turn contacts the maximum fuel stop in the top of the governor housing. (On turbo-charged engines the lever contacts the fuel stop rod in the boost control unit).

Should the engine speed continue to increase when the control rod has reached this position, the centrifugal force of the governor weights will overcome the spring load and move the sleeve and thrust pad along the camshaft. The rocking lever will then push the control rod to reduce the volume of fuel delivered until engine speed falls.

The engine speed is therefore at all times proportional to the governor spring load, enabling accurate and sensitive speed control to be maintained throughout the engine speed range.

SERVICING THE FUEL INJECTION PUMP

The complete procedure for dismantling, overhauling, assembling and testing injection pumps is given in the separate publication '2720 Range Fuel Injection Equipment'. Consequently, the following information covers only removal, replacement and timing of the injection pump plus checks and adjustments that can be made while the pump is mounted on the engine.

Removing the Injection Pump

1. Disconnect the battery and, where fitted, detach the excess fuel electrical connection from the pump.

2. Disconnect the engine stop control cable or linkage and the throttle return spring and linkage.

3. Disconnect all fuel and oil pipes from the pump. On turbocharged engines, disconnect the boost control pipe.

4. Remove the pump flange securing bolts and lift out the pump. Fit a suitable blanking plate or cover over the gear housing aperture and fit blanking caps or plugs to all open ended pipes and connectors.

If the pump has automotive or G.P. governing and is to be renewed, remove the four outer socket headed screws from the pump driving gear and retain the gear ring, plate and screws for fitting to the new pump - see Fig. 31. Examine for satisfactory condition and renew parts as necessary.

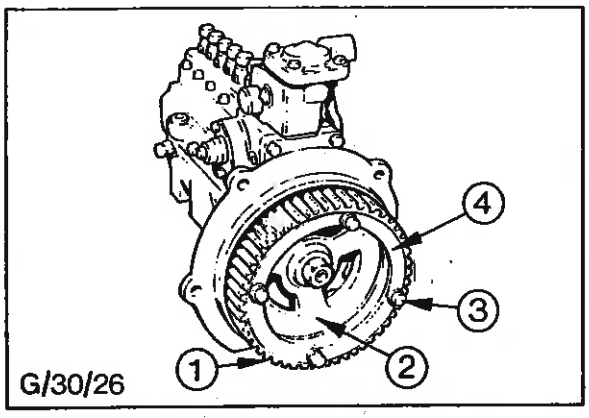


Fig. 31 - Injection Pump Drive Gear - Automotive and G.P. Governed Pumps Only
1. Ring Gear
2. Drive Hub
3. Clamping Screws
4. Clamping Plate

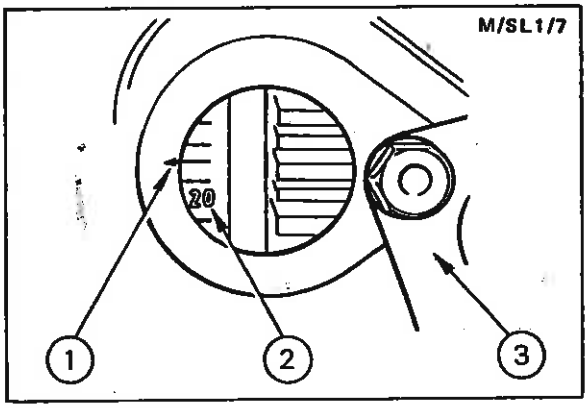


Fig. 32 - Engine Timing
1. Timing Mark on Housing
2. Timing Scale on Flywheel
3. Timing Aperture Cover

Replacing the Injection Pump

1. Remove the timing aperture cover from the flywheel housing and turn the engine in the normal direction of rotation until the specified number of degrees before T.D.C. on No. 1 cylinder is indicated against the timing mark on the edge of the timing aperture (Fig. 32). No. 1 cylinder must be on the compression stroke.

NOTE: If the correct piston stroke is in doubt, remove the rocker cover and check that both pushrods of No. 1 cylinder are free to rotate. If they are not, rotate the crankshaft through 360° and check the flywheel marking again.

2. If a new pump with automotive or G.P. governing is being installed, fit the ring gear and plate in position, but do not fully tighten the screws (Fig. 31). Drain any oil from the fuel gallery of the new pump.

3. Remove the blanking plug from the timing bush or aperture on the pump mounting flange - refer to Fig. 33 or 34 as appropriate.

4. Rotate the pump drive gear until the timing hole is centred in the bush or flange aperture then screw the timing tool (23-507 or 23-504) into position - see Fig. 33 or 34 as appropriate. Rotate the drive gear slightly as necessary to engage the tool plunger in the hole in the gear.

5. On automotive and G.P. governed pumps, remove the adjustment cover plate on the front of the timing cover (Fig. 35).

6. Fit a new 'O' ring to the pump mounting flange and install the pump carefully, tightening the bolts to the specified torque.

NOTE: In the case of automotive or G.P. governed pumps, if the pump flange holes cannot be aligned with the holes in the engine timing gear case, slacken the four drive gear clamping screws to enable the pump to be rotated slightly, relative to the gear.

7. In the case of automotive or G.P. governed pumps, tighten the drive gear clamping screws to the specified torque and check that the correct flywheel marking is still indicated. Replace the timing cover adjustment plate and the flywheel timing aperture cover and tighten the securing screws. Remove the timing tool and replace and tighten the blanking plug.

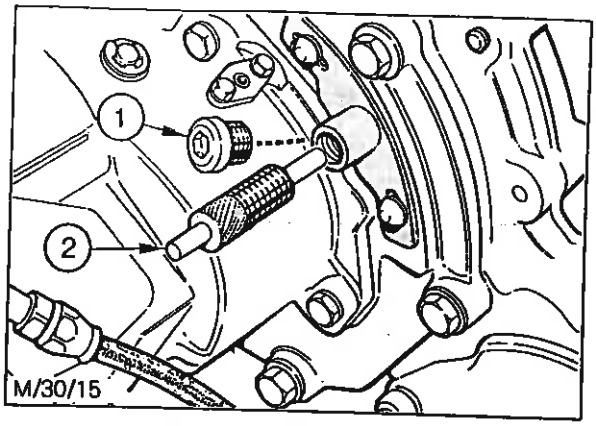


Fig. 33 - Injection Pump Timing - Automotive and G.P. Governed Pumps
1. Timing Bush Blanking Plug
2. Timing Tool 23-507

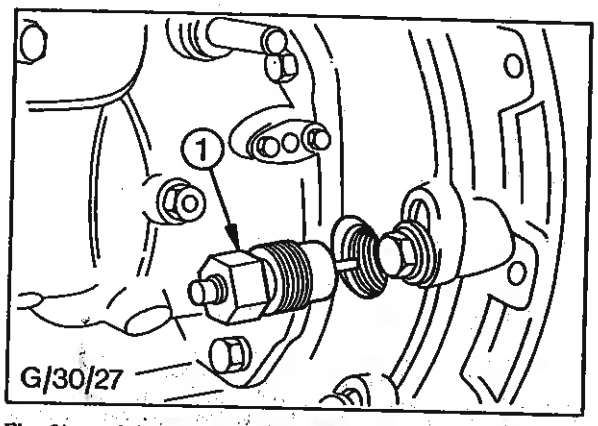


Fig. 34 - Injection Pump Timing - Class 'A' and Combine Harvester Governed Pumps
1. Timing Tool No. 23-504

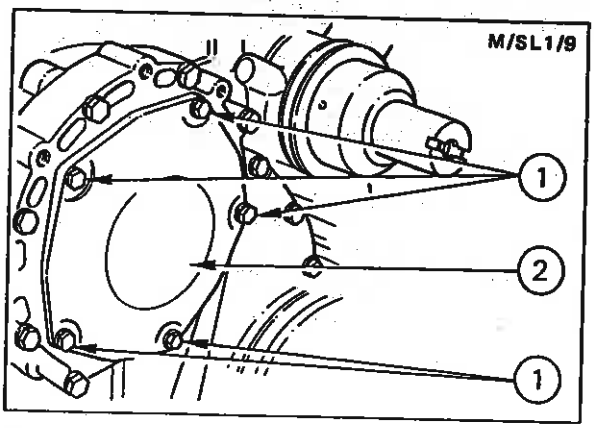


Fig. 35 - Removing Injection Pump Timing Aperture Cover Plate - Automotive and G.P. Governed Pumps
1. Securing Bolts
2. Cover Plate

8. Connect the high pressure pipes, the oil feed pipe (where applicable) and the fuel inlet pipe to the pump, tightening the unions to the specified torque figures. On turbocharged engines, reconnect the boost control pipe.

9. Reconnect the throttle cable or linkage and spring and the engine stop control cable or linkage.

10. Where applicable, reconnect the excess fuel electrical connection.

11. On thermostart reservoirs which have been disconnected, reconnect all except the overflow pipe. Where no thermostart(s) are fitted, remove the fuel pipe from injection pump non-return valve.

12. Prime the system by operating the priming pump until air free fuel flows from the pump non-return valve or thermostart overflow. Refit the pipe.

13. On new pumps with automotive or G.P. governing only, remove the oil filler plug and insert the specified quantity of engine oil. Refit and tighten the plug.

14. In the case of Class 'A' or combine harvester governed pumps, remove the oil filler and level plugs and top up with new engine oil as necessary. Refit and tighten plugs - see Fig. 36.

15. Connect the battery.

Checking/Adjusting the Injection Pump Timing

Carry out operations 1 and 2 under 'Replacing the Injection Pump' then proceed as follows:

1. Screw the appropriate timing tool into position. If the pump is correctly timed, the tool plunger will engage in the hole in the drive gear hub. If the tool plunger will not engage, carry out the following operations as applicable:

2. On automotive and G.P. governed pumps, remove the adjustment cover plate (Fig. 35) and slacken the four drive gear clamping screws. Rotate gear slightly as necessary until tool plunger engages, then tighten clamping screws to recommended torque value. Check that correct flywheel marking is still indicated. Replace the timing cover adjustment plate and tighten the securing screws (Fig. 35).

3. On Class 'A' and combine harvester governed pumps, slacken injection pump securing bolts and rotate complete pump until tool plunger engages. If necessary, slacken high pressure pipe clamps to assist pump movement. Tighten pump securing bolts and check that correct flywheel marking is still indicated.

4. Remove timing tool and replace and tighten blanking plug.

5. Replace flywheel timing aperture cover plate and tighten securing screw.

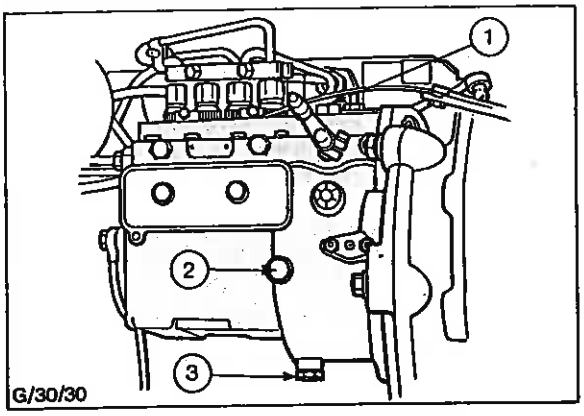


Fig. 36 - Injection Pump Oil Plugs (Class 'A' and Combine Harvester Governing Only)
1. Filler Plug
2. Level Plug
3. Drain Plug

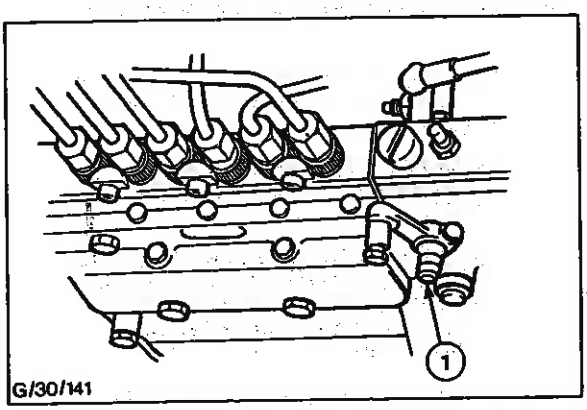


Fig. 37 - Excess Fuel Control - Manual Type
1. Excess Fuel Button

CHECKS AND ADJUSTMENTS ON THE ENGINE

Excess Fuel Operation - Class 'A' and Combine Harvester Governed Pumps with Manual Operation

1. Move the fuel injection pump throttle lever to the maximum fuel delivery position and hold.

2. Press the excess fuel button (Fig. 37) in until a distinct 'click' is heard.

3. Release the throttle lever allowing it to return to the idle position.

4. Move the fuel injection pump stop control lever to the 'no fuel' delivery position. The excess fuel button should now throw out.

5. If the button does not throw out, then ease back the gaiter on the excess fuel shaft and apply a few drops of clean engine oil to the shaft. Work the shaft in and out until it is free; the throttle should be held in the idle position.

6. Test for button 'throw out' again as formerly described. If sticking occurs the shaft may be bent; if so, it must be renewed - refer to separate publication '2720 Range Fuel Injection Equipment' for overhaul procedures.

Excess Fuel Operation - Automotive and G.P. Governed Pumps and Class 'A' and Combine Harvester Governed Pumps with Optional Automatic Operation

Operation during starting depends on whether or not the 'excess fuel temperature switch' contacts are closed (see Fig. 38). The switch is fitted on or near the engine thermostat housing to sense the metal temperature (not the coolant temperature). At or below 0 to 8°C (32 to 46°F) the closed contacts will complete a circuit to the solenoid when the starter relay is energised. Operating the throttle lever will then cause the control rod to move into the excess fuel position.

If the temperature is too high for normal operation, the solenoid can be tested by connecting its 'Lucar' blade terminal directly to the battery positive terminal with a length of insulated wire. The solenoid should be heard to 'click' when the connection is made and again when the wire is removed. If no 'click' can be heard the solenoid is probably faulty and should be renewed - refer to the separate publication '2720 Range Fuel Injection Equipment'.

An alternative excess fuel temperature switch was introduced to operate positively up to 8°C. This unit, Part No. 81DB-8A564-BA should be fitted in place of the earlier unit, Part No. 785F-8A564-BA if cold starting difficulties are experienced.

Idling Speed Adjustment

1. Run the engine until normal operating temperature is reached, then adjust the idling speed stop screw (Fig. 39) to give the idling speed recommended by the equipment manufacturer. Blip the throttle to ensure a consistent return to this setting.

2. Where an idling damper is fitted, remove the cover at the front of the pump (Fig. 39), slacken the locknut and unscrew the damper screw approximately five turns.

3. When the idle speed adjustment is completed, screw in the damper screw until it just begins to affect the idling speed, then unscrew it half a turn and tighten the locknut. Replace cover.

NOTE: A completely cold engine, with the correct idling adjustment, may stall but will run satisfactorily after approximately 30 seconds warm-up. Do not increase the idling speed to compensate for this stalling condition when the engine is cold.

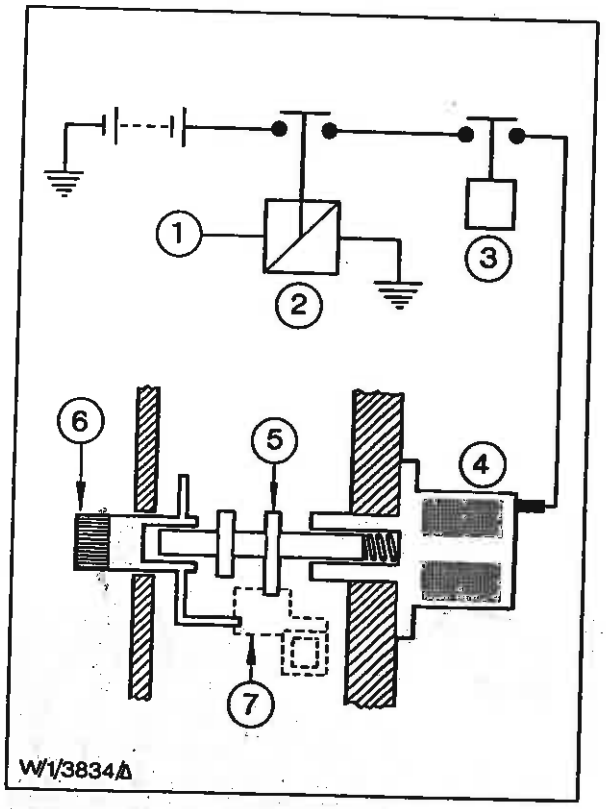


Fig. 38 - Excess Fuel Device Schematic
1. Ignition Switch Contacts
2. Starter Relay
3. Excess Fuel Temperature Switch
4. Excess Fuel Solenoid
5. Maximum Stop Lever
6. Engine Stop Lever Shaft
7. Control Rod Bracket

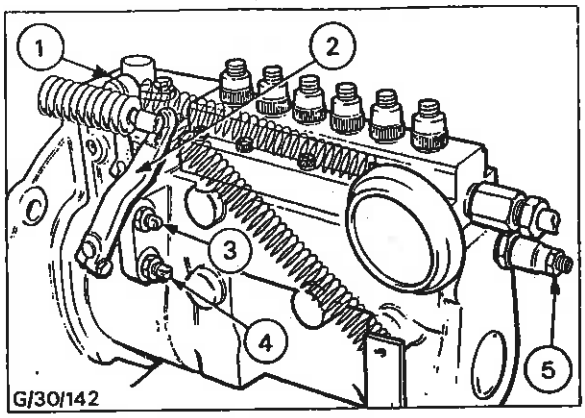


Fig. 39 - Speed Adjustments
1. Stop Control Lever
2. Speed Control Lever
3. Idle Speed Stop Screw
4. Maximum Speed Stop Screw
5. Idling Speed Damper (Cover Removed)

MAXIMUM NO-LOAD SPEED ADJUSTMENT

1. With the engine running at normal operating temperature, with no load applied, operate the throttle control to hold the governor control lever against the maximum speed stop. Adjust the stop screw (see Fig. 39) to give the specified no-load speed.

2. Tighten the locknut and seal the adjusting screw.

TURBOCHARGER

DESCRIPTION

The turbocharger consists of three main sections; the compressor housing, the turbine housing and the central core assembly - refer to Fig. 40.

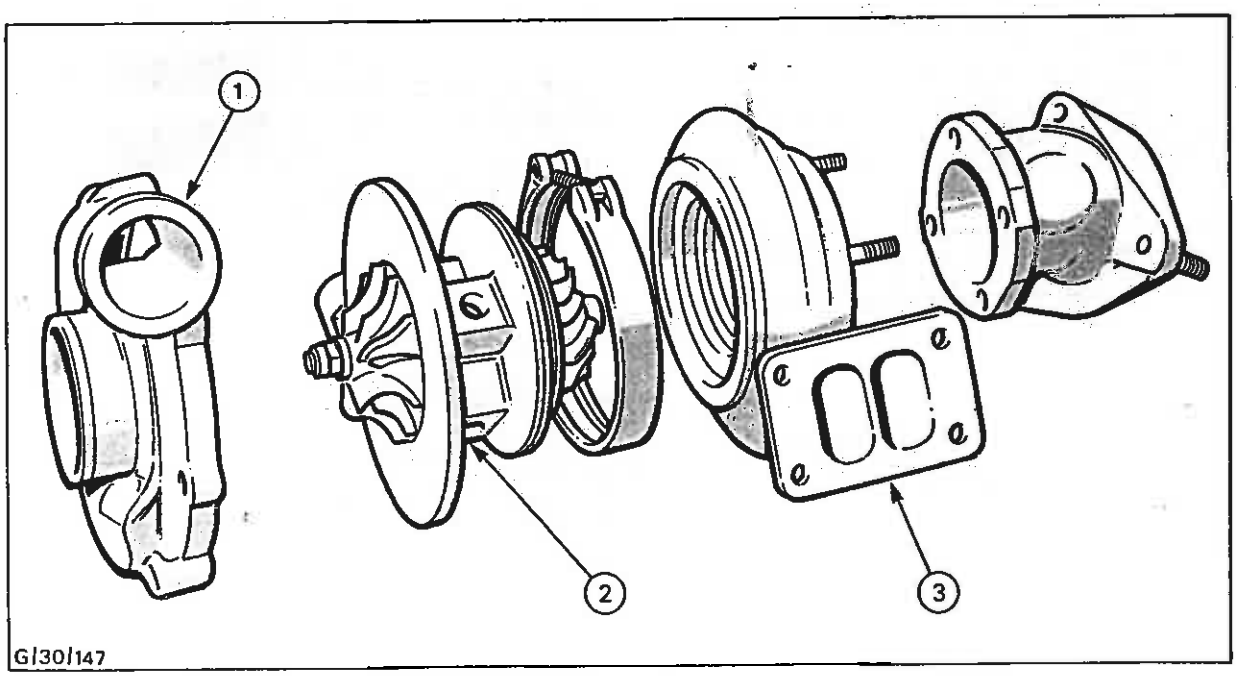


Fig. 40 - Turbocharger Main Assemblies
1. Compressor Housing
2. Centre Core (or Rotor) Assembly
3. Turbine Housing

The Compressor Housing

The compressor housing is made of aluminium alloy and is partly machined locally inside to ensure a very close fit around the compressor wheel. This close fit reduces the air leakage back past the compressor wheel to a minimum and contributes to a high volumetric efficiency in the compressor.

The Turbine Housing

The turbine housing is made of high heat-resistant cast iron and is also machined locally inside, like the compressor housing, for close fit with the turbine wheel for high volumetric efficiency.

The Central Core Assembly

The central core contains a finely machined bore for the bearing, which being fully floating, is a running fit in the housing. An oil drilling in the housing conveys oil to the bearing. The axial location of the shaft and wheel assembly relative to the housing is controlled by a bronze thrust plate which is located in the housing by a pair of dowels, a circular insert and a large circlip. The insert together with a spacer sleeve on the shaft, provide an air seal between the compressor housing and the bearing cavity by means of a sealing 'piston' ring which is held in a groove in the spacer sleeve.

Exhaust gas sealing between the turbine housing and the bearing cavity is similarly effected by two 'piston' ring seals. However, in this case the rings are held in grooves machined in a shoulder on the shaft itself immediately behind the turbine wheel.

The compressor wheel is a separate component made of high strength aluminium alloy secured to the shaft by a self-locking nut. The turbine wheel is made of high-grade heat and creep resistant steel and is integral with the shaft. The tin-plated bronze bush type bearing has an internal and external recess machined in the middle. Six oil drillings in the bush connect the inner and outer recesses and permit lubricating oil under pressure to flow first to the inner recess and then, between the shaft and the bearing. An oil deflector plate is fitted between the thrust plate and the housing insert to limit the amount of oil leaving the bearing at the compressor end from reaching the compressor 'piston' sealing ring. Normally, pressure outboard of the 'piston' sealing ring is in excess of the pressure in the bearing housing; except when the air cleaner element is blocked causing increased lubricating oil consumption.

Lubrication

An external feed pipe supplies oil to the turbocharger and is specially shaped to form a small reservoir. When the engine has been stationary for a period, overnight for instance, the lubricating oil in the galleries and in the turbocharger bearing tends to drain away. This small pocket of oil assists in initial lubrication of the turbocharger bearing on start-up while the main lubricating oil feed system to the turbocharger is priming.

OPERATION - Refer to Fig. 41

The exhaust gases, as they leave the exhaust manifold, enter the turbine housing by a passage cast in the housing, which connects tangentially with a hollow annular ring. The annular ring is of progressively decreasing cross-sectional area and is also part of the casting. The hot gas, still expanding, progresses round this ring and reaches a very high velocity. At this point the gas enters the outer periphery of the turbine wheel and catches the blades of the turbine wheel, driving it round at very high speed. The gas leaves at the centre, or 'eye', of the turbine and is directed into the exhaust pipe.

The turbine wheel and the compressor wheel, since they are directly connected, run at the same speed. Clean air, from the air cleaner, is drawn into the compressor housing at the 'eye' of the compressor wheel, it is caught by the compressor wheel blades and whirled round with the wheel at very high speed. At this speed the air acquires 'weight' and is flung outwards by centrifugal force into a hollow annular ring and is discharged, at approximately twice atmospheric pressure, tangentially into a feed pipe which is connected to the engine inlet manifold.

REMOVING THE TURBOCHARGER

1. Disconnect and remove the turbocharger oil feed pipe and oil return pipe.

2. Slacken clips securing hose between turbocharger and inlet manifold adaptor. On the industrial engine, slacken clips securing hose between turbocharger and air inlet pipe.

3. Remove nuts securing turbocharger to support plate and detach the exhaust outlet elbow and/or the exhaust pipe. Discard gasket(s). Remove turbocharger support plate and bracket from cylinder block.

4. Remove bolts securing turbocharger to exhaust manifold and detach the turbocharger. Discard the gasket. Protect turbocharger from ingress of dirt and foreign bodies until it is overhauled and/or replaced on the engine.

TURBOCHARGER OVERHAUL - GARRETT AIRESEARCH TYPE

Dismantling

1. Clean the exterior of the assembly before dismantling. Dry clean if possible. DO NOT use any caustic solvents.

2. Carefully mark and also note the position of the housings and backplate relative to the centre housing for correct reassembly.

3. Bend back the locktabs, remove the bolts, clamps and lockplates, and separate the compressor and turbine housings from the centre housing assembly. If the housings are tight, tap them off with a soft faced hammer.

CAUTION: ONCE THE HOUSINGS ARE REMOVED TAKE EXTREME CARE NOT TO DAMAGE THE COMPRESSOR OR TURBINE BLADES. IF A TURBINE OR COMPRESSOR WHEEL IS DAMAGED IT CANNOT BE REPAIRED AND THE WHEEL MUST BE RENEWED.

4. Mount the centre housing assembly in a suitable fixture to stop the turbine wheel turning. If the nut on the turbine end of the shaft has not been ground off for balancing this may be located in a socket held in a vice. Otherwise manufacture a simple fixture as shown in the illustration, Fig. 42.

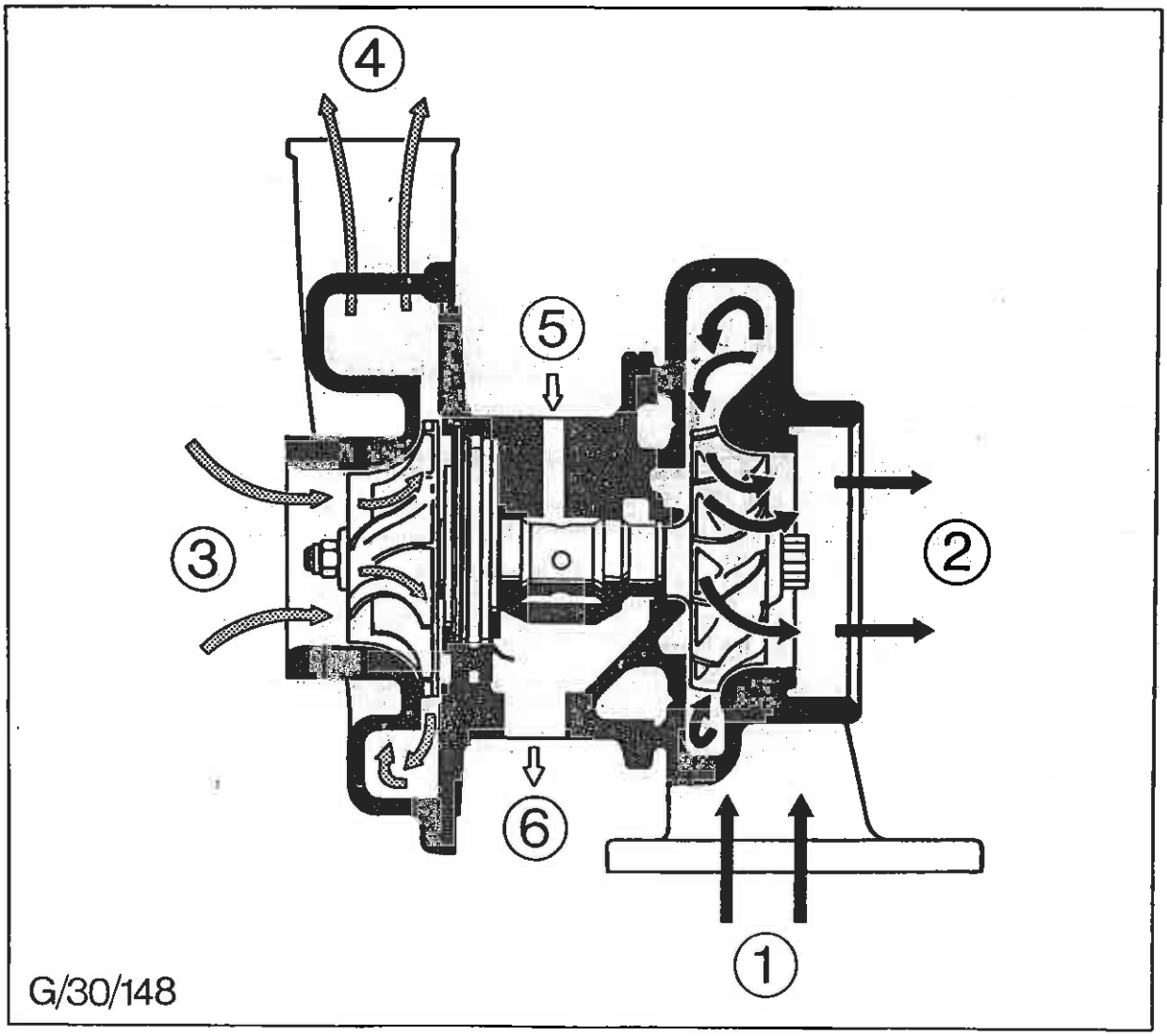


Fig. 41 - Turbocharger Operation
1. Exhaust Gases from Manifold
2. Exhaust Gases to Exhaust Pipe/Silencer
3. Air Inlet
4. Compressed Air to Inlet Manifold
5. Lubricating Oil Inlet
6. Lubricating Oil Drain

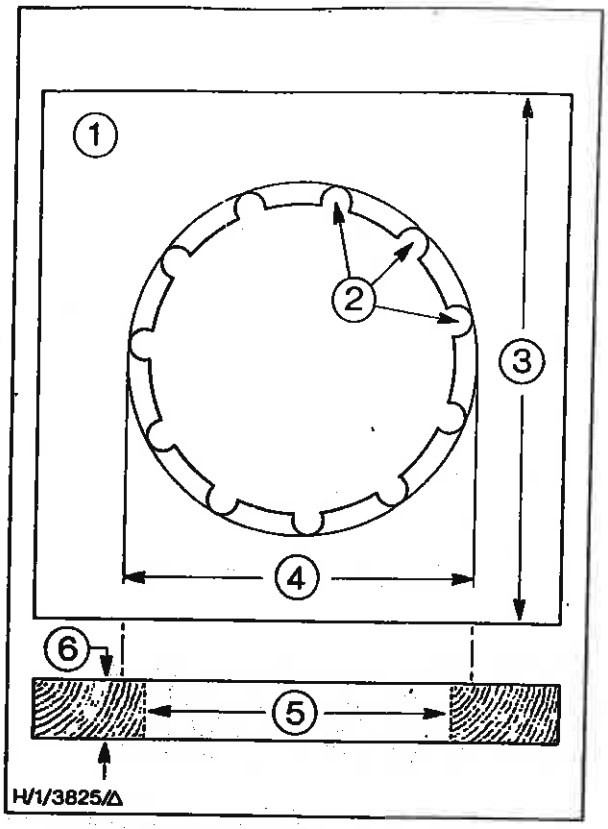


Fig. 42 - Holding Fixture Dimensions
1. Plywood or Hardwood Block
2. 11 Holes 8 mm (0,3125 in) Dia. Equidistant
3. 115 mm (4,5 in)
4. 75 mm (3,0 in)
5. 66 mm (2,625 in)
6. 12 mm (0,5 in)

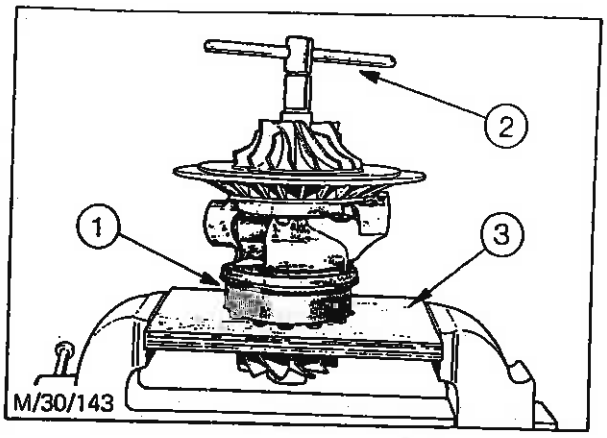


Fig. 43 - Compressor Wheel Locknut Removal
1. Centre Housing Group Located in Fixture
2. T-Handled Wrench
3. Fixture Held in Vice

5. Using a T-handled wrench slacken the compressor wheel locknut, applying equal pressure to both ends of the 'T' to avoid possible bending of the shaft (Fig. 43).

6. Support the turbine wheel, remove the compressor wheel locknut and lift the compressor wheel off the shaft.

7. Withdraw the turbine wheel and shaft out of the housing, keeping the shaft central until clear of the bearings. At the same time the turbine wheel shroud, which is not secured, can be lifted off.

8. Remove the locktabs and bolts, and separate the backplate from the housing. Tap the plate off with a soft faced hammer if it is tight.

9. Remove the thrust bearing and collar.

10. Remove the outer circlips and the bearings from the centre housing. Remove the inner circlips.

Cleaning and Inspection

Before cleaning, inspect all parts for signs of rubbing, burning or other damage which might not be evident after cleaning.

Soak all the parts in clean, non-caustic, carbon solvent. After soaking remove all dirt particles using a soft bristle brush as necessary, and blow dry.

Inspect all components for signs of damage, corrosion, wear or deterioration.

Turbine Wheel:

The turbine wheel and shaft assembly must not show signs of rubbing, scoring, scratching or seizure in the bearings. The shaft must not be bent, or the threads damaged. The turbine blades must not be torn, chipped or worn to a feather edge.

Compressor Wheel:

The compressor wheel must not show signs of wear, rubbing or damage by dirt or other materials. The bearing faces and bore of the wheel must be free from scores or signs of 'pick-up'.

The piston seal grooves and surfaces must not show signs of wear, rubbing or scoring of sealing surfaces.

Housings:

The housings must not show signs of contact with rotating parts. Oil and air passages must be clean and free from obstructions. If the bearing bores in the centre housing are damaged or worn, renew the housing.

Thrust Bearing:

Renew the thrust bearing and collar if they show signs of wear, scoring, nicks, varnish deposits or deeply embedded grit.

Minor surface damage can be removed from any component by polishing or burnishing with abrasive cloth. Use silicon carbide cloth for aluminium parts and polishing (crocus) cloth for steel parts.

Assembly - Refer to Figs. 44 and 45

NOTE: The internal parts of the turbocharger rotate at very high speeds. It is of particular importance that scrupulous attention is given to cleanliness to prevent the ingress of foreign matter during assembly. DO NOT use fluffy cloths or cleaning materials.

1. Install the inner circlips, lubricate and install the bearings and secure them in the centre housing with the outer circlips.

2. Fit the new piston ring seal to the turbine shaft, install the shroud over the end of the centre housing and, holding the turbine wheel upright, gently slide the shaft through the shroud and bearings. Take care to ensure that the piston ring seal locates correctly in the end of the centre housing and is not damaged on entry.

3. Fit the new piston ring seal to the thrust collar, assemble the collar to the thrust bearing and carefully install the assembly over the end of the shaft so that the thrust bearing locates on the anti-rotating pegs and lies flat against the centre housing.

NOTE: The anti-rotating pins are offset to ensure correct fitting.

4. Ensure that the thrust spring is correctly located in the backplate. Place the new seal ring into the groove in the centre housing, fit the backplate over the end of the shaft to locate over the end of the thrust collar, engage the piston ring seal in the bore of the backplate taking care not to damage the seal on entry. Align the mounting bolt holes using the marks made on dismantling, install the bolts with new lockplates, evenly tighten them to the specified torque and secure the locktabs.

5. Fit the compressor wheel over the end of the shaft, lightly oil the threads and face of the locknut and screw it onto the shaft. Using a T-handle torque wrench or torque driver (to avoid any possibility of bending the shaft), carefully tighten the locknut to the specified torque and then through a further angle of 90°.

6. Locate the compressor housing to the backplate, line it up correctly with the marks made on dismantling, install the clamps, lockplates and bolts and tighten them to the specified torque.

7. Locate the turbine housing to the centre housing, line it up correctly with the marks made on dismantling. Apply the specified anti-seize compound to the bolt threads, install the clamps, lockplates and bolts and tighten them to the specified torque.

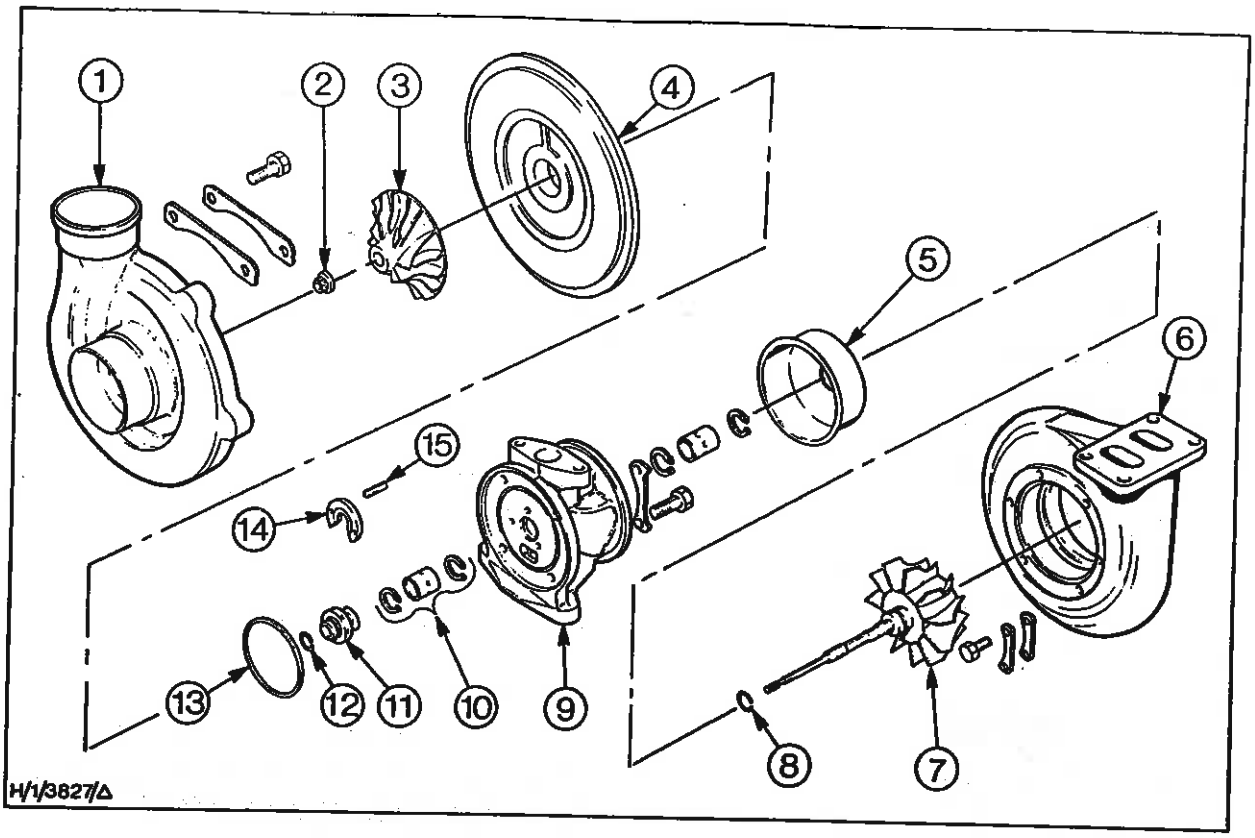


Fig. 44 - Exploded View of Garret AiResearch Turbocharger

1. Compressor Housing
2. Locknut
3. Compressor Wheel
4. Backplate
5. Shroud
6. Turbine Housing
7. Turbine Wheel and Shaft
8. Piston Ring Seal
9. Centre Housing
10. Bearing and Retainers
11. Thrust Collar
12. Piston Ring Seal
13. Seal Ring
14. Thrust Bearing
15. Anti-Rotating Peg

8. Push the turbine shaft fully one way then the other and check that it rotates freely in all positions without rubbing or binding.

9. Fit protective covers to all openings until the turbocharger is fitted to the engine.

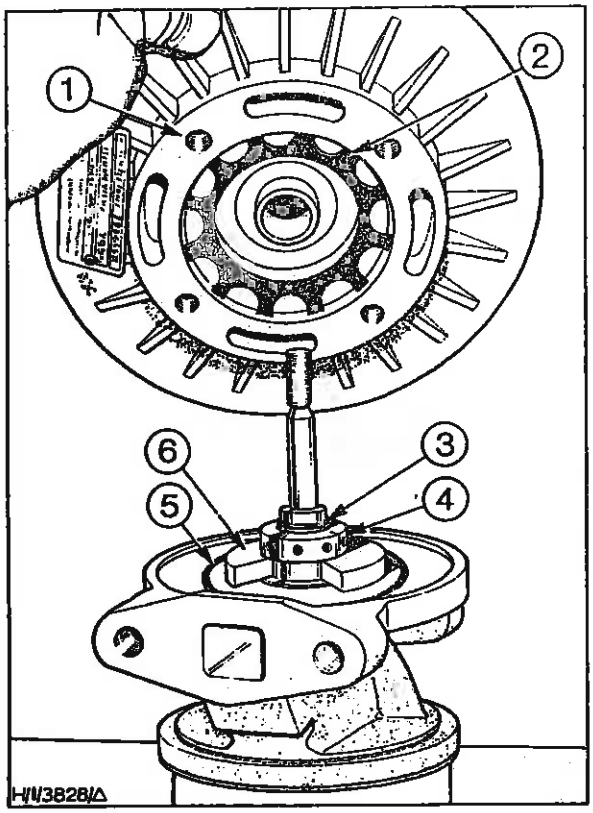


Fig. 45 - Thrust Bearing and Backplate Installation
1. Backplate
2. Thrust Spring
3. Piston Ring Seal
4. Thrust Collar
5. Seal Ring
6. Thrust Bearing

TURBOCHARGER OVERHAUL - HOLSET TYPE - Refer to Fig. 46

Dismantling

1. Clamp unit upright in vice on turbine inlet flange.

2. Mark relative positions of turbine housing (24), bearing housing (20), compressor diffuser (4) and compressor housing (1).

3. Knock back all tabs on lockplates fitted to turbine housing bolts (16) and also compressor housing and diffuser bolts, if fitted.

4. Remove bolts (7) and clamping plates (6) fastening compressor housing (1) to compressor diffuser (4) and lift off housing.

5. Remove bolts (16) and clamping plates (18) fastening turbine housing (24) to bearing housing (20) and lift the core assembly clear of the turbine housing.

6. Holding the turbine wheel at the hub in a suitable fixture, remove the impeller locknut (2).
Note: Left Hand Thread. Take care not to bend the shaft.

7. Slide the compressor impeller (3) off the shaft.

8. Remove bolts (19) fastening compressor diffuser (4) to bearing housing (20). Remove compressor diffuser (4) with oil slinger (9) from shaft. Push out oil slinger (9) from compressor diffuser (4) and remove 'SQ' ring seal (5) from rear of compressor diffuser.

9. Lift out oil baffle (10).

10. Remove the three screws (11) retaining thrust bearing (12). Lift out thrust bearing (12) and thrust collar (13).

11. Remove shaft and wheel (23) together with its seal (split ring) (22) and lift turbine heat shield (21) off shaft.

12. Remove outboard retaining ring (14) at compressor end. Insert finger tip into bearing (15) and remove. Remove inboard retaining ring (14).

13. Remove outboard retaining ring (14) at turbine end. Insert finger tip into bearing (15) and remove. Remove inboard retaining ring (14).

Cleaning and Inspection

Use a commercially approved cleaner only. Caustic solutions will damage certain parts and should NOT be used.

Soak parts in cleaner until all deposits have been loosened.

Use a plastic scraper or bristle type brush on aluminium parts. Vapour blast may also be used provided the shaft and other bearing surfaces are protected.

Clean all drilled passages with compressed air jet.

Make certain that surfaces adjacent to wheels on stationary housings are free of deposits and are clean and smooth.

Shaft and Wheel

Inspect bearing journals for excessive scratches and wear. Minor scratches may be tolerated.

Inspect seal (split ring) groove walls for scoring. Minor scratches are acceptable.

Check carefully for cracked, bent or damaged blades but DO NOT ATTEMPT TO STRAIGHTEN BLADES.

Thrust Parts

Renew if thrust faces are mutilated. Minor scratches are acceptable.

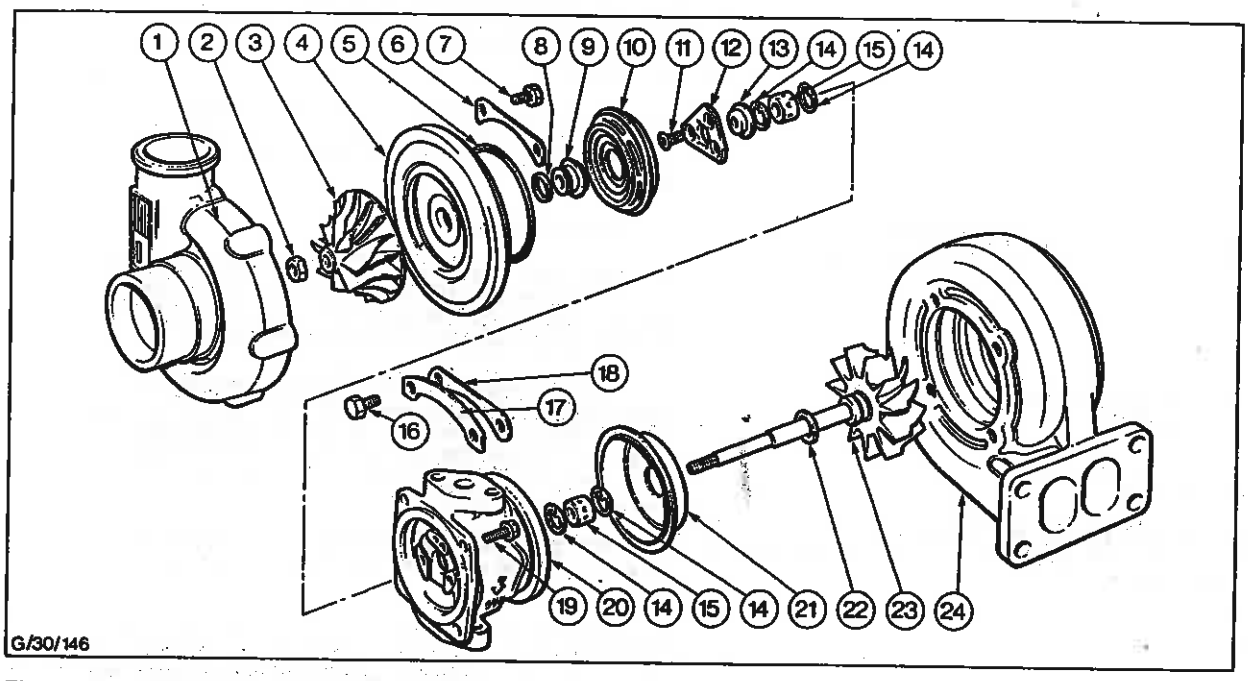


Fig. 46 - Exploded View of Holset Turbocharger

1. Compressor Housing
2. Locknut
3. Compressor Impeller
4. Compressor Diffuser
5. 'SQ' Ring Seal
6. Clamping Plate
7. Hex Head Setscrew and Washer
8. Seal (Split Ring)
9. Oil Slinger
10. Oil Baffle
11. Flat Head Capscrew
12. Thrust Bearing
13. Thrust Collar
14. Retaining Ring
15. Bearing
16. Hex Head Capscrew
17. Lockplate
18. Clamping Plate
19. Hex Head Setscrew and Washer
20. Bearing Housing
21. Heat Shield
22. Seal (Split Ring)
23. Shaft and Wheel
24. Turbine Housing

Renew thrust bearing if faces are worn excessively, unevenly or are severely scratched and otherwise mutilated.

The small feed grooves in the thrust bearing must be clean and free of obstruction.

Compressor Impeller

Check carefully for cracked, bent or damaged blades, but DO NOT ATTEMPT TO STRAIGHTEN BLADES.

Bearings

Renew bearings if excessively scratched or worn.

Bearing Housing

Renew bearing housing if bearing or seal (split ring) bores are excessively scratched or worn.

Rotor Parts

Check the rotor for balance (assembly instructions and Holset Publication "Balancing Turbochargers" gives details).

'SQ' Ring Seal

Renew if section through ring has taken a permanent set or if broken or damaged.

Compressor Housing

Inspect profile for damage due to contact with rotor. Slight damage may be tolerated, otherwise replace the housing with a new one.

Turbine Housing

Inspect profile for damage due to contact with rotor, cracks, flaking or signs of overheating. Slight damage may be tolerated otherwise renew the housing.

Assembly

When the turbocharger has been thoroughly cleaned, inspected and any damaged parts renewed, assembly can commence. It is advised that the following points be noted if a satisfactory rebuild is to be obtained.

a) The rotor should be check-balanced within 0,002 oz in (1,44 gm mm) at each end, and the parts suitably marked to ensure correct alignment (correlation) during subsequent re-assembly.

b) When replacing the retaining rings (14), ensure that the bevelled face is toward the bearing (15).

c) Lubricate bearings, bearing housing bore, thrust parts, seals (split ring) and rotor shaft with clean engine oil.

1. Replace inboard retaining ring (14) at turbine end, insert bearing (15) and secure with outboard retaining ring (14).

2. Replace inboard retaining ring (14) at compressor end, insert bearing (15) and secure with outboard retaining ring (14).

3. Ensure that split ring seal (22) is in position on the rotor shaft, place heat shield (21) on the housing (20), then slide the shaft carefully through the heat shield and bearings. Do not force the split ring seal (22) into the housing bore, as an off-centre ring will fracture, causing the shaft to bind.

4. Slide thrust collar (13) and thrust bearing (12) into position and secure bearing with the three screws (11). Tighten screws to specified torque value, using suitable adaptor.

5. Replace oil baffle (10).

6. Insert split ring seal (8) into compressor diffuser (4); do not force it into the bore as an off-centre ring will fracture causing the shaft to bind. Push the oil slinger (9) fully into position in the compressor diffuser.

7. Insert 'SQ' ring seal (5) in the compressor diffuser (4) and slide the diffuser over the shaft and up to the housing (20); take care not to trap or damage the 'SQ' ring seal. Secure the diffuser to the housing with the four setscrews and washers (19) tightened to the specified torque value.

8. Slide the compressor impeller (3) onto the shaft and screw on the locknut (2). Note that it has a left hand thread.

9. Hold the turbine wheel hub in a suitable fixture and tighten the impeller locknut to the specified torque, using a 'T' handled torque wrench to avoid bending the shaft. Remove from fixture and check that rotor spins freely.

10. Using a dial gauge indicator, check axial travel of the shaft between extreme positions. Total travel should be within 0,10 mm to 0,16 mm (0,004 in to 0,006 in). (This reading may be less if a great deal of oil was smeared on the thrust parts and bearings during assembly).

11. Mount the dial gauge indicator on the housing so that the anvil is resting on the compressor impeller boss and check extreme radial travel of the shaft by pushing the impeller towards and away from the dial indicator. Total travel should be within the following limits:

H1C/D: 0,46 mm to 0,30 mm (0,018 in to 0,012 in)
H2A: 0,47 mm to 0,31 mm (0,0185 in to 0,012 in)

12. Assemble bearing housing (20) to turbine housing (24) in the correct relative positions - refer to marks made when dismantling. Secure assembly with the two clamping plates (18) and lockplates (17) and four setscrews (16). Tighten screws to the specified torque value and check that rotor can spin freely. Bend up corners of lockplates to secure screw heads.

13. Assemble the compressor housing (1) to the diffuser (4) in the correct relative position - refer to marks made when dismantling. Secure assembly with the three clamping plates (6) and six setscrews and washers (7). Tighten screws to the specified torque value, then check that rotor can still spin freely.

14. Fit protective covers to all openings until the turbocharger is fitted to the engine.

Replacing the Turbocharger

1. Inspect air intake system for cleanliness and to ensure absence of foreign material.

2. Inspect exhaust manifold to ensure absence of foreign bodies.

3. Inspect oil drain line. Make certain that line is not clogged.

4. Inspect oil supply line for clogging, deterioration or possibility of leaking under pressure.

5. Inspect the turbocharger mounting pad on the manifold to make certain that all of the old gasket has been removed.

6. Assemble the turbocharger to the exhaust manifold using a new gasket. Secure with the four nuts tightened to the specified torque value.

7. Assemble the turbocharger support plate and bracket into position, placing a new gasket between support plate and turbocharger. DO NOT tighten the nuts securing the turbocharger to the support plate as a new gasket will be needed when fitting the exhaust pipe and/or elbow.

8. Connect the hose between turbocharger and inlet manifold and tighten hose clips.

9. On industrial engines connect the hose between turbocharger and air inlet pipe and tighten hose clips.

10. Connect the turbocharger oil feed pipe and oil return pipe but do not tighten the oil feed pipe union at the turbocharger.

NOTE: When the oil feed pipe is fitted to the engine and the bottom gland nut is finger tight, the gap between the pipe flange and the turbocharger housing (with gasket in place) must not exceed 2mm (0,080in). If this requirement is not met, pre-form the pipe until the specified gap is achieved.

11. Operate the starter motor while holding the injection pump fuel shut-off lever in the stop position. Crank the engine until oil flows from the turbocharger oil feed pipe, then tighten the connection and dry up the spilt oil. Crank again until oil pressure is indicated on the gauge (or the warning light goes out) and check for oil leaks.

NOTE: Before running the engine, the following 'Start-up Procedure' must be followed.

Start-Up Procedure

Serious damage to the turbocharger bearing can result from inadequate lubrication if the following recommendations are not observed.

Prior to the first start after a turbocharger has been newly installed or if, for any reason, the oil supply to the turbocharger has been disconnected, you should ensure that the turbocharger housing is filled with engine oil before reconnecting the oil feed pipe - see under 'Replacing the Turbocharger', Operation No. 11.

In the above circumstances, or in cases where the engine is being started for the first time after an oil change or after a period of 4 weeks or more without use, the following procedure shuld be used.

1. Fully pull out the stop control.

2. Crank the engine with the starter motor for 15 seconds.

3. Push the stop control fully in.

4. Start the engine and allow to idle (1000 rpm maximum).

5. Observe the oil pressure gauge or oil pressure warning light. If oil pressure is not registered on the gauge, or if the oil pressure warning light is not extinguished in the first few seconds of idling, stop the engine immediately and contact your dealer.

On every start up the engine should be allowed to idle (1000 rpm maximum) for 30 seconds before operating on load, to ensure an adequate oil supply to the turbocharger bearing. The engine should also be allowed to idle without load for two minutes before shut-down to enable the oil to dissipate the heat from the turbocharger bearing.

NOTE: Standby Generator and Alternator Sets. Because standby generator and alternator sets make fewer starts and stops than other industrial applications, the idling requirement of the stop/start procedure can be waived without undue risk of reduced life.

However, the recommended start-up procedure must be carried out for engines which have been inoperative for periods of four weeks or more.

Thermostarts are fitted as standard equipment on Turbocharged engines. It is recommended that this starting aid is used on every initial engine start. If, however, the engine has been 'shut down' for less than one hour, the thermostart operation can be waived.

Where possible, disconnect the driven equipment before starting.

SPECIFICATIONS

INJECTION PUMP

Make	C.A.V.	
Type	In-line with Mechanical Governor	
Rotation	Clockwise (from Drive End)	
Engine/Governing	Injection Pump Part No.	CAV Pump Part No.
2722/G.P.I	826F-9A543-DBB	P5510/2
2722/G.P.II	826F-9A543-DCB	P5513/2
2722/Class A, 1500/1800	826F-9A543-DDA	P5537/A
2722/Automotive	826F-9A543-DAC	P5485/3
2723/G.P.I.	826F-9A543-EBB	P5515/2
2723/Class A, 1500/1800	826F-9A543-EDA	P5538/A
2723/Automotive	826F-9A543-EAB	P5486/2
2723/Combine	826F-9A543-ECA	P5542
2725/G.P.I	826F-9A543-FCB	P5519/2
2725/G.P.II	826F-9A543-FDB	P5520/2
2725/Class A, 1500/1800	826F-9A543-FFA	P5539/A
2725/Automotive	826F-9A543-FAC	P5487/3
2725 Combine	826F-9A543-FEA	P5543
2726T/G.P.	826F-9A543-HCB	P5523/2
2726T/Class A, 1500/1800	826F-9A543-HFA	P5540/A
2726T/Automotive	826F-9A543-HAB	P5488/2
2726T/Marine*	826F-9A543-HHA	P5488/2E
2728T/Marine*	826F-9A543-HDB	P5525/2

* Fitted with two-lead (insulated return) excess fuel solenoid.

Oil Priming Quantities - Automotive and G.P. Governed Pumps Only (See Section 2 for Oil Specification)

4 cylinder engines	215 ml
6 cylinder engines	430 ml

Injection Timing to No. 1 Engine Cylinder: See Following Table

Idle Speed: See Following Table

Maximum No-Load Speed: See Following Table

Engine/Governing	Pump Timing B.T.D.C.	Engine Idling Speed in RPM	Engine Maximum No Load Speed in RPM
2722/G.P.I	22°	625 to 675	2705 to 2715
2722/G.P.II	22°	625 to 675	2815 to 2825
2722/Class A, 1500/1800	24°	850 to 950	1565 to 1575
2722/Automotive	22°	625 to 675	1880 to 1890
2723/G.P.I.	23°	625 to 675	2915 to 2920
2723/Class A, 1500/1800	26°	850 to 950	2705 to 2715
2723/Automotive	22°	625 to 675	1565 to 1575
2723/Combine	24°	1150 to 1250	1880 to 1890
2725/G.P.I	22°	625 to 675	2915 to 2920
2725/G.P.II	22°	625 to 675	2645 to 2650
2725/Class A, 1500/1800	24°	850 to 950	2705 to 2715
2725/Automotive	22°	625 to 675	2815 to 2825
2725/Combine	25°	1150 to 1250	1565 to 1575
2726T/G.P.	24°	625 to 675	1880 to 1890
2726T/Class A, 1500/1800	24°	850 to 950	2915 to 2920
2726T/Automotive	24°	625 to 675	2640 to 2645
2726T/Marine	24°	625 to 675	2600 to 2610
2728T/Marine	24°	625 to 675	1565 to 1575
			1880 to 1890
			2720 to 2730
			2720 to 2730
			2760 to 2770

NOTE: The maximum no-load speeds shown for combine engines are applicable to a residual load of 18,75 kW.
The maximum no-load speeds shown for all other engines are applicable to a residual load of 7,5 kW.

EXCESS FUEL TEMPERATURE SWITCH

Contacts Close (Decreasing Temperature)	+3° to -3°C (37° to -22°F)
Contacts Open (Increasing Temperature)	5° to 11°C (41° to 52°F)

OIL BATH AIR CLEANER

Oil Specification	FORD SM-2C-1017A

INJECTORS - CAV

Engine/Governing	Injector Part No.	CAV Injector Part No.	CAV Nozzle Part No.
2722/G.P.I	826F-9K546-DAB	LRB 6700807	6801018
2722/G.P.II	826F-9K546-DAB	LRB 6700807	6801018
2722/Class A, 1500/1800	826F-9K546-DAB	LRB 6700807	6801018
2722/Automotive	826F-9K546-DAB	LRB 6700807	6801018
2723/G.P.I	826F-9K546-DAB	LRB 6700807	6801018
2723/Class A, 1500/1800	826F-9K546-DAB	LRB 6700807	6801018
2723/Automotive	826F-9K546-DAB	LRB 6700807	6801018
2723/Combine	826F-9K546-DAB	LRB 6700807	6801018
2725/G.P.I	826F-9K546-DAB	LRB 6700807	6801018
2725/G.P.II	826F-9K546-DAB	LRB 6700807	6801018
2725/Class A, 1500/1800	826F-9K546-DAB	LRB 6700807	6801018
2725/Automotive	826F-9K546-DAB	LRB 6700807	6801018
2725/Combine	826F-9K546-DAB	LRB 6700807	6801018
2726T/G.P.	826F-9K546-HAA	LRB 6700805	6801016
2726T/Class A, 1500/1800	826F-9K546-HAA	LRB 6700805	6801016
2726T/Automotive	826F-9K546-HAA	LRB 6700805	6801016
2726T/Marine	826F-9K546-HAA	LRB 6700805	6801016
2728T/Marine	826F-9K546-HBA	LRB 6700806	6801017

Engine/Governing	Setting Pressure - New or Reconditioned with new spring that has not exceeded 10 hours life in an engine	Working Pressure - for Injectors that have exceeded 10 hours in an engine
2722/G.P.I 2722/G.P.II 2722/Class A, 1500/1800 2722/Automotive	208 to 218 bar (3016 to 3160 lbf/in^2)	197 bar (1407 lbf/in^2)
2723/G.P.I 2723/Class A, 1500/1800 2723/Automotive 2723/Combine	208 to 218 bar (3016 to 3160 lbf/in^2)	197 bar (1407 lbf/in^2)
2725/G.P.I 2725/G.P.II 2725/Class A, 1500/1800 2725/Automotive 2725/Combine	208 to 218 bar (3016 to 3160 lbf/in^2)	197 bar (1407 lbf/in^2)
2726T/G.P.I 2726T/Class A, 1500/1800 2726T/Automotive 2726T/Marine	208 to 218 bar (3016 to 3160 lbf/in^2)	197 bar (1407 lbf/in^2)
2728T/Marine	208 to 218 bar (3016 to 3160 lbf/in^2)	197 bar (1407 lbf/in^2)

Nozzle Holes	
Quantity:	Four (all types)
Diameter:	Type 6801018: 0,295 to 0,305 mm Type 6801016: 0,325 to 0,335 mm Type 6801017: 0,335 to 0,345 mm

Back Leakage Time

	Test Oil Ambient Temperature °C	Test Oil Ambient Temperature °F	Back Leak Time in Seconds
For a fall in pressure from 150 to 100 bar (2175 to 1450 lb/in^2)	10	50	7 to 34,5
	16	60	6 to 30
	21	70	5,5 to 27
	27	80	5 to 24
	32	90	4,5 to 21

Test Oil	Shell Calibration Fluid 'B' or 'C' or Equivalent

HOLSET TURBOCHARGERS

	Model H1C/D		Model H2A	
	mm	in	mm	in
Centre (Bearing) Housing				
Bearing bore diameter	15,875 - 15,885	0,6250 - 0,6254	15,875 - 15,885	0,625 - 0,6254
Seal (piston ring) bore diameter	19,305 - 19,330	0,760 - 0,7610	19,305 - 19,330	0,760 - 0,7610
Turbine Wheel Assembly				
Shaft journal diameter	10,972 - 10,980	0,432 - 0,4323	10,972 - 10,980	0,432 - 0,4323
Piston ring groove width	1,680 - 1,730	0,0661 - 0,0681	1,680 - 1,730	0,0661 - 0,0681
Journal Bearings				
Inside diameter	11,006 - 11,013	0,4333 - 0,4336	11,006 - 11,013	0,4333 - 0,4336
Outside diameter	15,801 - 15,811	0,6221 - 0,6225	15,801 - 15,811	0,6221 - 0,6225
Rotating Assembly				
Radial movement at compressor impeller hub	0,300 - 0,458	0,0118 - 0,018	0,282 - 0,464	0,0111 - 0,0138
Total end float	0,100 - 0,155	0,0039 - 0,0061	0,100 - 0,155	0,0039 - 0,0061
Turbine speed at normal full speed/full load engine conditions	125,000 rpm		110,000 rpm	

GARRETT AiRESEARCH TURBOCHARGER TYPE TA 3503

Turbine Speed at Maximum Rated Power 100,000 rpm

	mm	in
Centre Housing		
Bearing bore diameter	15,80 - 15,81	0,6220 - 0,6223
Seal bore diameter	17,75 - 17,81	0,699 - 0,701
Turbine Wheel Assembly		
Journal diameter	10,152 - 10,16	0,3997 - 0,4000
Seal hub diameter	17,32 - 17,35	0,682 - 0,683
Ring groove width	1,64 - 1,74	0,0645 - 0,0735
Backplate		
Seal bore diameter	12,687 - 12,713	0,4995 - 0,5005
Thrust Collar		
Bearing groove width	4,42 - 4,44	0,1740 - 0,1748
Ring groove width	1,621 - 1,659	0,0638 - 0,0653
Thrust Bearing Thickness	4,36 - 4,37	0,1716 - 0,1720
Journal Bearing		
Outside diameter	15,70 - 15,71	0,6182 - 0,6187
Inside diameter	10,19 - 10,20	0,4010 - 0,4014
Impeller Bore	6,345 - 6,353	0,2498 - 0,2501
Rotating Assembly		
Radial clearance of shaft Bearings	0,076 - 0,165	0,003 - 0,0065
End float	0,025 - 0,102	0,0005 - 0,004
Turbocharger Turbine Housing Bolts - Anti-seize compound	FORD Specification SAM-1C-9107 A	

Typical turbocharger boost pressures for the 2726T and 2728T engines on full load are as follows:

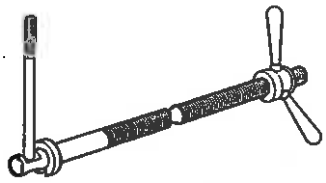
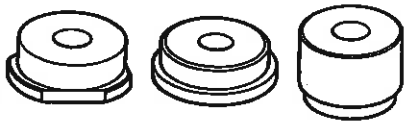
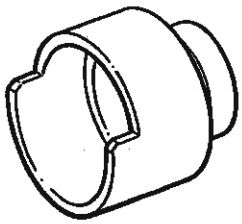
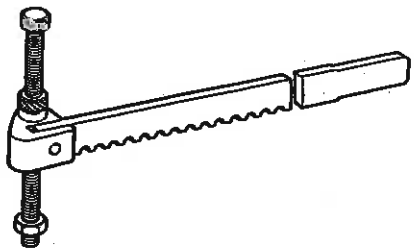
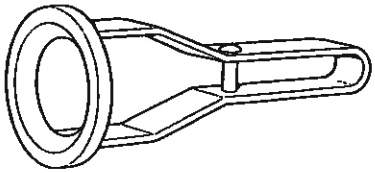
Engine/Application	Engine Full Load Speed	Typical Boost Pressure
2726T/Industrial	2400 rpm	800 mm Hg (15,47 lbf/in^2)
2726T/Marine	2400 rpm	700 mm Hg (13,54 lbf/in^2)
2728T/Marine	2450 rpm	825 mm Hg (15,95 lbf/in^2)

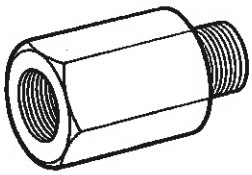
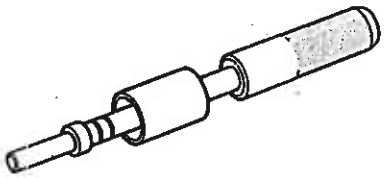
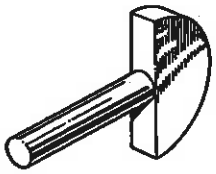
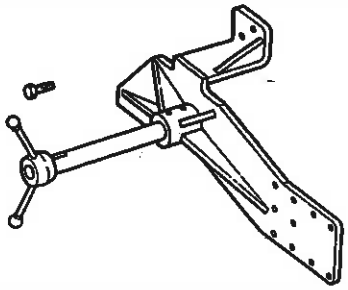
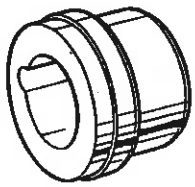
TIGHTENING TORQUES

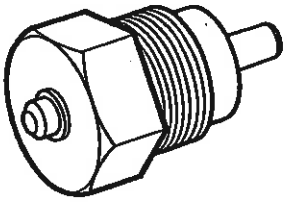
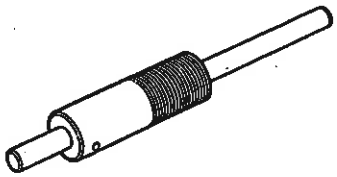
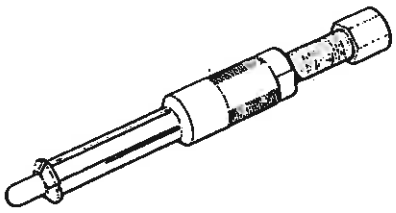
	Nm	kgf m	lbf ft
Fuel Lift Pump - Standard Low Pressure Type			
Pump retaining nuts	20 to 25	2,0 to 2,5	15 to 18
Cover plate securing screw	5,1 to 6,2	0,5 to 0,6	3,8 to 4,6
Fuel Lift Pump – Bosch High Pressure Type			
Pump retaining bolts	9 to 11	0,9 to 1,1	7 to 8
Pre-filter banjo bolt	30 to 40	3,0 to 4,1	22 to 29
Priming plunger assembly	45 to 55	4,6 to 5,6	33 to 40
Inlet and outlet adaptors	30 to 40	3,0 to 4,1	22 to 29
Plunger spring plug	80 to 100	8,2 to 10,2	60 to 74
Fuel lift Pump – AC Delco High Pressure Type			
Pump retaining bolts	19 to 24	1,9 to 2,4	14 to 18
Pre-filter banjo bolt			
Using original inlet adaptor	25 to 30	2,5 to 3,0	18 to 22
Using new aluminium adaptor	14 to 18	1,4 to 1,8	10 to 13
Inlet/outlet adaptors-to-pump (aluminium)	25 to 30	2,5 to 3,0	18 to 22
Water supply pipe bracket bolt (turbo and intercooled engines only)	31 to 39	3,2 to 4,0	23 to 29
Fuel pipe gland nut-to-adaptor	15 to 18	1,5 to 1,8	11 to 13
Adaptor to pre-filter	30 to 35	3,1 to 3,6	22 to 25
Fuel Filter Retaining (Centre) Bolt	6,8 to 9,5	0,7 to 1,0	5 to 7
Injectors			
Injector retaining bolts	17 to 22	1,8 to 2,2	12 to 16
High pressure fuel pipes			
gland nuts	17 to 20	1,8 to 2,0	12 to 15
oil seal nuts	22 to 27	2,2 to 2,8	16 to 20
Injector leak-off pipe banjo bolts	16 to 20	1,6 to 2,0	12 to 15
Rocker pedestal bolts	23 to 30	2,3 to 3,0	17 to 22
Rocker cover retaining screws	4,0 to 5,5	0,4 to 0,6	3 to 4
Fuel Injection Pump			
Injection pump securing bolts	22 to 27	2,2 to 2,7	16 to 20
Delivery pipe unions (high pressure)	17 to 20	1,8 to 2,0	12 to 15
Low pressure pipe unions	11 to 16	1,1 to 1,7	8 to 12
Drive ring gear locking bolts (Automotive & G.P. governed pumps only)	20 to 25	2,0 to 2,5	15 to 18
Drive gear hub nut (Automotive & G.P. governed pumps only)	60 to 65	6,1 to 6,6	44 to 48
Filler, level and drain plugs	4 to 6,8	0,4 to 0,7	3 to 5
Bleed screws	4 to 6,8	0,4 to 0,7	3 to 5
Turbochargers - General			
Turbocharger to exhaust manifold nuts	41 to 51	4,2 to 5,2	30 to 38
Turbocharger to support plate nuts	20 to 25	2,0 to 2,5	15 to 18
Support bracket to cylinder block bolts			
5/16 UNC bolts	18 to 22	1,8 to 2,2	13 to 16
7/16 UNC bolts	50 to 62	5,1 to 6,3	37 to 46
Support plate to support bracket bolts	41 to 51	4,2 to 5,2	30 to 38
Oil feed pipe flange bolts	20 to 25	2,0 to 2,5	15 to 18
Oil drain pipe flange bolts	20 to 25	2,0 to 2,5	15 to 18
Turbocharger - Garret AiResearch Type			
Thrust bearing screws	4,5	0,45	3,4
Bearing housing to diffuser bolts	5,7	0,58	4,2
Diffuser to compressor housing bolts	5,7	0,58	4,2
Bearing housing to turbine housing bolts	11,3	1,13	8,3
Compressor impeller locknut	14	1,4	10
Turbocharger - Holset Type			
Bearing housing to backplate bolts	8,5 to 10	0,9 to 1,0	6,5 to 7,5
Compressor housing to backplate bolts	11,5 to 14,5	1,2 to 1,5	8,5 to 10,5
Bearing housing to turbine housing bolts	11,5 to 14,5	1,2 to 1,5	8,5 to 10,5
Compressor impeller locknut - 1st stage	2,0 to 2,2	0,21 to 0,23	1,5 to 1,7
2nd stage	Tighten through a further 90°		

SPECIAL TOOLS AND EQUIPMENT

All the special tools listed are available from:
V. L. Churchill Limited, P.O. Box 3, Churchill Way, Daventry, Northants. England. Telephone: 0327 704461. Telex 31326

Tool No.	Description	Identification
21-022	Camshaft Bearing Remover/Installer	
21-022-51A	Adaptor for 21-022	
21-022-53	Adaptor for 21-022	
21-024	Valve Spring Compressor	
21-024-02	Adaptor for 21-024	

Tool No.	Description	Identification
21-516	Adaptor for 21-024	
21-500	Valve Guide Remover/Installer	
21-506	Crankshaft Rear Seal Installer	
21-535	Engine Mounting Bracket	
21-536	Crankshaft Front Seal Installer	

Tool No.	Description	Identification
21-537	Valve Stem Seal Installer	
23-504	CAV Pump Timing Tool - Class 'A' and Combine Harvester Governed Pumps	
23-507	CAV Pump Timing Tool - G.P. and Automotive Governed Pumps	
21-036	Clutch Pilot Bearing Remover	
STU 3375515	Pressure Regulator Pump Used for Injector Leak-Off Rail Test